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The thin layer activation method and its applications in industry

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FOREWORD

Nuclear techniques are widely used to investigate complex physical and chemical phenomena, including wear, mass transfer, corrosion and erosion.

The thin layer activation (TLA) method is one of the most effective and precise methods of corrosion (erosion) and wear measurement and monitoring in industry, used for on-line remote measurement of wear and corrosion rate of critical parts in machines or processing vessels under real operating conditions.

The TLA technique was developed in the early 1970s in a number of industrialized countries. While most of the development and commercial applications took place in developed countries, many laboratories from developing countries also started introducing this technique for tribological measurements.

In 1990 the IAEA convened a consultants meeting to discuss the state of the art of the TLA technique and to assess the possibilities and potential limitations of introducing it to developing countries. Following the recommendations of the consultants meeting, the IAEA initiated a Co-ordinated Research Programme (CRP) on Nuclear Methods in Monitoring Wear and Corrosion in Industry in 1992. For three years research workers from Hungary, India, Italy, Romania and the Russian Federation contributed significantly to the development of different aspects of the TLA methodology and technology.

The final research co-ordination meeting (RCM), held in Debrecen, Budapest on 4-8 June 1996, discussed and evaluated the work done in the framework of this CRP and concluded that the objectives had been achieved.

The CRP contributed to a better understanding of the TLA method and the development of new measuring and application techniques. The achievements included: tables of reliable nuclear data for TLA monitoring of various elements; the testing of on-site wear measuring systems using a battery operated NaI (TI) detection system; the application of the isotope diffusion technique as a complementary and rather simple technique for the formation of thin active layers; and the measurement of corrosion in oil and gas pipelines.

Developing Member States with appropriate and relatively simple irradiation facilities are encouraged to initiate the implementation of the TLA method, which has already been proved as an efficient, precise and cost-effective technique in industrialized countries. One of the main requirements of future work is to make the technique better known to industry as capable of solving their long standing problems and to make end users aware of its safety and its benefits.

This TECDOC is intended to be a comprehensive manual on thin layer activation method in its applications for monitoring wear and corrosion in industry. It describes the theory and gives case studies on TLA method applications in industry. It will be useful for all IAEA Member States interested in introducing nuclear methods for tribological studies and applications.

The IAEA is grateful to the participants of the CRP who contributed to this TECDOC, and in particular to F. Ditrói of the Institute of Nuclear Research of the Hungarian Academy of Sciences who drafted the report.

EDITORIAL NOTE

In preparing this publication for press, staff of the IAEA have made up the pages from the original manuscript(s). The views expressed do not necessarily reflect those of the governments of the nominating Member States or of the nominating organizations.

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CONTENTS

1. INTRODUCTION

It is well known that the reliability of industrial equipment, transportation systems, nuclear and conventional power plants, pipes, etc. is substantially influenced by such degradation processes as wear, corrosion and erosion; consequently, the development of effective methods of detection, measurement and monitoring of the above processes is of great importance. The appropriate methods of monitoring could prevent dangerous accidents during operation of industrial installation and transport vehicles and avoid production losses due to breakdown of machinery.

When the surfaces are not really accessible or are concealed by overlaying structures, nuclear methods such as Charged Particle and Neutron Activation, become the most powerful tool for measurement and monitoring of wear and corrosion.

The neutron activation method by using nuclear reactors produces homogeneous activity distribution in the whole sample (bulk activation). The advantage, that one can measure the average wear of every part of the irradiated sample, but the removed activity proportion is so small, that it can only be measured in the cooling/lubricating liquid to reach a reasonable sensitivity. In this case a large surplus activity is also produced in the bulk which allows the use of the method only in laboratories with suitable radiation protection.

To put the method into in-situ application the Thin Layer Activation (TLA) method was developed by using charged particle activation. In this case only the surface layers in the m-mm range at the desired parts of the sample are activated. The sensitivity is high and the produced low activity level allows the free handling of the sample.

Tracer techniques of machine part wear and corrosion control being applied in different fields of modern industry are in a constant progress. The modifications of the techniques differ in method of radioactive label creation in the material of component under investigation. Up to the present time more than a dozen labelling methods have been developed according to the activity distribution they can be divided into volumetrical and surface methods. Volumetrical methods include the material irradiation by neutrons and gamma-rays as well as doping the melt by radioactive substances. The bulk activation of the material requires the monitoring of activity removed and therefore leads to large total and specific activity of the component. Such techniques may be used only in special laboratories providing handling and operation safety.

When the above mentioned procedures cannot be used, there are alternative methods to produce activity in the surface layers, such as: isotope diffusion (producing activity in the sample by allowing controlled diffusion of radioactive tracers from special solution into the surface of the sample); Recoil activation (by using the energetic (several MeV) heavy radioactive products from nuclear reactions one can produce a very thin layer (UTLA = Ultra Thin Layer Activation) with relative low activity); radionuclide absorption; thermal-spraying; galvanic deposition; surface treatment with radioactive electrode; irradiation with radioactive beams, etc. These alternative methods are used only when special requirements emerge.

2. THE THIN LAYER ACTIVATION METHOD

2.1. PRINCIPLE

The working principle of TLA may be illustrated by the example of a combustion engine, very schematically delineated in Fig. 1 by the piston ring, the cylinder wall, the cooling water jacket and the housing wall. Subject to wear measurement is the cylinder wall, which has been labelled in its

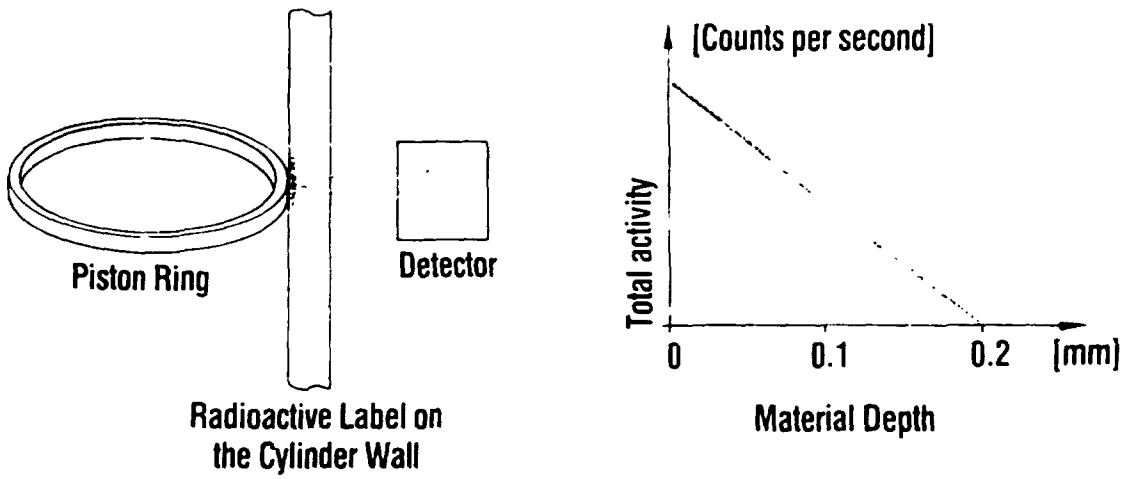

FIG. 1. Working principles of TLA: The activity of the cylinder wall is monitored by a detector outside the engine. The right part shows a simplified calibration curve of total activity vs. material depth.

critical zone around the upper dead point of the piston ring by thin layer activation at a cyclotron. The thickness of the radioactive surface layer is adjustable by beam energy and angle alteration to within 20 micrometer and around 0.2 mm according to the expected wear measurement depth.

The characteristic gamma radiation emitted from the labelled zone of the component penetrates the cylinder wall, water jacket and housing wall without major attenuation and is recorded by a radiation measuring equipment (detector) appropriately located outside the machine, as indicated in Fig. 1 (left part). The right part of the figure shows the time dependence of material wear. The wear of the component can be observed easily and exactly via the variation of the activity caused by the loss of material. It is essential to trap the removed activity at a shielded place in order to avoid the influence of the measurement of the remaining activity.

The main advantages of TLA are as follows:

- non-destructive remote monitoring of surface degradation, including wear, corrosion and erosion
- in-situ, on-line measurement of degradation of critical machine-parts in operation
- simultaneous measurement of surface degradation of several components in the same machine
- high sensitivity in monitoring the slow rate degrading processes
- no influence on the operating conditions of machine or system
- very low level of radioactivity (≤ 370 kBq(=10 μCi))
- cheaper and quicker compared to the conventional methods.

2.2. THEORY OF THE TLA

When a beam of accelerated ions enters a material, the particles rapidly lose energy and penetrate to a well defined depth (Fig. 2). A small number of charged particles interact with atomic nuclei of the material, induce a nuclear reaction and produce radioactive isotopes. The concentration of radioactive atoms produced within the under-surface layer is very low (1 to 10^{10}). The activation produces only a minute level of radioactivity, typically a few microcuries. Once the radioactive label is created under the surface, it decays with the emission of gamma-rays.

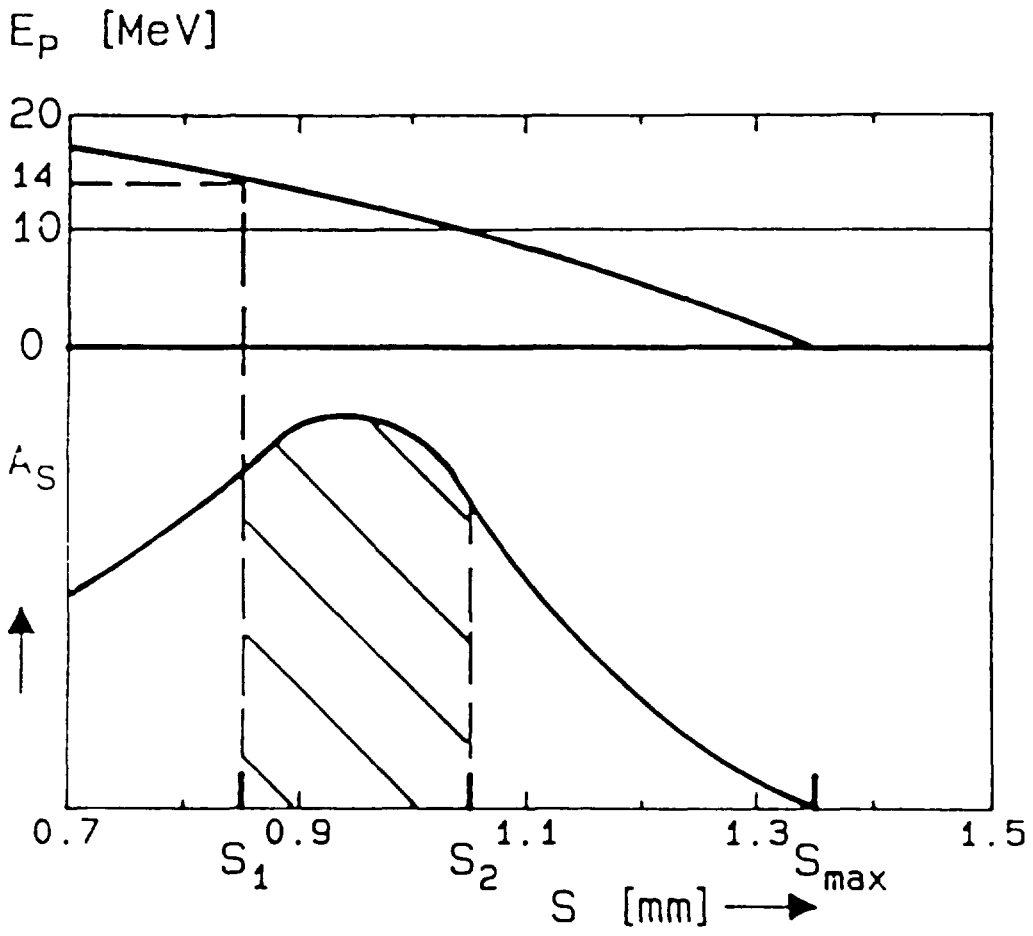

FIG.2 The scheme of TLA: Dependence of proton energy (upper part) and activity concentration (lower part) on depth for irradiation of iron by 30 MeV protons. Only the last part of the range is shown. The hatched area indicates the depth range of approximately constant activity concentration.

The parameters of a label must correspond to the problem under consideration in the best way. Its radionuclide composition must be utmost simple to have reliable measurement results in industrial conditions The depth of radioactive layer must be comparable with the expected loss. The activity depth distribution must be precisely known in depth as it is used to convert the decrease of counting intensity into linear or mass destruction parameters.

Creation of a label adequate to the problem needs a certain information base including range-energy data in matter, values of nuclear reaction thresholds, thick target yields and their energy dependence. Ranges of charged particles in different elements are well known and available information [1] permit to select the appropriate particle-energy for a specific problem. Ranges in compounds and alloys may be calculated according to Bragg's formula:

$$\frac{1}{R_0} = \sum_i \frac{\eta_i}{R_i} \qquad 1.$$

where R_Σ is the range in alloy, R_i is the range in element i and η_i is the concentration of element i. The depth of the radioactive layer depends on the particle energy and beam incidence angle:

$$d = \left[R(E_0) - R\left(E_{th}^{min}\right)\right]\sin(\Theta) = R_0 \sin(\Theta) \qquad 2.$$

where E_o and E_{th} are particle energy and reaction threshold, R is the particle range of energy E in a certain material and Θ is the angle between the beam axis and the surface. The TLA technique allows to adjust the thickness of the label and thereby the sensitivity of the measurement.

Q-reaction values and thresholds are tabulated in handbooks [2] but one must bear in mind that real effective thresholds include the values of Coulomb barrier.

The activation of chemical elements and the main construction materials in the majority of cases is well studied [3,4,5], some recommendations are given in Table 1. These recommendations may serve only as a rough guide since a large variety of problems, materials and irradiation means may lead to another choice of radionuclides and solutions. For example, for lack of high energy alpha-particles the Al-alloys is to be studied by any admixture, and a large Fe-component in bronze allows to investigate the wear of this material by ^{58}Co.

The main characteristic of material activation is the thick target yield [6]. It is determined as the radionuclide activity per irradiation unit, usually μAh.

$$Y = \frac{A}{I} \frac{\lambda}{1 - e^{-\lambda t}} \qquad 3.$$

where

A - the radionuclide activity at the end of irradiation.
I - irradiation current, λ - decay constant and t - irradiation time.

TABLE I. RECOMMENDATIONS ON THE ELEMENTS IRRADIATION AND ACTIVITY MEASUREMENT

Element	Accelerated particle	Radionuclide measured	Yield		Radioactive impurities	Time delay after irradiation	Measured spectrum part, MeV	Possible control duration
			Energy[MeV]	Y[kBq/μAh]				
Be	^{3}He	^{7}Be(53,3 d)	22.4	407	-	3 d	0.478	5-6 months
C	^{3}He	^{7}Be(53,3 d)	32.1	629	-	3 d	0.478	5-6 months
Mg	d	^{22}Na(2.62 y)	22.8	140.6	^{24}Na	10 d	1.0 - 1.5	years
Al		^{22}Na(2.62 y)	42.7	5.92	^{24}Na,^{28}Mg	10 d	1.0 - 1.5	years
Si	d	^{22}Na(2.62 y)	22.3	7.8	-	3 d	1.0 - 1.5	years
Ti	p	^{48}V(16.0 d)	22.5	18870	^{46}Sc,^{47}Sc	20 d	0.9 - 1.5	2 months
V	d	^{51}Cr(27.7 d)	21.6	17020	-	3 d	0.32	3 months
Cr	p	^{52}Mn(5.7 d)	11.0	40737	^{54}Mn	3 d	1.0 - 1.6	20 months
		^{54}Mn(312.3 d)	45.0	240.5	^{51}Cr,^{52}Mn	40 d	0.84	1 year
Mn	p	^{54}Mn(312.3 d)	22.5	629	^{51}Cr,^{55}Fe	3 d	0.84	1 year
Fe	p	^{56}Co(78.5 d)	11.0	444	^{57}Co	7 d	0.65 - 1.4	7-8 months
		^{58}Co + ^{56}Co	45.0	1110 +59	^{57}Co,^{55}Fe	7 d	0.7 - 0.9	7-8 months
Co	p	^{58}Co(70.8 d)	22.7	4070	-	7 d	0.81	7-8 months
Ni	d	^{58}Co + ^{56}Co	22.5	196 + 4921	^{57}Co, ^{60}Co	7 d	0.7 - 0.9	7-8 months
Cu	p	^{65}Zn(244.1 d)	11.0	251.6	-	7 d	1.12	1 year
Zn	d	^{65}Zn(244.1 d)	20.5	469.9	^{67}Ga	3 d	1.12	1 year
Zr	p	^{92m}Nb(10.1 d)	22.4	3885	^{87,88}Y,^{89} Zr	7 d	0.8 - 1.1	1 month
Nb	p	^{92m}Nb(10.1 d)	20.5	469.9	^{89}Zr, ^{93m}Mo	7 d	0.8 - 1.1	1 month
		^{95m}Tc(61 d)	45.0	111	^{92m}Nb, ^{96}Tc	1.5 months	0.5 - 1.0	6-7 months
Mo	p	^{95m}Tc(61 d)	22.4	518	^{96}Tc, ^{97}Tc	1 month	0.5 - 1.0	6-7 months
Sn	d	^{124}Sb(60.2 d)	22.3	333	^{120m}Sb, ^{122}Sb	20 d	1.69	6 months
W	p	^{184}Re(38 d)	22.0	2590	^{183}Re	7 d	0.7 - 1.0	4 months

The yield from the alloy can be calculated from the formula:

$$Y_{\Sigma} = Y_i \times \eta_i \frac{R_{\Sigma}}{R_i} \qquad 4.$$

Here Y_{Σ} - is the yield from the alloy, Y_i - the radionuclide yield from pure element i and η_i - the concentration of the element i in the alloy.

It is seen that thick target yield is a physical constant, which depends on bombarding particle energy and describes the numerical ratio of radionuclides produced in nuclear reactions at certain irradiation conditions in a given substance.

The irradiated zone contains a complex mixture of radionuclides produced in various nuclear reactions, which are allowed by interaction energetics. In general case the total activity monitoring is inexpedient, since different depth distributions of radionuclides with different decay rates result in diverse and changing in time ratio of radionuclides in every point of material depth. The monitoring of label should be carried out by measuring the gamma-ray intensity of one radionuclide. Such radionuclide must be characterized by long half-life (about several days or more) hard gamma-rays weakly absorbed in the walls of mechanism and large yield in material irradiation.

The selective monitoring of one radionuclide may be realized using different reaction thresholds (varying particle-energy), different half-lives (waiting for the decay of short-lived radionuclides) and different energy of gamma-rays (selecting the appropriate energy interval).

The data on thick target yields are periodically published in various scientific papers. The usual precision of these data is not less than 10 % [30-37].

A very important characteristic of a label is the depth distribution of radionuclide. It represents the calibration curve used for conversion the activity change into the depth of the layer removed [7]. The calibration curves may be described and represented in two ways. One of them correlates the remaining activity A with the removed layer x:

$$A = F(x) = \frac{N_i - N_b}{N_0 - N_b} e^{-\lambda t} \qquad 5.$$

where N_0 and N_b are counting rates from the irradiated sample and background, N_i is counting rate from the sample after removing the layer x_i and t_i is time interval between measuring N_b and N_i, and λ is the decay constant.

The second description directly correlates with the layer x_i and the removed activity a_i. In this case x=f(a) and

$$a = \frac{(N_0 - N_b) - (N_i - N_b)}{N_0 - N_b} e^{-\lambda t} \qquad 6.$$

It is evident that $A_i = 1 - a_i$. Fig 3 shows the calibration curves *A* and *a* in the case $^{56}Fe + p \rightarrow ^{56}Co$ at E=11.4 MeV. It seems that the second one is more convenient for mathematical description of metrological characteristics.

In this case the function f(a) may be described by polynom of power m with non-negative coefficients:

$$x = \sum_{k-1}^{m} b_k \times a^k \qquad 7.$$

Such representation is possible when the bombarding energy does not exceed the excitation function maximum position. For many practically important materials a sufficient part of coefficients is near zero. Consequently the above expression is simplified: $x = b_1 a + b_k a^k$. In particular the curve given on the Fig. 3. may be described in the range $a < 0.6\text{-}0.8$ with the error about 3 % by the polynom $x = 127.a + 31.8.a^{3.5}$. Table II gives information on the iron activation by protons at 11 MeV.

The most important form of the calibration curve is a straight line; in this case the activity decrease is proportional to the removed layer thickness. The material irradiation by accelerated ions with the energy near the excitation function maximum gives a good approximation.

This information may be obtained by bombarding the machine part surface covered by a thin foil of the same material and monitoring the activity with the foil and without it. However, the error of such approximation is often rather significant and it is in general incorrect for low activation depth (less than 50 μm).

Several ways exists to obtain calibration curves. Some researchers use curves calculated from the known excitation functions [8,9]. Their integration was carried out either numerically or using some approximate expression for the range R [10] and the stopping power dE/dx [11]. The calculated radionuclide profile has a large error (can reach 20 % [9]) which is connected not only with the calculation difficulties. While measuring the excitation functions with a typical error of 10 % the investigators try to deliver from such factors as recoil nuclei leaving their formation points and activity arising below the reaction threshold owing to straggling. In the real activity distribution these phenomena take place, therefore the calculated calibration curve may serve as a certain approximation.

Experimental calibration curves are more precise, they may be obtained either by the "stack of foils" technique, or by abrasion of a standard. The depth distribution measurements allow to obtain the A(x)-curve with a minimum relative error reaching in some cases less than 1 % for both coordinates. Thick target yield curves are measured usually in the same way. This technique is simple and can be realized with foils either of machine part material or of pure element initial for the measured radionuclide production. Iron can represent all steels, copper-bronze and brass etc., the error of such approximation does not exceed 1-2 %. A modification of this technique for non-plastic materials is the irradiation of thick samples by particles of different energy values.

Abrasion of standards is a good way of calibration the only possible for a very thin radioactive layer. A standard must be manufactured of the same material as the component part and identically irradiated. The calibration curve is obtained by its radiometry while taking away the upper layers. This procedure is carried out either by abrasion with the help of special tools and abrasives or by chemical etching and electropolishing. It is rather labour-consuming and impossible to repeat otherwise than with a new sample. The error of such calibration does not exceed 2-3 %. The activity leaning the very surface layer owing to removal of recoil nuclei may be corrected by the irradiation of a surface covered by a thin foil of a similar composition.

The obtaining and use of calibration curves require a good reproductivity of irradiation conditions. The main errors arise from the particle energy and angle of beam incidence instability.

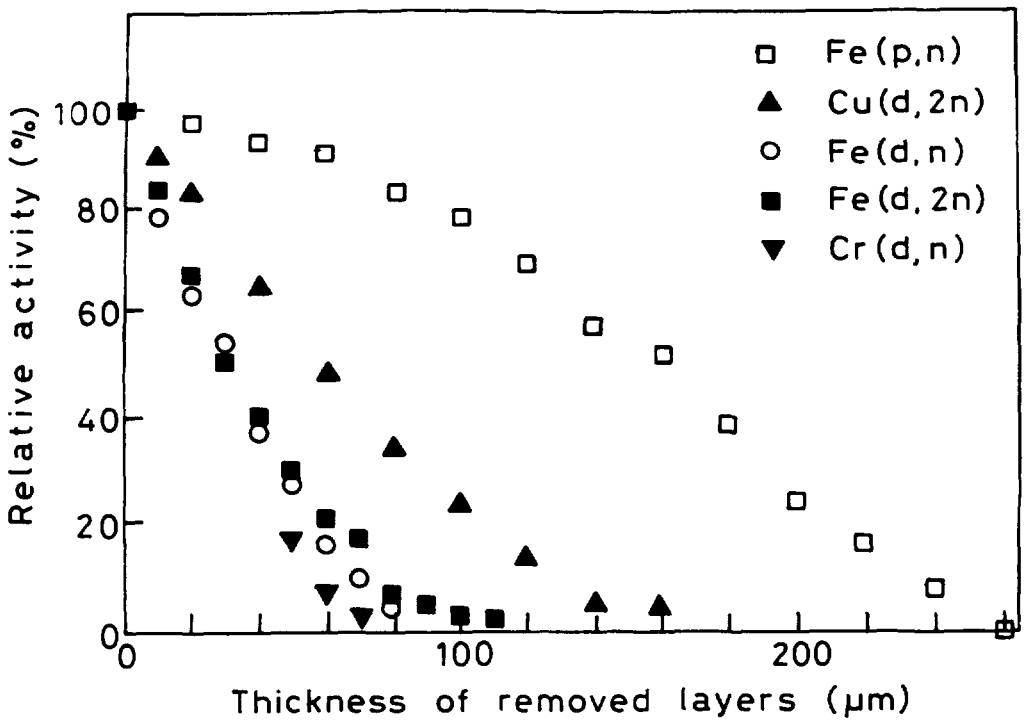

FIG. 3. Calibration curves by using different nuclear reactions: 1. $^{56}Fe(p,n)^{56}Co$ E_p = 14 MeV; 2. $^{65}Cu(d.2n)^{65}Zn$ E_d = 13 MeV; 3. $^{56}Fe(d,n)^{57}Co$ E_d = 8 MeV; 4. $^{56}Fe(d,2n)^{56}Co$ E_d = 13 MeV; 5. $^{54}Cr(d,2n)^{54}Mn$ E_d = 13 MeV.

TABLE II. ACTIVATION OF IRON BY PROTONS WITH INITIAL ENERGY 11MeV (FE+P → ^{56}CO)

Particle energy	Range	Yield	Activity	
E, MeV	R,	Y	A	a
relat. units	$mg.cm^{-2}$	$kBq.\mu A^{-1}.h^{-1}$	rel. units	rel. units
11.0	245.1	392.2	1.000	0
10.5	226.7	329.3	0.842	0.158
10.0	208.3	262.7	0.668	0.338
9.5	191.0	196.1	0.500	0.500
9.0	174.3	136.9	0.352	0.648
8.5	158.2	92.5	0.238	0.762
8.0	142.9	59.2	0.153	0.847
7.5	128.2	33.3	0.087	0.913
7.0	114.3	18.5	0.048	0.952
6.5	101.0	7.4	0.025	0.975
6.0	88.5	0.37	0.009	0.991

The latter is considerable at low angles (Θ <15°). Energy change affects not only the abscissa axis (material depth) but also the ordinate (activity), becoming significant at the steep part of the excitation function. Not only the average value of bombarding energy but also its distribution width are of importance and the calibration curves obtained at Tandems and Cyclotron may somewhat differ for the same mean energy of the ion beam.

Thus it is evident that calibration is to be carried out at the very similar irradiation conditions. If they are stable and well checked the calibration curve may be obtained with an error about 1-5 % from a set of curves received beforehand for the basic materials and irradiation conditions.

Since TLA technique is a measuring method, it is necessary to estimate its metrological possibilities and characteristics, such as error, sensitivity, determination limit [12]. The error of the layer removed value depends on the measuring error of a-value (S_a) and on the lack of coincidence of the machine part and the standard irradiation conditions. It may be evaluated by an expression:

$$S_x^2 = \left[\frac{df}{da} S_a\right]^2 + S_{act}^2 \qquad 8.$$

The measuring error includes statistical and mean-square components, the latter is caused by the irreproductivity of the measurement geometry and instability of equipment. When using a single-channel scintillation spectrometer for a label-detector distance (r > 10 cm) this error is scarcely less than 2-3 %.

The main contribution in the S_x - value is introduced by the second term, particularly at low irradiation angles (Θ < 15°) and large x-value. In traditional application of TLA techniques when d > 50 μm and 0.1 < a < 0.7 the relative error S_x/x is about 10 %, though in some cases it may be lower.

An important characteristic gives the detection limit, i.e. the minimum depth loss that can be evaluated with a given reliability. In usual conditions given above this value is about 0.5-2.0 μm. Its lowering requires thinner labels and precise calibration. The sensitivity of TLA techniques [dA/dx ⊗ 1/A] or [dA/dx - A^{-1}] is determined as the activity of the upper elemental layer; the resolution is the depth loss increment evaluated with a given reliability.

The parameters introduced and determined above allow to choose the irradiation and calibration conditions. The main requirement of the technique is the close coincidence of these conditions.

3. ALTERNATIVE METHODS FOR PRODUCTION OF THIN RADIOACTIVE LAYERS

In some special cases one cannot use the above mentioned arrangements to introduce thin radioactive layers in the surface of different samples. The reasons of that could be the followings:

- Suitable particle accelerator is not available.
- The machine part in question is too big or has too complicated form to irradiate.
- Extremely thin radioactive layer is necessary.
- The matrix or trace elements of the sample cannot be activated by using the available bombarding particles and energies.

For solving the above cases some alternative methods have been developed.

3.1. ISOTOPE DIFFUSION

The isotope diffusion means the diffusion of radioactive isotopes under artificial inducing conditions into the surface of the sample from a prepared chemical solution of the above isotope.

3.2. RECOIL ACTIVATION

If the major matrix or minor elements of the machine part to be investigated cannot be activated with the available bombarding particles at the available energies of the given particle accelerator, there is a possibility to introduce secondary radioactive particles from nuclear reactions. This case is also a proper solution when the amount is very small, so extremely thin radioactive layer is necessary for testing.

A thin target (few tens of micrometers) containing the element **A** is bombarded by a beam of charged particles **a**, and the element **A** is activated through the nuclear reaction **A(a,b)B.** A part of radioactive nuclei **B** have sufficient kinetic energy to leave the implantation target and to penetrate into the target.

In case of foil target bombardment by light incident particles where the energy does not exceed 40 MeV, the energies of the recoiling radioactive ions **B** are between a few hundreds keV and several MeV. The maximum implantation depths in the material are between a few micrometers for medium mass radioactive nuclei (^{7}Be, ^{22} Na) and tens to hundreds of nanometres for heavier nuclei (^{48}V, ^{56}Co, ^{65}Zn).

The calibration procedure differs in accordance with the implantation depth. If the implantation depth in the micrometer range, the depth profile of the radioactive recoil nuclei can be determined by using the stacked foil technique [17,18,30]. Under the micrometer range the calibration procedure is based on the thin film technique, where the composition of the film must be similar to that of the sample.

4. MEASURING METHODS

4. 1. ACCELERATORS, IRRADIATION

For the purpose of thin layer activation mainly charged particle accelerators (cyclotron, van de Graaff, ...) are used in the medium energy range (5-30 MeV) and in special cases when volumetrical irradiation is necessary also nuclear reactors or neutron generators, but in this case the rules of radiation protection probably does not allow an in-situ measurement because of the high level of radioactivity.

For the irradiation of the diverse size machine parts a well developed irradiation station is necessary, possible with large volume vacuum chamber, but for big samples an external beam is extremely suggested. In the case of external beam the beam hits the sample surface after several cm path in air, which means several hundred to 1-2 MeV energy loss, which must be taken into account by planning of the irradiation. The scheme of the typical irradiation geometry is shown in Fig. 4.

To keep the expenses of the method at the lowest level, the intensity (beam current) of the irradiation should be high to achieve well measurable activity within maximum 1-2 hours. This

beam-current is typically in the 0.1-10 μA range, and the produced activity - after suitable cooling-time - allows in-situ measurements.

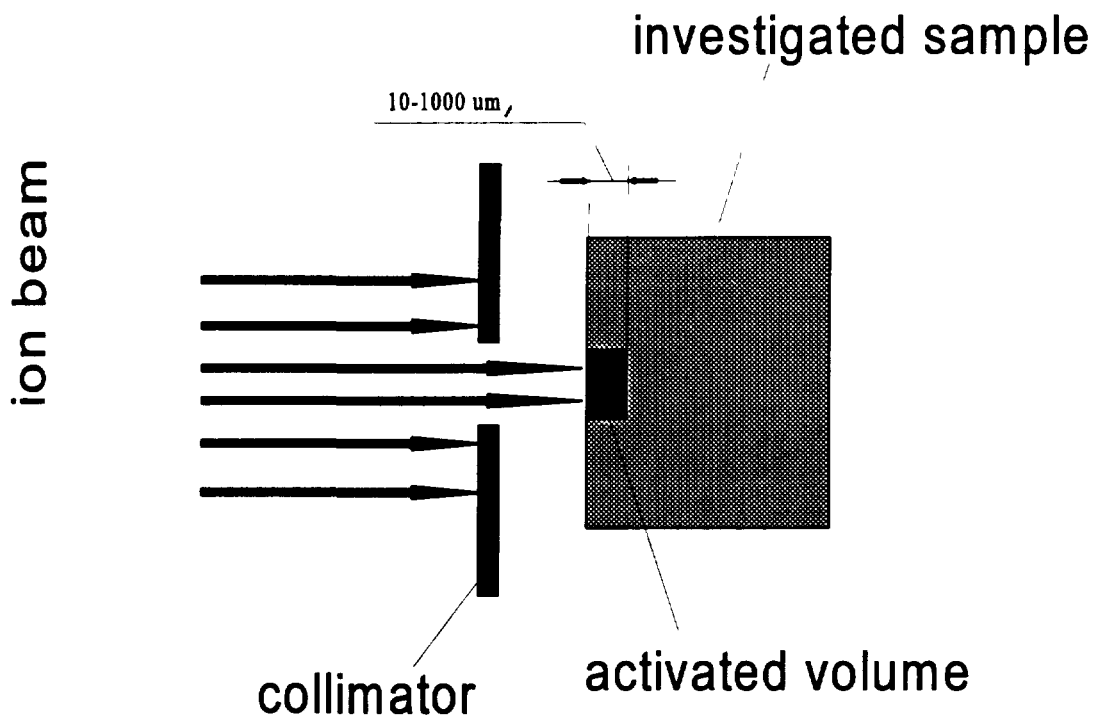

FIG. 4. Typical irradiation geometry for Thin Layer Activation.

4.2. MEASURING THE ACTIVITY AND THE WEAR

After irradiating the sample a so called cooling time is necessary to allow the produced short lived isotopes to disintegrate under a level which does not influence the wear measurements and not dangerous for the health of the personal.

Depending on the half-life of the produced isotope the monitoring time (the time within the wear measurement must be performed) and the cooling time varies from days to months (even years).

The activity of the irradiated machines parts should be measured by gamma spectrometer. The type of gamma spectrometer depends on particular application of TLA and can be either a single channel or multichannel spectrometer. The first measurements (e.g. measuring the calibration curves) can be performed in laboratory conditions by using the relatively expensive semiconductor detector systems (Fig. 5.). When the particular method has already been developed and tested, it can be put into on-site application by using the cheaper scintillation technique (Fig. 6.).

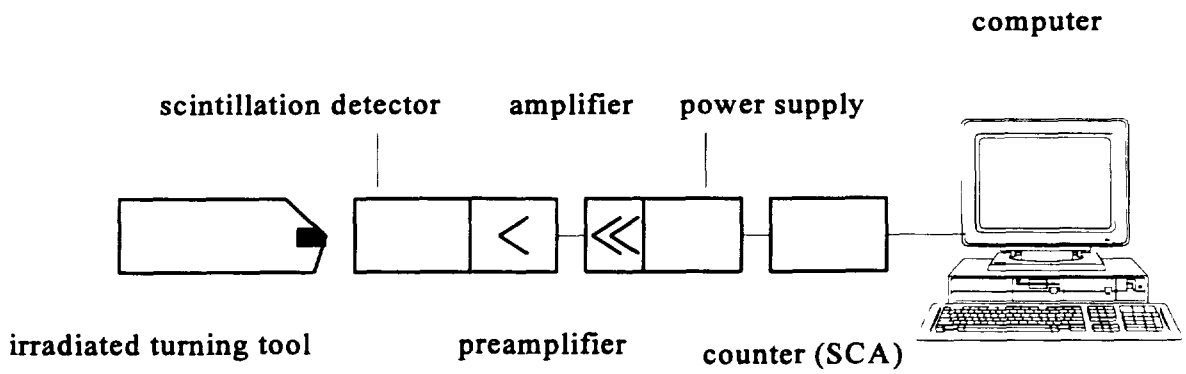

FIG. 5. Typical arrangement for wear measurements with scintillation technique.

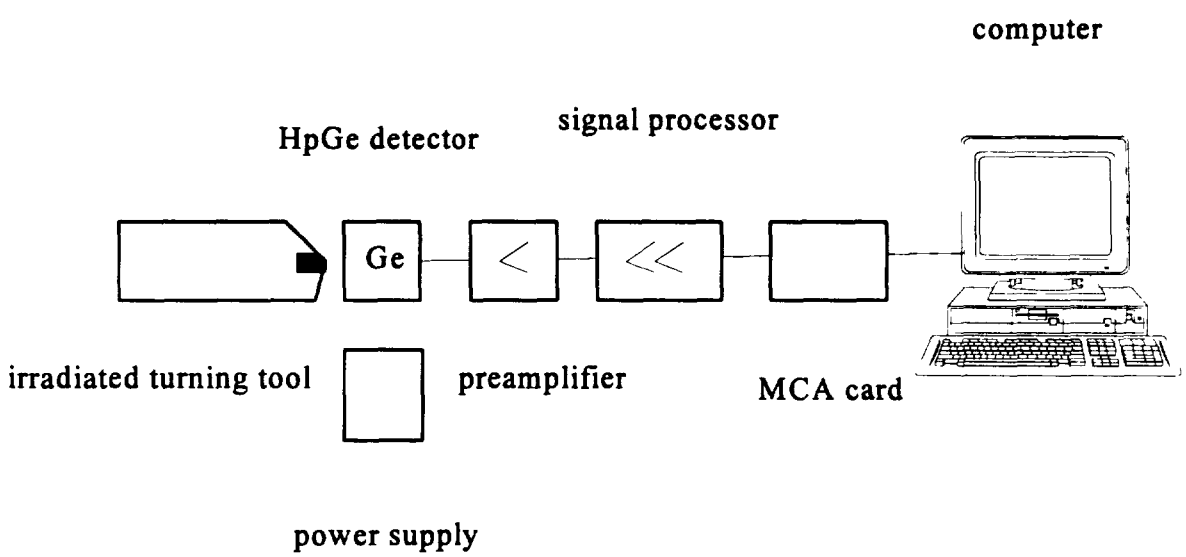

FIG. 6. Set-up of a spectrometer system for wear measurements based on semiconductor detectors.

The simplest spectrometer is a single channel analyzer coupled with scintillation NaJ(TI) detector. Such spectrometers cost around US$ 4,000 and are widely used in the field conditions In turn, a multichannel analyzer (sometimes PC-based) coupled with (HpGe) detectors cost around US$ 15,000 and are used in laboratory conditions mainly.

There are many commercially available gamma-spectrum evaluation programs which differ from one another in the services and presentation capability.

In most cases of TLA application a simple photopeak search and fitting with background is enough.

The measurement of the amount of wear (corrosion, erosion) is based on the comparison of the measured activity values after different periods with the calibration curves, and converting the loss of the activity into material loss.

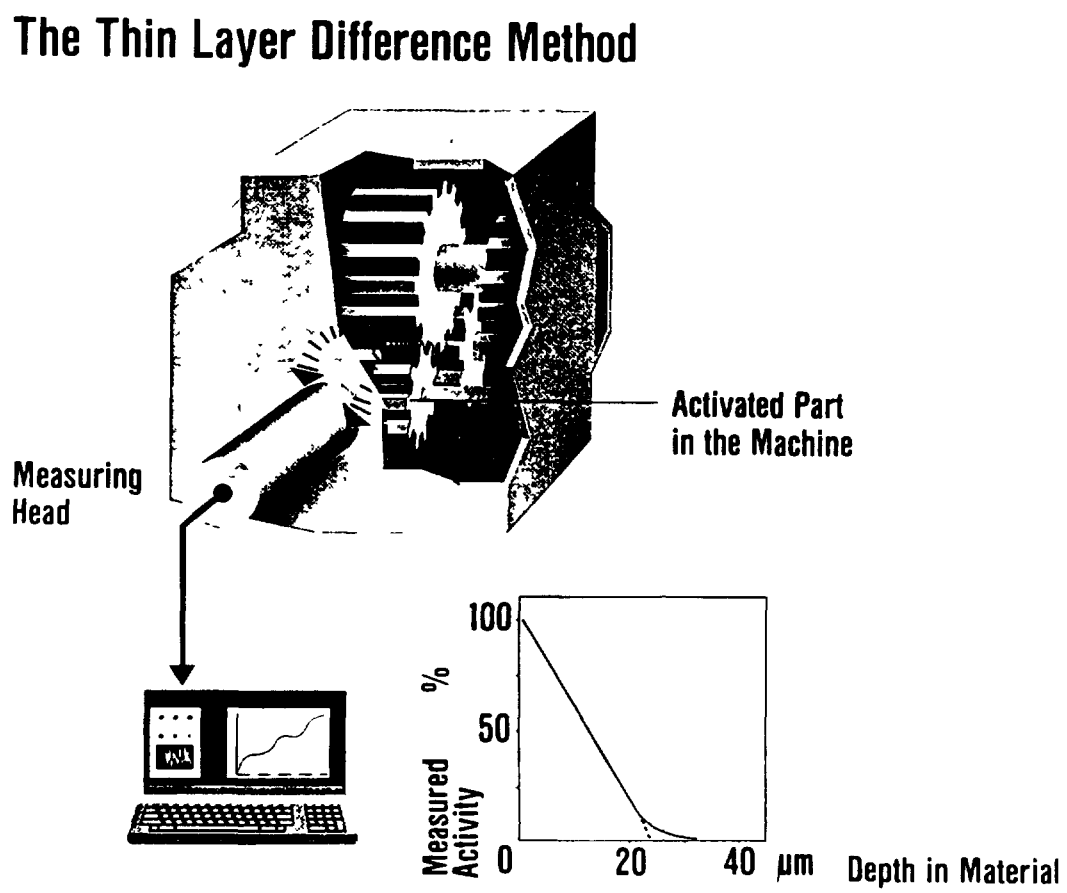

FIG. 7. The layer difference technique.

5. APPLICATIONS

5.1. APPLICATION TECHNIQUES

There are two techniques in TLA application, namely the thin layer difference technique and the concentration measurement technique.

In the first technique, the activity of the irradiated machine part is measured by gamma spectrometry systems (Fig. 5.,10.). The loss of activity is converted to the wear rate using the calibration curves. The sensitivity of this technique depends on the type of applications and a typical value of wear rate is around 0,01 μm/h.

In the second technique, the activity of the removed layer (e.g. wear products) is measured by one or more gamma spectrometry systems (Fig. 5.,11.). The activity of the wear products can be measured either in a special oil filter or in oil flow itself. This technique allows to monitor at least two wearing areas simultaneously.

The sensitivity of this technique for the typical cases is around 1 nm/h.

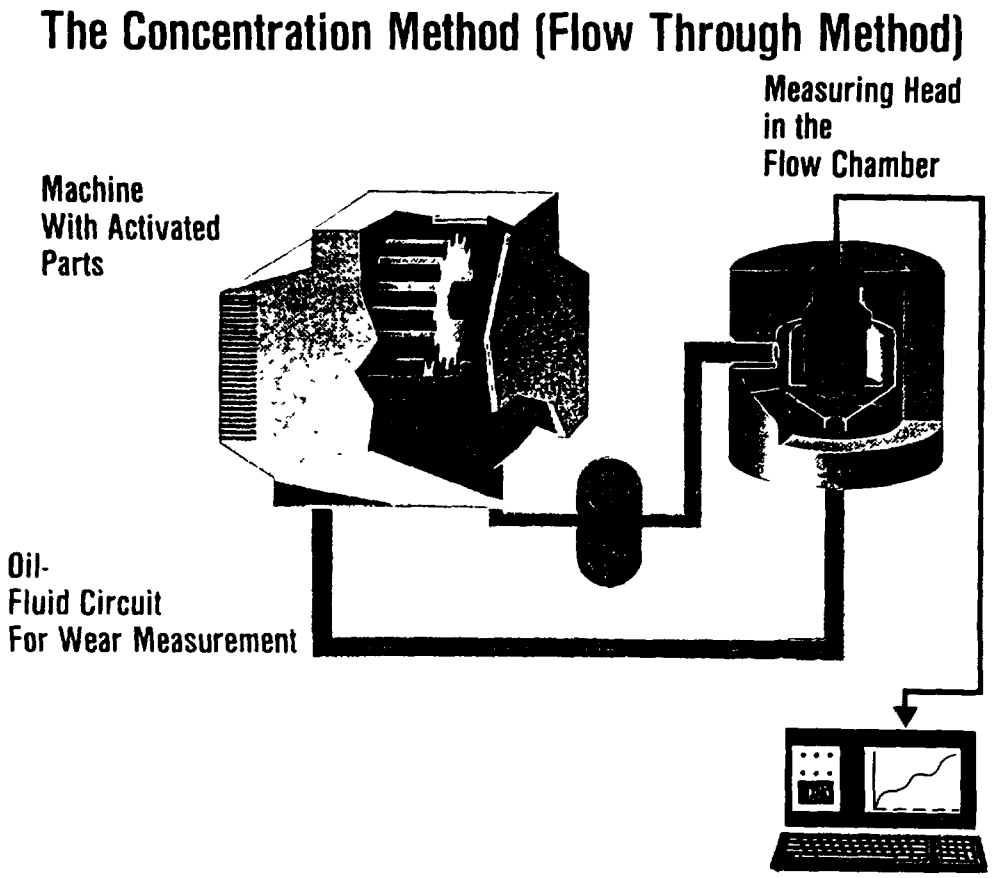

FIG. 8. The concentration measurement technique.

5.2. PRACTICAL EXAMPLE

Task: To measure the real wear rate of the steel-made camshaft, provided that the expected rate is around 10 nm/h and the maximum monitored wear is around 150 μm.

Solution: To create an uniform distribution of radionuclide ^{56}Co (which is produced by irradiation of iron component of steel by protons), it is necessary to irradiate the camshaft with 13.8 MeV energy protons (see Fig. 9.).

The thickness of the activated layer is equal to 190 μm. To create the requested 150 μm thickness layer, the camshaft has to be irradiated at the angle as follows:

The typical experimental activity ≈ 3,6 MBq can be reached by dose irradiation around 10 μA.hr.

$$\Theta = \sin^{-1}\left(\frac{150}{190}\right) = 52^{o} \qquad 9.$$

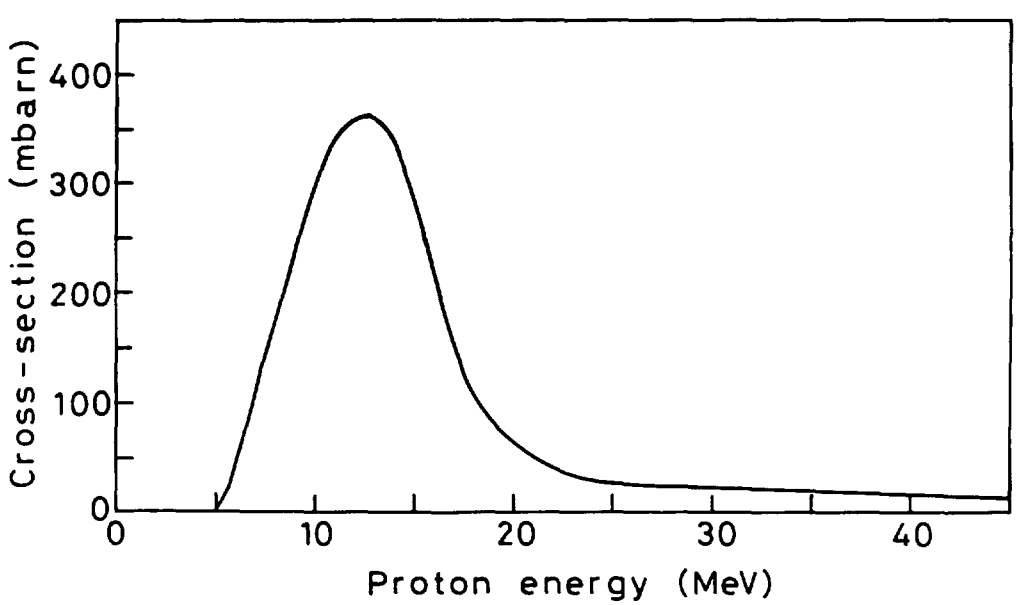

FIG. 9. Cross section of nuclear reaction Fe + p → ^{56}Co

5.3. PRACTICAL IRRADIATION SET-UP

Activation of a large machine part could be demonstrated by irradiation set-up for a cylinder block of combustion engine (Fig. 10.). The beam from a cyclotron leaves the evacuated beam tube through a thin metal window and hits the cylinder adjusted at a distance of 150 mm in from of the tube head. The engine block is rotated precisely around the axis of the bore. The incident particles beam produces a regular annular label in the Top Dead Centre (TDC) of the piston ring [20].

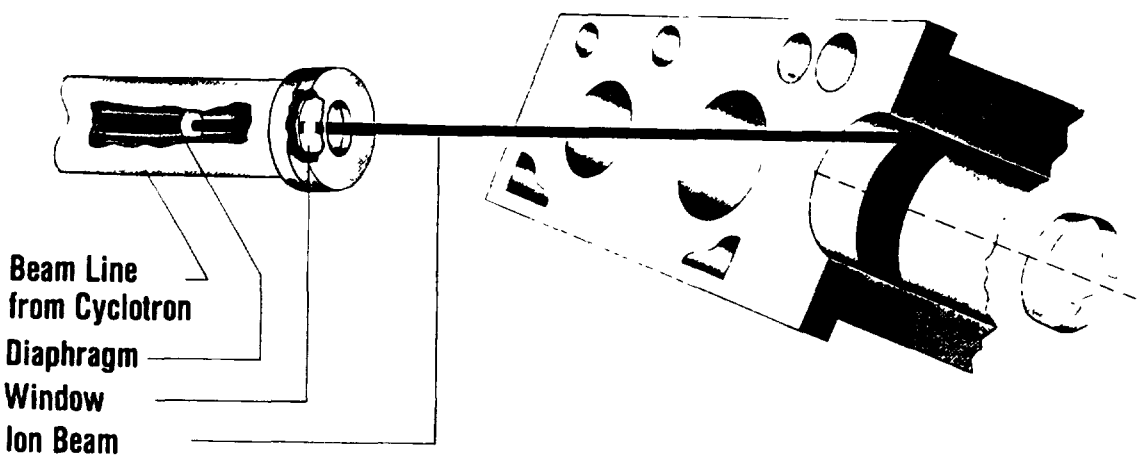

FIG. 10. Irradiation set-up of an engine block: precise and uniform labelling on the cylinder bore for wear measurement in the TDC of the first piston ring ("gusset wear").

5.4. CASE STUDIES

In the following sub-sections we have chosen some typical applications from the works of the participants of this program.

5.4.1 Measurement of the wear of piston rings in internal combustion engines

I.O. Konstantinov
Institute of Physics and Power Engineering, Obninsk, Russia

The wear profile and azimuthal movement of piston rings are studied with the help of the radionuclide technique. A thin layer of the friction surface was labelled with ^{56}Co by charged particle

irradiation [12,16-17,22]. The wear of a certain section of the ring was determined from measurements of the gamma-ray intensity. The angular coordinate of the section observed is determined by radiation detection of the point labelled with another radionuclide (^{51}Cr) confined to the unworn surface.

Piston rings of a tractor engine were activated with external beam of a cyclotron[24,28]. The friction surface of cast iron rings was irradiated by protons to produce ^{56}Co ($T_{1/2}$ = 78.5 d., E_γ = 847., 1238. keV) in the material. The proton energy of 7 MeV and an incident angle of 30° were chosen to provide and activation depth of 20 μm, which slightly exceeds the expected wear. A compressed ring mounted in a special jig was rotated in front of the bombarding beam to provide uniform activity distribution along the activated circumference.

As a second label a 3 mm diameter pin with ^{51}Cr ($T_{1/2}$ = 27.7 d., E_γ = 323. keV) was inserted in the butt-end surface of the ring gap. The total value of the labels did not exceed the free handling limit in Russia [see Table III.].

Two NaI(Tl) scintillation detectors were connected to single-channel analyzers and mounted on special brackets on the outside of the installation in a plane normal to the cylinder axis. The discriminator level of unit 1 was set to 0.7 MeV to detect only the radiation from ^{56}Co. A slit collimator in front of this unit limited the observed sector to about 10°. The radiometer unit 2 detected the radiation energy in the range of 0.25-0.4 MeV for determination the angular position, allowing to collect the counts from ^{51}Cr and a contribution of ^{56} Co in less then 20%, which were later taken into account in background calculation.

The evaluation was made concerning the normal wear measurements [16]. The calibration curves were taken, and the removed layer thickness to removed activity function was determined [28]. The advantage of the method for such type of studies was proven.

5.4.2. Measuring the wear of railway rails

P.M. Racolta
Institute of Atomic Physics, Cyclotron Laboratory, Bucharest, Romania

A study aiming to evaluate the wear of a rail vs. traffic and loading was made based on the remnant activity measuring method [29]. A piece of rail (2 m long) was labelled with 8.5 MeV deuterons in several points placed at different distances from the inner edge [Fig. 11.]. After checking this rail sector was fixed in real operating conditions in a testing loop. Sensitivities of about 1 μm depth were enough for obtaining good wear curves [16,21-23],. This test proved to be useful for the Romanian Railway Company for an optimum rail replacement planning.

5.4.3. Anti wear testing of synthetic and mineral oils

P.M. Racolta
Institute of Atomic Physics, Cyclotron Laboratory, Bucharest, Romania

Testing of the anti-wear properties of both synthetic and mineral oils was performed intensively in the last years [23,27,39]. A study of wear characteristics of various Romanian mineral oils was made with usual mechanical transmission. The aim of the experiment was to obtain solutions for oil-consumption reduction and real working time determination. The experiment was performed on a gear box testing stand, and the possibility of controlling the gear torque in steps was available. The whole surface of the teeth was homogeneously labelled by 8.5 MeV deuterons. The results are presented in Fig. 12.: gripping limit determinations for twelve type of mineral oils (the mechanical

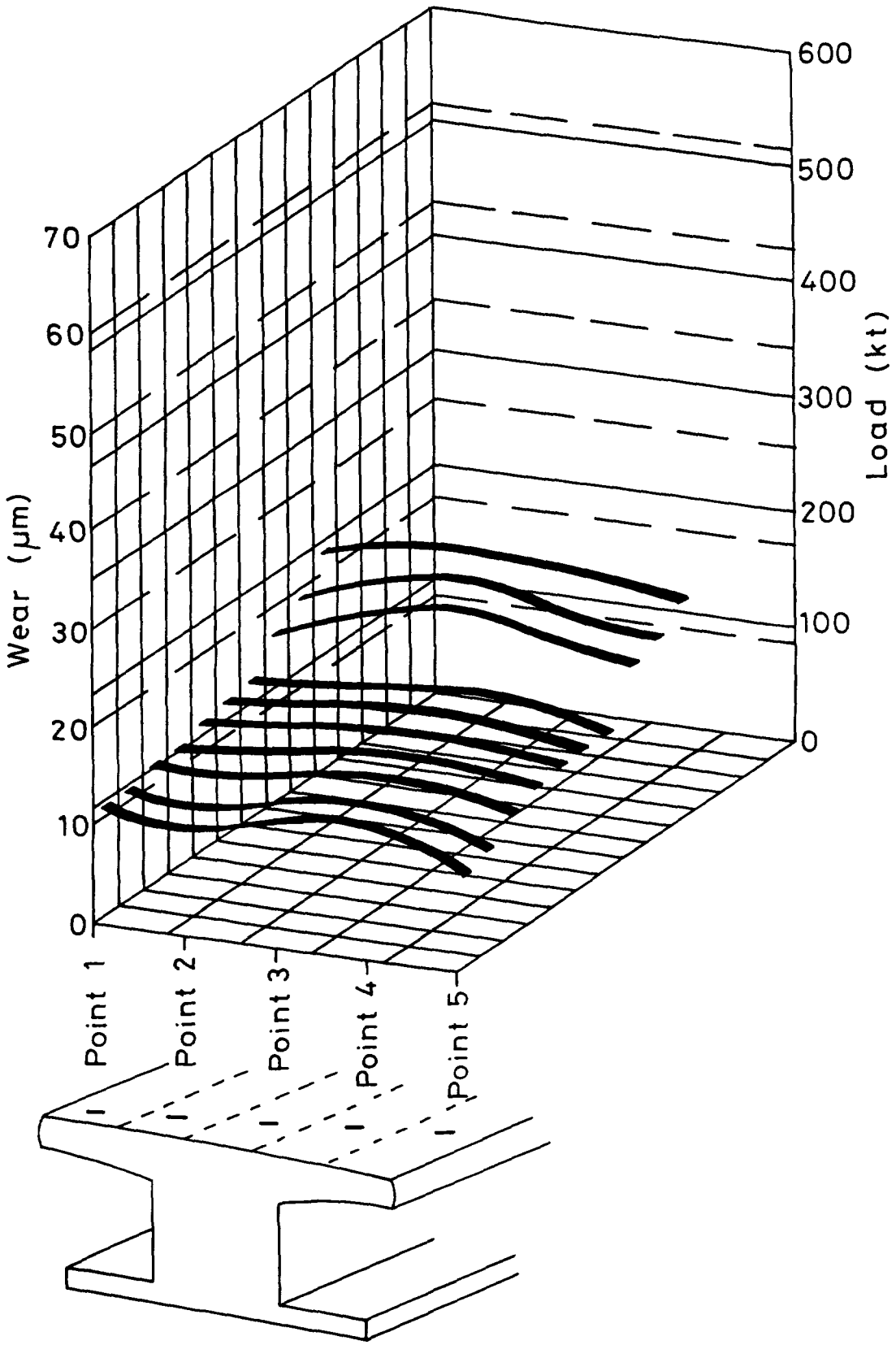

FIG 11. Irradiation and wear-test geometry of a piece of rail.

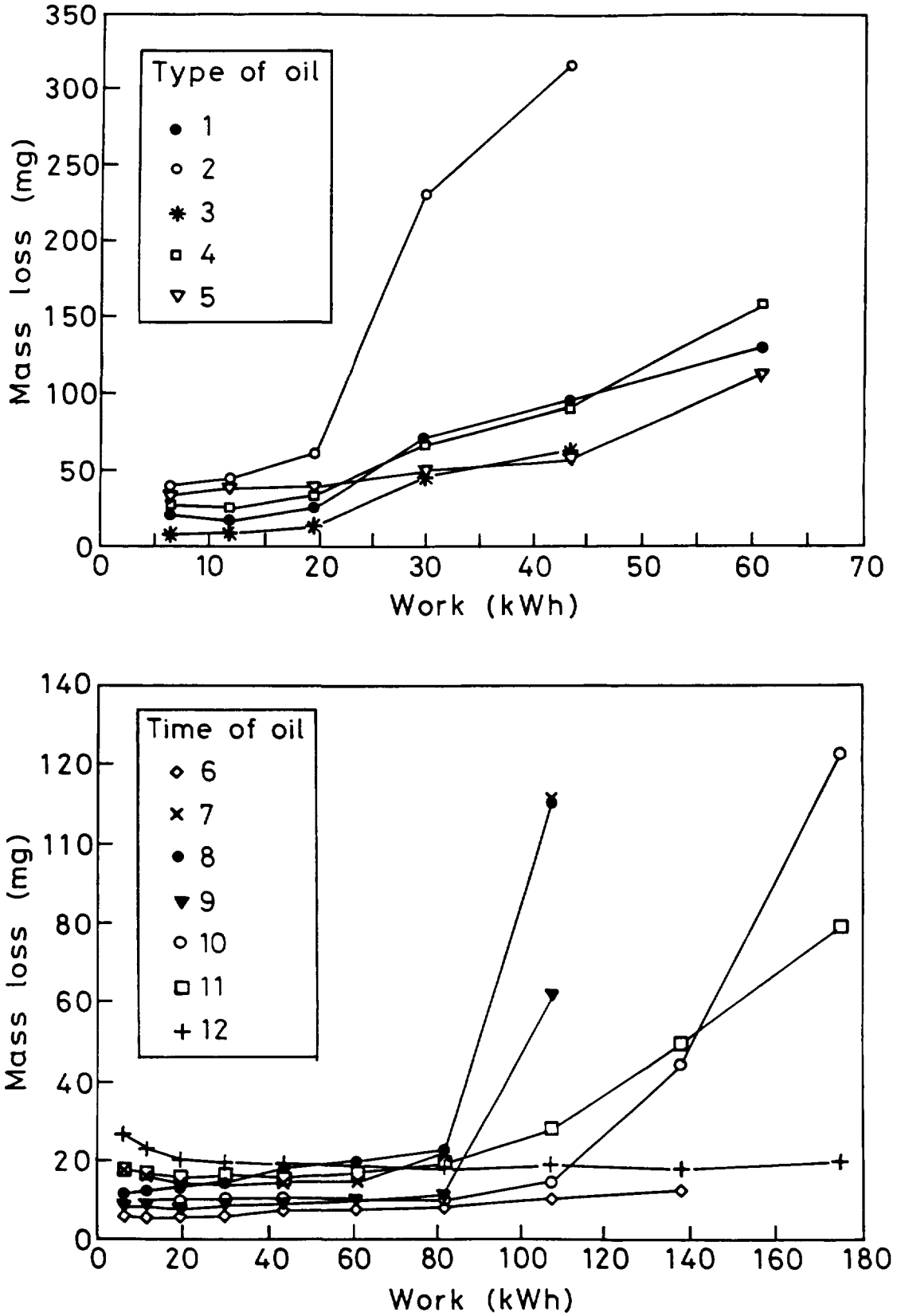

FIG. 12. Investigation of wear of different mineral oils.

work values correspond to the gripping working regime). Of course the wear rate was determined by measuring the radioactivity level of the wear particles from the oil bath [25-26].

As a conclusion we could state, that the TLA method can well distinguish between the different types of oils on the basis of their anti-wear properties.

5.4.4. Thin layer activation with isotope diffusion

A.S. Khanna
Indian Institute of Technology, Bombay, India

3700 kBq $^{59}FeCl_3$ was used to diffuse ^{59}Fe into steel sample. Two drops of this solution were placed onto the sample surface. After drying the ferric-chloride solution, the sample was heated in hydrogen atmosphere for 4 hours at 4000 °C to transform the ferric chloride into the metal. The sample was then heat treated, at 900 °C for 20 hours in hydrogen to diffuse ^{59}Fe into the iron matrix.
After the 20 hours period, the sample was cooled to room temperature in the furnace in hydrogen atmosphere.

Initially the sample had an activity of about 30,000 counts, when counted in contact with the detector 20 for seconds. The activated sample was then exposed to 1M hydrochloric acid solution and the activity of the sample was measured periodically.

The activity of the sample was decreased with the time. After 600 minutes the rate of decrease in activity of the sample was very small. In other words, the decrease in activity was found to level off with time. It can be said that as the thickness increases, the presence of radioactive species will reduce and beyond a particular thickness their distribution will be low.

The observed behaviour can then be attributed to this low distribution of the radioactive species as thickness increases. The increase in activity of the solution with time also shows the same trend, confirming the behaviour.

To study the response of the irradiated sample to the variation in the applied potential the variation of the activity with the electrochemical potential can be studied. For the study a corrosion cell has been fabricated, made of perspex, with provision for inserting reference electrode and counter electrodes. The sample holder is made from nylon rod. The cell assembly can be coupled to a scintillation detector for the in-situ measurement of corrosion rate, with simultaneous monitoring of activity loss due to material dissolution.

This method is proved to be useful when only very thin layer have to be activated [19] and the conventional [16,21-23] or other alternative methods [17-18] are not available.

Abrasive wear tests were also carried out on these samples and a good correlation between weight loss and corresponding wear rate was established. Fig. 13. shows the variation in the number of counts (which corresponds to the weight loss due to wear) with the number of strokes of the sample on the abrasive paper. It can be seen, that with increase in the number of strokes, the number of counts detected decreases in a linear fashion which is due to the reduction in the activity due to abrasion.

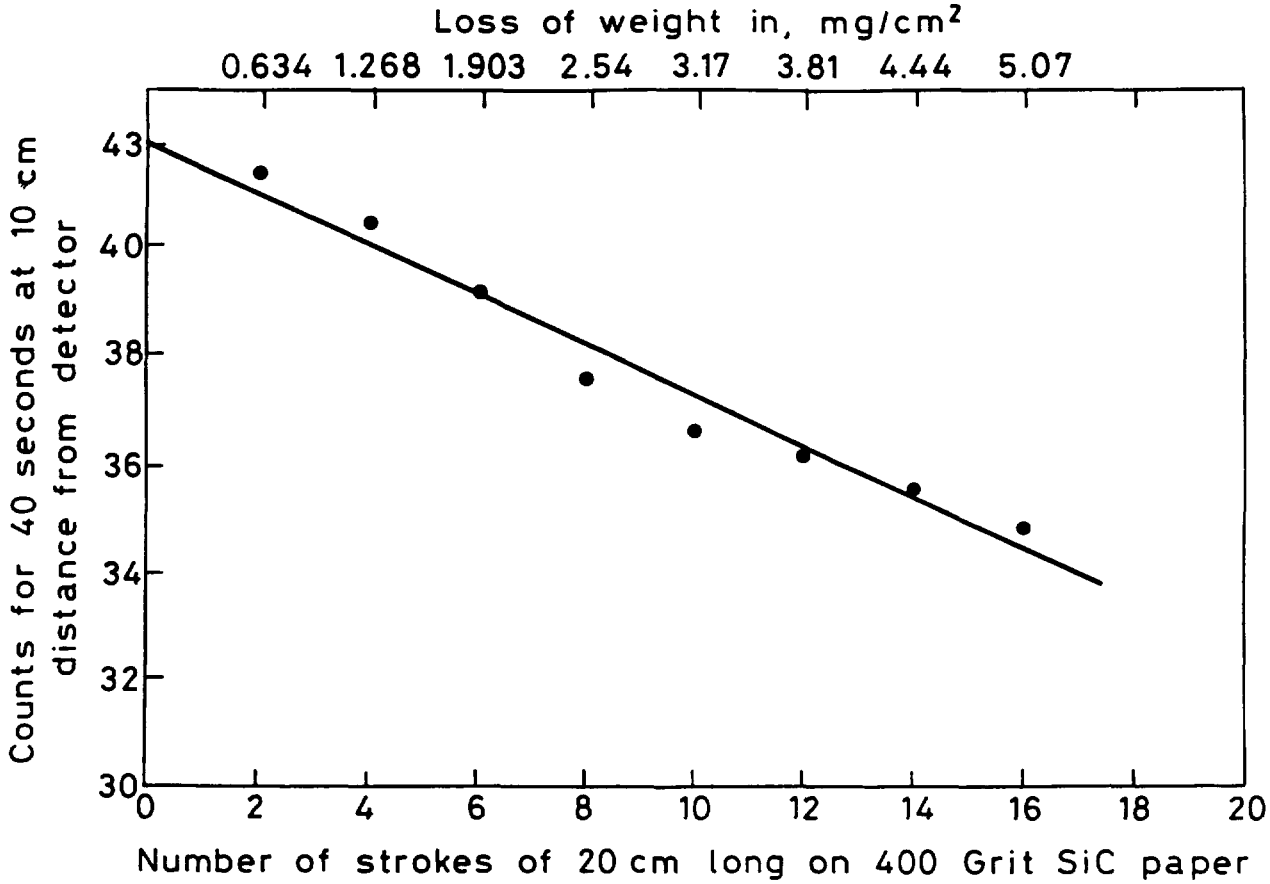

FIG. 13. Wear rate using isotope diffusion method - a plot of loss in activity of the active layer as a function of number of times the active sample was rubbed on 400 Grit SiC paper.

5.4.5. Corrosion study of mild steel samples

A.S. Khanna
Indian Institute of Technology, Bombay, India

Mild steel samples of 8 mm diameter were polished and irradiated 20 MeV protons by using a Pelletron accelerator. The corrosion experiments were carried out in 1M hydrochloric acid solution. The sides of the sample were covered with lacquer and only the irradiated surface was exposed to the hydrochloric solution. Before immersing into the acid, the activity of the sample was measured by a Na(Tl) scintillation detector [16,21]. The measured counts were corrected by subtracting the background. Initially, the sample had an activity of 86,100 counts at a distance of 10 cm from the detector when counted for 20 seconds. After the immersion the sample was periodically removed, washed, dried, and the activity was measured under similar conditions.

To find the correlation between the activity loss and the metal dissolution, another pin sample with known weight was exposed to the same acidic solution under identical conditions. This sample was also periodically observed, and the weight-loss was measured. After 18 hours exposure the sample activity was reduced by only 4 %. But the measured corrosion rate was quite high, corresponding the behaviour of the material in acidic solution. The reason for the higher remaining activity of the sample can be attributed to the presence of a relatively thick active layer in the range of 300-400 μm.

Since the decrease in activity with time is not very appreciable, it was decided to increase the corrosivity of the solution by setting its concentration to 6M. The above studies were repeated in 6M hydrochloric acid solution. In this solution the activity loss of the sample was found to be 17 %. In this case the corrosion rate was 2.4 times higher than before. Corrosion process leads to a decrease in the activity of the irradiated sample with time, and the activity of the solution will increase at the same time. To correlate between the activity gain of the test solution and the weight loss of the sample, the activity of the hydrochloric acid was measured at regular intervals of time. The correlation between the weight loss of the sample and the increase in the activity of the solution was found to be good.

5.4.6. Measurement of the wear of cutting edges of turning tools

F. Ditrói, I. Mahunka
Institute of Nuclear Research, Debrecen, Hungary

Wear measurement of superhard boron nitride and artificial diamond turning tools was performed using thin layer activation technique [7,15-16,21-23]. The samples were irradiated in two different geometries to improve the sensitivity of the method and to change the region of wear to be investigated.

All the irradiations were carried out with an extracted beam. The charged particle beam was extracted from the vacuum chamber through a thin Al closing foil of the beam extractor. The closing Al foil was 13 μm thick and air cooled. For proper sensitivity and accuracy only a small part of the turning tool should be activated. Our beam can only be focused to an area of 1 cm^2. The further decrease of the beam size could be done by collimating. It means, that we have to use a small part of the extracted beam and the turning tool must be precisely positioned in front of the beam. For the required collimating of the beam and positioning of the turning tool a special sample holder was developed. This sample holder allows positioning of the turning tool behind the collimator under a microscope and clamp it down in a required angle to the beam. During the irradiation the beam current can be measured both on the collimator and on the target.

The sample holder with the turning tool was mounted on a remote controlled X-Y micro-positioning unit. Highest beam current on the target was found by moving the sample holder in the beam in X-Y directions.

At the investigations of turning tools we measured the residual activity of the tool after the forced wear process. For these measurements we could use different detector systems, such as high purity germanium semiconductor (HpGe) and NaI scintillation crystal. With the high resolution HpGe system one can measure gamma-spectra with high accuracy. In this case, with the sophisticated home-made evaluation program we could precisely subtract the background and separate the different peaks, and such a way precisely measure the calibration curves. It was also used to calibrate the NaI system to the special wear study.

The NaI system is much cheaper and more durable and less sensitive for shocks, than the HpGe above, so it can also be used at industrial plants. In most cases it is enough to use it with a differential discriminator and counter, when the calibration curves determined by the HpGe system are available.

For the simulation of the wear of the cutting edge a grinding machine with diamond wheel was developed. This machine was equipped with a microscope to measure the geometrical parameters of the ground part of the tool. With this machine we could perform the forced wear of the tools. The exact repeatability of the positioning of the tools in the sample holder of the machine was also solved. The revolving speed of the grinding plate and the wearing force can also be adjusted to perform normal wear in considerable time.

After measuring the calibration curves with the above arrangement the whole system including the NaI(Tl) spectrometer and counter was mounted in an experimental workshop on a turning machine to predict the optimal changing time of the very expensive tools.

For a more detailed description see Annex I and Ref. [16].

5.4.7. Thin layer activation with recoil implantation

F. Ditrói, I. Mahunka
Institute of Nuclear Research, Debrecen, Hungary

Aluminium machine parts and plastic protective coatings were investigated by using the recoil implantation method of the ^{7}Be radioisotope. This method is especially useful for wear measurements when only an extremely thin active layer is necessary [21] or the matrix material itself cannot be activated.

For measuring the calibration curves the spatial distribution of the radioactive ejectiles must be determined [19]. It has been measured by using a small implantation chamber, and bombarding both beryllium and carbon containing foils with ^{3}He beams. The optimum bombarding energy the foil thickness was also determined to assure the highest implantation rate from the reaction. At the same time the cross-section of the nuclear reactions in question were also determined by using the stacked-foil technique [17-18,30-37]

The investigated reactions for the above purpose:

Requirements

1. good mass ratio between the primary bombarding particle and the secondary ejectile (kinematic factor)
2. the secondary product (ejectile) must be light enough to penetrate the into the surface of the sample material
3. high yield of the chosen reaction at the available bombarding energy
4. strong gamma-line(s) from the product ejectile
5. considerable half-life of the product ejectile
6. availability of the implantation target.

Investigated reactions	*Fulfilment of requirements*
• ^{nat}B(p,x)^{7}Be	2,4,5
• ^{nat}B(d,x)^{7}Be	*1*,2,4,5
• ^{nat}C(^{3}He,2α)^{7}Be	1,2,4,5,6
• ^{9}Be(^{3}He,αn)^{7}Be	1,2,3,4,5,6
• ^{nat}Fe(p,xn)^{56,57,58}Co	3,4,5,6

From the above list it is obvious, that the best choice for recoil implantation is the ^{7}Be. Which has considerable half-life (53.2 d) and the gamma-energy is high enough (477 keV) to penetrate several cm iron without considerable loss of intensity.

5.4.8. Measurements of sparking plug cathode erosion rate by thin layer activation

*J.M. Petit *, T. Sauvage, G. Blondiaux, P. Rouveirolles***
Centre d'Etudes et de Recherces par Irradiation

The methodology of Thin layer Activation method has been developed to measure the erosion rate of an internal combustion engine spark plug cathode. The cathode composition is 95% nickel. The irradiation conditions have been chosen to obtain a loss of depth detection sensitivity about to one micrometer. The suitable nuclear reaction for this application is $^{58}Ni(p,2p)^{57}Co$ at proton energy of 15 MeV [30,35]. The erosion rate measurements must be performed after spark plug dismantling, because the removed particles by erosion phenomena can be caught by plug anode. The erosion rate of sparking plug cathode has been measured for several conditions of spark discharge (energy, electrode distance .....).

5.4.9. Use of thin layer activation for wear measurements of aeronautic components

T. Sauvage, O. Lacroix, G. Blondiaux
Centre d'Etudes et de Recherces par Irradiation

The Thin Layer Activation method has been applied in wear studies of external bearing race and carbon radial joint in reaction engine.

The nuclear reaction for external bearing race labelling is $^{56}Fe(p,n)^{56}Co$ at proton energy of 15 MeV [15,16]. A magnetic catcher is placed in oil closed circuit to collect removed radioactive particles. The caught particles activity is measured on line by NaI detector. Because of particle sedimentation into engine and oil circuit, the wear measurements are semi-quantitative. In this application, the method is used as alarm when the removed mass is greater than a fixed threshold. For an activation yield about to 500 kBq, the detection sensitivity is 45 μg.

The irradiation conditions of carbon have been studied to avoid any mechanic deterioration of the radial joint. Three area (static or dynamic contact) of the joint are irradiated by $^{12}C(^{3}He,2\alpha)^{7}Be$ nuclear reaction at ^{3}He incident energy of 13.6 MeV [17-19]. The wear measurements are performed after joint dismantling by HpGe detector. The depth loss detection sensitivity is 2μm.

6. POSSIBILITIES AND LIMITATIONS

A typical mode of the techniques considered above allows to determine the removed depth being average over the label area and ranging from nm up to mm and more. However, there exist more complex problems which may be worked out by this method.

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** Renault (FRANCE).

They concern the cases when several questions must be answered for one component part. Here we include such problems as the wear control of several points in one mechanism, determining of large and low wear rates with equal precision, non-uniform material loss control and others. The first of them is concerned a simultaneous wear control of several points in a mechanism or at the same surface. The remote points are measured separately by collimated detectors, the area resolution depends on the gamma-ray energy monitored and the installation geometry. Close or nearly matching radiation sources must be of different radioisotopes - it is possible for different materials and limited for similar ones.

The solving of some other problems is in the activity depth distribution adjustment. This procedure may be realized by combination of different irradiation conditions forming the ion beam of a required energy spectrum. The superposition of several profiles obtained may give a more steep shape of the calibration curve at the first part, make this curve being linear at the most part of activation depth or having several maximums.

When taking a specific problem it is necessary to obtain a lot of information concerning the component part itself and its operation or test conditions. Material information must include its chemical composition, structure, density, thermoresistivity and conductivity, design of the component and the surface are to be examined.

The test conditions must be described by external parameters (temperature, load, medium and agents involved) and approximate data of destruction rate, test duration and precision necessary. This information determines the experimental conditions of the techniques realization, particularly, particles type and energy, irradiation current and necessary cooling, incidence angle and activation rig design as well as the measurement geometry and conditions.

The numerous advantages of TLA techniques are evident. However, every specific technical problem has some restrictions of these abilities owing to the problem conditions and possibilities of the method. A short analysis of these restrictions will give a more clear view at the TLA techniques and its applications.

Absence of long-lived radionuclides resulting charged particle irradiation of N,O,F,P,S,Cl and weak activation of C and Si, as well as significant heating make very difficult the techniques application in the control of polymers, rubber, plastics, resins, fluoroplastic etc. Study of such materials would be more successful with a label created by the implantation of radioactive ions [19]. The activation by charged particles is preferably suitable for metals and alloys.

The maximum duration of wear (corrosion) monitoring by Thin Layer Activation Method depends on half-life of the radionuclide measured and ranges from 2-3 months for Ti,V and their alloys to several years for materials based on Al,Cr,Cu,Zn,Pb. The materials composed of Fe,Ni,Zr,Nb,Mo,W and some others may be studied during a year.

An important role for TLA applicability plays the effect of activation process on the bulk and surface properties of materials owing to heating and radiation damages. Typical irradiation conditions have no influence and it is necessary in any cases that this effect should not change the rate of the process under investigation.

Since the TLA control is carried out by the monitoring of tracer element different from the initial material (steel and iron - by ^{56}Co, copper alloys - by ^{58}Zn, etc.) its adequate behaviour must be reliable. While for wear there is no doubt about that for other destruction process, in particular, for corrosion the absence of selectivity to the different atoms of very small concentration (1.10^{8} - 10^{9}) must be verified.

The activity depth distribution must remain constant during the whole period of control. The effect of high temperature (several 100°C) and local stress may cause the radionuclide diffusion beyond the initial volume and the calibration will be useless. The presence of such conditions requires a special test of the technique applicability.

Substantial distance and thick walls between the radiation source and detector unit lead to counting decrease and put certain restriction on the measurement geometry if activity value ranges within the safety standards.

The restrictions of TLA applicability listed above do not reduce its advantages as most of real problems lie within the limits of its efficiency. In many cases these restriction may be removed by an appropriate modification or combination with other methods of control.

The thin Layer Activation method is a nuclear method and radiation safety aspect plays an important role in its spreading. Fortunately, the typical levels of activity do not exceed so-called "free handling" limits which are shown below [13, 14]:

TABLE III. FREE HANDLING LEVELS OF SOME ISOTOPES IN GERMANY AND RUSSIA

	Value of "free handling" limit, kBq	
Radionuclide	Germany	Russia
^{51}Cr	370	3700
^{56}Co	37	370
^{65}Zn	370	370

7. CONCLUSION

The Thin Layer Activation method is used in the industrial research and development in the developed and the developing countries. This method helps to increase the lifetime and reliability of various machines, installations and technological processes. At the same time the results obtained, for example, in automobile industry allow to design and to manufacture transport vehicles with low fuel consumption. The positive impact on the environment pollution has also been proved.

The most promising areas for TLA applications are as follows:

1. **Automobile and engine industry**
   piston rings (running surface, flanks)
   piston ring groves
   piston skirt
   all kinds of bearings: crankshafts, camshafts, connecting rods, etc.
   camshaft, camheads
   cylinder liner
   valve seat, valve shaft guidance
   fuel injection nozzle, injection pump, fuel tubes
   all kinds of gear wheels
   gear and gear-parts

2. ***Pumps***
   all kinds of sealing-surfaces of the housing, blades, roller, wheelers, etc

3. **Turbines**
   blades, distance-pins, shaft-bearings

4. **Refrigeration systems**
   compressor parts
   piston skirts
   cylinder wall
   shaft bearings
   rod bearings
   blades
   roller wheels and valves

5 **Printing machines**
   needles, guidance, bearings

6 **Textile machinery**
   Knitting machines: guidance, needles, connecting rods and bearings
   Mills: bearings, shafts, guidance

7 **Railway**
   wheel surfaces, brake discs, brake shoes, part of rails

8 **Chemical industry**
   reactor vessel, tubes and pipes, valve system, nozzle

9. **Oil industry**
   Test of anti-wear and anti-corrosion properties of lubricants
   transport pipe-lines

10 **Machinery**
   fabricating tools (turning tools, etc)
   bearings and other machine parts

11 **Other**
   cooling systems with liquid metals

REFERENCES

[1] WILLIAMSON, C.F., BOUJOT, J.P., PICARD, J., Table of range and stopping power of chemical elements for charged particles, Rapport CEA-R-3042 (1966).

[2] LANDOLT-BÖRNSTEIN. Numerical date and functional relationships in science and technology. New Series. Group 1: Nuclear and Particles Physics.

[3] MALUHIN, V.V., KONSTANTINOV I.O., Activation of construction materials on the cyclotron. Isotopi v SSSR, 44 (1975) 67.

[4] DMITRIEV, P.P., The radionuclide yield in the reaction with protons, deuterons, alpha-particles and He-3 ions. Energoatomizdat, Moscow (1986).

[5] ALBERT, P., et al., Thick target yields for the production of radioisotopes, Handbook on Nuclear Activation Data, Technical Reports Series No. 273, IAEA, Vienna (1987) 537.

[6] KRASNOV, N.N., Thick target yield, Int. Journal. Appl. Rad. and Isotopes, 25 (1974) 223.

[7] KONSTANTINOV, I.O., LEONOV, A.I., MIRONOV, V.N., The calibration of thin layer activation techniques, Isotopi v SSSR, 66 (1983) 20.

[8] SWITKOVSKI, et al., A new technique for the measurement of sputtering yields, Radiation effects, 29 (1976) 65.

[9] BEAGLEY, T.M., Laboratory assessment for a wear measurement technique using thin layer activation, Wear, 32 (1975) 117.

[10] MAXIMOV, M.Z., Range-energy relation for different substances, Journal. Exper. and Theor. Phys., 37 (1959) 127.

[11] ISHII, K., VALLANDON, J.-L., DEBRUN, The average stopping power method for accurate charge particle activation analysis, Nucl. Instr. and method, 150 (1978).

[12] LEONOV, A.I., KONSTANTINOV, I.O., TARASKO, M.Z., The metrological parameters of thin layer activation techniques. Preprints IPPE-1405 (1983) AND ippe-1615 (1984).

[13] DEUTSCHE STRAHLENSCHUTZVERORDNUNG, ver. 1986.

[14] THE STANDARD FOR RADIATION SAFETY (76/87) AND THE GENERAL SANITARY RULES (72/87). Russia.

[15] S. TAKÁCS, L. VASVÁRY, F.V TÁRKÁNYI, Remeasurement and compilation of excitation function of proton induced reactions on iron for activation techniques.Nucl. Instr. Meth. in Phys. Res. B89 (1994) 88.

[16] L. VASVÁRY, F. DITRÓI, S. TAKÁCS, Z. SZABÓ, J. SZÛCS, J. KUNDRÁK, I. MAHUNKA,Wear measurement of the cutting edge of superhard turning tools using TLA technique, Nucl. Instr. Meth. in Phys. Res. B85 (1994) 255.

[17] F. DITRÓI, S. TAKÁCS, F. TÁRKÁNYI, A. FENYVESI, J. BERGMAN, S.–J. HESELIUS, O. SOLIN, Investigation of the charged particle nuclear reactions on natural boron for the purposes of the thin layer activation (TLA). Nucl. Instr. Meth. in Phys. Res. B102 (1995) 389.

[18] F. DITRÓI, S. TAKÁCS, F. TÁRKÁNYI, I. MAHUNKA, Study of the $^{nat}C(^3He,2\alpha)^7Be$ and $^9Be(^3He,\alpha n)^7Be$ nuclear reactions and their applications for wear measurements, Nucl. Instr. Meth. in Phys. Res. B103 (1995) 412.

[19] F. DITRÓI, I. MAHUNKA, Thin layer activation of non–metallic materials by using nuclear implantation, Nucl. Instr. Meth. in Phys. Res. B113 (1996) 415.

[20] P. FEHSENFELD, A, KLEINRAHM, H. SCHWEIKERT, Radionuclide technique in mechanical engineering in Germany, J. Radioanal. Nucl. Chem., Articles, 160(1) (1992) 141.

[21] I.O. KONSTANTINOV, N.N. KRASNOV, Determination of the wear of machine parts by charged particle surface activation, J. Radioanal, Nucl. Chem. 8 (1971) 357.

[22] P.M. RACOLTA, L. POPA–SIMIL, E.A. IVANOV, B. ALEXANDREANU, Cyclotron accelerated beams applied in wear and corrosion studies, Radiat. Phys. Chem. 47(5) (1996) 677.

[23] P.M. RACOLTA, Nuclear Methods for Tribology, Appl. Radiat. Isot. 46(6/7) (1995) 663.

[24] B. CONSTANTINESCU, E.A. IVANOV, G. PASCOVICI, L. POPA-SIMIL, P.M. RACOLTA, Thin layer activation techniques at the U-120 cyclotron of Bucharest, Nucl. Instr. Meth. in Phys. Res. B89 (1994) 83.

[25] E.A. IVANOV, G. PASCOVICI, P.M. RACOLTA, A nuclear scanning method for estimating wear level nonuniformities, Nucl. Instr. Meth. in Phys. Res. B82 (1993) 604.

[26] P.M. RACOLTA, L. POPA-SIMIL, E.A. IVANOV, B. ALEXANDREANU, Cyclotron accelerated beam applied in wear and corrosion studies, Radiat. Phys. Chem. 47(5) (1996) 677.

[27] O. LACROIX, T. SAUVAGE, G. BLONDIAUX, P.M. RACOLTA, L. POPA-SIMIL, B.ALEXANDREANU, Metrology conditions for thin layer activation in wear and corrosion-studies, Nucl. Instr. Meth. in Phys. Res. A369 (1996) 427.

[28] I.O. KONSTANTINOV, A.I. LEONOV, V.I. MIKHEEV, Surface activation for wear profile studies of piston rings, Wear 141 (1990) 17.

[29] P.M. RACOLTA, L. POPA-SIMIL, B. ALEXANDREANU, Resistance-to-wear testing of metallic machine components by charged particle surface activation, Appl.Rad.Isot. (in press).

[30] F. TÁRKÁNYI, F. SZELECSÉNYI, P.KOPECKY, Cross section data for proton, ^{3}He and α-particle induced reactions on ^{nat}Ni, ^{nat}Cu and ^{nat}Ti for monitoring beam performances, Proc.International Conf. on Nuclear Data for Sci. and Tech., Julich, Germany, 13-17 May 1991, Springer-Verlag Berlin Heidelberg 1992; pp.529-532.

[31] P. KOPECKY, F. SZELECSÉNYI, T. MOLNÁR, P. MIKECZ AND F. TÁRKÁNYI Excitation functions of (p,xn) reactions on ^{nat}Ti: Monitoring of bombarding proton beams. Appl. Radiat. Isot. 44 (1993) 687.

[32] F. SZELECSÉNYI, T. E. BOOTHE, S. TAKÁCS, F. TÁRKÁNYI, E. TAVANO AND M. PLITNIKAS , Nuclear data relevant to the production of ^{67}Ga: A critical comparison of excitation functions/thick target yield data for ^{67}Zn(p,n) and ^{68}Zn(p,2n) nuclear reactions. Proc. of the Fifth Int. Workshop on Targetry and Target Chemistry,BNL, September 19-23, 1993 (J. R. DAHL, R. FERRIERI, R. FINN and D. J. SCHLYER, Eds), BNL, 1994, p. 234.

[33] F. SZELECSÉNYI, T.E. BOOTHE, E.TAVANO, M.E. PLITNIKAS, F. TÁRKÁNYI, Compilation of Cross Section/Thick Target Yields for ^{66}Ga and^{68} Ga Production Using Zn Targets up to 30 MeV Proton Energy. J. Appl. Radiat. Isot. 45 (1994) 473.

[34] SZELECSÉNYI, F., BOOTHE, T.E., TAVANO, E., PLITNIKAS, M., FEIJOO, Y., TAKÁCS, S., TÁRKÁNYI F., SZÜCS, Z., New cross section data for ^{66,67,68} Zn+p reactions up to 26 MeV. Proc. International Conf. on Nuclear Data for Sci. and Tech., Gatlinburg, USA. May 1994 (DICKENS J. K., ed), American Nucl. Soc., Inc, La Grande Park, 1994, p. 393.

[35] TAKÁCS, S., TÁRKÁNYI, F., FESSLER, A., ALFASSI, Z.B., QAIM, S.M., Excitation functions of ^{3}He-particle induced nuclear reactions on natural nickel with special reference to the monitoring of beam energy and intensity. J. App l. Radiat. Isot. 46 (1995) 249.

[36] TAKÁCS, S., TÁRKÁNYI, F., KOVÁCS, Z., Excitation function of alpha-particle induced nuclear reactions on natural nickel. Nucl. Instr. Meth B113 (1996) 424.

[37] SZELECSÉNYI, F., BOOTHE, T.E., TAKÁCS, S., TÁRKÁNYI, F., TAVANO, E., Evaluated cross section and thick target yield data bases of Zn+p processes for practical applications, Submitted for publication in: Appl. Radiat. Isotopes.

[38] J.M. PETIT, T. SAUVAGE, G. BLONDIAUX, P. ROUVEIROLLES, Journal Entropie 188/189 (1995) 77.

[39] F. DITRÓI, I. MAHUNKA, S. TAKÁCS, S. SEIF EL-NASR, Trace element analysis of motor oil by CPAA method on external proton beam, J. Radioanal. Nucl. Chem., Articles, 130(2) (1989) 263.

Annex I

USE OF TLA TECHNIQUE TO MEASURE WEAR OF SUPERHARD TURNING TOOLS

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1. INTRODUCTION

Thin Layer Activation (TLA) technique is a useful nuclear method for wear measurement of cutting tools used in machinery [1] Tools made from superhard materials are frequently used in this field One of the most important fields of their using is the high precision turning Nowadays, for measuring the wear of the turning tool the lathe must be stopped, and the machining process must be interrupted In this case the working condition of the tool is not the same as it is by continuous cutting, and the economical efficiency of the machining is lower

Due to these considerations it is important to develop a method and equipment for continuous (in situ) wear measurement of the cutting edge of superhard turning tools This method must allow to measure the wear of the cutting tools during the turning process, and immediately detect the breaking of the tool`s edge, and to interact with CNC (computerised) lathe controller to increase the accuracy of machining It makes possible to investigate the behaviour of tools under different working conditions, similar to that in industrial production

We have developed a TLA based technique to investigate superhard turning tools made of cubic Boron-Nitride (BN) and polycrystalline artificial diamond (DIA) On the basis of preliminary experiments it was found that for the activation the $^{10}B(p,\alpha)^{7}Be$ ($T_{1/2}$=53 3d) and the $^{56}Fe(p,n)^{56}Co$ ($T_{1/2}$=77 7 d) reactions can be used for BN and DIA tools respectively [2] After activation the calibration curve was measured by step-by-step grinding away of thin slices from the irradiated surface of the tool The residual activity was measured after each step of grinding

The shape of the calibration curve is determined principally by the irradiation geometry We have investigated two different geometries In the first case the main axis of the tool was positioned approximately parallel to the ion beam and the activated volume was determined by a collimator of 0 2 mm diameter and the beam energy The shape of the calibration curve produced by this axial irradiation is suitable for wear measurement, but it is difficult to predict it because of the uncertainty of nuclear data

At the second geometry the tools were irradiated from rake side with possibly high energy It means, that the beam was perpendicular to the main axis of the tool (wear direction) On this way it is possible to predict the calibration curve with higher accuracy, because the nuclear data can be eliminated from the formulas, because the stopping power and cross sections are acting perpendicular to the wear direction The shape of the calibration curve is better than using the first geometry, and the irradiation time is considerably shorter (less than 1 hour) and the measuring depth can be easily adjusted These demands can be fulfilled using the following method, based on Thin Layer Activation (TLA) technique [1,2,3]

2. EXPERIMENTAL TECHNIQUE

2.1. EQUIPMENTS

TLA method requires a charged particle accelerator for irradiation with particle energies higher than the threshold energies of the reactions, which are most frequently used for wear measurement [4]. For this purpose we used the MGC-20 isochronous cyclotron of our institute.

All of the irradiations were carried out with extracted beam. The charged particle beam was getting out from the vacuum chamber through a thin Al closing foil of the beam extractor. The closing Al foil is 13 μm thick and air cooled. For proper sensitivity and accuracy only a small part of the turning tool should be activated [2,3]. Our beam can only be focused to an area of 1 cm^2. The further decrease of the beam size could be done by collimating. It means, that we have to use a small part of the extracted beam and the turning tool must be precisely positioned in front of the beam. For the required collimating of the beam and positioning of the turning tool a special sample holder was developed. This sample holder allows to position the turning tool behind the collimator under a microscope and clamp it down in a required angle to the beam. During the irradiation the beam current can be measured both on the collimator and on the target.

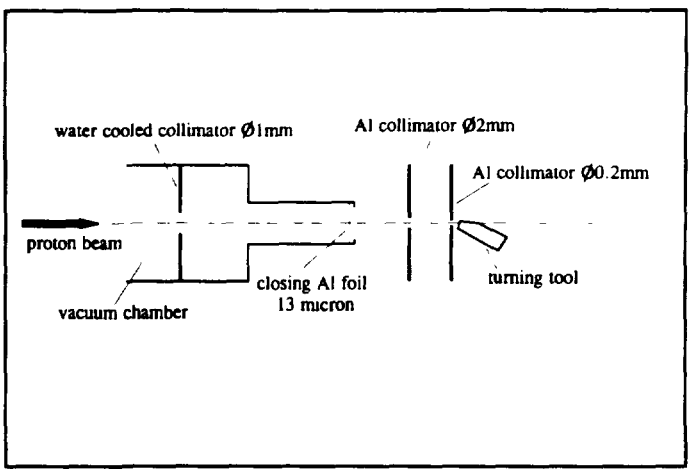

Figure 1 *Schematic arrangement for irradiation of turning tools*

The sample holder with the turning tool was mounted on a remote controlled X-Y micropositioning unit. Highest beam current on the target was found by moving the sample holder in the beam in X-Y directions. Schematic arrangement of the beam extractor and the target holder is shown on Fig.1.

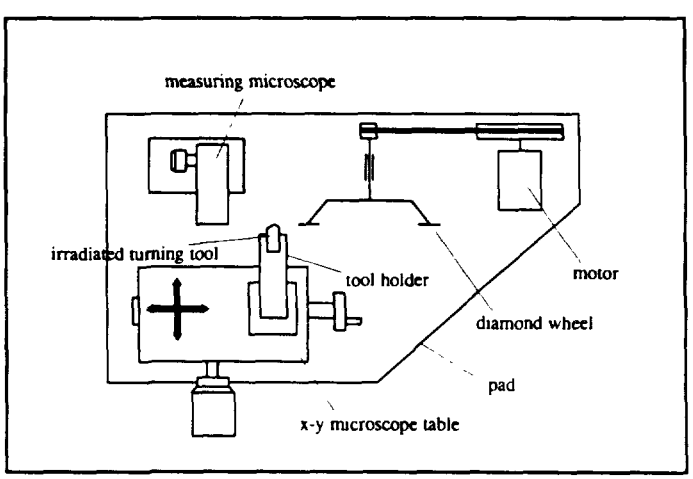

Figure 2 *Home made grinding machine with diamond wheel and measuring microscope*

At the investigations of turning tools we measured the residual activity of the tool after the forced wear process. For these measurements we could use different detector systems, such as high purity germanium semiconductor (HpGe), and NaI scintillation crystal. With the high resolution HpGe system one can measure gamma-spectra with high accuracy. In this case with the sophisticated home-made evaluation program we could precisely subtract the background and separate the different peaks, and such a way precisely measure the calibration curves. It was also used to calibrate the NaI system to the special wear study.

The NaI system is much cheeper and more durable and less sensitive for shocks, than the HpGe above, so it can also be used at industrial plants. In most cases it is enough to use it with a differential discriminator and counter, when the calibration curves determined by the HpGe system are available.

For the simulation of the wear of the cutting edge a grinding machine with diamond wheel was developed. This machine was equipped with a microscope to measure the geometrical parameters of the ground part of the tool (see Fig.2). With this machine we could perform the forced wear of the tools. The exact repeatability of the positioning of the tools in the sample holder of the machine was also solved. The revolving speed of the grinding plate and the wearing force can also be adjusted to perform normal wear in considerable time.

2.2. NUCLEAR REACTIONS

The turning tools under investigations are made from different superhard materials. In this work we have investigated two types of them: tools made from policrystallic artificial diamond (DIA), and cubic Boron-nitride (BN). Composition of these materials is not exactly known because of the confidential technology. To determine the best activation conditions (collimatuon, dose, current) an extra irradiation is needed. In that investigation we found, that the DIA tools contain homogeneously distributed iron in the glue-material among the diamond crystals. The amount of the iron component (1-3 %) is enough for performing wear measurements. A typical dose for activation of both materials was 500-1000 nA in 1 hour irradiation time. For activation of the DIA tools the

$$.^{56}Fe(p,n)^{56}Co; \quad T_{1/2}=71.1\ days; \quad Q=-5.4\ MeV$$

(most intensive gamma-lines: 846.8, 1037.9, 1238.3, 1771.5, 2598.6 keV) reaction was used.

For activation of BN tools we used the

$$.^{10}B(p,\alpha)^{7}Be; \quad T_{1/2}=53\ days; \quad Q>0$$

(gamma-line: 477.6 keV) reaction.

The -rays of the produced isotopes can penetrate through a few centimetre of iron shielding which gives a possibility to measure the wear of the tool during turning process [4].

2.3. IRRADIATION GEOMETRY AND CONDITIONS

Wear information can be collected only from the irradiated volume of the tools. The geometry of the activated part of the tools determines the shape of the calibration

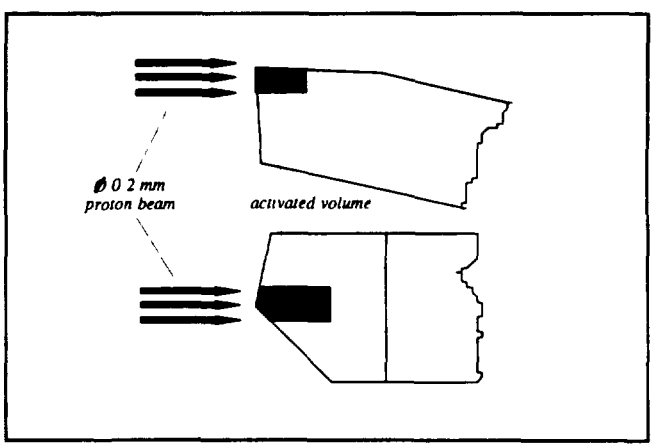

Figure 3 *Irradiated volume in turning tool (Geometry 1.)*

curve [1]. One can perform high sensitivity wear measurements on a turning tool only if the produced activity is located in a small volume.

For the first step of investigations an irradiation geometry, producing a ⌀0.2 mm cylinder shaped activated volume parallel to the axis of the tool was chosen (Geometry 1., see Fig.3). In The second geometry we have irradiated a small triangle of the cutting edge of the tools, perpendicular to their main axis (Geometry 2., see Fig 4.)

The thickness of the activated layer and the depth distribution of produced activity are depending on the energy of the ion beam, the excitation function and the Q-value of the chosen nuclear reaction. In our experiments we had to produce an activated layer of a few tens of micrometers. Due to these considerations, the beam energy was set to 8 MeV for DIA, and 5.4 MeV for BN tools using the Geometry 1. and 18 MeV at the Geometry 2.

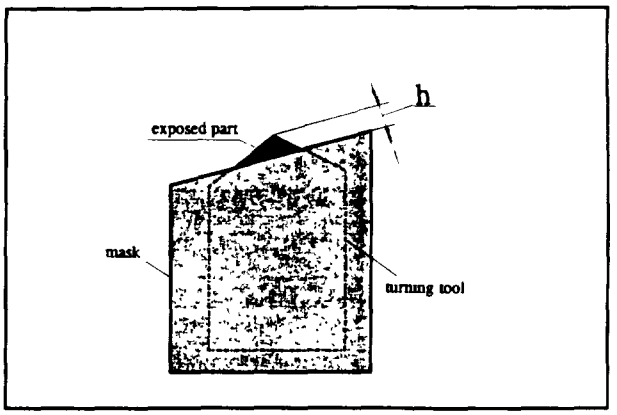

Figure 4 *Perpendicular irradiation (Geometry 2.)*

2.4. DETERMINATION OF THE CALIBRATION CURVES

Calibration curves for the above described irradiation geometry were determined by grinding away small parts of the activated volume. For this purpose the grinding machine with diamond wheel was used (Fig.2).

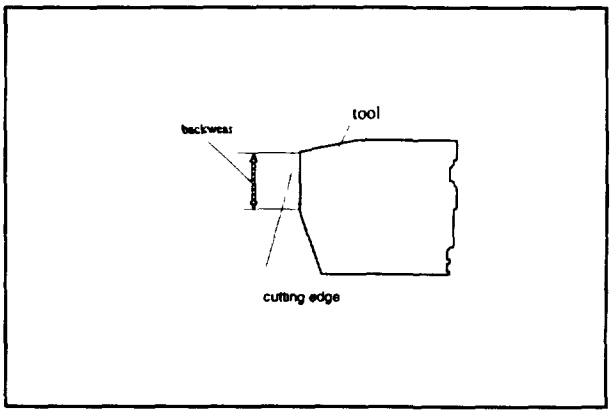

Figure 5 *Wear of the cutting edge and the definition of the backwear*

The most frequently used parameter, characterizing the wear of such types of turning tools is the wear of the back edge "backwear" [1] (see Fig. 5). After each step of grinding we measured the backwear by using a microscope, and the residual activity by using both above described detector systems. On this way calibration curves were determined for all activated tools. The calibration curves of different tools have the same shape within the statistical error.

In Fig. 6 calibration curves, measured by different detector systems are shown. We have found, that the cheapest scintillation detector is also good enough for wear measurement.

At the second type of irradiation geometry (perpendicular irradiation), using our stopping and depth distribution calculations we have estimated the wear curves at different irradiation parameters (Fig. 7). It is shown, that our calculation at 0.3 mm irradiation parameter (a 0.3 mm high triangle is irradiated) is in good agreement with the measured data.

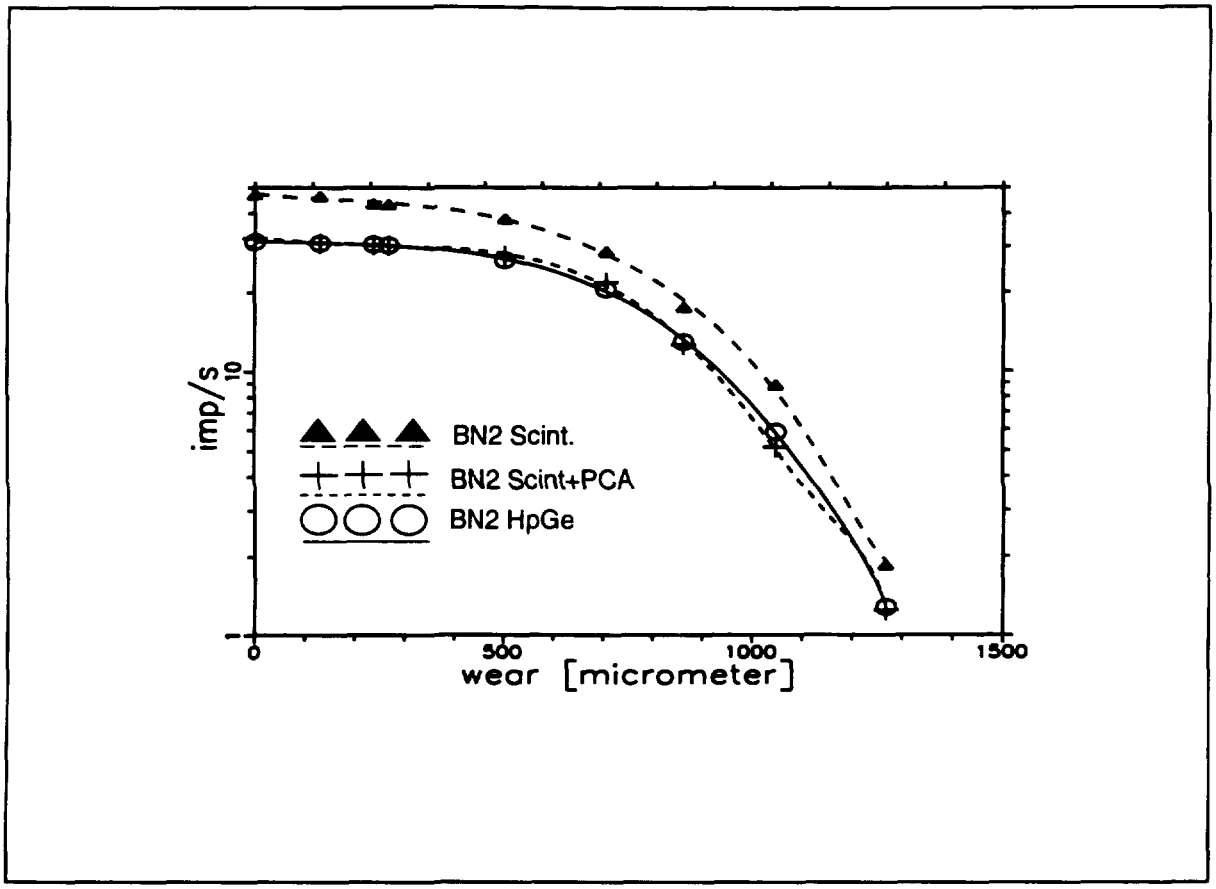

Figure 6 *Comparison of wear measurements with different detector systems*

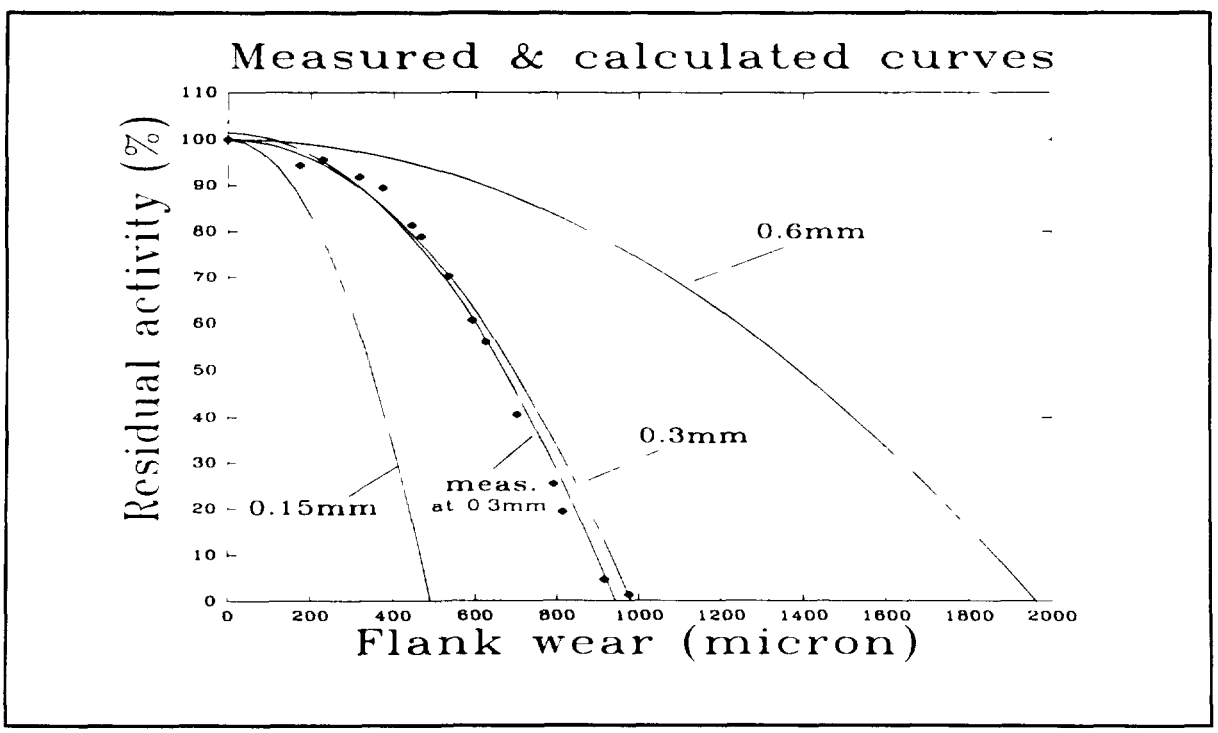

Figure 7 *Calculated and measured calibration curves for rake side irradiation, for h=0.15, 0.3 0.6 mm*

3. DISCUSSION AND CONCLUSIONS

The calibration curves for the above described irradiation conditions have a sharply increasing sensitivity at the end of the activated interval, but they change only slightly at the beginning of it. Due to these facts the wear measurement has low accuracy or simply impossible to use it at the first time of turning. Using this irradiation geometry we could produce calibration curves, allowing to detect the maximum enabled backwear, and the breaking of the tool's cutting edge. By this way we can determine the moment when the tool must be changed.

From engineering point of view, by using the TLA technique it would be preferable to have a calibration curve with higher sensitivity close to the beginning of the wear process. It means, that we could monitor the wear of the tool with considerable accuracy at the most important phase of the lifetime of the tool. On the basis of this tool monitoring it is possible to build up some algorithms for interaction with controller of the CNC lathe for adjusting it's program or stopping the turning process if it is needed [5]. By this interaction the motion program of the slide system of the lathe can be adjusted.

Our investigations has proved, that the TLA technique is a powerful method for the measuring the wear of superhard cutting edges. Measuring systems used in our investigations fulfil demands both on calibration measurements in laboratory conditions and serial measurements in workshops.

The backwear-activity curves, produced by axial irradiation are useful for determining the end of the lifetime of the tool. The perpendicular irradiation geometry can be used to measure the wear of the tools with adjustable depth and sensitivity.

For some of proposed irradiation geometries estimated calibration curves are calculated. Considering these calculations and some experiments the best arrangement has been investigated in detail. For proving the applicability of the method in industrial conditions a scintillation detector based system was established at the experimental workshop of the Technical University of Miskolc/Hungary where the wear of cutting tools was measured on a real turning machine by turning standard metal-probes.

REFERENCES

[1] JETLEY S.K., Int.J.Appl.Rad. and Isotopes, 33(1982) 763.
[2] BHATTACHARYYA B.B., JETLEY S., IVKOVIC B., Wear, 48/2(1978) 399.
[3] AMINI E., WINTERTON R.H.S., Proc.Inst.Mech.Eng. 195(1981) 241.
[4] S. JETLEY, Wear 76(1982)153.
[5] KUNDRÁK J., SZABÓ Z., SZŰCS J., MAHUNKA I., VASVÁRY L., Mechatroninfo '92, Budapest, 10-12 November 1992. pp 305-312.

Annex II

NUCLEAR DATA RELATING TO TLA

The following tables are based on I.O. Konstantinov, Catalogue of Nuclear Data for the Thin Layer Activation Technique.

TABLE I. THE MAIN CHARACTERISTICS OF THE RADIONUCLIDES' DECAY

Radionuclide	$T_{1/2}$,days	E, keV	rel. unit
^{22}Na	949	1274.5	0.99
^{48}V	16.1	928.2	0.012
		944.3	0.08
		983.5	1.0
		1311.6	0.98
^{51}Cr	27.7	320.07	0.0983
^{52}Mn	5.6	744	0.87
		936	0.94
		1434	1.0
^{56}Co	78.8	847	1.0
		1038	0.14
		1238	0.68
		1272	0.16
^{57}Co	271.7	122	1.0
		137	0.1
^{58}Co	70.8	811	1.0
^{60}Co	1924	1173.23	0.9986
		1332.51	0.9998
^{56}Ni	6.1	158.3	0.99
		269.6	0.4
		480.7	0.41
		750.6	0.538
		812.2	0.905
		1562.5	0.125
^{57}Ni	1.5	127.28	0.15
		1377.62	0.849
		1757.61	0.063
		1919.57	0.15
^{65}Zn	244.5	1115	0.51
^{67}Ga	3.26	184.6	0.208
		300.2	0.153
^{89}Zr	3.268	909.2	0.9987
^{88}Y	106.6	1325.01	0.94
		1836.01	0.9936
^{92m}Nb	10.16	934.53	0.995

Radionuclide	$T_{1/2}$,days	E , keV	rel. unit
^{95m}Tc	61	203.94	0.642
		582.15	0.356
		835.14	0.275
^{96}Tc	4.35	778.3	1.0
		812.8	0.82
		850.3	0.99
^{97}Ru	2.88	215.2	0.86
		324.4	0.104
^{183}Re	70.	162.32	0.25
		208.8	0.031
		291.72	0.033
^{185}Os	94.	646.11	0.81
		717.42	0.043

Contents

TABLE II. DEPTH DISTRIBUTION OF ^{52}Mn IN CHROMIUM, IRRADIATED BY PROTONS ($Cr+p \rightarrow {}^{52}Mn$, E_p=22MeV)

Particle energy. E, MeV	Depth χ ,g.cm^{-2}	Activity, rel. units A	a
22.0	0	1.000	0
21.5	31.9	0.960	0.040
21.0	63.8	0.920	0.080
20.5	94.5	0.881	0.119
20.0	125.2	0.842	0.158
19.5	154.8	0.800	0.200
19.0	184.4	0.759	0.241
18.5	212.8	0.722	0.278
18.0	241.1	0.685	0.315
17.5	268.4	0.642	0.358
17.0	295.6	0.602	0.398
16.5	321.6	0.562	0.435
16.0	347.6	0.527	0.473
15.5	372.4	0.486	0.514
15.0	397.1	0.446	0.554
14.5	420.7	0.407	0.593
14.0	444.2	0.368	0.632
13.5	471.5	0.328	0.672
13.0	488.8	0.289	0.711
12.5	509.9	0.249	0.751
12.0	530.9	0.211	0.789
11.5	550.6	0.174	0.826
11.0	570.3	0.138	0.862
10.5	588.8	0.100	0.900
10.0	607.2	0.064	0.936
9.5	624.6	0.046	0.954
9.0	641.4	0.029	0.971
8.5	657.4	0.016	0.984
8.0	672.8	0.009	0.991
7.5	687.5	0.006	0.994
7.0	701.4	0.002	0.998

TABLE III. THICK TARGET YIELD OF ^{52}Mn IN CHROMIUM, IRRADIATED BY PROTONS ($Cr + p \rightarrow {}^{52}Mn$, $E_p = 22$ MeV)

Particle energy E, MeV	Range, R,mg.cm^{-2}	Yield Y,kBq. μA^{-1}.h^{-1}
22.0	815.0	20350
21.5	783.1	19536
21.0	751.2	18722
20.5	720.5	17945
20.0	689.8	17131
19.5	660.2	16280
19.0	630.6	15429
18.5	602.2	14689
18.0	573.9	13949
17.5	546.6	13061
17.0	519.4	12247
16.5	493.4	11507
16.0	467.4	10730
15.5	442.6	9879
15.0	417.9	9065
14.5	394.3	8288
14.0	370.8	7474
13.5	343.5	6660
13.0	326.2	5883
12.5	305.1	5069
12.0	284.1	4292
11.5	264.4	3626
11.0	244.7	2812
10.5	226.2	2035
10.0	207.8	1295
9.5	190.4	925
9.0	173.6	592
8.5	157.6	325.6
8.0	142.2	192.4
7.5	127.5	125.8
7.0	113.6	59.2

TABLE IV. DEPTH DISTRIBUTION OF ^{52}Mn IN CHROMIUM, IRRADIATED BY PROTONS
(Cr + p → ^{52}Mn. E_p = 11 MeV)

Particle energy	Depth	Activity, rel. units	
E, MeV	χ, mg.cm^{-2}	A	a
11.0	0	1.000	0
10.5	18.5	0.834	0.166
10.0	36.9	0.683	0.317
9.5	54.3	0.533	0.467
9.0	71.1	0.402	0.598
8.5	86.1	0.294	0.706
8.0	102.5	0.201	0.799
7.5	117.2	0.121	0.879
7.0	131.1	0.055	0.945
6.5	144.4	0.019	0.981
6.0	156.9	0.03	0.997

TABLE V. ACTIVATION OF ALUMINIUM BY ^{3}He IONS (E=30 MeV)
($Al + {}^{3}He \rightarrow {}^{22}Na$)

Particle energy	**Range**	**Depth**	**Yield**	**Activity**
E, MeV	**R mg/cm^2**	**x mg/cm^2**	**Y kBq/μAh**	**A rel. units**
30	127.1	0.0	4.33	1.000
29	119.8	7.3	4.04	0.934
28	112.7	14.4	3.76	0.869
27	105.8	21.3	3.48	0.803
26	99.1	28.0	3.2	0.739
25	92.6	34.5	2.9	0.671
24	86.3	40.8	2.59	0.598
23	80.1	47.0	2.29	0.530
22	74.2	52.9	1.97	0.455
21	68.5	58.6	1.67	0.385
20	63.0	64.1	1.39	0.321
19	57.7	69.4	1.14	0.263
18	52.6	74.5	0.9	0.209
17	47.7	79.4	0.7	0.161
16	43.1	84.1	0.53	0.122
15	38.6	88.5	0.39	0.089
14	34.4	92.8	0.26	0.060
13	30.3	96.8	0.17	0.039
12	26.5	100.6	0.1	0.022
11	23.0	104.1	0.06	0.013
10	19.6	107.5	0.033	0.008
9	16.5	110.6	0.02	0.004
8	13.7	113.4	0.009	0.002
7	11.1	116.0	0.004	0.001

TABLE VI. ACTIVATION OF TITANIUM BY PROTONS (E=22 MeV)

(Ti + p → ^{48}V)

Particle energy E, MeV	Range R mg/cm^2	Depth x mg/cm^2	Yield Y MBq/μAh	Activity A rel. units
22.0	815.0	0.0	22.94	1.000
21.5	783.1	32.9	22.53	0.982
21.0	751.2	63.8	21.97	0.958
20.5	720.5	94.5	21.57	0.941
20.0	689.8	125.2	21.16	0.922
19.5	660.2	154.8	20.72	0.904
19.0	630.6	184.6	20.27	0.884
18.5	602.3	212.7	19.64	0.857
18.0	573.9	241.1	19.12	0.835
17.5	546.6	268.4	18.57	0.810
17.0	519.4	295.6	18.05	0.785
16.5	488.4	326.6	17.24	0.751
16.0	467.4	347.6	16.39	0.715
15.5	442.6	372.4	15.50	0.675
15.0	417.9	397.1	14.46	0.630
14.5	394.3	420.7	13.35	0.582
14.0	370.8	444.2	12.21	0.533
13.5	348.5	466.5	11.02	0.482
13.0	326.2	488.8	9.84	0.429
12.5	305.2	509.8	8.65	0.377
12.0	284.1	530.9	7.51	0.328
11.5	264.4	550.6	6.43	0.281
11.0	244.7	570.3	5.47	0.238
10.5	226.3	588.7	4.51	0.196
10.0	207.8	607.2	3.62	0.158
9.5	190.4	624.6	2.84	0.124
9.0	173.6	641.4	2.11	0.092
8.5	157.6	657.4	1.37	0.060
8.0	142.2	672.8	0.89	0.039
7.5	127.5	687.5	0.52	0.023
7.0	113.6	701.4	0.24	0.011
6.5	100.3	714.2	0.12	0.005
6.0	87.8	727.2	0.05	0.002

TABLE VII. ACTIVATION OF TITANIUM BY PROTONS (E=11 MeV)

(Ti + p → ^{48}V)

Particle energy E, MeV	Range R mg/cm²	Depth x mg/cm²	Yield Y MBq/μAh	Activity A rel. units
11.0	244.7	0.0	5.5	1.000
10.5	226.3	18.4	4.77	0.860
10.0	207.8	36.9	3.99	0.720
9.5	190.4	54.3	3.28	0.591
9.0	173.6	71.1	2.62	0.472
8.5	157.6	87.1	2.03	0.365
8.0	142.2	102.5	1.39	0.250
7.5	127.5	117.2	0.99	0.178
7.0	113.6	131.1	0.64	0.115
6.5	100.3	144.4	0.31	0.056
6.0	87.8	156.9	0.11	0.020
5.5	76.0	168.7	0.03	0.005

TABLE VIII. ACTIVATION OF TITANIUM BY PROTONS (E=7 MeV)

(Ti + p ^{48}V)

Particle energy E, MeV	Range R mg/cm²	Depth x mg/cm²	Yield Y kBq/μAh	Activity A rel. units
7.0	113.60	0.00	629	1.00
6.8	108.30	5.30	479.2	0.76
6.6	103.00	10.60	370	0.59
6.4	97.90	15.70	275.7	0.44
6.2	92.80	20.80	190.6	0.30
6.0	87.80	25.80	111	0.18
5.8	83.00	30.60	53.7	0.09
5.6	78.30	35.30	14.8	0.02

TABLE IX. ACTIVATION OF TITANIUM BY DEUTERONS (E=22 MeV)

(Ti + d → ^{48}V)

Particle energy E, MeV	**Range R mg/cm²**	**Depth x mg/cm²**	**Yield Y kBq/μAh**	**Activity A rel. units**
22.0	489.50	0.00	11470	1.000
21.5	470.40	19.10	10952	0.955
21.0	452.00	37.50	10397	0.906
20.5	433.60	55.90	9805	0.855
20.0	415.80	73.30	9213	0.802
19.5	398.00	91.50	8584	0.748
19.0	380.90	108.60	7955	0.695
18.5	363.80	125.70	7363	0.643
18.0	347.40	142.10	6771	0.590
17.5	331.00	158.50	6142	0.537
17.0	315.30	174.20	5587	0.486
16.5	299.50	190.00	5032	0.440
16.0	284.50	205.00	4551	0.396
15.5	269.50	220.00	4070	0.354
15.0	255.20	234.30	3600.1	0.314
14.5	240.80	248.70	3167.2	0.276
14.0	227.20	262.30	2752.8	0.240
13.5	213.60	275.90	2353.2	0.205
13.0	200.70	288.80	1949.9	0.170
12.5	187.80	301.70	1583.6	0.138
12.0	175.60	313.90	1283.9	0.112
11.5	163.40	326.10	987.9	0.086
11.0	152.00	337.50	745.6	0.065
10.5	140.50	349.00	573.5	0.052
10.0	129.90	359.60	458.8	0.040
9.5	119.40	370.10	344.1	0.030
9.0	109.40	380.10	240.9	0.021
8.5	99.65	389.85	160.6	0.014
8.0	90.34	399.16	91.8	0.008
7.5	81.43	408.07	51.8	0.005
7.0	72.92	416.58	17.4	0.002

TABLE X. ACTIVATION OF TITANIUM BY DEUTERONS (E=10 MeV)

(Ti + d → ^{48}V)

Particle energy E, MeV	**Range R mg/cm²**	**Depth x mg/cm²**	**Yield Y kBq/μAh**	**Activity A rel. units**
10.0	129.90	0.0	444	1.000
9.8	125.70	4.2	399	0.898
9.6	121.60	8.3	355.2	0.800
9.4	117.50	12.4	310.8	0.700
9.2	113.40	16.5	267.9	0.603
9.0	109.40	20.5	230.1	0.518
8.8	105.50	24.4	195.4	0.440
8.6	101.60	28.3	166.5	0.375
8.4	97.86	32.0	139.5	0.314
8.2	94.10	35.8	112.5	0.253
8.0	90.34	39.6	90.7	0.204
7.8	86.76	43.1	74	0.167
7.6	83.16	46.7	58.5	0.132
7.4	79.66	50.2	44.4	0.100
7.2	76.24	53.7	30.7	0.069
7.0	72.92	57.0	18.1	0.041
6.8	69.68	60.2	6.7	0.015

TABLE XI. ACTIVATION OF TITANIUM BY ALPHA-PARTICLES (E=44 MeV)

			(Ti + α → ^{51}Cr)		*(Ti + α → ^{48}V)*	
Particle energy E, MeV	**Range R mg/cm²**	**Depth *x* mg/cm²**	**Yield Y kBq/μAh**	**Activity A rel. units**	**Yield Y kBq/μAh**	**Activity A rel. units**
44	245.50	0.0	539.1	1.000	1332	1.000
43	236.00	9.5	514.3	0.954	1320.2	0.991
42	226.80	18.7	489.5	0.908	1308	0.982
41	217.60	27.9	464.7	0.862	1296.1	0.973
40	208.70	36.8	439.9	0.816	1282.8	0.963
39	199.70	45.8	412.9	0.766	1268	0.952
38	191.20	54.3	385.9	0.716	1252.1	0.940
37	182.70	62.8	361.1	0.669	1234.7	0.927
36	174.50	71.0	336	0.623	1217.3	0.914
35	166.20	79.3	310.8	0.577	1199.5	0.901
34	158.40	87.1	286	0.531	1180.7	0.886
33	150.40	95.1	263.1	0.488	1161.4	0.872
32	143.00	102.5	240.1	0.445	1141.5	0.857
31	135.40	110.1	218.3	0.405	1120.4	0.841
30	128.30	117.2	196.8	0.365	1098.9	0.825
29	121.20	124.3	175	0.325	1077.4	0.809
28	114.30	131.2	152.1	0.282	1054.9	0.792
27	107.50	138.0	132.1	0.245	1028.2	0.772
26	101.00	144.5	116	0.215	1000.5	0.751
25	94.61	150.9	99.9	0.185	965	0.728
24	88.41	157.1	84.4	0.157	937.6	0.707
23	82.40	163.1	71	0.132	901.7	0.677
22	76.58	168.9	57.7	0.107	864.3	0.649
21	70.94	174.6	45.9	0.085	823.3	0.618
20	65.50	180.0	36.3	0.067	772.6	0.580
19	60.24	185.3	28.6	0.053	711.1	0.534
18	55.18	190.3	22.2	0.041	635.3	0.477
17	50.31	195.2	17	0.032	544.6	0.409
16	45.64	199.9	12.6	0.023	463.6	0.348
15	41.17	204.3	8.9	0.017	391.5	0.294
14	36.91	208.6	5.9	0.011	322.3	0.242
13	32.84	212.7	244.9	0.184		
12	28.99	216.5	175.8	0.132		
11	25.34	220.2	111.7	0.084		
10	21.91	223.6	61.4	0.046		
9	18.70	226.8	33.3	0.025		
8	15.71	229.8	16.7	0.012		
7	12.95	232.6	9.3	0.007		
6	10.42	235.1	4.1	0.003		

TABLE XII. ACTIVATION OF TITANIUM BY ^{3}He ION (E=30 MeV)

(Ti + ^{3}He → ^{48}V)

Particle energy E, MeV	Range R mg/cm²	Depth x mg/cm²	Yield Y kBq/μAh	Activity A rel. units
30	156.20	0.00	1943	1.000
29	147.40	8.80	1647	0.848
28	138.90	17.30	1388	0.714
27	130.50	25.70	1129	0.581
26	122.50	33.70	925	0.476
25	114.60	41.60	740	0.381
24	107.00	49.20	581	0.299
23	99.57	57.63	451	0.232
22	92.40	63.80	352	0.181
21	85.47	70.73	278	0.143
20	78.78	77.42	215	0.111
19	83.87	83.87	174	0.090
18	66.12	90.08	137	0.071
17	60.16	96.04	107	0.055
16	54.45	101.75	78	0.040
15	48.98	107.22	56	0.029
14	43.78	112.42	37	0.019
13	38.83	117.37	22	0.011
12	34.14	122.06	7	0.004

TABLE XIII. ACTIVATION OF IRON BY PROTONS (E=11 MeV)

(Fe + p → ^{56}Co)

Particle energy E, MeV	Range R mg/cm²	Depth x mg/cm²	Yield Y kBq/μAh	Activity A rel. units
11.0	245.1	0.0	543.9	1.000
10.5	226.7	18.4	451.4	0.830
10.0	208.3	36.8	360.8	0.663
9.5	191.0	54.1	276.4	0.508
9.0	174.3	70.8	201.3	0.370
8.5	158.2	86.9	136.9	0.252
8.0	142.9	102.2	95.1	0.175
7.5	128.2	116.9	59.9	0.110
7.0	114.3	130.8	34	0.063
6.5	101.0	144.1	17.4	0.032
6.0	88.5	156.6	5.6	0.010
5.5	65.6	179.5	0.7	0.001

TABLE XIV ACTIVATION OF IRON BY PROTONS (E=7 MeV)

(Fe + p → ^{56}Co)

Particle energy E, MeV	**Range R mg/cm²**	**Depth x mg/cm²**	**Yield Y kBq/μAh**	**Activity A rel. units**
7.0	114.3	0.0	51.8	1.000
6.8	108.9	5.3	38.5	0.739
6.6	103.7	10.6	24.8	0.479
6.4	98.5	15.8	15.9	0.305
6.2	93.5	20.8	9.3	0.182
6.0	88.5	25.8	4.8	0.091
5.8	83.8	30.5	2.6	0.044
5.6	79.1	35.2	0.7	0.016

TABLE XV. ACTIVATION OF IRON BY DEUTERONS (E=22 MeV)

			(Fe + d → ^{56}Co)		*(Fe + d → ^{57}Co)*	
Particle energy E, MeV	**Range R mg/cm²**	**Depth *x* mg/cm²**	**Yield Y kBq/μAh**	**Activity A rel. units**	**Yield Y kBq/μAh**	**Activity A rel. units**
22.0	490.0	0	1665	1	370	1
21.5	471.6	18.7	1591	0.958	367	0.992
21.0	452.9	34.7	1510	0.905	364.5	0.985
20.5	434.8	55.5	1432	0.860	360.8	0.975
20.0	416.8	73.5	1351	0.810	357.8	0.967
19.5	399.4	90.9	1269	0.762	354.1	0.957
19.0	382.1	108.2	1188	0.713	350	0.946
18.5	365.4	124.9	1110	0.667	346	0.935
18.0	348.7	141.6	1025	0.615	341.5	0.923
17.5	332.6	157.7	947	0.569	337.4	0.912
17.0	316.6	173.7	866	0.516	333	0.900
16.5	301.2	189.1	784	0.472	327.5	0.885
16.0	285.9	204.4	707	0.425	321.2	0.868
15.5	271.2	219.1	629	0.377	313.4	0.847
15.0	256.6	233.7	548	0.329	304.1	0.822
14.5	242.6	247.7	470	0.282	293.4	0.793
14.0	228.7	261.6	385	0.232	283.8	0.767
13.5	215.4	274.9	326	0.191	272	0.735
13.0	202.2	288.1	244	0.152	259.7	0.702
12.5	189.6	300.7	192	0.115	247.2	0.668
12.0	177.1	313.2	137	0.083	232.7	0.629
11.5	165.3	325.0	93	0.056	218.3	0.590
11.0	156.6	336.7	59	0.036	203.5	0.550
10.5	142.7	347.6	37	0.023	185	0.500
10.0	131.8	358.5	23	0.014	166.5	0.450
9.5	121.2	369.1	13	0.008	152.1	0.411
9.0	110.7	379.6	5	0.003	137.3	0.371
8.5	101.1	389.2			121	0.327
8.0	91.6	398.7			104.3	0.282
7.5	82.9	407.4			89.5	0.242
7.0	74.1	416.2			73.6	0.199
6.5	66.2	424.2			61.1	0.165
6.0	58.2	432.1			47.7	0.129
5.5	51.1	439.2			37.4	0.101
5.0	44.0	446.4			27.8	0.075
4.5	37.7	452.6			19.2	0.052
4.0	31.4	458.9			12.6	0.034
3.5	26.1	464.2			8.1	0.022
3.0	20.7	469.6			4.4	0.012
2.5	15.7	474.6			3	0.008
2.0	11.0	479.3			0.7	0.002

TABLE XVI. ACTIVATION OF IRON BY DEUTERONS (E=10 MeV)

(Fe + d → ^{57}Co)

Particle energy E, MeV	Range R mg/cm^2	Depth x mg/cm^2	Yield Y kBq/μAh	Activity A rel. units
10.0	131.8	0.0	166.5	1.000
9.5	121.2	10.6	152.1	0.913
9.0	110.7	21.1	137.3	0.824
8.5	101.1	30.7	121	0.727
8.0	91.6	40.2	104.3	0.627
7.5	82.9	48.9	89.5	0.538
7.0	74.1	57.7	73.6	0.442
6.5	66.2	65.7	61.1	0.367
6.0	58.2	74.6	47.7	0.287
5.5	51.1	80.7	37.4	0.224
5.0	44.0	87.9	27.8	0.167
4.5	37.7	94.1	19.2	0.116
4.0	31.4	100.4	12.6	0.076
3.5	26.1	105.7	8.1	0.049
3.0	20.7	111.1	4.4	0.027
2.5	15.7	116.1	3	0.018
2.0	11.0	120.8	0.7	0.004

TABLE XVII. ACTIVATION OF IRON BY DEUTERONS (E=7 MeV)

(Fe + d → ^{57}Co)

Particle energy E, MeV	Range R mg/cm^2	Depth x mg/cm^2	Yield Y kBq/μAh	Activity A rel. units
7.0	74.1	0.0	74	1.000
6.5	66.2	8.0	61.1	0.825
6.0	58.2	15.9	48.1	0.650
5.5	51.1	23.0	37	0.500
5.0	44.0	30.2	27.8	0.375
4.5	37.7	36.4	19.2	0.260
4.0	31.4	42.7	12.6	0.170
3.5	26.1	48.0	8.1	0.110
3.0	20.7	53.4	4.4	0.060
2.5	15.7	58.4	3	0.030
2.0	11.0	63.1	0.7	0.010

TABLE XVIII. ACTIVATION OF IRON BY ^{3}He IONS (E=30 MeV)

			(Fe + ^{3}He → ^{56}Co)		*(Fe + ^{3}He → ^{57}Co)*	
Particle energy E, MeV	**Range R mg/cm²**	**Depth *x* mg/cm²**	**Yield Y kBq/μAh**	**Activity A rel. units**	**Yield Y kBq/μAh**	**Activity A rel. units**
30	156.60	0.00	50.32	1.000	270.84	1.000
29	147.80	8.80	48.84	0.971	260.85	0.963
28	139.30	17.30	47.18	0.938	250.12	0.924
27	131.00	25.60	45.33	0.901	236.8	0.874
26	122.90	33.70	43.29	0.860	223.11	0.824
25	115.10	41.50	41.07	0.816	208.68	0.771
24	107.50	49.10	38.85	0.772	193.88	0.716
23	100.10	56.50	36.45	0.724	176.86	0.653
22	92.93	63.67	34.04	0.677	160.95	0.594
21	86.01	70.59	31.45	0.625	143.93	0.531
20	79.32	77.28	28.9	0.574	126.91	0.469
19	72.87	83.73	26.46	0.526	109.89	0.406
18	66.66	89.94	24.09	0.479	93.24	0.344
17	60.69	95.91	21.5	0.427	76.59	0.283
16	54.97	101.63	19.02	0.378	59.94	0.221
15	49.50	107.10	16.39	0.326	44.77	0.165
14	44.28	112.32	13.51	0.268	31.6	0.117
13	39.31	117.29	10.58	0.210	21.02	0.078
12	34.61	121.99	8.07	0.160	13.69	0.051
11	30.16	126.44	5.33	0.106	8.51	0.031
10	25.99	130.61	3.22	0.064	4.81	0.018
9	22.09	134.52	1.67	0.033	1.89	0.007
8	18.45	138.15	0.07	0.015	0.37	0.001

TABLE XVIII (CONT.) ACTIVATION OF IRON BY ^{3}He IONS

			(Fe + ^{3}He → ^{57}Ni)		*(Fe + ^{3}He → ^{56}Co)*	
Particle energy E, MeV	**Range R mg/cm²**	**Depth x mg/cm²**	**Yield Y kBq/μAh**	**Activity A rel. units**	**Yield Y kBq/μAh**	**Activity A rel. units**
30	156.60	0.00	2571	1.000	187.96	1.000
29	147.80	8.80	2534.5	0.986	157.99	0.841
28	139.30	17.30	2475.3	0.963	126.91	0.675
27	131.00	25.60	2390.2	0.930	99.16	0.528
26	122.90	33.70	2269.95	0.883	72.15	0.384
25	115.10	41.50	2168.2	0.843	51.06	0.272
24	107.50	49.10	2042.4	0.794	34.41	0.183
23	100.10	56.50	1909.2	0.742	21.2	0.113
22	92.93	63.67	1780.07	0.692	12.21	0.065
21	86.01	70.59	1620.6	0.630	6.29	0.033
20	79.32	77.28	1450.03	0.564	2.74	0.015
19	72.87	83.73	1259.85	0.490	1.67	0.009
18	66.66	89.94	1060.05	0.412	0.93	0.005
17	60.69	95.91	852.85	0.332		
16	54.97	101.63	666	0.259		
15	49.50	107.10	496.17	0.193		
14	44.28	112.32	361.12	0.140		
13	39.31	117.29	257.15	0.100		
12	34.61	121.99	177.97	0.069		
11	30.16	126.44	111	0.043		
10	25.99	130.61	55.5	0.022		
9	22.09	134.52	19.24	0.008		
8	18.45	138.15	1.67	0.007		

TABLE XIX. ACTIVATION OF NICKEL BY PROTONS (E=22 MeV)

(Ni + p → ^{57}Co)

Particle energy E, MeV	**Range R mg/cm^2**	**Depth x mg/cm^2**	**Yield Y kBq/μAh**	**Activity A rel. units**
22.0	806.0	0.0	1295	1.000
21.5	774.6	31.4	1025	0.792
21.0	743.3	62.7	759	0.585
20.5	713.1	92.9	570	0.440
20.0	682.9	123.1	459	0.355
19.5	653.8	152.2	377	0.290
19.0	624.7	181.3	318	0.246
18.5	596.7	209.3	281	0.217
18.0	568.8	237.2	255	0.196
17.5	542.0	264.0	233	0.180
17.0	515.2	290.8	211	0.162
16.5	489.6	316.4	192	0.148
16.0	464.0	342.0	174	0.135
15.5	439.5	366.5	155	0.120
15.0	415.1	390.9	137	0.106
14.5	391.8	414.2	118	0.093
14.0	368.6	437.4	104	0.080
13.5	346.6	459.4	89	0.068
13.0	324.6	481.4	78	0.060
12.5	303.8	502.2	67	0.052
12.0	283.1	522.9	59	0.046
11.5	263.6	542.4	52	0.039
11.0	244.1	561.9	44	0.033
10.5	225.8	580.2	34	0.026
10.0	207.6	598.4	25	0.019
9.5	190.4	615.6	21	0.016
9.0	173.8	632.2	18	0.014
8.5	157.9	648.1	15	0.011
8.0	142.6	663.4	12	0.009
7.5	128.0	678.0	7	0.005

TABLE XX. ACTIVATION OF NICKEL BY PROTONS (E=10 MeV)

(Ni + p - ^{57}Co)

Particle energy E, MeV	**Range R mg/cm^2**	**Depth x mg/cm^2**	**Yield Y kBq/μAh**	**Activity A rel. units**
10.0	207.6	0.0	24.05	1.000
9.8	200.7	6.9	21.83	0.908
9.6	193.8	13.8	19.8	0.823
9.4	187.1	20.5	17.76	0.738
9.2	180.4	27.2	15.73	0.654
9.0	173.8	33.8	13.69	0.569
8.8	167.4	40.2	11.84	0.492
8.6	161.1	46.5	9.99	0.415
8.4	154.9	52.7	8.33	0.346
8.2	148.7	58.9	6.85	0.285
8.0	142.6	65.0	5.37	0.223
7.8	136.8	70.8	4.07	0.169
7.6	130.9	76.7	2.96	0.123
7.4	125.3	82.3	2.04	0.085
7.2	119.7	87.9	1.3	0.054
7.0	114.2	93.4	0.56	0.023
6.8	108.9	98.7	0.19	0.008

TABLE XXI. ACTIVATION OF NICKEL BY DEUTERONS (E=22 MeV)

			(Ni + d → ^{56}Co)		*(Ni + d → ^{58}Co)*	
Particle energy E, MeV	**Range R mg/cm²**	**Depth *x* mg/cm²**	**Yield Y kBq/μAh**	**Activity A rel. units**	**Yield Y kBq/μAh**	**Activity A rel. units**
22.0	488.3	0.0	192.4	1.000	4625	1.000
21.5	469.8	18.5	186.9	0.971	4329	0.937
21.0	451.2	37.1	181.3	0.942	3996	0.864
20.5	433.3	55.0	175.4	0.912	3700	0.800
20.0	415.4	72.8	166.5	0.865	3404	0.735
19.5	398.1	90.2	159.1	0.827	3101	0.670
19.0	380.9	107.4	148	0.769	2812	0.608
18.5	364.3	124.0	136.9	0.713	2531	0.547
18.0	347.7	140.6	127.7	0.663	2242	0.485
17.5	331.8	156.5	115.4	0.600	1983	0.429
17.0	315.9	172.4	101.8	0.529	1721	0.372
16.5	300.6	187.7	87.3	0.454	1458	0.315
16.0	285.3	203.0	72.2	0.375	1199	0.259
15.5	270.7	217.6	55.5	0.290	955	0.206
15.0	256.2	232.1	40.7	0.212	718	0.155
14.5	242.3	246.0	28.9	0.150	514	0.111
14.0	228.4	259.9	20.4	0.106	370	0.080
13.5	215.2	275.1	14.1	0.073	244	0.053
13.0	202.1	286.2	10	0.052	163	0.035
12.5	189.6	298.7	7	0.037	89	0.019
12.0	177.1	311.2	4.4	0.023	52	0.011
11.5	165.3	323.0	3	0.015	19	0.004
11.0	153.6	334.7	1.5	0.008		
10.5	142.5	345.8	0.4	0.002		

TABLE XXII. ACTIVATION OF NICKEL BY ^{3}He IONS (E=30 MeV)

			(Ni + ^{3}He → ^{56}Co)		*(Ni + ^{3}He → ^{57}Co)*	
Particle energy E, MeV	**Range R mg/cm²**	**Depth *x* mg/cm²**	**Yield Y kBq/μAh**	**Activity A rel. units**	**Yield Y kBq/μAh**	**Activity A rel. units**
30	156.00	0.00	109	1.000	13.39	1.000
29	147.30	8.70	103.23	0.947	11.62	0.867
28	138.90	17.10	97.2	0.892	9.99	0.746
27	130.60	25.40	90.76	0.833	8.55	0.638
26	122.60	33.40	83.99	0.771	7.25	0.541
25	114.80	41.20	76.15	0.699	6.14	0.459
24	107.30	48.70	68.3	0.627	5.18	0.387
23	99.92	56.08	60.31	0.553	4.4	0.329
22	92.80	63.20	52.39	0.481	3.77	0.282
21	85.92	70.08	44.81	0.411	3.29	0.246
20	79.26	76.74	37.7	0.346	2.89	0.216
19	72.85	83.15	31.3	0.287	2.52	0.188
18	66.67	89.33	25.2	0.231	2.22	0.166
17	60.73	95.27	19.8	0.182	1.92	0.144
16	55.03	100.97	14.69	0.135	1.67	0.124
15	49.58	106.42	10.4	0.095	1.41	0.105
14	44.37	111.63	7.03	0.065	1.18	0.088
13	39.42	116.58	4.77	0.044	0.89	0.066
12	34.73	121.27	3.11	0.028	0.59	0.044
11	30.29	125.71	1.7	0.016	0.33	0.025
10	26.12	129.88	0.44	0.004	0.07	0.006

TABLE XXII. (CONT.) ACTIVATION OF NICKEL BY ^{3}He IONS (E=30 MeV)

(Ni + ^{3}He → ^{58}Co)

Particle energy E, MeV	**Range R mg/cm²**	**Depth *x* mg/cm²**	**Yield Y kBq/μAh**	**Activity A rel. units**
30	156.00	0.00	192.99	1.000
29	147.30	8.70	171.01	0.886
28	138.90	17.10	149	0.772
27	130.60	25.40	126.98	0.658
26	122.60	33.40	105.01	0.544
25	114.80	41.20	86.28	0.447
24	107.30	48.70	68.49	0.355
23	99.92	56.08	52.98	0.275
22	92.80	63.20	39.52	0.205
21	85.92	70.08	28.71	0.149
20	79.26	76.74	20.79	0.108
19	72.85	83.15	15.21	0.079
18	66.67	89.33	11.21	0.058
17	60.73	95.27	8.58	0.045
16	55.03	100.97	6.36	0.032
15	49.58	106.42	4.74	0.025
14	44.37	111.63	3.11	0.016
13	39.42	116.58	1.41	0.007
12	34.73	121.27	0.81	0.004
11	30.29	125.71	0.44	0.002
10	26.12	129.88	0.22	0.001

TABLE XXII (CONT.) ACTIVATION OF NICKEL BY ^{3}He IONS

			$(Ni + {}^{3}He \rightarrow {}^{56}Ni)$		$(Ni + {}^{3}He \rightarrow {}^{57}Ni)$	
Particle energy E, MeV	**Range R mg/cm²**	**Depth x mg/cm²**	**Yield Y kBq/μAh**	**Activity A rel. units**	**Yield Y kBq/μ Ah**	**Activity A rel. units**
30	156.00	0.00	21.46	1.000	1060.1	1.000
29	147.30	8.70	20.54	0.957	976.8	0.922
28	138.90	17.10	19.39	0.903	893.2	0.843
27	130.60	25.40	17.98	0.838	810.3	0.764
26	122.60	33.40	16.54	0.771	725.2	0.686
25	114.80	41.20	15.1	0.703	655.6	0.619
24	107.30	48.70	13.62	0.635	590.2	0.557
23	99.92	56.08	11.99	0.559	533.5	0.503
22	92.80	63.20	10.51	0.490	482.9	0.456
21	85.92	70.08	8.99	0.419	434	0.409
20	79.26	76.74	7.47	0.345	385.2	0.363
19	72.85	83.15	6.07	0.283	343	0.324
18	66.67	89.33	4.85	0.226	303	0.286
17	60.73	95.27	3.81	0.178	260.1	0.245
16	55.03	100.97	2.89	0.135	225	0.212
15	49.58	106.42	2.15	0.100	192	0.181
14	44.37	111.63	1.59	0.074	159.8	0.151
13	39.42	116.58	1.04	0.048	132.8	0.125
12	34.73	121.27	0.59	0.028	108	0.102
11	30.29	125.71	0.19	0.009	84.4	0.080
10	26.12	129.88	0.07	0.003	59.2	0.056
9	22.22	133.78	40.7	0.038		
8	18.59	137.41	25.9	0.024		
7	15.24	140.76	14.8	0.014		

TABLE XXIII. ACTIVATION OF COPPER BY PROTONS (E=22 MeV)

(Cu + p → ^{65}Zn)

Particle energy E, MeV	Range R mg/cm²	Depth x mg/cm²	Yield Y kBq/μAh	Activity A rel. units
22.0	849.0	0.0	611	1.000
21.5	816.0	33.0	603	0.990
21.0	783.0	66.0	599	0.981
20.5	751.2	97.8	592	0.970
20.0	719.4	129.6	588	0.961
19.5	688.8	160.2	577	0.948
19.0	658.2	190.8	570	0.935
18.5	628.8	220.2	562	0.922
18.0	599.4	249.6	555	0.910
17.5	571.2	277.8	544	0.893
17.0	543.0	306.0	537	0.876
16.5	516.0	333.0	522	0.855
16.0	489.1	359.9	511	0.834
15.5	463.3	385.7	492	0.807
15.0	437.6	411.4	477	0.781
14.5	413.1	435.9	455	0.748
14.0	388.7	460.3	437	0.716
13.5	365.5	483.5	414	0.676
13.0	342.4	506.6	389	0.636
12.5	320.5	528.5	363	0.593
12.0	298.6	550.4	337	0.551
11.5	278.0	571.0	307	0.503
11.0	257.5	591.5	278	0.455
10.5	238.3	610.7	244	0.388
10.0	219.1	629.9	211	0.345
9.5	201.0	648.0	170	0.279
9.0	183.5	665.5	141	0.230
8.5	166.7	682.3	115	0.187
8.0	150.6	698.4	93	0.149
7.5	135.3	713.7	70	0.116
7.0	120.6	728.4	56	0.089
6.5	106.7	742.3	44	0.070
6.0	93.6	755.4	30	0.050
5.5	81.2	767.8	21	0.034
5.0	69.6	779.4	13	0.022
4.5	58.7	790.3	9	0.014
4.0	48.7	800.3	4	0.008
3.5	39.5	809.5	2	0.004
3.0	31.0	818.0	1	0.002

TABLE XXIV. ACTIVATION OF COPPER BY PROTONS (E=11 MeV)

(Cu + p → ^{65}Zn)

Particle energy E, MeV	**Range R mg/cm^2**	**Depth x mg/cm^2**	**Yield Y kBq/μAh**	**Activity A rel. units**
11.0	257.5	0.0	270.1	1.000
10.5	238.3	19.2	236.8	0.876
10.0	219.1	38.4	201.3	0.745
9.5	201.0	56.5	167.6	0.620
9.0	183.5	74.0	134.7	0.498
8.5	166.7	90.8	107.3	0.397
8.0	150.6	106.9	79.9	0.296
7.5	135.3	122.2	61.4	0.228
7.0	120.6	136.9	47	0.174
6.5	106.7	150.8	34.4	0.127
6.0	93.6	163.9	23.3	0.086
5.5	81.2	176.3	14.4	0.053
5.0	69.6	187.9	7.4	0.028
4.5	58.7	198.8	3	0.011
4.0	48.7	208.3	1.5	0.007
3.5	39.5	218.0	0.7	0.005
3.0	31.0	226.5	0.4	0.002

TABLE XXV. ACTIVATION OF COPPER BY PROTONS (E=7 MeV)

(Cu + p → ^{65}Zn)

Particle energy E, MeV	**Range R mg/cm^2**	**Depth x mg/cm^2**	**Yield Y kBq/μAh**	**Activity A rel. units**
7.0	120.6	0.0	44.4	1.000
6.8	114.0	6.6	38.48	0.863
6.6	109.7	10.9	32.93	0.738
6.4	104.6	16.0	28.86	0.647
6.2	99.2	21.4	24.79	0.561
6.0	93.6	27.0	20.72	0.468
5.8	88.6	32.0	17.39	0.390
5.6	83.8	36.8	13.69	0.311
5.4	78.9	41.7	10.73	0.245
5.2	74.0	46.6	8.51	0.189
5.0	69.6	51.0	6.66	0.148
4.8	65.1	55.0	5.18	0.117
4.6	60.8	59.8	4.07	0.088
4.4	56.6	65.0	2.85	0.064
4.2	52.6	68.0	2.04	0.046
4.0	48.7	71.9	1.3	0.029
3.8	44.9	75.7	0.78	0.018
3.6	41.3	79.3	0.63	0.014
3.4	37.7	82.9	0.44	0.010
3.2	34.3	86.3	0.26	0.006
3.0	31.1	89.6	0.15	0.003

TABLE XXVI. ACTIVATION OF COPPER BY DEUTERONS (E=22 MeV)

(Cu + d → ^{65}Zn)

Particle energy E, MeV	Range R mg/cm^2	Depth x mg/cm^2	Yield Y kBq/μAh	Activity A rel. units
22.0	512.2	0.0	703	1.000
21.5	495.6	19.6	677.1	0.962
21.0	476.1	39.1	651.2	0.924
20.5	457.2	58.0	621.6	0.882
20.0	438.4	76.8	592	0.841
19.5	420.2	95.0	558.7	0.796
19.0	402.1	113.1	529.1	0.752
18.5	384.6	130.6	495.8	0.704
18.0	367.1	148.1	462.5	0.656
17.5	350.3	164.9	429.2	0.609
17.0	333.5	181.7	395.9	0.562
16.5	317.4	197.8	362.6	0.515
16.0	301.4	213.8	329.3	0.468
15.5	286	229.2	298.2	0.424
15.0	270.6	244.6	267.1	0.380
14.5	256	259.2	236.8	0.337
14.0	241.4	273.8	207.2	0.294
13.5	227.5	287.7	179.5	0.255
13.0	213.6	301.6	151.7	0.216
12.5	200.4	314.8	133.2	0.189
12.0	187.2	328.0	108.4	0.154
11.5	174.8	340.4	88.1	0.125
11.0	162.5	352.8	68.8	0.098
10.5	150.8	364.4	53.3	0.076
10.0	139.2	376.0	40.7	0.058
9.5	128.1	387.1	28.9	0.041
9.0	117.3	397.9	19.6	0.028
8.5	107.7	407.5	14.1	0.020
8.0	97.4	417.8	8.5	0.012
7.5	87.9	427.3	5.6	0.008
7.0	78.9	436.3	3	0.004

TABLE XXVII. ACTIVATION OF COPPER BY DEUTERONS (E=10 MeV)

(Cu + d → ^{65}Zn)

Particle energy E, MeV	**Range R mg/cm²**	**Depth x mg/cm²**	**Yield Y kBq/μAh**	**Activity A rel. units**
10.0	139.2	0	40.7	1.000
9.8	134.8	4.4	35.15	0.864
9.6	130.3	8.9	30.53	0.750
9.4	125.9	13.3	26.46	0.650
9.2	121.6	17.6	22.57	0.555
9.0	117.3	21.9	19.61	0.482
8.8	113.5	25.7	16.35	0.402
8.6	109.6	29.6	13.95	0.343
8.4	105.5	33.7	11.95	0.294
8.2	101.4	37.8	10.06	0.247
8.0	97.4	41.8	8.51	0.209
7.8	93.6	45.6	7.25	0.178
7.6	89.8	49.4	5.92	0.145
7.4	86.1	53.1	4.88	0.120
7.2	82.5	56.7	3.89	0.095
7.0	78.9	60.3	2.96	0.073
6.8	75.3	63.9	2.04	0.050
6.6	71.8	67.4	1.48	0.036
6.4	68.4	70.8	0.96	0.024

TABLE XXVIII. ACTIVATION OF COPPER BY ^{3}He IONS (E=30 MeV)

			$(Cu + {}^{3}He \rightarrow {}^{58}Co)$		$(Cu + {}^{3}He \rightarrow {}^{60}Co)$	
Particle energy E, MeV	**Range R mg/cm²**	**Depth *x* mg/cm²**	**Yield Y kBq/μAh**	**Activity A rel. units**	**Yield Y kBq/μAh**	**Activity A rel. units**
30	164.60	0.0	5180	1.000	74	1.0000
29	155.50	9.1	4810	0.929	59.94	0.8100
28	146.60	18.0	4440	0.856	48.84	0.6600
27	137.90	26.7	4040.4	0.780	38.48	0.5200
26	129.50	35.1	3603.8	0.696	30.71	0.4160
25	121.30	43.3	3148.7	0.608	23.68	0.3170
24	113.30	51.3	2726.9	0.526	18.5	0.2510
23	105.50	59.1	2323.6	0.448	14.06	0.1880
22	98.04	66.6	1927.7	0.372	10.36	0.1390
21	90.78	73.8	1565.1	0.302	7.77	0.1030
20	83.76	80.8	1232.1	0.238	5.55	0.0770
19	77.00	87.6	902.8	0.174	4.07	0.0520
18	70.48	94.1	677.1	0.131	2.48	0.0330
17	64.21	100.4	492.1	0.095	1.52	0.0200
16	58.20	106.4	358.5	0.069	0.81	0.0110
15	52.45	112.2	250.1	0.048	0.44	0.0060
14	46.96	117.6	168	0.032	0.11	0.0016
13	41.73	122.9	111.7	0.022		
12	36.78	127.8	71	0.014		
11	32.09	132.5	35.2	0.007		
10	27.68	136.9	11.5	0.002		

TABLE XXVIII. (CONT.) ACTIVATION OF COPPER BY ^{3}He IONS (E=30 MeV)

			(Cu + ^{3}He → ^{65}Zn)		*(Cu + ^{3}He → ^{67}Ga)*	
Particle energy E, MeV	**Range R mg/cm^2**	**Depth *x* mg/cm^2**	**Yield Y kBq/μAh**	**Activity A rel. units**	**Yield Y kBq/μAh**	**Activity A rel. units**
30	164.60	0.0	74	1.000	87.32	1.000
29	155.50	9.1	66.23	0.896	83.99	0.962
28	146.60	18.0	58.83	0.793	81.03	0.926
27	137.90	26.7	51.43	0.694	77.33	0.886
26	129.50	35.1	44.03	0.595	73.63	0.843
25	121.30	43.3	39.59	0.504	69.93	0.801
24	113.30	51.3	31.08	0.418	66.23	0.759
23	105.50	59.1	25.16	0.338	62.53	0.716
22	98.04	66.6	19.98	0.270	58.83	0.674
21	90.78	73.8	15.91	0.216	55.13	0.631
20	83.76	80.8	12.58	0.168	51.43	0.589
19	77.00	87.6	9.62	0.129	47.73	0.547
18	70.48	94.1	7.4	0.098	43.66	0.500
17	64.21	100.4	5.55	0.074	39.22	0.449
16	58.20	106.4	4.44	0.058	34.71	0.398
15	52.45	112.2	3.4	0.046	30.12	0.345
14	46.96	117.6	2.66	0.036	25.49	0.292
13	41.73	122.9	2.04	0.028	21.2	0.243
12	36.78	127.8	1.48	0.020	16.87	0.194
11	32.09	132.5	0.96	0.013	12.8	0.147
10	27.68	136.9	0.59	0.008	9.25	0.106
9	23.56	141.0	0.26	0.003	5.66	0.065
8	19.72	144.9	0.07	0.001	3.48	0.040
7	16.18	148.4	1.59	0.018		
6	12.94	151.7	0.3	0.003		

TABLE XXIX. ACTIVATION OF ZINC BY PROTONS (E=22 MeV)

			(Zn + p → ^{65}Zn)		*(Zn + p → ^{67}Ga)*	
Particle energy E, MeV	**Range R mg/cm²**	**Depth *x* mg/cm²**	**Yield Y kBq/μAh**	**Activity A rel. units**	**Yield Y kBq/μAh**	**Activity A rel. units**
22	849.0	0	444	1.000	25160	1.000
21	783.0	66.0	355.2	0.800	21238	0.844
20	719.4	129.6	262.7	0.592	17575	0.699
19	658.2	190.8	185	0.417	14060	0.559
18	599.4	249.6	122.1	0.275	11100	0.441
17	543.0	306.0	70.3	0.158	8325	0.331
16	489.1	359.9	31.45	0.071	6401	0.254
15	437.6	411.4	12.95	0.029	5106	0.203
14	388.7	460.3	4.44	0.010	4255	0.169
13	342.4	506.6			3700	0.147
12	298.6	550.4			2960	0.118
11	257.5	591.5			1961	0.078
10	219.1	629.9			1110	0.044
9	183.5	665.5			666	0.026
8	150.6	698.4			370	0.015
7	120.6	728.4			185	0.007
6	93.6	755.4			74	0.003

TABLE XXX. ACTIVATION OF ZINC BY PROTONS (E=11 MeV)

			(Zn + p → ^{67}Ga)	
Particle energy E, MeV	**Range R mg/cm²**	**Depth x mg/cm²**	**Yield Y kBq/μAh**	**Activity A rel. units**
11.0	257.5	0	1850	1.000
10.5	237.7	19.8	1480	0.800
10.0	219.1	38.4	1110	0.600
9.5	201.0	56.5	870	0.470
9.0	183.5	74.0	666	0.360
8.5	166.7	90.8	481	0.260
8.0	150.6	106.9	370	0.200
7.5	135.3	122.2	266	0.144
7.0	120.6	136.9	185	0.100
6.5	106.7	150.8	122	0.066
6.0	93.6	163.9	74	0.040

TABLE XXXI. ACTIVATION OF ZINC BY DEUTERONS (E=22 MeV)

			(Zn + d → ^{65}Zn)		*(Zn + d → ^{67}Ga)*	
Particle energy E, MeV	**Range R mg/cm²**	**Depth *x* mg/cm²**	**Yield Y kBq/μAh**	**Activity A rel. units**	**Yield Y kBq/μAh**	**Activity A rel. units**
22	515.2	0.0	481	1.000	21460	1.000
21	476.1	39.1	440.3	0.915	19499	0.909
20	438.4	76.8	403.3	0.838	17760	0.828
19	402.1	113.1	373.7	0.777	16132	0.752
18	362.1	153.1	347.8	0.723	14800	0.690
17	333.5	181.7	324.1	0.674	13394	0.624
16	301.4	213.8	304.1	0.632	12099	0.564
15	270.6	244.6	281.2	0.585	11100	0.517
14	241.4	273.8	259	0.538	9805	0.457
13	213.6	301.6	227.6	0.473	8621	0.402
12	187.2	328.0	197.2	0.410	7622	0.355
11	162.4	352.8	162.8	0.338	6364	0.297
10	139.2	376.0	129.5	0.269	5106	0.238
9	117.3	397.9	92.5	0.192	3441	0.160
8	97.4	417.8	61.1	0.127	2035	0.095
7	78.9	436.3	33.3	0.069	925	0.043
6	62.1	453.1	20.4	0.042	444	0.021
5	47.1	468.1	9.3	0.019	74	0.003
4	33.8	481.4	4.8	0.010		

TABLE XXXII. ACTIVATION OF ZINC BY DEUTERONS (E=10 MeV)

			(Zn + d → ^{65}Zn)		*(Zn + d → ^{67}Ga)*	
Particle energy E, MeV	**Range R mg/cm²**	**Depth *x* mg/cm²**	**Yield Y kBq/μAh**	**Activity A rel. units**	**Yield Y kBq/μAh**	**Activity A rel. units**
10.0	139.2	0.0	129.5	1.000	5180	1.000
9.5	128.1	11.1	111	0.857	4255	0.821
9.0	117.3	21.9	92.5	0.714	3515	0.679
8.5	107.7	31.5	77	0.594	2701	0.521
8.0	97.4	41.8	61.1	0.471	2035	0.393
7.5	87.9	51.3	46.3	0.357	1184	0.229
7.0	78.9	60.3	35.2	0.271	925	0.179
6.5	70.3	68.9	25.9	0.200	666	0.129
6.0	62.1	77.1	20.4	0.157	444	0.086
5.5	54.4	84.8	14.1	0.109	222	0.043
5.0	47.1	92.1	9.3	0.071	74	0.014
4.5	40.2	99.0	5.9	0.046		
4.0	33.8	105.4	4.1	0.031		

TABLE XXXIII. ACTIVATION OF ZINC BY ^{3}He IONS (E=30 MeV)

(Zn + ^{3}He → ^{65}Zn)

Particle energy E, MeV	**Range R mg/cm²**	**Depth *x* mg/cm²**	**Yield Y kBq/μAh**	**Activity A rel. units**
30	164.6	0.0	151.7	1.000
29	155.5	9.1	142.5	0.945
28	146.6	18.0	134.7	0.883
27	137.9	26.7	125.8	0.829
26	129.5	35.1	118	0.771
25	121.3	43.3	109.9	0.655
24	113.3	51.3	93.2	0.597
23	105.5	59.1	85.1	0.532
22	98.0	66.6	75.9	0.468
21	90.8	73.8	66.6	0.405
20	83.8	80.8	57.7	0.343
19	77.0	87.6	48.8	0.286
18	70.4	94.2	40.7	0.226
17	64.2	100.4	32.2	0.174
16	58.2	106.4	24.8	0.130
15	52.5	112.1	18.5	0.091
14	46.9	117.7	13	0.060
13	41.7	122.9	8.5	0.034
12	36.8	127.8	4.8	0.018
11	32.1	132.5	2.6	0.000

TABLE XXXIII.(CONT.) ACTIVATION OF ZINC BY ^{3}He IONS (E=30 MeV)

			(Zn + ^{3}He → ^{67}Ga)		*(Zn + ^{3}He → ^{68}Ge)*	
Particle energy E, MeV	**Range R mg/cm²**	**Depth *x* mg/cm²**	**Yield Y kBq/μAh**	**Activity A rel. units**	**Yield Y kBq/μAh**	**Activity A rel. units**
30	164.6	0.0	4995	1.000	27.8	1.000
29	155.5	9.1	4773	0.956	24.4	0.880
28	146.6	18.0	4551	0.911	21.5	0.773
27	137.9	26.7	4292	0.859	18.5	0.667
26	129.5	35.1	4033	0.807	15.9	0.573
25	121.3	43.3	3774	0.756	13.7	0.493
24	113.3	51.3	3471	0.695	11.5	0.413
23	105.5	59.1	3167	0.634	9.3	0.333
22	98.0	66.6	2849	0.570	7.4	0.267
21	90.8	73.8	2520	0.504	5.9	0.213
20	83.8	80.8	2198	0.440	4.8	0.173
19	77.0	87.6	1876	0.376	3.7	0.133
18	70.4	94.2	1565	0.313	3	0.107
17	64.2	100.4	1306	0.261	2.2	0.080
16	58.2	106.4	1006	0.201	1.5	0.053
15	52.5	112.1	796	0.159	0.7	0.027
14	46.9	117.7	592	0.119		
13	41.7	122.9	407	0.081		
12	36.8	127.8	259	0.052		
11	32.1	132.5	148	0.030		
10	27.7	136.9	85	0.017		

TABLE XXXIV. ACTIVATION OF NIOBIUM BY PROTONS (E=22 MeV)

			(Nb + p → ^{89}Zr)		*(Nb + p → ^{92m}Nb)*	
Particle energy E, MeV	**Range R mg/cm²**	**Depth *x* mg/cm²**	**Yield Y kBq/μAh**	**Activity A rel. units**	**Yield Y kBq/μAh**	**Activity A rel. units**
22.0	954.4	0.0	222	1.000	3700	1.000
21.5	917.7	36.7	173.2	0.780	3182	0.860
21.0	881.1	73.3	126.5	0.570	2738	0.740
20.5	845.7	108.7	88.8	0.400	2331	0.630
20.0	810.3	144.1	58.5	0.263	1998	0.540
19.5	776.2	178.2	38.1	0.172	1665	0.450
19.0	742.2	212.2	27.4	0.123	1332	0.360
18.5	709.4	245.0	14.1	0.063	1073	0.290
18.0	776.6	177.8	3.3	0.015	851	0.230
17.5	645.1	309.3			629	0.170
17.0	613.7	340.7			481	0.130
16.5	583.6	370.8			370	0.100
16.0	553.6	400.8			296	0.080
15.5	524.8	429.6			241	0.065
15.0	496.1	458.3			185	0.050
14.5	468.7	485.7			148	0.040
14.0	441.4	513.0			111	0.030
13.5	416.4	538.0			74	0.020
13.0	389.5	564.9			37	0.010

TABLE XXXV. ACTIVATION OF NIOBIUM BY DEUTERONS (E=22 MeV)

(Nb + d → ^{92m}Nb)

Particle energy E, MeV	**Range R mg/cm²**	**Depth x mg/cm²**	**Yield Y kBq/μAh**	**Activity A rel. units**
22	588.8	0.0	769.6	1.000
21	544.9	43.9	590.15	0.767
20	502.4	86.4	422.91	0.550
19	461.5	127.3	290.08	0.377
18	422.0	166.8	213.12	0.277
17	384.1	204.7	165.02	0.214
16	347.8	241.0	129.87	0.169
15	318.0	270.8	99.9	0.130
14	279.8	309.0	76.96	0.100
13	248.2	340.6	56.98	0.074
12	218.3	370.5	39.96	0.052
11	190.0	398.8	28.12	0.037
10	163.4	425.4	18.13	0.024
9	138.5	450.3	8.14	0.011
8	115.4	473.4	2.96	0.004

TABLE XXXVI. ACTIVATION OF NIOBIUM BY ^{3}He IONS (E=30 MeV)

(Nb + ^{3}He → ^{95m}Tc)

Particle energy E, MeV	**Range R mg/cm²**	**Depth *x* mg/cm²**	**Yield Y kBq/μAh**	**Activity A rel. units**
30	188.6	0.0	0.444	1.000
29	178.3	10.3	0.42.18	0.950
28	168.3	20.3	0.4033	0.908
27	158.5	30.1	0.3867	0.871
26	149.0	39.6	0.3707	0.835
25	139.7	48.9	0.3552	0.800
24	130.7	57.9	0.3404	0.767
23	121.9	66.7	0.3226	0.727
22	113.4	75.2	0.3053	0.688
21	105.2	83.4	0.2886	0.650
20	97.2	91.4	0.2731	0.615
19	89.5	99.1	0.2564	0.578
18	82.1	106.5	0.2375	0.535
17	75.0	113.7	0.2176	0.490
16	68.1	120.5	0.198	0.446
15	61.5	127.1	0.2131	0.480
14	55.2	133.4	0.1543	0.348
13	49.2	139.4	0.1314	0.296
12	43.5	145.1	0.1058	0.238
11	38.1	150.5	0.0777	0.175
10	33.0	155.6	0.0629	0.142
9	28.2	160.4	0.0459	0.103
8	23.7	164.9	0.0296	0.067
7	19.6	169.0	0.0148	0.033
6	15.7	172.9	0.0037	0.008

TABLE XXXVI. (CONT.) ACTIVATION OF NIOBIUM BY ^{3}He IONS (E=30 MeV)

			(Nb + ^{3}He → ^{88}Y)		*(Nb+ ^{3}He → ^{92m}Nb)*	
Particle energy E, MeV	**Range R mg/cm²**	**Depth *x* mg/cm²**	**Yield Y kBq/μAh**	**Activity A rel. units**	**Yield Y kBq/μAh**	**Activity A rel. units**
30	188.6	0.0	0.7215	1.000	48.1	1.000
29	178.3	10.3	0.5106	0.708	38.9	0.808
28	168.3	20.3	0.3811	0.528	31.5	0.654
27	158.5	30.1	0.2812	0.390	27	0.562
26	149.0	39.6	0.1961	0.272	22.9	0.477
25	139.7	48.9	0.1369	0.190	19.6	0.408
24	130.7	57.9	0.0888	0.123	16.7	0.346
23	121.9	66.7	0.0555	0.077	14.1	0.292
22	113.4	75.2	0.0296	0.041	11.1	0.231
21	105.2	83.4	0.0111	0.015	8.5	0.177
20	97.2	91.4			6.7	0.138
19	89.5	99.1			4.995	0.104
18	82.1	106.5			3.404	0.071
17	75.0	113.7			2.294	0.048
16	68.1	120.5			1.332	0.028
15	61.5	127.1			0.29	0.013
14	55.2	133.4			0.222	0.005

TABLE XXXVII. ACTIVATION OF MOLYBDENUM BY PROTONS (E=22 MeV)

			(Mo + p → ^{95m}Tc)		*(Mo + p → ^{96}Tc)*	
Particle energy E, MeV	**Range R mg/cm²**	**Depth *x* mg/cm²**	**Yield Y kBq/μAh**	**Activity A rel. units**	**Yield Y kBq/μAh**	**Activity A rel. units**
22	967.8	0.0	532.8	1.000	20720	1.000
21	893.6	74.2	481	0.903	18500	0.893
20	822.0	145.8	428.5	0.804	16465	0.795
19	753.0	214.8	379.3	0.712	14578	0.704
18	686.6	281.2	335.2	0.629	12691	0.613
17	622.9	344.9	289.7	0.544	11100	0.536
16	562.0	405.8	246.1	0.462	9509	0.459
15	503.8	464.0	195	0.366	8399	0.405
14	448.3	519.5	154.3	0.290	7030	0.339
13	395.8	572.0	114.3	0.215	5550	0.268
12	346.1	621.7	78.1	0.147	4070	0.196
11	299.3	668.5	47	0.088	2775	0.134
10	255.5	712.3	30.3	0.057	1924	0.093
9	214.7	753.1	22.2	0.042	1221	0.059
8	177.0	790.8	11.1	0.021	629	0.030
7	142.5	825.3	7.4	0.014	296	0.014
6	111.3	856.5			111	0.005

TABLE XXXVIII. ACTIVATION OF MOLYBDENUM BY PROTONS (E=11 MeV)

			(Mo + p → ^{95m}Tc)		*(Mo + p → ^{96}Tc)*	
Particle energy E, MeV	**Range R mg/cm²**	**Depth *x* mg/cm²**	**Yield Y kBq/μAh**	**Activity A rel. units**	**Yield Y kBq/μAh**	**Activity A rel. units**
11.0	299.30	0.00	46.99	1.000	2775	1.000
10.5	277.30	22.00	38.85	0.827	2301	0.829
10.0	255.50	43.80	32.19	0.685	1943	0.700
9.5	234.70	64.60	26.09	0.555	1543	0.556
9.0	214.70	84.60	20.54	0.437	1217	0.439
8.5	195.50	103.80	15.91	0.339	910	0.328
8.0	177.00	122.30	12.1	0.257	651	0.235
7.5	159.40	139.90	9.07	0.193	455	0.164
7.0	142.50	156.80	6.66	0.142	303	0.109
6.5	126.50	172.80	4.81	0.102	174	0.063
6.0	111.30	188.00	3.03	0.065	94	0.034
5.5	96.93	202.37	1.85	0.039	48	0.017
5.0	83.41	215.89	1.07	0.023	26	0.009
4.5	70.77	228.53	0.48	0.010	15	0.005
4.0	59.00	240.30	0.22	0.005		

TABLE XXXIX. ACTIVATION OF MOLYBDENUM BY PROTONS (E=7 MeV)

			(Mo + p → ^{95m}Tc)		*(Mo + p → ^{96}Tc)*	
Particle energy E, MeV	**Range R mg/cm²**	**Depth *x* mg/cm²**	**Yield Y kBq/μAh**	**Activity A rel. units**	**Yield Y kBq/μAh**	**Activity A rel. units**
7.0	142.5	0.00	6.4	1.000	296	1.000
6.8	135.9	6.60	5.59	0.873	249.4	0.843
6.6	129.5	13.00	4.81	0.751	190.2	0.643
6.4	123.2	19.30	4.11	0.642	156.1	0.528
6.2	117.2	25.30	3.52	0.549	118.4	0.400
6.0	111.3	31.20	3	0.468	95.1	0.321
5.8	105.5	37.00	2.52	0.393	71.8	0.243
5.6	99.79	42.71	2.11	0.329	55.5	0.188
5.4	94.23	48.27	1.74	0.272	40.7	0.138
5.2	88.81	53.69	1.37	0.214	29.6	0.100
5.0	83.41	59.09	1.04	0.162	22.2	0.075
4.8	78.24	64.26	0.74	0.116	16.3	0.055
4.6	73.22	69.28	0.48	0.075	11.1	0.038
4.4	68.33	74.17	0.26	0.040	7.4	0.025

TABLE XXXX. ACTIVATION OF MOLYBDENUM BY DEUTERONS (E=22 MeV)

			(Mo + d → ^{95m}Tc)		*(Mo + d → ^{96}Tc)*	
Particle **energy E, MeV**	Range **R mg/cm²**	Depth ***x*** **mg/cm²**	Yield **Y kBq/μAh**	Activity **A rel. units**	Yield **Y kBq/μAh**	Activity **A rel. units**
22	598.7	0.0	277.5	1.000	21460	1.000
21	554.2	44.5	263.4	0.949	19536	0.910
20	511.1	87.6	247.2	0.891	17242	0.803
19	469.6	129.1	229.4	0.827	15096	0.703
18	429.6	169.1	212	0.764	12987	0.605
17	391.1	207.6	193.1	0.696	10915	0.509
16	354.2	244.5	173.9	0.627	9176	0.428
15	318.9	279.8	154.7	0.557	7659	0.357
14	285.2	313.5	134.3	0.484	6512	0.303
13	253.1	345.6	113.2	0.408	5476	0.255
12	222.7	376.0	91.8	0.331	4292	0.200
11	193.9	404.8	69.9	0.252	3330	0.155
10	166.9	431.8	46.6	0.168	2479	0.116
9	141.6	457.1	26.6	0.096	1665	0.078
8	118.0	480.7	13	0.047	814	0.038
7	96.3	502.4	5.9	0.021	444	0.021

TABLE XXXXI. ACTIVATION OF MOLIBDENUM BY ^{3}He IONS (E=30 MeV)

(Mo + ^{3}He → ^{95m}Tc)

Particle energy E, MeV	**Range R mg/cm²**	**Depth *x* mg/cm²**	**Yield Y kBq/μAh**	**Activity A rel. units**
30	191.8	0.0	9.25	1.000
29	181.4	10.4	8.251	0.892
28	172.2	19.6	7.326	0.792
27	161.3	30.5	6.512	0.704
26	151.6	40.2	5.809	0.628
25	142.2	49.6	5.106	0.552
24	133.0	58.8	4.403	0.476
23	124.2	67.6	3.737	0.404
22	115.5	76.3	3.108	0.336
21	107.2	84.6	2.516	0.272
20	99.08	92.7	1.998	0.216
19	91.27	100.5	1.554	0.168
18	83.73	108.1	1.147	0.124
17	76.47	115.3	0.814	0.088
16	69.49	122.3	0.518	0.056
15	62.80	129.0	0.296	0.032
14	56.40	135.4	0.148	0.016
13	50.30	141.5	0.074	0.008

TABLE XXXXI (CONT.) ACTIVATION OF MOLYBDENUM BY ^{3}He IONS (E=30 MeV)

			(Mo + ^{3}He → ^{96}Tc)		*(Mo + ^{3}He → ^{97}Ru)*	
Particle energy **E, MeV**	Range **R** **mg/cm²**	Depth ***x*** **mg/cm²**	Yield **Y** **kBq/μAh**	Activity **A** **rel. units**	Yield **Y** **kBq/μAh**	Activity **A** **rel. units**
30	191.8	0.0	1388	1.000	5476	1.000
29	181.4	10.4	1232	0.888	5113	0.934
28	172.2	19.6	1092	0.787	4751	0.868
27	161.3	30.5	962	0.693	4385	0.801
26	151.6	40.2	844	0.608	4018	0.734
25	142.2	49.6	729	0.525	3652	0.667
24	133.0	58.8	614	0.443	3289	0.601
23	124.2	67.6	511	0.368	2960	0.541
22	115.5	76.3	426	0.307	2649.2	0.484
21	107.2	84.6	348	0.251	2338.4	0.427
20	99.08	92.7	281	0.203	2027.6	0.370
19	91.27	100.5	222	0.160	1720.5	0.314
18	83.73	108.1	174	0.125	1417.1	0.259
17	76.47	115.3	130	0.093	1128.5	0.206
16	69.49	122.3	93	0.067	888	0.162
15	62.80	129.0	59	0.043	647.5	0.118
14	56.40	135.4	33	0.024	455.1	0.083
13	50.30	141.5			303.4	0.055
12	44.48	147.3			159.1	0.029
11	38.98	152.8			7.4	0.001

TABLE XXXXII. ACTIVATION OF TUNGSTEN BY PROTONS (E=22 MeV)

			$(W + p \rightarrow {}^{183}Re)$		$(W + p \rightarrow {}^{184g}Re)$	
Particle energy E, MeV	**Range R mg/cm²**	**Depth x mg/cm²**	**Yield Y kBq/μAh**	**Activity A rel. units**	**Yield Y kBq/μAh**	**Activity A rel. units**
22	1222.0	0.0	1258	1.000	2960	1.000
21	1131.0	91.0	1177	0.935	2146	0.725
20	1042.0	180.0	1080	0.859	1450.4	0.490
19	957.1	264.9	962	0.765	962	0.325
18	875.0	347.0	792	0.629	660.1	0.223
17	796.0	426.0	618	0.491	467.7	0.158
16	720.0	502.0	426	0.338	346.3	0.117
15	647.4	574.6	315	0.250	287.1	0.097
14	578.6	643.4	229	0.182	222	0.075
13	512.7	709.3	155	0.124	168.7	0.057
12	450.3	771.7	89	0.071	138.5	0.047
11	391.4	830.6	48	0.038	88.8	0.030
10	336.0	886.0	19	0.015	59.2	0.020
9	284.2	937.8	7	0.006	3	0.001
8	236.1	985.9			0.9	0.000

TABLE XXXXIII. ACTIVATION OF TUNGSTEN BY PROTONS (E=11 MeV)

			$(W + p \rightarrow {}^{183}Re)$		$(W + p \rightarrow {}^{184g}Re)$	
Particle energy E, MeV	**Range R mg/cm²**	**Depth x mg/cm²**	**Yield Y kBq/μAh**	**Activity A rel. units**	**Yield Y kBq/μAh**	**Activity A rel. units**
11.0	391.4	0.0	48.1	1.000	89.9	1.000
10.5	363.5	27.9	30.3	0.631	74	0.823
10.0	336.0	55.4	17.8	0.369	58.1	0.646
9.5	309.7	81.7	10.4	0.215	42.9	0.477
9.0	284.2	107.2	6.3	0.131	27.8	0.309
8.5	259.7	131.7	3.52	0.073	16.3	0.181
8.0	236.1	155.3	2.04	0.042	9.3	0.103
7.5	213.5	177.9	1.07	0.022	4.63	0.051
7.0	191.8	199.6	0.59	0.012	1.96	0.022
6.5	171.1	220.3	0.22	0.005	0.56	0.006

TABLE XXXXIV. ACTIVATION OF TUNGSTEN BY DEUTERONS (E=22 MeV)

			$(W + d \rightarrow {}^{183}Re)$		$(W + d \rightarrow {}^{184g}Re)$	
Particle energy E, MeV	**Range R mg/cm²**	**Depth *x* mg/cm²**	**Yield Y kBq/μAh**	**Activity A rel. units**	**Yield Y kBq/μAh**	**Activity A rel. units**
22	782.9	0.0	1480	1.000	1110	1.000
21	726.7	56.2	1272.8	0.860	1017.5	0.917
20	672.2	110.7	1065.6	0.720	932.4	0.840
19	619.5	163.4	873.2	0.590	899.1	0.810
18	568.6	214.3	711.9	0.481	828.8	0.747
17	519.6	263.3	571.3	0.386	762.2	0.687
16	472.4	310.5	436.6	0.295	691.9	0.623
15	427.1	355.8	325.6	0.220	573.5	0.517
14	383.7	399.2	230.9	0.156	484.7	0.437
13	342.2	440.7	161.3	0.109	373.7	0.337
12	302.7	480.2	109.5	0.074	273.8	0.247
11	265.2	517.7	68.1	0.046	177.6	0.160
10	229.7	553.2	34	0.023	99.9	0.090
9	196.2	586.7	17.8	0.012	40.7	0.037
8	164.9	618.0	5.9	0.004	18.5	0.017

TABLE XXXXV. ACTIVATION OF TUNGSTEN BY ^{3}He IONS (E=30 MeV)

			$(W + {}^{3}He \rightarrow {}^{183}Re)$		$(W + {}^{3}He \rightarrow {}^{184g}Re)$	
Particle energy E, MeV	**Range R mg/cm²**	**Depth x mg/cm²**	**Yield Y kBq/μAh**	**Activity A rel. units**	**Yield Y kBq/μAh**	**Activity A rel. units**
30	251.8	0.0	96.2	1.000	65.1	1.000
29	238.6	13.2	82.51	0.858	55.1	0.847
28	225.7	26.1	68.82	0.715	45.1	0.693
27	213.1	38.7	55.13	0.573	37	0.568
26	200.7	51.1	41.44	0.431	28.5	0.438
25	188.7	63.1	29.23	0.304	20.4	0.313
24	177.0	74.8	20.35	0.212	14.1	0.216
23	165.6	86.2	14.43	0.150	9.6	0.148
22	154.5	97.3	10.36	0.108	5.9	0.091
21	143.8	108.0	6.29	0.065	3.7	0.057
20	133.3	118.5	3.33	0.035	1.9	0.028
19	123.2	128.6	1.11	0.012		0.000

TABLE XXXXV. (CONT.) ACTIVATION OF TUNGSTEN BY ^{3}He IONS (E=30 MeV)

			$(W + {}^{3}He \rightarrow {}^{185}Os)$	
Particle energy E, MeV	**Range R mg/cm²**	**Depth x mg/cm²**	**Yield Y kBq/μAh**	**Activity A rel. units**
30	251.8	0.0	33.3	1.000
29	238.6	13.2	27.75	0.833
28	225.7	26.1	22.57	0.678
27	213.1	38.7	17.76	0.533
26	200.7	51.1	13.32	0.400
25	188.7	63.1	9.25	0.278
24	177.0	74.8	5.92	0.178
23	165.6	86.2	3.33	0.100
22	154.5	97.3	1.85	0.056
21	143.8	108.0	0.74	0.022

Annex III

INIS DATABASE ON THIN LAYER ACTIVATION

DOCUMENT NUMBER = INI27:067062

VVSS	= 2720	RN	= 27 067062	CTRY	= NL
YEAR	= 1996	TYPE	= J	CAT	= G3620
LVLS	= AS	ISSN	= 0168-583X		
AU	= DITROI, F	SRCE	= NUCLEAR INSTRUME		
TSRCE	= JNUCLEAR INSTRUME				

TI: **Thin layer activation** of non-metallic materials by using nuclear implantation.
AU: Ditroi, F. (Magyar Tudomanyos Akademia, Debrecen (Hungary). Atommag Kutato Intezete); Mahunka, I. (Magyar Tudomanyos Akademia, Debrecen (Hungary). Atommag Kutato Intezete).
LA: English
JR: Nuclear Instruments and Methods in Physics Research. Section B, Beam Interactions with Materials and Atoms. ISSN 0168-583X. CODEN: NIMBEU. (Jun 1996). v. 113(1-4). p. 415-419.
CF: (4. European conference on accelerators in applied research and technology (ECAART-4). Zurich (Switzerland). 29 Aug - 2 Sep 1995.)
CN: NL (Netherlands) J (Journal Article)
LI: K (Conferences)
CC: G3620 (Physics of radiations other than neutrons) B1330
AB: Nuclear implantation of the cyclotron produced "7Be isotope was used for labeling of plastic and other materials that cannot be activated in nuclear wear measurements In our experiments boron of natural composition was used in the form of a NiBSi metallic-glass foil as implantation target through the "n"a"tB(p,x)"7Be nuclear reactions. Kapton (C_2_2H_1_0O_5N_2) and beryllium targets are also suitable by using a "3He beam /(through "1"2C("3He,2#alpha#)"7Be and "9Be("3He,#alpha#n)"7Be reactions, respectively/) to produce a high flux of radioactive "7Be in order to implant a very **thin surface layer** of the secondary target. The chosen secondary target should have a composition which does not contain elements which can be activated by the bombarding beam. This condition was controlled separately by the bombardment with the same beam. This control- irradiation is also useful to make corrections for possible interferences. Based on our early and recent experiences we have chosen Be as implantation target, having the most proper conditions for nuclear implantation (orig).
CT: (iad), alpha particles; beryllium ions; beryllium 7, beryllium 9 target, boron 10 target, boron 11 target; carbon 12 target, helium 3 reactions; ion implantation, isotope production, knock-out reactions, layers, metallic glasses; mev range 10-100, neutron transfer, nickel borides; nickel silicides, one-nucleon transfer reactions, plastics, proton reactions; target chambers; three- nucleon transfer reactions; (cad), accelerator facilities; baryon reactions; beryllium isotopes; beta decay radioisotopes, borides, boron compounds; charged particles; days living radioisotopes direct reactions; electron capture radioisotopes; energy range, even-odd nuclei, hadron reactions; helium ions, ionizing radiations, ions; isotopes, light nuclei, mev range, multi-nucleon transfer reactions, nickel compounds; nuclear reactions, nuclei, nucleon reactions; organic compounds, organic polymers; petroleum products, polymers; radiations; radioisotopes; silicides; silicon compounds; targets; transfer reactions; transition element compounds;
MQ: beryllium 7: isotope production; ion implantation: isotope production.

DOCUMENT NUMBER = INI27:064810

VVSS	= 2720	RN	= 27:064810	CTRY	= NL
YEAR	= 1996	TYPE	= J	CAT	= B1110
LVLS	= AS	ISSN	= 0168-583X		
AU	= RACOLTA, P	SRCE	= NUCLEAR INSTRUME		
TSRCE	= JNUCLEAR INSTRUME				

TI: Ion beam-based studies for tribological phenomena
AU: Racolta, P M (Institute of Atomic Phys, Bucharest (Romania) Cyclotron Lab), Popa-Simil, L (Institute of Atomic Phys, Bucharest (Romania) Cyclotron Lab), Alexandreanu, B (Institute of Atomic Phys, Bucharest (Romania) Cyclotron Lab)
LA: English
JR: Nuclear Instruments and Methods in Physics Research Section B Beam Interactions with Materials and Atoms ISSN 0168-583X CODEN NIMBEU (Jun 1996) v 113(1-4) p 420-423
CF: (4 European conference on accelerators in applied research and technology (ECAART-4) Zurich (Switzerland) 29 Aug - 2 Sep 1995)
CN: NL (Netherlands) J (Journal Article)
LI: K (Conferences)
CC: B1110 (Nuclear methods in chemical and isotopic analysis) D2200
AB: Custom-designed experiments based on the **thin layer activation** technique (TLA) were completed, providing information on the wear level of some engine components with additional data on transfer and adhesion of material between metallic friction couples using the RBS method RBS experimental results concerning material transfer for a steel-brass friction couple are presented and discussed in the paper Also, the types and concentrations of the wear products in used lubricant oils were determined by in-air PIXE A sequential lubricant filtering-based procedure for determining the dimension distribution of the resulting radioactive wear particles by low level #gamma#-spectrometry is presented Experimental XRF spectra showing the non-homogeneous distribution of the retained waste particles on the filtering paper are shown (orig)
CT: (iad), abrasion, **activation** analysis, adhesion, backscattering, brass, filtration, friction gamma spectroscopy, layers, low level counting, lubricating oils, lubrication, nuclear reaction analysis; particle size, pixe analysis, rutherford scattering, steels, wear, x- ray fluorescence analysis, (cad), alloys, carbon additions, chemical analysis, copper alloys, copper base alloys, counting techniques, elastic scattering; iron alloys, iron base alloys, lubricants, nondestructive analysis, petroleum products, scattering; separation processes, size, spectroscopy; transition element alloys, x-ray emission analysis, zinc alloys,
MQ: gamma spectroscopy particle size, nuclear reaction analysis wear, pixe analysis wear, wear **activation** analysis, x-ray fluorescence analysis wear

DOCUMENT NUMBER = INI27 059745

VVSS	= 2718	RN	= 27 059745	CTRY	= HU
YEAR	= 1996	TYPE	= J	CAT	= D2200
LVLS	= AS	ISSN	= 0231-3596		
AU	= DITROI, F	SRCE	= ATOMKI ANNUAL RE		
TSRCE	= JATOMKI ANNUAL RE				

TI: **Thin layer activation** of non-metallic materials by using nuclear implantation
AU: Ditroi, F, Mahunka, I (Magyar Tudomanyos Akademia, Debrecen (Hungary) Atommag Kutato Intezete)
LA: English
JR: ATOMKI Annual Report ISSN 0231-3596 CODEN AREAE9 (Apr 1996) (no 9) p 65
CN: HU (Hungary) J (Journal Article) Related to 26 074961
LI: E (Short Communication)
CC: D2200 (Industrial Applications, Radiometric) B1110
AB: Short communication
CT: (iad), **activation** analysis, beryllium 7, labelling, **thin** films, tracer techniques, (cad), beryllium isotopes, beta decay radioisotopes, chemical analysis days living radioisotopes, electron capture radioisotopes, even-odd nuclei, films, isotope applications, isotopes, light nuclei, nondestructive analysis, nuclei, radioisotopes,
MQ: beryllium 7 **activation** analysis

DOCUMENT NUMBER = INI27 053116

VVSS = 2716 RN = 27 053116 CTRY = GB
YEAR = 1996 TYPE = J CAT = B2250
LVLS = AS ISSN = 0969-806X
AU = RACOLTA P SRCE = RADIATION PHYSIC
TSRCE = JRADIATION PHYSIC

TI: Cyclotron accelerated beams applied in wear and corrosion studies
AU: Racolta, P M Popa-Simil L, Ivanov E A, Alexandreanu B (Institute of Physics and Nuclear Engineering Bucharest (Romania) Cyclotron Lab)
LA: English
JR: Radiation Physics and Chemistry (1993) ISSN 0969-806X CODEN RPCHDM (May 1996) v 47(5) p 677-680
CF: (2 conference on radiation physics Menoufia (Egypt) 20-24 Nov 1994)
CN: GB (United Kingdom) J (Journal Article)
LI: K (Conferences)
CC: B2250 (Corrosion and erosion) B1110 E1610
AB: Wear and corrosion processes are characterized by a loss of material that is, for machine parts and components, usually in a micrometer's range In the last two decades many direct applications in machine construction petrochemical and metallurgical industries based on the **Thin Layer Activation** (TLA) technique have been developed In this paper general working patterns together with a few examples of TLA applications carried out using our laboratory s U-120 Cyclotron are presented The relation between the counting rate of the radiation originating from the component s irradiated zone and the loss of the worn material can be determined mainly by two methods the oil circulation method and the remnant radioactivity measuring method The first method is illustrated with some typical examples such as the optimization of the running- in program of a diesel engine and anti-wear features certifying of lubricant oils There is also presented an example where the second method mentioned above has been applied to corrosion rate determinations for different kinds of unoxidable steels used in inert gas generator construction (author)
CT: (iad), cyclotrons, deuteron beams, diesel engines lubricating oils, mev range 10-100, optimization, proton beams, radioactivity, sensitivity, spectroscopy, wear, (cad), accelerators, beams, cyclic accelerators energy range, engines, heat engines internal combustion engines, ion beams, lubricants, mev range, nucleon beams particle beams, petroleum products,
MQ: diesel engines spectroscopy, diesel engines wear lubricating oils spectroscopy lubricating oils wear

DOCUMENT NUMBER = INI27 042828

VVSS = 2712 RN = 27 042828 CTRY = IN
YEAR = 1995 TYPE = B CA = G3440
LVLS = AM AU = CHOWDHURY
SRCE = PROCEEDINGS OF N TSRCE = BPROCEEDINGS OF N

TI: The activity profile and cross section of isotopes from #alpha#- induced nuclear reaction on Zr for radioanalytical applications
AU: Chowdhury D P Pal, Sujit (Variable Energy Cyclotron Centre, Calcutta (India) Analytical Chemistry Div), Chaudhuri, Jayanta (Variable Energy Cyclotron Centre, Calcutta (India))
LA: English
MS: Proceedings of nuclear and radiochemistry symposium Kulkarni, S G, Manohar, S B, Sood D D (eds) (Bhabha Atomic Research Centre, Bombay (India)) Department of Atomic Energy Bombay (India) Board of Research in Nuclear Sciences
IM: Bombay (India) Bhabha Atomic Research Centre 1995 480 p p 99-100
CF: (NUCAR-95 nuclear and radiochemistry symposium Kalpakkam (India) 21-24 Feb 1995)
CN: IN (India) B (Book) Related to 27 040415
LI: K (Conferences)
CC: G3440 (2H-, 3H- and He-induced reactions and scattering) G3560
AB: The cross section and activity profile of different radioisotopes produced by #alpha#-induced nuclear reaction on natural zirconium have been obtained by stacked

foil **activation** using 40 MeV #alpha#- particles from Variable Energy Cyclotron (VEC) machine at Calcutta The activity profile would be used to study the surface loss of zircaloy materials of engineering components by **thin layer activation** (TLA) technique Generally, isotopes with suitable #gamma#-rays and long half-lives are the most useful in TLA technique e g , "9"2Nb, "9"5"gNb and "9"5Zr (author) 2 refs , 1 tab

CT: (iad) alpha particles, alpha reactions, cross sections, mev range 10-100, niobium 92, niobium 95, niobium 97, protons, radioactivity, zirconium, zirconium 90 target zirconium 92 target, zirconium 94 target, zirconium 95, zirconium 96 target, (cad), baryons, beta decay radioisotopes, beta-minus decay radioisotopes, beta-plus decay radioisotopes, cations, charged particles, days living radioisotopes; electron capture radioisotopes, elementary particles, elements, energy range, even- odd nuclei, fermions; hadrons, helium ions, hours living radioisotopes, hydrogen ions hydrogen ions 1 plus, intermediate mass nuclei ionizing radiations; ions, isomeric transition isotopes, isotopes, metals, mev range niobium isotopes, nuclear reactions, nuclei, nucleons, odd-even nuclei, odd-odd nuclei, radiations, radioisotopes, seconds living radioisotopes targets, transition elements, years living radioisotopes, zirconium isotopes,

MQ: zirconium alpha reactions zirconium cross sections

DOCUMENT NUMBER = INI27 031827

VVSS	= 2710	PN	= 27 031827	CTRY	= NL
YEAR	= 1996	TYPE	= J	CAT	= E1700
LVLS	= AS	ISSN	= 0168-9002		
AU	= LACROIX O	SRCE	= NUCLEAR INSTRUME		
TSRCE	= JNUCLEAR INSTRUME				

TI: Metrology conditions for **thin layer activation** in wear and corrosion studies

AU: Lacroix, O (CERI-CNRS, Orleans (France)), Sauvage, T (CERI-CNRS, Orleans (France)), Blondiaux, G (CERI-CNRS, Orleans (France)), Racolta, P M (Institu of Atomic Phys., Bucharest (Romania) Cyclotron Lab), Popa-Simil, L. (Institu of Atomic Phys , Bucharest (Romania) Cyclotron Lab), Alexandreanu, B (Institu of Atomic Phys , Bucharest (Romania) Cyclotron Lab)

LA: English

JR: Nuclear Instruments and Methods in Physics Research Section A, Accelerators Spectrometers, Detectors and Associated Equipment ISSN 0168-9002 CODEN NIMAER (1 Feb 1996) v 369(2-3) p 427- 430

CF: (International symposium on radionuclide metrology and its applications Paris (France) 15-19 May 1995.)

CN: NL (Netherlands) J (Journal Article)

LI: K (Conferences)

CC: E1700 (Materials Testing) D2400 D2200

AB: **Thin Layer Activation** (TLA) is an ion beam technique This method consists of an accelerated ion bombardment of the surface of interest of a machine part subjected to wear Radioactive tracers are created by nuclear reactions in a well defined volume of material Loss of material owing to wear, corrosion or abrasion phenomena is characterized by monitoring the resulting changes in radioactivity For the industrial application of this method special attention has been paid during irradiation to the range of activated thickness, yields and **activation** homogeneity and to on- line radioactivity measurements There are two basic methods for measuring the material loss by TLA technique One of them is based on remanant radioactivity measurements using a previously obtained calibration curve The second is based on measuring the increasing radioactivity in the lubricant due to suspended wear particles In this paper, we have chosen to present some calibration curves for both proton and deuteron irradiation of Fe, Cr, Cu, Ti and Ni samples Thickness ranges are indicated and intrinsic error checking and calculational procedures are also presented The article ends with a review of some typical experiments involving running-in programme optimization and lubricant certifying procedures (orig)

CT: (iad), abrasion, **activation** analysis, calibration, chromium; copper, corrosion, deuteron reactions, errors, ion beams, iron, isotope production, layers, losses, lubricants, nickel; nondestructive testing, on-line measurement systems, proton

reactions, radiation monitoring, sensitivity, suspensions thickness titanium tracer techniques, wear (cad) baryon reactions beams chemical analysis chemical reactions, dimensions, dispersions, elements, hadron reactions, isotope applications, materials testing, metals monitoring nondestructive analysis nuclear reactions, nucleon reactions, on- line systems testing transition elements,

MQ: nondestructive testing tracer techniques, tracer techniques **activation** analysis

DOCUMENT NUMBER = INI27:014909

VVSS	= 2705	RN	= 27 014909	CTRY	= MA
YEAR	= 1994	TYPE	= I	CAT	= E1700
LVLS	= M	AU	= RACOLTA P		
SRCE	= NUCLEAR METHODS		TSRCE	= INUCLEAR METHODS	

TI: Nuclear methods for tribology

AU: Racolta, P M

CO: Association des Ingenieurs en Genie Atomique du Maroc, Casablanca (Morocco), Centre National de l'Energie, des Sciences et des Techniques Nucleaires (CNESTEN), Rabat (Morocco), Faculte des Sciences, Rabat (Morocco) Lab de Physique Office Cherifien des Phosphates (OCP), Casablanca (Morocco), Office National d Electricite (ONE) Casablanca (Morocco)

LA: English

IM: 1994 10 p Available from Faculte des Sciences Laboratoire de physique, Rabat (MA)

CF: (6 international symposium on radiation physics (ISRP-6) Rabat (Morocco) 18-22 Jul 1994)

CN: MA (Morocco) I (Miscellaneous)

LI: K (Conferences) N (Numerical Data) X (Non-Conventional Literature unavailable from INIS)

CC: E1700 (Materials Testing)

AB: The tribological field of activity is mainly concerned with the relative movement of different machine components, friction and wear phenomena and their dependence upon lubrication Tribological studies on friction and wear processes are important because they lead to significant parameter-improvements of engineering tools and machinery components A review of fundamental aspects of both friction and wear phenomena is presented A number of radioindicator-based methods have been known for almost four decades, differing mainly with respect to the mode of introducing the radio-indicators into the machine part to be studied All these methods briefly presented in this paper are based on the measurement of the activity of wear products and therefore require high activity levels of the part For this reason, such determinations can be carried out only in special laboratories and under conditions which do not usually agree with the conditions of actual use What is required is a sensitive, fast method allowing the determination of wear under any operating conditions, without the necessity of stopping and disassembling the machine The above mentioned requirements are the features that have made the **Thin Layer Activation** technique (TLA) the most widely used method applied in wear and corrosion studies in the last two decades The TLA principle, taking in account that wear and corrosion processes are characterised by a loss of material, consists in an ion beam irradiation of a well defined volume of a machine part subjected to wear The radioactivity level changes can usually be measured by gamma-ray spectroscopy methods A review of both main TLA fields of application in major laboratories abroad and of those performed at the U-120 cyclotron of I P N E -Bucharest together with the existing trends to extend other nuclear analytical methods to tribological studies is presented as well. (author) 25 refs, 6 figs, 2 tabs

CT: (iad), charged-particle **activation** analysis, corrosion, experimental data, friction, irradiation, lubrication, machinery, tribology, uses, wear, (cad), **activation** analysis, chemical analysis, chemical reactions, data, equipment, information, nondestructive analysis, numerical data,

MQ: tribology charged-particle **activation** analysis, tribology irradiation

DOCUMENT NUMBER = INI27 012571

VVSS = 2704 RN = 27 012571 CTRY = NL
YEAR = 1995 TYPE = J CAT = G6300
LVLS = AS ISSN = 0168-583X
AU = CHOWDHURY SRCE = NUCLEAR INSTRUME
TSRCE = JNUCLEAR INSTRUME

TI: Determination of cross section of #alpha#-induced nuclear reaction on natural Cr and Zr by stacked foil **activation** for **thin layer activation** analysis
AU: Chowdhury, D P (Variable Energy Cyclotron Centre, Calcutta (India) Analytical Chem Div), Pal, S (Variable Energy Cyclotron Centre, Calcutta (India). Analytical Chem Div), Saha, S K. (Radio Chemistry Division, VECC, BARC, 1/AF Bidhan Nagar Calcutta 700064 (India)), Gangadharan, S (Analytical Chemistry Division, BARC, Trombay, Bombay 400085 (India))
LA: English
JR: Nuclear Instruments and Methods in Physics Research Section B, Beam Interactions with Materials and Atoms ISSN 0168-583X CODEN NIMBEU (Nov 1995) v 103(3) p 261-266
CN: NL (Netherlands) J (Journal Article)
CC: G6300 (Interactions Between Beams and Condensed Matter)
AB: The cross sections of different #alpha#-induced nuclear reactions on natural chromium and zirconium have been determined at different energies of the #alpha#-particles by the stacked foil **activation** technique using the 40 MeV #alpha#-beam from Variable Energy Cyclotron at Calcutta The reaction channels studied from the stable isotopes of natural Cr and Zr are (#alpha#, xn), (#alpha# p), (#alpha#, pxn) and (#alpha#, #alpha#n) (where x=1 and 2). The excitation functions have also been reported for the energy range from 10 to 40 MeV of #alpha#-particles The experimentally determined cross sections have been compared with the theoretical values computed on the basis of the hybrid model using a program ALICE 85/300 The analytical validation of the experimental values has been carried out with a vanadium target for which cross sections are already reported in the literature The purpose of generating of the above cross sections is to support the **thin layer activation** technique for the study of surface wear in Cr and Zr based metals/ alloys (orig)
CT: (iad) **activation** analysis, alpha reactions, chromium, cross sections, data analysis foils, zirconium, (cad), chemical analysis, elements, metals, nondestructive analysis, nuclear reactions, transition elements,
MQ: alpha reactions cross sections, chromium alpha reactions, zirconium alpha reactions

DOCUMENT NUMBER = INI26-070801

VVSS = 2621 RN = 26 070801 CTRY = NL
YEAR = 1995 TYPE = J CAT = G6300
LVLS = AS ISSN = 0168-583X
AU = LAGUZZI G SRCE = NUCLEAR INSTRUME
TSRCE = JNUCLEAR INSTRUME

TI: **Thin layer activation** of chromium with deuterons
AU: Laguzzi, G (Commission of the European Communities, Ispra (Italy) Joint Research Centre), Bisconti, R (Commission of the European Communities, Ispra (Italy) Joint Research Centre), Macchi, G (Commission of the European Communities, Ispra (Italy) Joint Research Centre), Stroosnijder, M F (Commission of the European Communities Ispra (Italy) Joint Research Centre)
LA: English
JR: Nuclear Instruments and Methods in Physics Research Section B, Beam Interactions with Materials and Atoms ISSN 0168-583X CODEN NIMBEU (Jun 1995) v 100(4) p 540-542
CN: NL (Netherlands) J (Journal Article)
CC: G6300 (Interactions Between Beams and Condensed Matter)

AB: In view of the recent increased interest in chromium based materials, the **thin layer activation** of chromium has been studied This paper considers relative activity as a function of depth for the deuteron induced reaction in natural chromium The presented results are based on calculations using computer codes and experimental verification using the stacked foil technique and electropolishing of activated bulk samples A very good agreement of the various methods was obtained It is shown that using 10 MeV deuterons, a reasonable homogeneous **activation** over 120 #mu#m can be obtained. ((orig.)).

CT: (iad), **activation** analysis, chromium, computer codes, deuteron reactions; deuterons, differential cross sections, electropolishing, foils, mev range 10-100; (cad); charged particles, chemical analysis, cross sections, electrolysis, elements; energy range, metals, mev range, nondestructive analysis; nuclear reactions, polishing, surface finishing, transition elements,

MQ: chromium **activation** analysis

DOCUMENT NUMBER = INI26.068422

VVSS	= 2620	RN	= 26 068422	CTRY	= US
YEAR	= 1994	TYPE	= B	CAT	= G3430
LVLS	= AM	RP	= CONF940507V0		
AU	= DITRC' F	SRCE	= PROCEEDINGS OF T		
TSRCE	= BPROCEEDINGS OF T				

TI: Measurement of excitation function of "n"a"tB(p,x)"7Be nuclear reaction

AU: Ditroi, F, Fenyvesi A, Takacs, S, Tarkanyi, F (Institute of Nuclear Research of the Hungarian Academy of Sciences, Debrecen (Hungary)), Bergman, J, Heselius S J Solin, O (Abo Akademi Accelerator Lab, Turku (Finland))

LA: English

MS: Proceedings of the international conference nuclear data for science and technology Volume 1 Dickens, J K (ed)

RP: CONF-940507--Vol 1

IM: La Grange Park, IL (United States) American Nuclear Society, Inc. 1994 592 p p 383-385 American Nuclear Society Inc, 555 N Kensington Avenue, La Grange Park IL 60525 (United States)

CF: (International conference on nuclear data for science and technology nuclear data for the twenty-first century Gatlinburg, TN (United States) 9-13 May 1994)

CN: US (United States) B (Book)

LI: K (Conferences)

CC: G3430 (Nucleon-induced reactions and scattering) G3520

AB: Boron of natural composition was irradiated to measure the cross section function of the "n"a"tB(p,x)"7Be nuclear reaction The reaction is very important from the point of view of **Thin Layer Activation** (TLA) technique to monitor the wear of boron containing superhard materials (e g BN) The aim was to determine the cross section of above reaction in the energy region used in wear measurements because practically there is no cross section data available below 10 MeV.

CT: (iad), boron cross sections, excitation functions, mev range 01-10, mev range 10-100, neutron reactions, (cad), baryon reactions, elements, energy range, hadron reactions, mev range, nuclear reactions, nucleon reactions, semimetals,

MQ: boron neutron reactions, neutron reactions cross sections, neutron reactions excitation functions

DOCUMENT NUMBER = INI26 060011

VVSS	= 2618	RN	= 26 060011	CTRY	= US
YEAR	= 1992	TYPE	= B	CAT	= E2200
LVLS	= AM	RP	= CONF910808		
AU	= TSAI C H	SRCE	= PROCEEDINGS OF T		
TSRCE	= BPROCEEDINGS OF T				

TI: Erosion-corrosion and cavitation-erosion measurements on copper alloys utilizing **thin layer activation** technique

AU: Tsai, C H, Hsu, K Y, Kai, J J (National Tsing Hua Univ, Taiwan (China)), Yang,

T N. (Institute of Nuclear Energy, Taiwan (China))
LA: English
MS: Proceedings of the fifth international symposium on environmental degradation of materials in nuclear power systems - water reactors Anon
RP: CONF-910808--
IM: La Grange Park, IL (United States). American Nuclear Society, Inc 1992 995 p p 430-435. American Nuclear Society, Inc, La Grange Park, IL 60525 (United States)
CF: (5 international symposium on environmental degradation of materials in nuclear power systems - water reactors. Monterey, CA (United States) 25-29 Aug 1991)
CN: US (United States) B (Book)
LI: K (Conferences)
CC: E2200 (Reactor Components and Accessories) B2250 B2260
AB: The surface layers of copper alloy specimens were made radioactive by bombarding with 5 MeV protons from a van de Graaff accelerator which converted Cu-65 into Zn-65 through (p,n) reaction. The amount of surface material loss could then be monitored by measuring the total remaining #gamma#-ray activity generated from Zn-65 decay This technique, termed **thin layer activation** (TLA), has the advantage of in situ monitoring the rate of surface removal due to corrosion, erosion-corrosion, wearing, etc In this work, the erosion-corrosion tests on aluminum brass and 90Cu-10Ni were conducted in circulating sea water and the erosion-corrosion rates measured using TLA and conventional methods such as linear polarization resistance (LPR) method and weight loss coupons were compared A vibrational cavitation-erosion test was also performed on aluminum bronze, in which the measurements by TLA were compared with those of weight loss measurements
CT: (iad), copper alloys, corrosion; erosion, heat exchangers, materials testing, nuclear power plants; tubes; (cad), alloys; chemical reactions, nuclear facilities, power plants, testing; thermal power plants, transition element alloys,
MQ: copper alloys corrosion, copper alloys erosion, heat exchangers tubes, nuclear power plants heat exchangers.

DOCUMENT NUMBER = INI26:052854

VVSS	= 2615	RN	= 26 052854	CTRY	= GB
YEAR	= 1995	TYPE	= J	CAT	= D2200
LVLS	= AS	ISSN	= 0967-8638		
AU	= DELVIGNE,	SRCE	= MATERIALS WORLD		
TSRCE	= JMATERIALS WORLD				

TI: **Thin layer activation**: measuring wear and corrosion
AU: Delvigne, T, Leyman, D. (Industrial Diagnosis Services (Belgium)), Oxorn, K (ANS Technologies, Quebec (Canada))
LA: English
JR: Materials World. ISSN 0967-8638. CODEN. MORLEE (Apr 1995) v 3(4) p 184-187
CN: GB (United Kingdom) J (Journal Article)
CC: D2200 (Industrial Applications, Radiometric) B2250
AB: The technique known as **thin layer activation** (TLA) is explained and assessed in this article Widely used, in for example the automotive industry, TLA allows on-line monitoring of the loss of matter from a critical surface, by wear erosion and corrosion The technique offers extremely high sensitivity thus leading to reduced test times On-line wear phenomena can be assessed during operation of a mechanical process, even through thick engine walls (UK)
CT: (iad), automotive industry; charged-particle **activation** analysis, corrosion, erosion, gamma radiation, labelling; on-line systems, radioactivation; **thin** films; thin-layer chromatography; wear; . (cad), **activation** analysis, chemical analysis, chemical reactions, chromatography, electromagnetic radiation, films; industry; ionizing radiations, nondestructive analysis; radiations, separation processes,
MQ: corrosion charged-particle **activation** analysis, erosion: charged- particle **activation** analysis, **thin** films charged-particle **activation** analysis; wear. charged-particle **activation** analysis

DOCUMENT NUMBER = INI26:023631

VVSS = 2607 RN = 26 023631 CTRY = RO
YEAR = 1994 TYPE = I CAT = B1110
LVLS = AM AU = RACOLTA, P
SRCE = NATIONAL PHYSICS TSRCE = INATIONAL PHYSICS

TI: **Thin layer activation** technique at the IAP-IPNE U-120 Cyclotron with regard to wear and corrosion processes.

AU: Racolta, P.M.; Popa-Simil, L.; Alexandreanu, B (Cyclotron Loboratory, Institute of Physics and Nuclear Engineering, Institute of Atomic Physics, PO Box MG-6, R-76900 Bucharest, (Romania))

LA: English

MS: National Physics Conference Sibiu, September 21-24, 1994 Dumitriu, M (ed.) (Institute of Atomic Physics, Information and Documentation Office, PO Box MG-6 R-76900 Bucharest, (Romania)). Institute of Atomic Physics, Bucharest (Romania) Paper Abstracts.

IM: Bucharest (Romania) Institute of Atomic Physics Information and Documentation Office 1994 176 p. p. 5 Available from Romanian Physical Society, PO Box MG-6 R-76900 Bucharest, (RO) Available from Romanian Physical Society, PO Box MG-6 R-76900 Bucharest, (RO)

CF: (National Physics Conference Sibiu (Romania) 21-24 Sep 1994)

CN: RO (Romania) I (Miscellaneous) Related to 26 026114

LI: K (Conferences) X (Non-Conventional Literature unavailable from INIS)

CC: B1110 (Nuclear methods in chemical and isotopic analysis) D2400

AB: Industrial applications of the **Thin Layer Activation** (TLA) technique require both specific experimental setups with respect to irradiation (yields radioactivity depth profiles, auto- radiographical film procedures for irradiation uniformity certifying, etc.) and proper measuring methods and dedicated electro- mechanical apparatus selection having in view the tribological phenomena to be studied. In this paper general criteria together with a few examples of TLA applications carried out using the U-120 Cyclotron of our laboratory are presented. Wear-determination experiments performed for some Diesel engine components such as 105 mm-diameter linear cylinder and injection pump piston and a study of characteristics of various Romanian mineral oil lubricants are also presented aiming an illustration of optimum industrial TLA applications (Author).

CT: (iad), charged-particle **activation** analysis, corrosion, cyclotrons, diesel engines lubricants, lubricating oils, machine parts, optimization, **thin** films, tribology, uses, wear, (cad), accelerators, **activation** analysis, chemical analysis chemical reactions, cyclic accelerators; engines; films; **heat** engines, internal combustion engines, nondestructive analysis, petroleum products,

MQ: charged-particle **activation** analysis. lubricating oils, charged- particle **activation** analysis machine parts

DOCUMENT NUMBER = INI26:008326

VVSS = 2603 RN = 26 008326 CTRY = RO
YEAR = 1992 TYPE = I CAT = D2200
LVLS = AM AU = STAN-SION,
SRCE = NATIONAL PHYSICS TSRCE = INATIONAL PHYSICS

TI: TLA-marker for wear rate monitoring

AU: Stan-Sion, C., Plostinaru, D., Ivan, A. (Institute of Atomic Physics Institute of Physics and Nuclear Engineering, R-76900 Bucharest, P.O Box MG-6, (Romania)), Catana, M., Roman, M. (Institute for Research and Design in Transportation, Bucharest, (Romania)).

LA: English

MS: National Physics Conference. Iasi, September 21-24, 1992 Paper Abstracts Marilena Dumitriu.

IM: Bucharest-Magurele (Romania). Institute of Atomic Physics Information and Documentation Office. 1992. 150 p. p. 28. Available from Romanian Physical Society,

R-76900 Bucharest- Magurele, P O Box MG-6, (RO) Available from Romanian Physical Society, R-76900 Bucharest-Magurele, P O.Box MG-6, (RO).
CF: (National Physics Conference. Iasi (Romania) 21-24 Sep 1992)
CN: RO (Romania) I (Miscellaneous) Related to 26 008150
LI: K (Conferences) X (Non-Conventional Literature unavailable from INIS)
CC: D2200 (Industrial Applications, Radiometric)
AB: A very effective and promising method of wear monitoring in industry is the **Thin Layer Activation** (TLA) method. The main feature of this technique is the creation of **thin** radioactive layers on the investigated surface by irradiation of the sample with an accelerated ion beam (protons, deuterons, 3-He). In the present paper we describe an extension of the TLA-Method to produce radioactive markers to be implanted into heavy object which can hardly be transported to an accelerator for direct surface **activation**. The sensitivity of wear measuring is usually 1% of the actual **layer** thickness. It is obvious that the TLA technique has a sensitivity about two orders of magnitude higher than the **activation** in the bulk volume, produced in a nuclear reactor. Controlling the **activation** depth (80 - 250 microns) we produced different marker sets with sensitivities of 1 - 3 microns. The TLA markers were used to measure the wear rate of railway-car brake disks and of the railroad. The measured data were corroborated with other physical parameters of interest (Author)
CT: (iad); brakes; charged-particle **activation** analysis, depth; deuterons, helium 3, ion implantation, layers, monitoring; protons, radioisotopes, sensitivity, surface coating, thickness; wear, . (cad), **activation** analysis; baryons, cations, charged particles, chemical analysis, deposition, dimensions, elementary particles, even-odd nuclei; fermions; hadrons, helium isotopes, hydrogen ions; hydrogen ions 1 plus, ions, isotopes; light nuclei, machine parts, nondestructive analysis, nuclei, nucleons; stable isotopes,
MQ: wear: brakes; wear: charged-particle **activation** analysis, wear· monitoring

DOCUMENT NUMBER = INI26:008325

VVSS	= 2603	RN	= 26 008325	CTRY	= RO
YEAR	= 1992	TYPE	= I	CAT	= D2200
LVLS	= AM	AU	= POPA-SIMIL		
SRCE	= NATIONAL PHYSICS		TSRCE	= INATIONAL PHYSICS	

TI: Radioisotope method for the study of wear particle for the coupled with lineal contact.
AU: Popa-Simil, L.; Racolta, P.M. (Cyclotron Laboratory, Institute of Atomic Physics, Institute of Physics and Nuclear Engineering, R- 76900 Bucharest, P.O.Box MG-6, (Romania)); Tudor, A. (Polytechnical University, 313 Splaiul Independentei, Bucharest, (Romania)).
LA: English
MS: National Physics Conference Iasi, September 21-24, 1992 Paper Abstracts Marilena Dumitriu.
IM: Bucharest-Magurele (Romania). Institute of Atomic Physics Information and Documentation Office. 1992. 150 p. p. 19. Available from Romanian Physical Society, R-76900 Bucharest- Magurele, P.O.Box MG-6, (RO) Available from Romanian Physical Society, R-76900 Bucharest-Magurele, P.O Box MG-6, (RO).
CF: (National Physics Conference. Iasi (Romania). 21-24 Sep 1992.)
CN: RO (Romania) I (Miscellaneous) Related to 26 008150
LI: K (Conferences) X (Non-Conventional Literature unavailable from INIS)
CC: D2200 (Industrial Applications, Radiometric) E1700
AB: An experimental method is presented, aimed at determining the sizes and distributions in the percentage of wear particles of a certain oil volume for the couples with a lineal contact, in correlation with the principal tribological and physical parameters (contact pressure, gliding speed, elasticity and plasticity of materials). The methods and installations were - **thin layer activation** technique by using Cyclotron U-120; - nuclear filters obtained in Tandem linear accelerator; -tribological Timken-stand for testing the friction and wear processes The diagrams of wear for certain steel samples at three different loads by TLA technique were establish. The average size and the distribution in the percentage in an oil volume

(0.5 l) were established by using nuclear filters of 0.45, 0.80, and 1.50 #mu#m, in correlation with the friction regime at contact area. Based on experimental data a theoretical model of wear degradation is suggested. This model assumes that the wear process as being an random and cumulative degradation process. The wear process is characterized by an energetic speed of wear and by the random sizes of wear particles, as well as by tribological and physical parameters. (Author).

CT: (iad); charged-particle **activation** analysis; cyclotrons; friction; irradiation, lubricants; mechanical filters; oils; radioactivation, romania; steels; tribology, wear; . (cad); accelerators; **activation** analysis; alloys; carbon additions, chemical analysis; cyclic accelerators; developing countries; eastern europe; europe; filters; iron alloys; iron base alloys; nondestructive analysis; organic compounds; other organic compounds;

MQ: charged-particle **activation** analysis· cyclotrons; charged-particle **activation** analysis: oils; charged-particle **activation** analysis· radioactivation; charged-particle **activation** analysis tribology; charged-particle **activation** analysis: wear; wear· friction; wear: oils; wear: tribology.

DOCUMENT NUMBER = INI25:068760

VVSS	= 2522	RN	= 25 068760	CTRY	= NL
YEAR	= 1994	TYPE	= J	CAT	= G6300
LVLS	= AS	ISSN	= 0168-583X		
AU	= ASHER, J	SRCE	= NUCLEAR INSTRUME		
TSRCE	= JNUCLEAR INSTRUME				

TI: MeV ion processing applications for industry

AU: Asher, J. (AEA Technology, Didcot (United Kingdom)).

LA: English

JR: Nuclear Instruments and Methods in Physics Research Section B, Beam Interactions with Materials and Atoms. ISSN 0168-583X CODEN: NIMBEU (May 1994) v 89(1-4) p 315-321.

CF: (3. European conference on accelerators in applied research and technology (ECAART-3). Orleans (France). 31 Aug - 4 Sep 1993)

CN: NL (Netherlands) J (Journal Article)

LI: K (Conferences)

CC: G6300 (Interactions Between Beams and Condensed Matter) E4300

AB: Ions beams with MeV energies produce a variety of interactions with matter, broadly classified as either electronic or nuclear. These interactions in turn lead to changes in the properties of the matter which may be beneficial or detrimental In high technology industry, use is increasingly made of ion beam technologies to process novel materials. Typical applications include high energy implantation, in which the deposition of a specific element at depth within the structure of material is the required objective, and irradiation modification, in which the balance between the beneficial and the detrimental effects of the fast ion interactions is exploited The basic principles behind MeV ion processing are described Broad areas of application in industrial materials include effects in ion beam analysis, **Thin Layer Activation** for wear and corrosion measurement, carrier lifetime control in electronic devices, and the simulation of radiation damage effects in, for example, solar cells for spacecraft New development areas are described in which subtle but potentially significant changes in the chemistry of surfaces and interfaces may be generated by exposure to MeV ion beams. (orig.)

CT: (iad); carrier lifetime; corrosion; electric conductivity; interfaces; ion beams, ion implantation; layers; lifetime; mev range 01-10, physical radiation effects, radioactivity; reviews; surface treatments; traps; wear, . (cad); beams, chemical reactions; document types; electrical properties; energy range, mev range, physical properties; radiation effects;

MQ: ion beams· physical radiation effects.

DOCUMENT NUMBER = INI25:068210

VVSS	= 2522	RN	= 25 068210	CTRY	= NL

YEAR = 1994 TYPE = J CAT = G3440
LVLS = AS ISSN = 0168-583X
AU = BISCONTI SRCE = NUCLEAR INSTRUME
TSRCE = JNUCLEAR INSTRUME

TI: Production of "5"1Cr by deuteron **activation** of natural chromium
AU: Bisconti, R (Inst for Advanced Materials Joint Research Centre Commission of the European Communities, Ispra (Italy), Dept of Nuclear and Theoretical Physics Univ of Pavia (Italy)), Casteleyn, K (Inst for Advanced Materials, Joint Research Centre, Commission of the European Communities, Ispra (Italy)), Castiglioni, M (Inst for Advanced Materials, Joint Research Centre, Commission of the European Communities, Ispra (Italy)), Fossati, F (Dept of Nuclear and Theoretical Physics, Univ of Pavia (Italy)), Manes, L (Inst for Advanced Materials Joint Research Centre, Commission of the European Communities, Ispra (Italy)), Stroosnijder M F (Inst for Advanced Materials, Joint Research Centre, Commission of the European Communities, Ispra (Italy))
LA: English
JR: Nuclear Instruments and Methods in Physics Research Section B Beam Interactions with Materials and Atoms ISSN 0168-583X CODEN NIMBEU (May 1994) v 88(3) p 282-286
CN. NL (Netherlands) J (Journal Article)
CC. G3440 (2H- 3H- and He-induced reactions and scattering) G6100 G3430
AB. The investigation of the nuclear **activation** yield of natural chromium was dictated by the technological interest of the use of the **thin layer activation** technique for the study of surface performances of chromium based materials For practical applications '5"1Cr has been selected as tracing element Three deuteron induced reactions lead to "5"1Cr in the energy range from 0 to 18 MeV 5 0Cr(d p) 5 1Cr 5 2Cr(d,p2n)'5"1Cr and "5"0Cr(d,n)"5"1Mn ("5 1Mn#->#"5"1Cr) The **activation** yield for the deuteron induced production of '5"1Cr as a function of the energy has been measured experimentally via the stacked-foil method using an energy variable cyclotron To compute the energy incident on each foil and its distribution due to multiscattering effects, a Monte Carlo program has been elaborated simulating the energy straggling of a particle beam passing through a stacked foil sample of given thickness and composition The yield profile has also been calculated using two computer codes, STAPRE and ALICE (orig)
CT: (iad), alpha reactions; chromium isotopes chromium 51, computer codes computerized simulation, deuteron reactions; differential cross sections, energy losses excitation functions, foils, gamma spectra, integral cross sections, mev range 01-10 mev range 10-100, monte carlo method nuclear reaction analysis nuclear reaction yield, tracer techniques, (cad), beta decay radioisotopes calculation methods, chemical analysis, cross sections, days living radioisotopes, electron capture radioisotopes, energy range, even-odd nuclei, intermediate mass nuclei, isotope applications, isotopes, mev range, nondestructive analysis, nuclear reactions, nuclei, radioisotopes, simulation, spectra, yields,
MQ: chromium 51 nuclear reaction yield, nuclear reaction yield deuteron reactions

DOCUMENT NUMBER = INI25:066122

VVSS = 2522 RN = 25 066122 CTRY = NL
YEAR = 1994 TYPE = J CAT = B2250
LVLS = AS ISSN = 0168-583X
AU = CONSTANTIN SRCE = NUCLEAR INSTRUME
TSRCE = JNUCLEAR INSTRUME

TI: **Thin layer activation** techniques at the U-120 cyclotron of Bucharest
AU: Constantinescu, B. (Cyclotron Lab, Inst of Physics and Nuclear Engineering, Bucharest (Romania)), Ivanov, E.A (Cyclotron Lab, Inst of Physics and Nuclear Engineering, Bucharest (Romania)), Pascovici, G (Cyclotron Lab, Inst of Physics and Nuclear Engineering, Bucharest (Romania)), Popa-Simil, L (Cyclotron Lab, Inst of Physics and Nuclear Engineering, Bucharest (Romania)), Racolta P M (Cyclotron Lab, Inst of Physics and Nuclear Engineering, Bucharest (Romania))
LA: English
JR: Nuclear Instruments and Methods in Physics Research Section B, Beam Interactions

with Materials and Atoms ISSN 0168-583X CODEN NIMBEU (May 1994) v 89(1-4) p 83-87

CF: (3 European conference on accelerators in applied research and technology (ECAART-3) Orleans (France) 31 Aug - 4 Sep 1993)

CN: NL (Netherlands) J (Journal Article)

LI: K (Conferences)

CC: B2250 (Corrosion and erosion) G6300

AB: The **Thin Layer Activation** (TLA) technique is a nuclear method especially used for different types of wear (or corrosion) investigations Experimental results for selection criteria of nuclear reactions for various tribological studies, using the IPNE U- 120 classical variable energy Cyclotron are presented Measuring methods for the main types of wear phenomena and home made instrumentations dedicated for TLA industrial applications are also reported Some typical TLA tribological applications, a nuclear scanning method to obtain wear profile of piston-rings are presented as well. (orig)

CT: (iad), **activation** energy, corrosion cyclotrons, deuteron reactions efficiency friction iron 56, measuring methods methane, nickel 60, nuclear reaction analysis tribology, variable energy cyclotrons, wear, (cad), accelerators, alkanes, chemical analysis, chemical reactions cyclic accelerators, energy, even-even nuclei hydrocarbons, intermediate mass nuclei, iron isotopes, isotopes, nickel isotopes, nondestructive analysis nuclear reactions nuclei, organic compounds stable isotopes

MQ: corrosion nuclear reaction analysis nuclear reaction analysis deuteron reactions

DOCUMENT NUMBER = INI25 047328

VVSS	= 2515	RN	= 25 047328	CTRY	= XA
YEAR	= 1994	TYPE	= J	CAT	= D2200
LVLS	= AS	ISSN	= 0020-6067		
AU	= KONSTANTIN	SRCE	= IAEA BULLETIN		
TSRCE	= JIAEA BULLETIN				

TI: Monitoring wear and corrosion in industrial machines and systems A radiation tool

AU: Konstantinov, I O (Gosudarstvennyj Komitet po Ispol'zovaniyu Atomnoj Ehnergii SSSR Obninsk (Russian Federation). Fiziko- Ehnergeticheskij Inst), Zatolokin, B V (International Atomic Energy Agency, Vienna (Austria) Dept of Research and Isotopes)

LA: English

JR: IAEA Bulletin ISSN 0020-6067 CODEN IAEBAB (1994) v 36(1) p 16-18

CN: XA (International Atomic Energy Agency (IAEA)) J (Journal Article)

CC: D2200 (Industrial Applications, Radiometric)

AB: Industrial equipment and machines, transport systems, nuclear and conventional power plants pipelines, and other materials is substantially influenced by degradation processes such as wear and corrosion For safety and economic reasons, appropriately monitoring the damage could prevent dangerous accidents When the surfaces of machine parts under investigation are not easy to reach or are concealed by overlying structures, nuclear methods have become powerful tools for examination They include X-ray radiography, neutron radiography, and a technique known as **thin layer activation** (TLA)

CT (iad) corrosion, industrial radiography, industry, nuclear power plants, pipes wear, x-ray detection, (cad), chemical reactions, detection, materials testing, nondestructive testing nuclear facilities, power plants, radiation detection testing thermal power plants,

MQ: industry wear, wear industrial radiography

DOCUMENT NUMBER = INI25 036779

VVSS	= 2512	RN	= 25 036779	CTRY	= GB
YEAR	= 1994	TYPE	= J	CAT	= D2200
LVLS	= AS	ISSN	= 0261-2097		
AU	= BARRETT J	SRCE	= EUREKA (BECKENHA		
TSRCE	= JEUREKA (BECKENHA				

TI: Radiation tagging measures wear at speed.
AU: Barrett, Jon.
LA: English
JR: Eureka (Beckenham). ISSN 0261-2097. CODEN: ERKAEF. (Feb 1994). v. 14(2). p. 30-32.
CN: GB (United Kingdom) J (Journal Article)
CC: D2200 (Industrial Applications, Radiometric)
AB: A new non-invasive technique for performing accelerated wear and corrosion analysis is particularly relevant to power transmission systems. Wear tests that would normally take days or weeks to complete can now be performed in hours. A tiny patch of the wearing component is made mildly radioactive and the drop in activity as material is worn away is monitored. Known as **Thin Layer Activation** (TLA), the technology was originally developed and pioneered in-house by the Atomic Energy Authority. Since then, the dominant partner has been the automotive sector where TLA has been used extensively for engine wear and lubrication performance analysis. However, TLA could be used in any wear or corrosion environment. Applications include wear analysis of machine tool cutting surfaces, pump impellers and brake linings to the corrosion monitoring of process plant and pipelines. (author).
CT: (iad); activity levels; charged-particle **activation** analysis; corrosion; depth, gamma detection; layers; materials testing; particle beams; ukaea; wear; . (cad); **activation** analysis; beams; chemical analysis; chemical reactions, detection; dimensions; national organizations; nondestructive analysis; radiation detection; testing; united kingdom organizations;
MQ: charged-particle **activation** analysis: materials testing; wear. charged-particle **activation** analysis; wear. materials testing

DOCUMENT NUMBER = INI25:018892

VVSS	= 2506	RN	= 25 018892	CTRY	= NL
YEAR	= 1993	TYPE	= J	CAT	= E4100
LVLS	= AS	ISSN	= 0168-583X		
AU	= IVANOV, E.	SRCE	= NUCLEAR INSTRUME		
TSRCE	= JNUCLEAR INSTRUME				

TI: A nuclear scanning method for estimating wear level nonuniformities.
AU: Ivanov, E.A. (Cyclotron Lab., Inst. of Physics and Nuclear Engineering, Bucharest (Romania)); Pascovici, G. (Cyclotron Lab., Inst. of Physics and Nuclear Engineering, Bucharest (Romania)); Racolta, P.M. (Cyclotron Lab., Inst. of Physics and Nuclear Engineering, Bucharest (Romania)).
LA: English
JR: Nuclear Instruments and Methods in Physics Research. Section B, Beam Interactions with Materials and Atoms. ISSN 0168-583X. CODEN: NIMBEU. (Sep 1993). v. 82(4). p. 604-606.
CN: NL (Netherlands) J (Journal Article)
CC: E4100 (Particle and Radiation Detection and Measuring Instruments and Methods)
AB: The residual radioactivity measuring method has been upgraded to estimate wear level nonuniformities in the circumference of a piston ring after a certain working time in the combustion engine testing bench. The piston ring was irradiated by the **thin layer activation** (TLA) technique and its radioactivity was continuously monitored. (orig.)
CT: (iad), **activation** energy; measuring methods; physical radiation effects; radioisotope scanning; wear; . (cad); counting techniques; energy; radiation effects;
MQ: wear. radioisotope scanning.

DOCUMENT NUMBER = INI25:012730

VVSS	= 2504	RN	= 25:012730	CTRY	= NL
YEAR	= 1993	TYPE	= J	CAT	= G3430
LVLS	= AS	ISSN	= 0168-583X		
AU	= OUELLET, J	SRCE	= NUCLEAR INSTRUME		
TSRCE	= JNUCLEAR INSTRUME				

TI: Cross sections and **activation** profiles for wear monitoring.
AU: Ouellet, J.M.L. (Lab. de Physique Nucleaire, Univ. de Montreal, PQ (Canada)); Oxorn, K. (Lab. de Physique Nucleaire, Univ. de Montreal, PQ (Canada)); Hamel, L.A. (Lab. de Physique Nucleaire, Univ. de Montreal, PQ (Canada)); Lessard, L. (Lab. de Physique Nucleaire, Univ. de Montreal, PQ (Canada)); Matte, C. (Lab. de Physique Nucleaire, Univ. de Montreal, PQ (Canada)).
LA: English
JR: Nuclear Instruments and Methods in Physics Research. Section B, Beam Interactions with Materials and Atoms. ISSN 0168-583X. CODEN: NIMBEU. (Jun 1993). v. 79(1-4). p. 579-581.
CF: (12. international conference on the application of accelerators in research and industry. Denton, TX (United States). 2-5 Nov 1992.)
CN: NL (Netherlands) J (Journal Article)
LI: K (Conferences) N (Numerical Data)
CC: G3430 (Nucleon-induced reactions and scattering) G3440 B1110
AB: **The thin layer activation** method is a procedure to monitor the wear of materials by producing radioisotopes over a small depth near the surface of an object and measuring the activity removed as the wear progresses. **Activation** profiles needed to use the technique have been measured, and irradiation setups for various purposes have been developed. (orig.).
CT: (iad); alpha particles; charge-exchange reactions; charged-particle **activation** analysis; chromium 53 target; cobalt 56; copper 65 target; counting rates; de-excitation; deuteron reactions; energy dependence; excitation functions; excited states; experimental data; gamma decay; gamma detection; integral cross sections; iron 56 target; isomeric nuclei; layers; manganese 54; mev range 01-10; molybdenum 95 target; monitoring; neutrons; nickel 58 target; one- nucleon transfer reactions; proton reactions; scandium 46; technetium 95; titanium 48 target; two-nucleon transfer reactions; vanadium 48; wear; zinc 65; . (cad); **activation** analysis; baryon reactions; baryons; beta decay radioisotopes; beta-minus decay radioisotopes; beta-plus decay radioisotopes; charged particles; chemical analysis; cobalt isotopes; cross sections; data; days living radioisotopes; decay; detection; direct reactions; electron capture radioisotopes; elementary particles; energy levels; energy range; energy-level transitions; even-odd nuclei; fermions; hadron reactions; hadrons; helium ions; hours living radioisotopes; information; intermediate mass nuclei; internal conversion radioisotopes; ionizing radiations; ions; isomeric transition isotopes; isotopes; manganese isotopes; mev range; multi-nucleon transfer reactions; nondestructive analysis; nuclear decay; nuclear reactions; nuclei; nucleon reactions; nucleons; numerical data; odd-even nuclei; odd-odd nuclei; radiation detection; radiations; radioisotopes; scandium isotopes; seconds living radioisotopes; targets; technetium isotopes; transfer reactions; vanadium isotopes; zinc isotopes;
MQ: wear: charged-particle **activation** analysis.

DOCUMENT NUMBER = INI24:069734

VVSS	= 2422	RN	= 24:069734	CTRY	= FR
YEAR	= 1993	TYPE	= J	CAT	= D2200
LVLS	= AS	ISSN	= 0032-6895		
AU	= DELVIGNE,	SRCE	= MATERIAUX ET TEC		
TSRCE	= JMATERIAUX ET TEC				

TI: Superficial **activation** techniques utilization for continuous measurement of wear, erosion and corrosion phenomena. Utilisation de la technique d'activation superficielle pour la mesure en continu des phenomenes d'usure, d'erosion et de corrosion.
AU: Delvigne, T. (Industrial Diagnosis Services, Louvain-la-Neuve (Belgium)).
LA: French
JR: Materiaux et Techniques. ISSN 0032-6895. CODEN: MATCBW. (1993). (no.1-3). p. 111-114.
CN: FR (France) J (Journal Article)
CC: D2200 (Industrial Applications, Radiometric) E1700
AB: **Thin layer activation** allows to follow and quantify in real time the kinetics of any

loss of matter (metals or ceramics, but not plastics) caused by wear, erosion or corrosion processes The method is based on surface components marking, using particles beam coming from an accelerator The wear measure consists -after the apparatus calibration- to the detection of the signal emitted by the radioisotopes created during the surface **activation** process This non destructive technique is extremely sensitive and allows the instantaneous determination of wear rates with a precision which can reach a few nanometers per hour This technique brings to its users a considerable time saving and costs reduction (author) 6 refs, 5 figs, 1 tab.

CT: (iad); alpha particles, ceramics, charged-particle **activation** an, corrosion, cyclotrons; deuteron beams, erosion; kinetics; metals; proton beams; radioactivation; surfaces; wear, (cad), accelerators; **activation** analysis, beams, charged particles; chemical analysis, chemical reactions, cyclic accelerators, elements, helium ions, ion beams, ionizing radiations, ions; nondestructive analysis, nucleon beams, particle beams, radiations,

MQ: charged-particle **activation** an· corrosion, charged-particle **activation** an erosion, charged-particle **activation** an: wear

DOCUMENT NUMBER = INI24 033082

VVSS	= 2409	RN	= 24 033082	CTRY	= HU
YEAR	= 1992	TYPE	= J	CAT	= D2200
LVLS	= AS	ISSN	= 0236-5731		
AU	= FEHSENFELD	SRCE	= JOURNAL OF RADIO		
TSRCE	= JJOURNAL OF RADIO				

TI: Radionuclide technique in mechanical engineering in Germany

AU: Fehsenfeld, P; Kleinrahm, A, Schweickert, H (Kernforschungszentrum Karlsruhe GmbH (Germany))

LA: English

JR: Journal of Radioanalytical and Nuclear Chemistry. ISSN 0236-5731. CODEN JRNCDM (Jul 1992). v. 160(1). p. 141-151.

CF: (2 International Conference on Methods and Applications of Radioanalytical Chemistry Kona, HI (United States) 21-27 Apr 1991)

CN: HU (Hungary) J (Journal Article)

LI: K (Conferences)

CC: D2200 (Industrial Applications, Radiometric)

AB: A subject of increasing application of cyclotron machines is the 'Radionuclide Technique in Mechanical Engineering' (RTM), a measuring system that enables wear and corrosion diagnostics of components of operating machines, apparatus or processing plants The three components of the RTM-system, the **thin** layer-activation at the cyclotron, the measuring methods and the measuring instruments for application in industry, have been developed systematically at KfK over more than 15 years and are being used increasigly by industry in Germany, Japan and the United States The present development of RTM to modern problems in engineering and material research as well as the successful application in new industrial areas will be reported (author) 9 refs, 10 figs

CT: (iad), **activation** analysis, civil engineering, corrosion, cyclotron radiation, equipment, federal republic of germany, industry, irradiation procedures, layers, machine parts; measuring instruments, wear, (cad), bremsstrahlung, chemical analysis; chemical reactions; developed countries, electromagnetic radiation, engineering; europe, nondestructive analysis, radiations,

MQ: cyclotron radiation: **activation** analysis

DOCUMENT NUMBER = INI24:023050

VVSS	= 2406	RN	= 24 023050	CTRY	= XA
YEAR	= 1993	TYPE	= R	CAT	= D2200
LVLS	= AM	RP	= INISMF13441		
AU	= FEHSENFELD	SRCE	= REPORT OF THE IA		
TSRCE	= RREPORT OF THE IA				

TI: Radionuclide technique in mechanical engineering in Germany
AU: Fehsenfeld, P, Kleinrahm, A., Schweickert, H (Kernforschungszentrum Karlsruhe GmbH (Germany) Inst fuer Kernphysik 3).
LA: English
MS: Report of the IAEA consultants' meeting on real-time nondestructive monitoring of wear and corrosion using the **thin layer activation** technique International Atomic Energy Agency, Vienna (Austria).
RP: INIS-mf--13441
IM: Jan 1993. 80 p. p 61-76 Availability: INIS.
CF: (IAEA consultants' meeting on real-time nondestructive monitoring of wear and corrosion using the **thin layer activation** technique. Vienna (Austria). 15-18 May 1990.)
CN: XA (International Atomic Energy Agency (IAEA)) R (Report) Related to 24 023045
LI: K (Conferences)
CC: D2200 (Industrial Applications, Radiometric) B1110
AB: A subject of increasing application of cyclotron machines is the "Radionuclide Technique in Mechanical Engineering" (RTM), a measuring system that enables wear and corrosion diagnostics of components of operating machines, apparatus or processing plants. The three components of the RTM-system, the **thin** layer-activation at the cyclotron, the measuring methods and the measuring instruments for application in industry, have been developed systematically at KfK over more than 15 years are are being used increasingly by industry in Germany, Japan and the United States. The present development of RTM to modern problems in engineering and material research as well as the successful application in new industrial areas will be reported (author) 10 figs
CT: (iad); **activation** analysis; cyclotrons; engineering, wear, (cad), accelerators, chemical analysis; cyclic accelerators, nondestructive analysis,
MQ: wear: **activation** analysis

DOCUMENT NUMBER = INI24:023049

VVSS	= 2406	RN	= 24 023049	CTRY	= XA
YEAR	= 1993	TYPE	= R	CAT	= D2200
LVLS	= AM	RP	= INISMF13441		
AU	= MAHUNKA, I	SRCE	= REPORT OF THE IA		
TSRCE	= RREPORT OF THE IA				

TI: **Activation** technique for industry at the Debrecen Cyclotron Laboratory. Status report.
AU: Mahunka, I.; Ditroi, F (Magyar Tudomanyos Akademia, Debrecen (Hungary) Atommag Kutato Intezete)
LA: English
MS: Report of the IAEA consultants' meeting on real-time nondestructive monitoring of wear and corrosion using the **thin layer activation** technique International Atomic Energy Agency, Vienna (Austria)
RP: INIS-mf--13441
IM: Jan 1993. 80 p p 47-59. Availability: INIS
CF: (IAEA consultants' meeting on real-time nondestructive monitoring of wear and corrosion using the **thin layer activation** technique. Vienna (Austria). 15-18 May 1990.)
CN: XA (International Atomic Energy Agency (IAEA)) R (Report) Related to 24 023045
LI: K (Conferences)
CC: D2200 (Industrial Applications, Radiometric) B1110
AB: The applications of **activation** techniques with charged particle beams produced by the Debrecen cyclotron are discussed. 11 refs, 2 figs, 1 tab.
CT: (iad); **activation** analysis; alpha reactions; corrosion; debrecen cyclotron; deuteron reactions; erosion; helium 3 reactions; proton reactions; wear; . (cad), accelerators; baryon reactions; chemical analysis; chemical reactions; cyclic accelerators; cyclotrons; hadron reactions; isochronous cyclotrons; nondestructive analysis; nuclear reactions; nucleon reactions;
MQ: corrosion: **activation** analysis; wear: **activation** analysis

DOCUMENT NUMBER = INI24:023048

VVSS = 2406 RN = 24 023048 CTRY = XA
YEAR = 1993 TYPE = R CAT = D2200
LVLS = AM RP = INISMF13441
AU = KONSTANTIN SRCE = REPORT OF THE IA
TSRCE = RREPORT OF THE IA

TI: **Thin layer activation** technique applications in the USSR.
AU: Konstantinov, I.O.; Leonov, A.I. (Gosudarstvennyj Komitet po Ispol'zovaniyu Atomnoj Ehnergii SSSR, Obninsk (Russian Federation). Fiziko-Ehnergeticheskij Inst.).
LA: English
MS: Report of the IAEA consultants' meeting on real-time nondestructive monitoring of wear and corrosion using the **thin layer activation** technique. International Atomic Energy Agency, Vienna (Austria).
RP: INIS-mf--13441.
IM: Jan 1993. 80 p. p. 37-45. Availability: INIS.
CF: (IAEA consultants' meeting on real-time nondestructive monitoring of wear and corrosion using the **thin layer activation** technique. Vienna (Austria). 15-18 May 1990.)
CN: XA (International Atomic Energy Agency (IAEA)) R (Report) Related to 24:023045.
LI: K (Conferences)
CC: D2200 (Industrial Applications, Radiometric) B1110
AB: The main applications of **thin layer activation** techniques using the U-150 cyclotron of the Institute of Physics and Power Engineering in Obninsk are discussed. 22 refs, 3 figs.
CT: (iad); **activation** analysis; cyclotrons; real time systems; wear; . (cad); accelerators; chemical analysis; cyclic accelerators; nondestructive analysis;
MQ: **activation** analysis: wear.

DOCUMENT NUMBER = INI24:023047

VVSS = 2406 RN = 24:023047 CTRY = XA
YEAR = 1993 TYPE = R CAT = D2200
LVLS = AM RP = INISMF13441
AU = JEANNEAU, SRCE = REPORT OF THE IA
TSRCE = RREPORT OF THE IA

TI: **Thin layer activation** with charged particles applications and remarks.
AU: Jeanneau, B. (Commissariat a l'Energie Atomique (France). Office de Rayonnements Ionisants).
LA: English
MS: Report of the IAEA consultants' meeting on real-time nondestructive monitoring of wear and corrosion using the **thin layer activation** technique. International Atomic Energy Agency, Vienna (Austria).
RP: INIS-mf--13441.
IM: Jan 1993. 80 p. p. 23-35. Availability: INIS.
CF: (IAEA consultants' meeting on real-time nondestructive monitoring of wear and corrosion using the **thin layer activation** technique. Vienna (Austria). 15-18 May 1990.)
CN: XA (International Atomic Energy Agency (IAEA)) R (Report) Related to 24:023045.
LI: K (Conferences)
CC: D2200 (Industrial Applications, Radiometric) B1110
AB: The applications of **thin layer activation** technique with charged particles produced by a cyclotron measure wear or corrosion of materials are presented. 5 refs.
CT: (iad); **activation** analysis; corrosion; cost; deuteron reactions; helium 3 reactions; isochronous cyclotrons; proton reactions; wear; . (cad); accelerators; baryon reactions; chemical analysis; chemical reactions; cyclic accelerators; cyclotrons; hadron reactions; nondestructive analysis; nuclear reactions; nucleon reactions;
MQ: corrosion: **activation** analysis; wear: **activation** analysis.

DOCUMENT NUMBER = INI24:023046

VVSS = 2406 RN = 24 023046 CTRY = XA
YEAR = 1993 TYPE = R CAT = D2200
LVLS = AM RP = INISMF13441
AU = CONLON, T. SRCE = REPORT OF THE IA
TSRCE = RREPORT OF THE IA

TI: **Thin layer activation** techniques in research and industry.
AU: Conlon, T.W. (AEA Technology (United Kingdom). Accelerator Applications Dept.)
LA: English
MS: Report of the IAEA consultants' meeting on real-time nondestructive monitoring of wear and corrosion using the **thin layer activation** technique. International Atomic Energy Agency, Vienna (Austria).
RP: INIS-mf--13441.
IM: Jan 1993. 80 p. p. 5-22. Availability: INIS.
CF: (IAEA consultants' meeting on real-time nondestructive monitoring of wear and corrosion using the **thin layer activation** technique. Vienna (Austria). 15-18 May 1990)
CN: XA (International Atomic Energy Agency (IAEA)) R (Report) Related to 24 023045
LI: K (Conferences)
CC: D2200 (Industrial Applications, Radiometric) B1110
AB: The following key application of **thin layer activation** technique (TLA) are discussed: ion-erosion in fusion tokamaks, bio-engineering technology, automobile industry. Future developments of the techniques, such as fission fragment TLA, multi-layer TLA and recoil implantation are discussed as well. 7 refs, 6 figs, 1 tab.
CT: (iad), **activation** analysis, automotive industry, corrosion; erosion, exhaust gases, ion implantation; layers; prostheses, tokamak devices; wear; . (cad); chemical analysis; chemical reactions; closed plasma devices; fluids; gaseous wastes, gases, industry; medical supplies; nondestructive analysis; thermonuclear devices, wastes,
MQ: **activation** analysis.

DOCUMENT NUMBER = INI24:023045

VVSS = 2406 RN = 24.023045 CTRY = XA
YEAR = 1993 TYPE = R CAT = D2200
LVLS = M RP = INISMF13441
AU = INTERNATIO SRCE = REPORT OF THE IA
TSRCE = RREPORT OF THE IA

TI: Report of the IAEA consultants' meeting on real-time nondestructive monitoring of wear and corrosion using the **thin layer activation** technique.
CO: International Atomic Energy Agency, Vienna (Austria).
LA: English
RP: INIS-mf--13441.
IM: Jan 1993. 80 p. Availability: INIS.
CF: (IAEA consultants' meeting on real-time nondestructive monitoring of wear and corrosion using the **thin layer activation** technique. Vienna (Austria). 15-18 May 1990.)
CN: XA (International Atomic Energy Agency (IAEA)) R (Report)
LI: K (Conferences)
CC: D2200 (Industrial Applications, Radiometric) B1110
AB: The report includes 5 papers presented by the participants and Conclusions and Recommendations of the meeting. A separate abstract was prepared for each paper. Refs, figs and tabs.
CT: (iad); **activation** analysis; corrosion; layers; monitoring; real time systems; wear; (cad); chemical analysis; chemical reactions; nondestructive analysis;
MQ: corrosion: **activation** analysis; wear: **activation** analysis.

DOCUMENT NUMBER = INI24:015480

VVSS	= 2404	RN	= 24:015480	CTRY	= FR
YEAR	= 1992	TYPE	= J	CAT	= D2200
LVLS	= AS	ISSN	= 0026-0193		
AU	= DELVIGNE,	SRCE	= MESURES, REGULAT		
TSRCE	= JMESURES, REGULAT				

TI: Wear measurement by **thin layer activation**. Mesure d'usure. Les protons en renfort.
AU: Delvigne, T.
LA: French
JR: Mesures, Regulation, Automatisme. ISSN 0026-0193. CODEN: MRAUA7. (Mar 1992). (no.643). p. 61-64.
CN: FR (France) J (Journal Article)
CC: D2200 (Industrial Applications, Radiometric)
AB: This nondestructive method allows to follow in real time wear or corrosion. The material is activated by a proton beam from a cyclotron in a thickness of 20 to 200 micrometers giving a very low activity, below 0.5 MBq, requiring no safety measure. Examples are given.
CT: (iad); charged-particle **activation** an; uses; wear resistance; . (cad); **activation** analysis; chemical analysis; mechanical properties; nondestructive analysis;
MQ: wear resistance: charged-particle **activation** an.

DOCUMENT NUMBER = INI24:001346

VVSS	= 2401	RN	= 24:001346	CTRY	= FR
YEAR	= 1992	TYPE	= J	CAT	= D2200
LVLS	= AS	ISSN	= 0245-8292		
AU	= CHEVALIER,	SRCE	= MEMOIRES ET ETUD		
TSRCE	= JMEMOIRES ET ETUD				

TI: Use of the **thin layer activation** technique to measure on-line aeronautical components wear. Utilisation de la technique d'activation superficielle pour la mesure en continu de l'usure de composants aeronautiques.
AU: Chevalier, A. (Ecole Polytechnique, Montreal, PQ (Canada)); Dubois, G.; Escuriol, M.; Monnot, R.; Pommier, S. (Societe Nationale d'Etude et de Construction de Moteurs d'Aviation (SNECMA), 75 - Paris (France)); Fehsenfeld, P.; Kleinrahm, A. (Kernforschungszentrum Karlsruhe GmbH (Germany)); Delvigne, T.; Le Menestrel, M.
LA: French
JR: Memoires et Etudes Scientifiques de la Revue de Metallurgie. ISSN 0245-8292. CODEN: MESMDJ. (May 1992). v. 89(5). p. 317-323.
CN: FR (France) J (Journal Article)
CC: D2200 (Industrial Applications, Radiometric)
AB: The superficial **activation** technique was applied in order to study the phenomena odscaling at the level of a reactor bearing. The exterior path of the bearing roller was activated on its whole contact surface and to a depth of 80 #mu#m, according to the reaction "5"6Fe(p, n)"5"6Co. In spite of a very low rate of **activation** of 0.5 MBq, the first signs of scaling were detected 30 min before a notable rise in the vibratory level could be recorded. Then, the amount of scaled matter escaping from the outer ring of the roller could be followed continuously, with a precision of 0.2 mg. 5 refs., 7 figs.
CT: (iad); charged-particle **activation** an; cobalt 56; filtration; layers; lubricating oils; roller bearings; scaling; **thin** films; wear; . (cad); **activation** analysis; bearings; beta decay radioisotopes; beta- plus decay radioisotopes; chemical analysis; chemical reactions; cobalt isotopes; corrosion; days living radioisotopes; electron capture radioisotopes; films; intermediate mass nuclei; isotopes; lubricants; nondestructive analysis; nuclei; odd-odd nuclei; petroleum products; radioisotopes; separation processes;
MQ: cobalt 56: charged-particle **activation** an; layers: charged-particle **activation** an; lubricating oils: filtration; roller bearings: scaling; roller bearings: wear; **thin** films: charged-particle **activation** an.

DOCUMENT NUMBER = INI23:075689

VVSS	= 2321	RN	= 23 075689	CTRY	= US
YEAR	= 1991	TYPE	= B	CAT	= E1700
LVLS	= AM	RP	= CONF910422		
AU	= FEHSENFELD	SRCE	= SECOND INTERNATI		
TSRCE	= BSECOND INTERNATI				

TI: Radionuclide technique in mechanical engineering in Germany.
AU: Fehsenfeld, P.; Kleinrahm, A.; Schweickert, H. (Kernforschungszentrum Karlsruhe GmbH (Germany)).
LA: English
MS: Second international conference on methods and applications of radioanalytical chemistry. Abstracts Anon.
RP: CONF-910422--.
IM: Washington, DC (United States) American Nuclear Society 1991 88 p p. 78.
CF: (International topical conference on methods and applications of radioanalytical chemistry II (MARC-2) Kona, HI (United States). 21-27 Apr 1991.)
CN: US (United States) B (Book)
LI: K (Conferences)
CC: E1700 (Materials Testing) B1110
AB: A subject of increasing application of cyclotron machines is the 'Radionuclide Technique in Mechanical Engineering' (RTM), a measuring system that enables wear and corrosion diagnostics of components of operating machines, apparatus or processing plants. The three components of the RTM-system, the **thin** layer-activation at the cyclotron, the measuring methods and the measuring instruments for application in industry, have been developed systematically at KfK over more than 15 years and are being used increasingly by industry in Germany, Japan and the US The present development of RTM to modern problems in engineering and material research as well as the successful application in new industrial areas is reported.
CT: (iad); corrosion; corrosion products; design; engineering; materials; multi-element analysis, radiometric analysis; wear; . (cad), chemical analysis; chemical reactions; quantitative chemical analysis;
MQ: corrosion products multi-element analysis.

DOCUMENT NUMBER = INI23:000066

VVSS	= 2301	RN	= 23 000066	CTRY	= NL
YEAR	= 1991	TYPE	= J	CAT	= B1110
LVLS	= AS	ISSN	= 0168-583X		
AU	= KOSAKO, TO	SRCE	= NUCL INSTRUM M		
TSRCE	= JNUCL INSTRUM M				

TI: The **thin layer activation** technique applied to the on-line iron wear measurement of an engine cam nose.
AU: Kosako, Toshiso (Research Center for Nuclear Science and Tech., Univ of Tokyo (Japan)), Nishimura, Kazuo (Central Research Lab, General Sekiyu KK, Kawasaki (Japan)).
LA: English
JR: Nucl. Instrum. Methods Phys Res, Sect B. ISSN 0168-583X. CODEN NIMBE. (May 1991) v. 56/57(pt.2) p. 900-903
CF: (11. international conference on the application of accelerators in research and industry. Denton, TX (United States) 5-8 Nov 1990.)
CN: NL (Netherlands) J (Journal Article)
LI: K (Conferences)
CC: B1110 (Nuclear methods in chemical and isotopic analysis) B2230
AB: The **thin layer activation** technique, in which 7 MeV proton beam was irradiating an iron surface to produce a very **thin** (several tens #mu#m) activated region, was applied to the on-line iron wear measurement of an engine cam nose. The wearing amount of this activated part was measured using a Ge-semiconductor detector in an on-line and nondestructive method. The calibration curve of iron wear was obtained

through the comparison of this radiometric method and the usual electromicrometer method in which an iron block wear test is performed by a polishing machine. For the application of this method to a real car engine part (engine cam nose), a data acquisition system was built using microcomputers. The wear characteristics were successfully measured and the effectiveness of this method was verified. (orig.).

CT: (iad); **activation** analysis; calibration; charged particles; data acquisition systems; inelastic scattering; iron; layers; mev range 01-10; microprocessors; proton beams; wear; . (cad); beams; chemical analysis; electronic circuits; elements; energy range; metals; mev range; microelectronic circuits; nondestructive analysis; nucleon beams; particle beams; scattering; transition elements;

MQ: charged particles: **activation** analysis; charged particles: iron; charged particles: wear.

DOCUMENT NUMBER = INI22:028104

VVSS	= 2208	RN	= 22:028104	CTRY	= JP
YEAR	= 1990	TYPE	= I	CAT	= B2260
LVLS	= AM	RP	= INISMF12714		
AU	= KOSAKO, TO	SRCE	= PROCEEDINGS OF T		
TSRCE	= IPROCEEDINGS OF T				

TI: On-line and precise measurement of iron wear using **thin layer activation** reactions by proton beam.

AU: Kosako, Toshiso (Tokyo Univ. (Japan). Research Center for Nuclear Science and Technology); Nishimura, Kazuo.

LA: English

MS: Proceedings of the 2nd international symposium on advanced nuclear energy research. Evolution by accelerators. Japan Atomic Energy Research Inst., Tokyo (Japan).

RP: INIS-mf--12714.

IM: May 1990. 778 p. p. 678-683. Availability: INIS.

CF: (2. international symposium on advanced nuclear energy research. Mito, Ibaraki (Japan). 24-26 Jan 1990.)

CN: JP (Japan) I (Miscellaneous) Related to 21:087511.

LI: K (Conferences)

CC: B2260 (Physical radiation effects on all metals and alloys)

AB: For the purpose of the on-line measurement of iron wear, **thin layer activation** (TLA) method or surface **layer activation** (SLA) method has been carried out since early 1970s. This method uses the irradiation of charged particle beam like protons from an accelerator onto a metal surface to produce a **thin** activated **layer** of several tens #mu#m. The wear of this activated **layer** is measured by nondestructive on-line method with a radiation detector. There are two methods of the measurement. One is the activity loss measurement on the surface, and the other is the activity measurement of the metal debris collected in a filter. The former method is considered here. The purpose it to measure the wear of engine cam noses to help the development of good engine oil. Proton beam irradiation with a tandem van de Graaff accelerator, wear calibration using a gamnia ray spectrometer, on-line wear measurement of cam noses of car engines by TLA method and so on are reported. The 7.00 MeV proton beam from a van de Graaff accelerator was used for **activation**, and Co-56, Co-57 and Co-58 were obtained in **thin** layers. (K.I.).

CT: (iad); calibration; gamma spectrometers; iron; motors; nuclear reaction analysis; on-line measurement systems; proton beams; **thin** films; wear; . (cad); beams; chemical analysis; elements; films; measuring instruments; metals; nondestructive analysis; nucleon beams; on-line systems; particle beams; spectrometers; transition elements;

MQ: wear: iron; wear: nuclear reaction analysis.

DOCUMENT NUMBER = INI21:086108

VVSS	= 2122	RN	= 21:086108	CTRY	= US
YEAR	= 1989	TYPE	= J	CAT	= B2260
LVLS	= AS	ISSN	= 0010-9312		
AU	= WALLACE, G	SRCE	= CORROSION (HOUST		

TSRCE = JCORROSION (HOUST

TI: Corrosion monitoring on a large steel pressure vessel by thin-layer **activation.**
AU: Wallace, G. (Inst. of Nuclear Sciences, Dept. of Scientific and Industrial Research, P.O. Box 31312, Lower Hutt (New Zealand)); Boulton, L.H. (Auckland Industrial Development Div., Dept. of Scientific and Industrial Research, P.O. Box 2225, Auckland (New Zealand)); Hodder, D. (NZFP Pulp and Paper Ltd., Private Bag, Tokoroa (New Zealand)).
LA: English
JR: Corrosion (Houston). ISSN 0010-9312. CODEN: CORRA. (Dec 1989). v. 45(12) p. 1016-1019.
CN: US (USA) J (Journal Article)
CC: B2260 (Physical radiation effects on all metals and alloys) B2250 E2200
AB: Thin-layer **activation** (TLA) is a technique in which a surface is irradiated by a nuclear accelerator and thereby labeled with an accurate depth profile of low-level radioactivity. By monitoring this activity it is possible to calculate how much of that surface has been removed by corrosion. As the radioactivity is marked by the emission of penetrating gamma rays, it is possible to monitor this corrosion remotely through several centimeters of steel. This technique has been used to monitor erosion-corrosion occurring on the inner carbon steel wall of a continuous Kraft pulp digester at a paper mill. Representative coupons of the same steel as the digester wall were irradiated and fixed to the walls in the liquor extraction zone during a maintenance shutdown. The loss of metal over the six months was measured by external monitoring of gamma radiation through the vessel wall, and converted to a corrosion rate. Subsequent weight-loss measurements and comparison with ultrasonic thickness measurements established that the corrosion rate measured gave accurate results over a much shorter time scale. TLA thus enables current, rather than historical corrosion rates to be measured in a large steel pressure vessel.
CT: (iad); **activation** analysis; **activation** energy; algorithms; carbon steels; gamma radiation; physical radiation effects; pressure vessels; radioactivity; reactor components; reactor physics; reliability; stress corrosion; . (cad); alloys; carbon additions; chemical analysis; chemical reactions; containers; corrosion; electromagnetic radiation; energy; ionizing radiations; iron alloys; iron base alloys; nondestructive analysis; radiation effects; radiations; steels;
MQ: carbon steels: physical radiation effects; pressure vessels: **activation** analysis.

DOCUMENT NUMBER = INI21:075624

VVSS	= 2119	RN	= 21:075624	CTRY	= DE
YEAR	= 1989	TYPE	= J	CAT	= D2200
LVLS	= AS	ISSN	= 0340-756X		
AU	= KLEINRAHM,	SRCE	= KFK NACHR.		
TSRCE	= JKFK NACHR.				

TI: Recent developments in wear measurements with the **thin layer activation** technique. Neuere Entwicklungen der Verschleissmesstechnik mit dem Verfahren der Duennschichtaktivierung.
AU: Kleinrahm, A.; Fehsenfeld, P. (Kernforschungszentrum Karlsruhe GmbH (Germany, F.R.). Inst. fuer Kernphysik 3).
LA: German
JR: KFK Nachr. ISSN 0340-756X. CODEN: KFKNA. (1989). v. 21(1/2) p. 22-26.
CN: DE (Germany, F.R.) J (Journal Article)
CC: D2200 (Industrial Applications, Radiometric)
AB: At the KfK's compact cyclotron an efficient serial radiation plant for the thin-layer **activation** of machine and plant components for industry and research was provided. By means of this fully automatic plant it is possible to carry out wear measurements on ceramic compositions, cermets and related hard materials. The further developed RTM **activation** and measuring technique was used for the investigation of the erosive and corrosive wear behaviour of pipelines and pump parts in liquid mediums with solid matter proportions, in the field of textile technology (knitting machines) and for the detection of material dislocations in the bearing surface of wheel-rail-tribo-systems. (DG).
CT: (iad); abrasion; alloys; automation; ceramics; cermets; cyclotrons; on-line

measurement systems, radioactivation tracer techniques, wear (cad), accelerators, composite materials, cyclic accelerators, isotope applications, materials, on-line systems,

MQ: abrasion radioactivation wear radioactivation

DOCUMENT NUMBER = INI21 074077

VVSS	= 2119	RN	= 21 074077	CTRY	= NL
YEAR	= 1990	TYPE	= J	CAT	= B1110
LVLS	= AS	ISSN	= 0168-583X		
AU	= NEUMANN, W	SRCE	= NUCL INSTRUM M		
TSRCE	= JNUCL INSTRUM M				

TI: Thin-layer **activation** of hip-joint prostheses for tribological tests

AU: Neumann, W.; Woelfli, W (Eidgenoessische Technische Hochschule, Zurich (Switzerland). Inst. fuer Mittelenergiephysik), Heimgartner, P., Streicher, R M (Sulzer Bros Ltd, Winterthur (Switzerland))

LA: English

JR: Nucl Instrum Methods Phys Res, Sect B ISSN 0168-583X CODEN NIMBE (Apr 1990). v. 50(1-4) p 57-61

CF: (1 European conference on accelerators in applied research and technology (ECAART-1). Frankfurt am Main (Germany, F R) 5-9 Sep 1989)

CN: NL (Netherlands) J (Journal Article)

LI: K (Conferences) N (Numerical Data)

CC: B1110 (Nuclear methods in chemical and isotopic analysis) A3414 A3416

AB: Thin-layer **activation** as a method of measuring wear has been applied in a tribological study of artificial hip joints made from CoCrMo forged alloy The **activation** of CoCrMo alloy using protons, deuterons, "3He, and #alpha#-particles has been studied systematically Excitation functions are reported for the reactions "5"9Co(d, p)"6"0Co and "1"0"0Mo(#alpha#, n)"1"0"3Ru (orig)

CT: (iad); alpha reactions; calibration; charged-particle **activation** an, chromium alloys; cobalt alloys; cobalt 59 target; cobalt 60, depth; deuteron reactions, energy dependence; excitation functions; experimental data, helium 3 reactions, integral cross sections; joints, layers; mev range 01-10, mev range 10-100, molybdenum alloys; molybdenum 100 target, neutron transfer, neutrons, one- nucleon transfer reactions, prostheses, proton reactions, protons ruthenium 103, three-nucleon transfer reactio, wear, (cad), **activation** analysis, alloys, baryon reactions, baryons, beta decay radioisotopes; beta-minus decay radioisotopes cations, charged particles, chemical analysis; cobalt isotopes, cross sections, data; days living radioisotopes, dimensions, direct reactions, elementary particles, energy range; even-odd nuclei, fermions, hadron reactions, hadrons, hydrogen ions, hydrogen ions 1 plus; information, intermediate mass nuclei, internal conversion radioisoto, ions; isomeric transition isotopes, isotopes, medical supplies, mev range; minutes living radioisotopes, multi-nucleon transfer reactio, nondestructive analysis, nuclear reactions, nuclei, nucleon reactions; nucleons, numerical data, odd-odd nuclei; radioisotopes, ruthenium isotopes, targets, transfer reactions, years living radioisotopes,

MQ: alpha reactions· three-nucleon transfer reactio, charged-particle **activation** an wear; cobalt 59 target deuteron reactions, deuteron reactions one-nucleon transfer reactions; molybdenum 100 target alpha reactions, prostheses charged-particle **activation** an

DOCUMENT NUMBER = INI21:068811

VVSS	= 2118	RN	= 21 068811	CTRY	= NL
YEAR	= 1990	TYPE	= J	CAT	= A1310
LVLS	= AS	ISSN	= 0168-583X		
AU	= NEUMANN, W	SRCE	= NUCL INSTRUM M		
TSRCE	= JNUCL INSTRUM M				

TI: Thin-layer **activation** applied to erosive wear

AU: Neumann, W (Inst. fuer Mittelenergiephysik, ETH-Hoenggerberg, Zurich

(Switzerland)), Stalder, C. (Swiss Federal Propellant Plant, Wimmis (Switzerland))
LA: English
JR: Nucl Instrum Methods Phys. Res., Sect B ISSN 0168-583X CODEN: NIMBE (Jan 1990) v 45(1-4) p 126-129
CF: (9. international conference on ion beam analysis (IBA-9) Kingston (Canada) 26-30 Jun 1989.)
CN: NL (Netherlands) J (Journal Article)
LI: K (Conferences)
CC: A1310 (Nuclear phenomena and techniques in solid state and fluid physics)
AB: Thin-layer **activation** as a method of measuring erosive wear in gun barrels due to hot propellant gases has been applied to a large- caliber Howitzer Three spots on the lands of a 105 mm barrel were activated during the "5"6Fe(p, n)"5"6Co reaction The instrumentation, the reproducibility and accuracy of the method as well as results on the erosivity of propellants are discussed (orig)
CT: (iad); **activation** analysis; cobalt 56, erosion, gamma radiation, guns, iron 56, mev range 10-100, neutrons; proton reactions; wear, (cad), baryon reactions; baryons, beta decay radioisotopes; beta- plus decay radioisotopes, chemical analysis, cobalt isotopes; days living radioisotopes, electromagnetic radiation, electron capture radioisotopes, elementary particles; energy range, even-even nuclei, fermions, hadron reactions; hadrons, intermediate mass nuclei, ionizing radiations, iron isotopes, isotopes, mev range; nondestructive analysis, nuclear reactions, nuclei, nucleon reactions, nucleons, odd-odd nuclei, radiations, radioisotopes, stable isotopes;
MQ: guns: wear

DOCUMENT NUMBER = INI21:010760

VVSS	= 2103	RN	= 21 010760	CTRY	= NZ
YEAR	= 1986	TYPE	= B	CAT	= D2200
LVLS	= AM	AU	= WALLACE, G		
SRCE	= INDUSTRIAL CORRO		TSRCE	= BINDUSTRIAL CORRO	

TI: **Thin layer activation.**
AU: Wallace, G. (Department of Scientific and Industrial Research, Lower Hutt (New Zealand). Inst of Nuclear Sciences).
LA: English
MS: Industrial corrosion monitoring. Proceedings of a one day symposium held at the Conference Centre Airport Travelodge, Auckland 28 August 1986 Boulton, L H (ed)
IM: Auckland (New Zealand). Australasian Corrosion Association, New Zealand Branch 1986. 109 p. p. 102-105. ISBN 0-9597812-0-X
CF: (Industrial Corrosion Monitoring. Auckland (New Zealand) 28 Aug 1986)
CN: NZ (New Zealand) B (Book)
LI: K (Conferences)
CC: D2200 (Industrial Applications, Radiometric)
AB: The technique of **thin layer activation** or surface **layer activation**, has been developed independently by the Atomic Energy Research Establishment in the U K and by Spire Corporation in the U.S. in the mid-1970's. The technique is a diagnostic tool for in situ measurement of material loss due to wear, erosion and corrosion It is particularly attractive for wear measurement in odd geometries or for parts that are normally inaccessible to other probes
CT: (iad), corrosion, erosion; materials testing, neutron **activation** analysis, nondestructive testing; surfaces; wear; . (cad), **activation** analysis, chemical analysis; chemical reactions; nondestructive analysis, testing;
MQ: materials testing: neutron **activation** analysis.

DOCUMENT NUMBER = INI21:010753

VVSS	= 2103	RN	= 21:010753	CTRY	= HU
YEAR	= 1989	TYPE	= J	CAT	= D2200
LVLS	= AS	ISSN	= 0231-3596		
AU	= TAKACS, S.	SRCE	= ATOMKI ANNU. REP		
TSRCE	= JATOMKI ANNU REP				

TI: Determination of wear by **thin layer activation** in iron.
AU: Takacs, S.; Ditroi, F.; Mahunka, I. (Magyar Tudomanyos Akademia, Debrecen (Hungary). Atommag Kutato Intezete).
LA: English
JR: ATOMKI Annu. Rep. ISSN 0231-3596. CODEN: AREAE. (Mar 1989). (no.3) p. 72.
CN: HU (Hungary) J (Journal Article)
LI: E (Short Communication)
CC: D2200 (Industrial Applications, Radiometric)
AB: Short communication.
CT: (iad); charged-particle **activation** an; corrosion; depth; doped materials; surfaces; uses; wear; . (cad); **activation** analysis; chemical analysis; chemical reactions; dimensions; materials; nondestructive analysis;
MQ: charged-particle **activation** an: uses.

DOCUMENT NUMBER = INI20:085317

VVSS	= 2024	RN	= 20:085317	CTRY	= DD
YEAR	= 1989	TYPE	= J	CAT	= D2200
LVLS	= AS	ISSN	= 0036-6226		
AU	= EIFRIG, C	SRCE	= SCHMIERUNGSTECHN		
TSRCE	= JSCHMIERUNGSTECHN				

TI: On the application of thin-layer **activation** to radiometric wear measurement. Zur Anwendung der Duennschichtaktivierung auf radiometrische Verschleissmessungen.
AU: Eifrig, C. (Akademie der Wissenschaften der DDR, Leipzig (German Democratic Republic). Zentralinstitut fuer Isotopen- und Strahlenforschung).
LA: German
JR: Schmierungstechnik. ISSN 0036-6226. CODEN: SHRGA. (Jul 1989). v. 20(7) p. 199-201.
CN: DD (German Democratic Republic) J (Journal Article)
CC: D2200 (Industrial Applications, Radiometric)
AB: Variants of **activation** and measurement are presented. An application example - radiometric wear measurement of refrigerant compressors - is given, and an improved version of the method, a two- nuclide technique used for measurements with wear debris losses, is described. The radiometric method of wear measurement can still be developed further and extended to include additional applications. (author).
CT: (iad); cobalt 56; cobalt 57; compressors; depth; deuterons; radioactivation; steels; **thin** films; wear; . (cad); alloys; beta decay radioisotopes; beta-plus decay radioisotopes; carbon additions; charged particles; cobalt isotopes; days living radioisotopes; dimensions; electron capture radioisotopes; films; intermediate mass nuclei; iron alloys; iron base alloys; isotopes; nuclei; odd-even nuclei; odd-odd nuclei; radioisotopes;
MQ: steels: radioactivation; wear: cobalt 56; wear: cobalt 57.

DOCUMENT NUMBER = INI20:079888

VVSS	= 2023	RN	= 20:079888	CTRY	= NL
YEAR	= 1989	TYPE	= J	CAT	= E1700
LVLS	= AS	ISSN	= 0168-583X		
AU	= BOUCHACOUR	SRCE	= NUCL INSTRUM. M		
TSRCE	= JNUCL. INSTRUM. M				

TI: Study of the corrosion-erosion phenomenon in nuclear power plants, using the **thin layer activation** method.
AU: Bouchacourt, M.; Marsigne, C.; Dubail, A. (Electricite de France, 77 - Mores-sur-Loing (France)); Blondiaux, G.; Debrun, J.L. (Centre National de la Recherche Scientifique, 45 - Orleans (France). CERI).
LA: English
JR: Nucl. Instrum. Methods Phys. Res., Sect. B. ISSN 0168-583X. CODEN: NIMBE. (Apr 1989). v. 40/41(pt.2) p. 1199-1201.
CF: (10. conference on the application of accelerators in research and industry. Denton, TX (USA). 7-9 Nov 1988.)
CN: NL (Netherlands) J (Journal Article)

LI: K (Conferences)
CC: E1700 (Materials Testing)
AB: In this work, the **thin layer activation** method was used to study the corrosion-erosion phenomenon Steel samples were activated with 9- 13 MeV protons from a cyclotron, and placed in test loops were the "5"6Co loss (from the "5"6Fe(p, n)"5"6Co reaction) was followed by gamma-ray spectrometry The studied parameters were steel composition, temperature, geometry, speed and composition of the circulating medium Two test loops were used: one for water alone, the other one for mixtures of steam and water The corrosion- erosion rates of various steel samples were determined under precise experimental conditions, resulting in a better knowledge of the materials and of the conditions of their use to achieve durable operating conditions of the nuclear power plants (orig)
CT: (iad), **activation** analysis, cobalt 56, corrosion, erosion, iron 56 target, mev range 01-10, mev range 10-100, neutrons, nuclear power plants, proton reactions, secondary coolant circuits, steels, (cad), alloys, baryon reactions, baryons, beta decay radioisotopes, beta-plus decay radioisotopes, carbon additions, chemical analysis, chemical reactions, cobalt isotopes; cooling systems, days living radioisotopes, electron capture radioisotopes, elementary particles, energy range, fermions, hadron reactions, hadrons, intermediate mass nuclei; iron alloys, iron base alloys, isotopes, mev range, nondestructive analysis, nuclear facilities, nuclear reactions, nuclei, nucleon reactions nucleons, odd-odd nuclei, power plants, radioisotopes, reactor components, reactor cooling systems, targets, thermal power plants,
MQ: secondary coolant circuits **activation** analysis

DOCUMENT NUMBER = INI20 075446

VVSS	= 2022	RN	= 20 075446	CTRY	= NL
YEAR	= 1989	TYPE	= J	CAT	= B2260
LVLS	= AS	ISSN	= 0168-583X		
AU	= KOSAKO, TO	SRCE	= NUCL INSTRUM M		
TSRCE	= JNUCL INSTRUM M				

TI: Wear measurement at depths of several tens micrometers on the surface of iron using a **thin layer activation** method by 7 MeV proton beam
AU: Kosako, Toshio (Tokyo Univ. (Japan). Research Center for Nuclear Science and Technology), Nishimura, Kazuo (General Sekiyu KK, Kawasaki (Japan) Central Research Lab)
LA: English
JR: Nucl Instrum Methods Phys Res, Sect. B ISSN 0168-583X CODEN NIMBE (Apr 1989) v 40/41(pt 1) p 587-590.
CF: (10 conference on the application of accelerators in research and industry. Denton, TX (USA) 7-9 Nov 1988)
CN: NL (Netherlands) J (Journal Article)
LI: K (Conferences) N (Numerical Data)
CC: B2260 (Physical radiation effects on all metals and alloys)
AB: A method of measuring iron wear using **thin layer activation** is discussed The iron surface is activated by a "5"6Fe(p, n)"5"6Co reaction etc using a 7 00 MeV proton beam from a tandem Van de Graaff accelerator Irradiation of 0 5-2 #mu#A beam currents produces 1-10 #mu#Ci of "5"6Co activities in a **layer** about 50 #mu#m thick To get the basic depth profile of cobalt activities a 1 5 cm iron cube with a 3 mm diameter **activation** area is used to produce a wear calibration curve Wear is produced by a polishing machine and wear thickness is measured by a precise electric micrometer Monitoring radiation instruments are a 3 in diameter x3 in NaI (Tl) scintillator and a high-purity Ge detector A detailed iron wear calibration curve using "5"6Co, "5"7Co and "5"8Co activities is obtained in accordance with iron weak thickness After discussion, a universal iron wear calibration curve using the "5"6Co/"5"7Co or "5"6Co/"5"8Co ratio is newly developed This convenient curve is expressed in an experimental formula with a correction for time attenuation. (orig)
CT: (iad), calibration, charged-particle **activation** an, cobalt 56, electron beams; experimental data, iron; iron 56 target; mev range 01-10, mev range 10-100; neutrons, proton beams; proton reactions; radiation monitoring, thickness, wear;

(cad), **activation** analysis baryon reactions baryons beams, beta decay radioisotopes, beta-plus decay radioisotopes, chemical analysis, cobalt isotopes, data, days living radioisotopes, dimensions, electron capture radioisotopes, elementary particles, elements, energy range fermions hadron reactions, hadrons, information, intermediate mass nuclei, isotopes, lepton beams, metals, mev range monitoring, nondestructive analysis, nuclear reactions, nuclei, nucleon beams, nucleon reactions, nucleons, numerical data, odd-odd nuclei, particle beams, radioisotopes, targets, transition elements,

MQ: iron wear, wear charged-particle **activation** an

DOCUMENT NUMBER = INI20.011404

VVSS = 2004 RN = 20 011404 CTRY = IN
YEAR = 1988 TYPE = J CAT = B2450
LVLS = AS ISSN = 0252-9262
AU = CHOWDHURY, SRCE = INDIAN J PHYS ,
TSRCE = JINDIAN J PHYS

TI: Study of wear between piston ring and cylinder housing of an internal combustion engine by **thin layer activation** technique

AU: Chowdhury, D P, Chowdhuri, J, Chakrabarti, A, Bhattacharjee, B B, Gangadharan G (Variable Energy Cyclotron Centre, Calcutta (India))

LA: English

JR: Indian J Phys, Part A ISSN 0252-9262 CODEN INJAD (Aug 1988) v 62(6) p 688-690

CF: (Seminar on physics and technology of particle accelerators and their applications Calcutta (India) 29 Jan - 3 Feb 1987)

CN: IN (India) J (Journal Article)

LI: K (Conferences)

CC: B2450 (Corrosion, erosion, and degradation) B1110

AB: The **thin layer activation** technique is a highly sensitive technique for measuring the material loss due to wear, corrosion, erosion, sputtering and the like This technique has been applied for investigating the wear on the surface of compression ring and cylinder housing using 40 MeV alpha beam The standard calibration curves of the yield against the depth of the thickness have been generated for iron and nickel targets through stacked foil **activation** measurements The experimental parameters for the irradiation of machine components and the subsequent measurements of the activity as a function of duration of running the engine are described The wear rates have been followed both for piston ring and cylinder housing In the total run of about 400 hours of I C Engine while the total loss in cylinder housing is 13 microns, the loss from the piston ring is 60 microns An interesting observation is that wear is not uniform in cylinder housing The sensitivity of the measurement of wear is 0 1 micron (author)

CT: (iad), alpha reactions, charged-particle **activation** an, iron, irradiation, motors, wear, (cad), **activation** analysis, chemical analysis, elements, metals, nondestructive analysis, nuclear reactions transition elements,

MQ: iron charged-particle **activation** an, iron wear, wear charged- particle **activation** an

DOCUMENT NUMBER = INI19-106230

VVSS = 1924 RN = 19 106230 CTRY = US
YEAR = 1988 TYPE = R CAT = E2200
LVLS = AM RP = EPRINP5490SR
AU = BLATCHLEY SRCE = NONDESTRUCTIVE E
TSRCE = RNONDESTRUCTIVE E

TI: Turbine erosion measurements by **thin layer activation.**

AU: Blatchley, C C (Spire Corp, Bedford, MA (USA))

LA: English

MS: Nondestructive Evaluation Program Progress in 1987 Avioli, M J Jr., Dau, G J, Edmonds, J, Gehl, S, Liu, S N, Stein, J, Viswanathan, R, Welty, C S Electric

Power Research Inst., Palo Alto, CA (USA); Coe Corp., Sunnyvale, CA (USA).
RP: EPRI-NP--5490-SR.
IM: Jun 1988. p. 31.1-31.6. Availability: Research Reports Center, Box 50490, Palo Alto, CA 94303.
CN: US (USA) R (Report)
LI: Y (Progress Report) X (Non-Conventional Literature not Available from INIS)
CC: E2200 (Reactor Components and Accessories) E1700
AB: The nature of the solid particle erosion (SPE) process was studied using surface layer and **thin layer activation** techniques for on-line monitoring of both stationary and rotating turbine components. SPE is caused by iron oxide scale exfoliated as magnetite from the inner surface of boiler tubes and piping, particularly from high-temperature reheaters. Maximum exfoliation of scale occurs during the thermal cycling associated with shut-downs. As a result, SPE is most severe during cold start-ups. However, owing to the lack of an on-line monitoring system, there has previously been no confirmation of these assumptions about the erosion phenomenon. The use of **thin layer activation** techniques to study turbine erosion is discussed.
CT: (iad); erosion; measuring methods; progress report; steam turbines; thermal power plants; thin-layer chromatography; turbine blades; . (cad); chromatography; power plants; separation processes; turbines;
MQ: steam turbines: erosion; turbine blades: erosion.

DOCUMENT NUMBER = INI19:103524

VVSS	= 1924	RN	= 19:103524	CTRY	= CS
YEAR	= 1988	TYPE	= I	CAT	= B1110
LVLS	= AM	RP	= INISMF11324		
AU	= TENDERA, P	SRCE	= 8TH CZECHOSLOVAK		
TSRCE	= I8TH CZECHOSLOVAK				

TI: An assessment of **thin layer activation** and gamma-ray spectroscopy for two-component measurements of wear.
AU: Tendera, P. (Statni Vyzkumny Ustav Materialu, Prague (Czechoslovakia)).
LA: English
MS: 8th Czechoslovak spectroscopic conference. Abstracts. Section S - special spectroscopic techniques. Ceskoslovenska Spektroskopicka Spolecnost, Prague.
RP: INIS-mf--11324.
IM: 2 Jun 1988 . 162 p. p. 129. Availability: INIS.
CF: (8. Czechoslovak spectroscopic conference. Ceske Budejovice (Czechoslovakia). 19-24 Jun 1988.)
CN: CS (Czechoslovakia) I (Miscellaneous) Related to 19:102190.
LI: K (Conferences) E (Short Communication)
CC: B1110 (Nuclear methods in chemical and isotopic analysis)
AB: Published in summary form only.
CT: (iad); charged-particle **activation** an; gamma spectroscopy; wear; . (cad); **activation** analysis; chemical analysis; nondestructive analysis; spectroscopy;
MQ: gamma spectroscopy: wear; wear: charged-particle **activation** an.

DOCUMENT NUMBER = INI19:092946

VVSS	= 1921	RN	= 19:092946	CTRY	= GB
YEAR	= 1988	TYPE	= J	CAT	= D2200
LVLS	= AS	ISSN	= 0007-1137		
AU	= SCHWABE, P	SRCE	= BR. J. NON-DESTR		
TSRCE	= JBR. J. NON-DESTR				

TI: The use of **thin layer activation** in condition monitoring.
AU: Schwabe, P.H. (CORMON Group (UK)); Asher, J. (UKAEA Harwell Lab. Nuclear Physics Div.).
LA: English
JR: Br. J. Non-Destr. Test. ISSN 0007-1137. CODEN: BJNTA. (Jul 1988). v. 30(4) p. 259-262.
CF: (Condition monitoring 87 Conference. Swansea (UK). 1987.)

CN: GB (UK) J (Journal Article)
LI: K (Conferences)
CC: D2200 (Industrial Applications, Radiometric)
AB: In the search for on-or off-line methods for condition monitoring of wear sensitive components. **Thin Layer Activation** (TLA) has much to offer. The basis of the technique is the creation by ion bombardment of a **thin layer** of a radioactive isotope within the weaning surface of the component. It is possible to measure very small surface losses directly, and by the use of double **layer**, or direct, or indirect sentinel **layer** modifications, wear of material to any depth can be measured. The technique can be applied to most materials and extended to virtually all materials and components by the use of treated plugs or inserts. Material loss can often be measured under operating conditions without dismantling equipment. The technique is reliable and of known useful life, i.e. there can be no electrical or mechanical failures of the implanted **layer**. The total radioactivity is very low and no modification of material surface properties is likely. The use of TLA in condition monitoring will speed up the identification of incipient faults. (author).
CT: (iad); ion beams; layers; monitoring; nondestructive testing; radioactivation; uses; wear; . (cad); beams; materials testing; testing;
MQ: wear: radioactivation.

DOCUMENT NUMBER = INI19:078332

VVSS	= 1918	RN	= 19:078332	CTRY	= ZA
YEAR	= 1987	TYPE	= J	CAT	= E1700
LVLS	= AS	ISSN	= 0038-2442		
AU	= SABATO, V.	SRCE	= S. AFR. MECH. EN		
TSRCE	= JS. AFR. MECH. EN				

TI: Wear monitoring in a diesel engine using **thin layer activation**.
AU: Sabato, V.; Wright, G.; Sellschop, F. (Wits-CSIR Schonland Research Centre for Nuclear Sciences, University of the Witwatersrand, South Africa).
LA: English
JR: S. Afr. Mech. Eng. ISSN 0038-2442. CODEN: SAMEA. (Mar 1987). v. 37(3) p. 99-102.
CN: ZA (South Africa) J (Journal Article)
LI: N (Numerical Data)
CC: E1700 (Materials Testing)
AB: **Thin layer activation** (TLA) is a nuclear technique for the dynamic monitoring quantitatively of the wear of specific components without the need for disassembly of the system. This technique involves the production of a **thin layer** of radioactive atoms at and near the surface of a component by bombardment with selected charged particles. The loss in radioactivity, as the material is worn away, can be accurately monitored and related quantitatively to the loss of material. This paper reports on the development and application of this technique for monitoring the wear of the second compression ring of a two-cylinder Lister diesel engine. Details of the experimental procedure and results of the dynamic wear monitoring programme are provided.
CT: (iad); charged-particle **activation** an; cobalt 56; diesel motors; efficiency; experimental data; filters; gamma radiation; iron 56; irradiation; mev range 01-10; radiation monitoring; radiation monitors; radioactivity; sodium iodides; surfaces; wear; . (cad); **activation** analysis; alkali metal compounds; beta decay radioisotopes; beta-plus decay radioisotopes; chemical analysis; cobalt isotopes; data; days living radioisotopes; electromagnetic radiation; electron capture radioisotopes; energy range; even-even nuclei; halides; halogen compounds; information; intermediate mass nuclei; iodides; iodine compounds; ionizing radiations; iron isotopes; isotopes; measuring instruments; mev range; monitoring; monitors; motors; nondestructive analysis; nuclei; numerical data; odd-odd nuclei; radiations; radioisotopes; sodium compounds; stable isotopes;
MQ: charged-particle **activation** an: diesel motors; charged-particle **activation** an: wear.

DOCUMENT NUMBER = INI19:028623

VVSS = 1907 RN = 19:028623 CTRY = IT
YEAR = 1986 TYPE = R CAT = E1700
LVLS = M RP = ENEARTTERM86
AU = DE MASSIMI SRCE = DIAGNOSTICS OF E
TSRCE = RDIAGNOSTICS OF E

TI: Diagnostics of erosive phenomena in the blades of a turbine. Possible uses of the **thin layer activation** technique. Diagnostica dei fenomeni erosivi nelle pale di turbina. Possibilita di impiego della tecnica di attivazione di strato sottile.
AU: De Massimi, A.; Imperiali, F. (ENEA, Casaccia (Italy). Centro Ricerche Energia); Frazzoli, F.V. (Rome Univ. (Italy)).
CO: ENEA, Rome (Italy).
LA: Italian
RP: ENEA-RT-TERM--86-8.
IM: 1986. 117 p. Availability: INIS.
NO: 48 refs.
CN: IT (Italy) R (Report)
CC: E1700 (Materials Testing)
AB: The factors examined are those considered to be of interest with regard to the possibility applying the technique of **thin layer activation** for the survey and on-line monitoring of erosive phenomena in the blades of a power turbine. The technique is described with its characteristics, the typical fields in which it is used and its developments; in particular, the main parameters that characterize it and the connections that exist between these and the kind of applications to be carried out are shown. The general characteristics of the turbine are presented; the study is aimed mainly at gathering the special data necessary to apply the technique. In particular, to verify the applicability of the method of analysis in turbines, the following objectives are considered: 1) Identification of suitable radioisotopes and of their level of activity; 2) Dimensioning of the area to activate and its location on the blades; 3) Necessary instrumentation; 4) Protectionist problems.
CT: (iad); calibration; depth; deuterium; energy losses; erosion; helium 3 beams; helium 4 beams; proton beams; radiation protection; radiation scattering analysis; scattering; turbine blades; wear; . (cad); beams; chemical analysis; dimensions; hydrogen isotopes; ion beams; isotopes; light nuclei; nondestructive analysis; nuclei; nucleon beams; odd-odd nuclei; particle beams; stable isotopes;
MQ: turbine blades: radiation scattering analysis.

DOCUMENT NUMBER = INI19:023086

VVSS = 1906 RN = 19:023086 CTRY = DD
YEAR = 1987 TYPE = J CAT = D2200
LVLS = AS ISSN = 0025-4495
AU = WERNER, T. SRCE = MASCHINENBAUTECH
TSRCE = JMASCHINENBAUTECH

TI: Application of **thin layer activation** in wear measurements of splined shaft joints. Anwendung der Duennschichtaktivierung zur Verschleissmessung an Keilwellenverbindungen.
AU: Werner, T. (VEB Traktoren- und Dieselmotorenwerk, Schoenebeck (German Democratic Republic)); Eichhorn, K. (Zentralinstitut fuer Kernforschung, Rossendorf bei Dresden (German Democratic Republic)).
LA: German
JR: Maschinenbautechnik. ISSN 0025-4495. CODEN: MTECA. (Sep 1987). v. 36(9) p. 410-411.
CN: DD (German Democratic Republic) J (Journal Article)
CC: D2200 (Industrial Applications, Radiometric)
AB: Wear at supporting flanks of a splined shaft joint can be determined by using thin-layer **activation** in assembled state of the mechanism. Prerequisites to using this method are suitable parameters for exposure as to measuring problem as well as the knowledge of adequate dependence of activity decrease on the rate of wear. (author).
CT: (iad); **activation** analysis; gears; helium 4 beams; joints; layers; radioactivation; wear; . (cad); beams; chemical analysis; ion beams; machine parts; nondestructive analysis;

MQ: layers: wear; wear: **activation** analysis.

DOCUMENT NUMBER = INI19:009114

VVSS	= 1903	RN	= 19:009114	CTRY	= DD
YEAR	= 1987	TYPE	= R	CAT	= E1700
LVLS	= AM	RP	= ZFK594		
AU	= EICHHORN,	SRCE	= PUBLICATIONS FRO		
TSRCE	= RPUBLICATIONS FRO				

TI: Application of **thin layer activation** to cavitation investigations. Anwendung der Duennschichtaktivierung auf Kavitationsuntersuchungen.
AU: Eichhorn, K.; Richter, E.; Taubert, H.
LA: German
MS: Publications from the department of large-scale devices of the Central Institute of Nuclear Research at Rossendorf. Arbeiten aus dem Bereich Grossgeraete des Zentralinstituts fuer Kernforschung, Rossendorf. Fuelle, R. (ed.). Zentralinstitut fuer Kernforschung, Rossendorf bei Dresden (German Democratic Republic).
RP: ZfK--594.
IM: Jul 1987. 52 p. p. 22-24. Availability: INIS.
CN: DD (German Democratic Republic) R (Report)
CC: E1700 (Materials Testing)
AB: Based on experiences in **thin layer activation** (TLA) applied to wear measurements first tests have been made to make use of this method in investigations of cavitation effects. Essential aspects for the preparation of the tests are given. It results, TLA is advantageous in cavitation research. (author).
CT: (iad); activity levels; alpha reactions; cavitation; depth; erosion; gamma spectra; half-thickness; layers; lead alloys; radioactivation; sensitivity; spatial distribution; tellurium 121; tellurium 123; tin alloys; wear; . (cad); alloys; beta decay radioisotopes; beta-plus decay radioisotopes; days living radioisotopes; dimensions; distribution; electron capture radioisotopes; even-odd nuclei; intermediate mass nuclei; internal conversion radioisoto; isomeric transition isotopes; isotopes; nuclear reactions; nuclei; physical properties; radioisotopes; spectra; stable isotopes; tellurium isotopes; years living radioisotopes;
MQ: tin alloys: cavitation; tin alloys: radioactivation.

DOCUMENT NUMBER = INI19:001854

VVSS	= 1901	RN	= 19:001854	CTRY	= DD
YEAR	= 1986	TYPE	= I	CAT	= D2200
LVLS	= AM	AU	= HAMMER, P.		
SRCE	= PROCEEDINGS OF T	TSRCE	= IPROCEEDINGS OF T		

TI: A study of wear in refrigerating machines using **thin layer activation.**
AU: Hammer, P. (VEB dkk Scharfenstein (German Democratic Republic)); Eichhorn, K. (Zentralinstitut fuer Kernforschung, Rossendorf bei Dresden (German Democratic Republic)); Eifrig, C. (Akademie der Wissenschaften der DDR, Leipzig. Zentralinstitut fuer Isotopen- und Strahlenforschung).
LA: English
MS: Proceedings of the third Working meeting Radioisotope Application and Radiation Processing in Industry. Vol. 4. Akademie der Wissenschaften der DDR, Leipzig. Zentralinstitut fuer Isotopen- und Strahlenforschung.
IM: 1986. 378 p. p. 1153-1161. Available from Central Institute of Isotope and Radiation Research, DDR-7050 Leipzig.
NO: Poster presentation.
CF: (3. working meeting on radioisotope application and radiation processing in industry. Leipzig (German Democratic Republic). 23- 27 Sep 1985.)
CN: DD (German Democratic Republic) I (Miscellaneous)
LI: K (Conferences) X (Non-Conventional Literature not Available from INIS)
CC: D2200 (Industrial Applications, Radiometric)
AB: Wear is studied in a ball-and-socket joint of a newly developed refrigerating machine. Using deuteron **activation** a 15 #mu#m deep Co- 57 **layer** is generated at the

ring-shaped friction area in the steel socket of the joint. The measurement of the Co-57 intensity of the wear particles held back on an oil filter provides information about the wear rate of the socket during machine operation. The measurement of the Co-57 contaminations occuring in the individual parts of the machine at the end of the test gives information about the distribution of the wear particles in the machine and about the material transfer in the ball-and-socket joint. (author).

CT: (iad); charged-particle **activation** an; depth; iron; machine parts; spatial distribution; time dependence; wear; . (cad); **activation** analysis; chemical analysis; dimensions; distribution; elements; metals; nondestructive analysis; transition elements;

MQ: wear: charged-particle **activation** an; wear: machine parts.

DOCUMENT NUMBER = INI18:073868

VVSS	= 1817	RN	= 18:073868	CTRY	= NL
YEAR	= 1987	TYPE	= J	CAT	= E1700
LVLS	= AS	ISSN	= 0168-583X		
AU	= JAMISON, K	SRCE	= NUCL. INSTRUM. M		
TSRCE	= JNUCL. INSTRUM. M				

TI: Erosion measurement techniques for plasma-driven railgun barrels.

AU: Jamison, K.A.; Niiler, A. (Army Ballistic Research Lab., Aberdeen Proving Ground, MD (USA)).

LA: English

JR: Nucl. Instrum. Methods Phys. Res., Sect. B. ISSN 0168-583X. CODEN: NIMBE. (Apr 1987). v. 24/25(pt.2) p. 909-913.

CF: (9. international conference on the application of accelerators in research and industry. Denton, TX (USA). 10-12 Nov 1986.)

CN: NL (Netherlands) J (Journal Article)

LI: K (Conferences)

CC: E1700 (Materials Testing)

AB: Plasma-driven railguns are now in operation at several locations throughout the world. All share common problems in barrel erosion arising from the fact that the bore surface must contain a high temperature plasma armature which transmits the acceleration force to a projectile. The plasma temperature at the core of the armature is estimated to be 30 000 K or higher. Such conditions are erosive to most materials even when the exposure time is 100 #mu#s or less. We have adapted two accelerator based techniques to aid in the study of this erosion. The first technique involves the collection and analysis of material ablated and left behind by the plasma. This analysis is baded on the unfolding of the Rutherford backscattered (RBS) spectra of 1 MeV deuterons incident on residue collected from a railgun bore. The second technique is an erosion measurement involving **thin layer activation** (TLA) of surfaces. In this process, the copper rail surface is activated by 2.4 MeV protons creating a relatively **thin** (3 #mu#m) **layer** sparsely seeded with a long lived zinc isotope. Monitoring the decay of the activated sample before and after a firing can detect surface wear of about 0.1 #mu#m. Results from the RBS and TLA experiments on the BRL plasma driven railgun are described. (orig.).

CT: (iad); backscattering; charged-particle **activation** an; copper; deuteron beams; energy spectra; erosion; gamma spectra; mev range 01- 10; nondestructive testing; *proton beams; railgun accelerators; rutherford scattering;* wear; . *(cad);* **activation** analysis; beams; chemical analysis; elastic scattering; elements; energy range; impact fusion drivers; ion beams; materials testing; metals; mev range; nondestructive analysis; nucleon beams; particle beams; scattering; spectra; testing; transition elements;

MQ: erosion: nondestructive testing; nondestructive testing: charged- particle **activation** an; nondestructive testing: rutherford scattering; railgun accelerators: nondestructive testing.

DOCUMENT NUMBER = INI18:041794

VVSS = 1810 RN = 18 041794 CTRY = CH
YEAR = 1986 TYPE = J CAT = D2200
LVLS = AS ISSN = 0374-4256
AU = ASHER, J - SRCE = REV POLYTECH
TSRCE = JREV POLYTECH

TI: Progress in the measurement of industrial corrosion Des progres dans la mesure de la corrosion industrielle.
AU: Asher, J. (**Thin Layer Activation** Unit, Harwell Lab (UK))
LA: French
JR: Rev. Polytech. ISSN 0374-4256. CODEN: RVPTB (25 Oct 1986) (no 10) p. 1217, 1219, 1221.
CN: CH (Switzerland) J (Journal Article)
CC: D2200 (Industrial Applications, Radiometric)
AB: A non-destructive method of measurement is described in which a small test piece of surface is given a light radioactive label of depth about 100 #mu#m by bombardment in an accelerator; subsequent erosion can be measured to within 1 #mu#m by measuring the fall in radioactivity. A portable industrial instrument, at present undergoing prototype trials, is described (D.A.J.)
CT: (iad), erosion, nondestructive testing, portable equipment; radioactivation; radiometric analysis, radiometric gages, specifications, surfaces, wear, (cad), chemical analysis, equipment, materials testing, measuring instruments, quantitative chemical analysis, testing,
MQ: radiometric gages nondestructive testing, radiometric gages radiometric analysis

DOCUMENT NUMBER = INI18:037132

VVSS = 1809 RN = 18 037132 CTRY = DD
YEAR = 1986 TYPE = J CAT = D2300
LVLS = AS ISSN = 0013-5399
AU = HENNIG, K SRCE = ELEKTRIE
TSRCE = JELEKTRIE

TI: Surface treatment by ion beams Oberflaechenveredlung mittels Ionenstrahlen.
AU: Hennig, K.; Richter, Edgar; Richter, Emil; Schmidt, A. (Zentralinstitut fuer Kernforschung, Rossendorf bei Dresden (German Democratic Republic))
LA: German
JR: Elektrie ISSN 0013-5399 CODEN: EKTRA (Dec 1986). v 40(12) p 445-446
CN: DD (German Democratic Republic) J (Journal Article)
CC: D2300 (Industrial Applications, Radiation Processing)
AB: Methods of ion implantation for reducing friction, abrasion and corrosion of metals are presented Applications and limits of application are indicated including modern methods of abrasion investigation by **thin layer activation.**
CT: (iad); abrasion, corrosion; friction; ion beams; ion implantation; metals; surface treatments; surfaces; (cad); beams; chemical reactions, elements;
MQ: ion implantation: metals; metals: surface treatments

DOCUMENT NUMBER = INI18:021706

VVSS = 1806 RN = 18 021706 CTRY = GB
YEAR = 1986 TYPE = R CAT = B1110
LVLS = M RP = AERER12151
AU = ASHER, J., SRCE = COMPARISON OF TH
TSRCE = RCOMPARISON OF TH

TI: Comparison of **thin layer activation,** electrical resistance and electrochemical techniques for corrosion monitoring in cooling water plant.
AU: Asher, J.; Sugden, S.; Lawrence, P.F.; Williams, D.E.; Naish, C.
CO: UKAEA Atomic Energy Research Establishment, Harwell. Nuclear Physics Div.; UKAEA Atomic Energy Research Establishment, Harwell Materials Development Div.
LA: English
RP: AERE-R--12151.
IM: Jul 1986. 26 p. ISBN 0-7058-1204-9. Available from H.M. Stationery Office, London, price Pound5.25

CN: GB (UK) R (Report)
LI: X (Non-Conventional Literature not Available from INIS)
CC: B1110 (Nuclear methods in chemical and isotopic analysis)
AB: A development trial is described in which the performance of a **thin layer activation** (TLA) instrument probe for corrosion monitoring is compared with that of an electrical resistance probe and electrochemical probes on a water cooling plant. The resulting data are discussed in the light of the nature of the physical corrosion processes involved, and the comparative performance of these techniques is assessed. (author).
CT: (iad); **cobalt 57; comparative evaluations**; cooling systems; corrosion; electric conductivity; electric impedance; electric probes; electrochemistry; materials testing; radioactivity; . (cad); beta decay radioisotopes; chemical reactions; cobalt isotopes; days living radioisotopes; electrical properties; electron capture radioisotopes; evaluation; impedance; intermediate mass nuclei; isotopes; nuclei; odd-even nuclei; physical properties; probes; radioisotopes; testing;
MQ: cooling systems: corrosion; cooling systems: materials testing.

DOCUMENT NUMBER = INI17:018819

VVSS	= 1706	RN	= 17:018819	CTRY	= FR
YEAR	= 1984	TYPE	= B	CAT	= B2250
LVLS	= AM	AU	= BERRY, R.;		
SRCE	= CORROSION EROSIO		TSRCE	= BCORROSION EROSIO	

TI: The use of **thin layer activation** techniques for studying corrosion in economiser piping.
AU: Berry, R.; Parr, H.M.; Tyzack, C. (Risley Nuclear Power development Laboratory (UK)).
LA: English
MS: Corrosion erosion of steels in high temperature water and wet steam. Proceedings. Corrosion-erosion des aciers dans l'eau et la vapeur humide. Recueil des communications. Electricite de France, 75 - Paris.
IM: Paris (France). Electricite de France. 1984. 572 p. no. 20 p. 1- 23.
CF: (EDF specialists meeting on the corrosion: erosion of steels in high temperature water and wet steam. Ecuelles (France). 12 May 1982.)
CN: FR (France) B (Book) Related to 17:018807.
LI: K (Conferences)
CC: B2250 (Corrosion and erosion) E3300
AB: The TLA technique has been utilised to study the relative corrosion resistance of various candidate economizer and restrictor tube materials for second generation AGR steam plant. A study of potentially susceptible areas of return bends in a serpentine platen geometry relevant to the economizer design has not indicated the occurrence of erosion-corrosion under the conditions studied. It is proposed to extend the studies to lower temperatures. 2 tables, 8 references and 12 figures are given.
CT: (iad); agr type reactors; carbon steels; charged-particle **activation** an; corrosion; corrosion resistance; economizers; erosion; orifices; ph value; steel-crmo; steel-cr9mo; tubes; water chemistry; . (cad); **activation** analysis; alloys; carbon additions; chemical analysis; chemical reactions; chromium additions; chromium alloys; chromium steels; enriched uranium reactors; ferritic steels; gas cooled reactors; graphite moderated reactors; high alloy steels; iron alloys; iron base alloys; low alloy steels; molybdenum additions; nickel additions; nondestructive analysis; openings; reactors; stainless steels; steels; water treatment;
MQ: carbon steels: corrosion; steel-crmo: corrosion; steel-cr9mo: corrosion.

DOCUMENT NUMBER = INI16:080286

VVSS	= 1623	RN	= 16:080286	CTRY	= NL
YEAR	= 1985	TYPE	= J	CAT	= B2250
LVLS	= AS	ISSN	= 0168-583X		
AU	= LETERRIBLE	SRCE	= NUCL. INSTRUM. M		
TSRCE	= JNUCL. INSTRUM. M				

TI: Study of the influence of the speed of circulating water on the corrosion of unalloyed steel (A 42), using the **thin layer activation** method.
AU: Leterrible, P.; Blondiaux, G.; Valladon, M. (Centre National de la Recherche Scientifique, 45 - Orleans-la-Source (France). Service du Cyclotron); Ducreux, M.; Guerrand, M. (Electricite de France, 77 - Ecuelles. Centre de Recherches des Renardieres); Debrun, J.L.
LA: English
JR: Nucl. Instrum. Methods Phys. Res., Sect. B. ISSN 0168-583X. (15 May 1985). v. 10/11(pt.2) p. 1054-1057. CODEN: NIMBE.
CF: (8. international conference on the application of accelerators in research and industry. Denton, TX (USA). 12-14 Nov 1984.)
CN: NL (Netherlands) J (Journal Article)
LI: K (Conferences)
CC: B2250 (Corrosion and erosion)
AB: The corrosion of unalloyed steel (A 42) used in nuclear reactors was studied using the **thin layer activation** method; 12 to 15 MeV protons were used to produce the /sup 56/Fe(p,n)/sup 56/Co reaction. The phenomenon of corrosion was found to be complex, three different domains being observed: (1) linear variation of the speed of corrosion, Vsub(corr) with the mass transfer coefficient K, at low circulating speed; (2) at medium circulating speed, Vsub(corr) approx.= aK/sup 3/; (3) at high circulating speed, Vsub(corr) varies again linearly with K. Equations for the variation of Vsub(corr) with K were derived by combining the various equations describing the chemical and/or electrochemical phenomena taking place: these equations are in good agreement with the experimental data. (orig.).
CT: (iad); charge-exchange reactions; charged-particle **activation** an; cobalt 56; corrosion; fluid flow; iron 56 target; layers; mass transfer; mev range 10-100; neutrons; proton beams; proton reactions; reactor materials; reactors; steels; water; . (cad); **activation** analysis; alloys; baryon reactions; baryons; beams; beta decay radioisotopes; beta-plus decay radioisotopes; carbon additions; chemical analysis; chemical reactions; cobalt isotopes; days living radioisotopes; electron capture radioisotopes; elementary particles; energy range; fermions; hadron reactions; hadrons; hydrogen compounds; intermediate mass nuclei; iron alloys; iron base alloys; isotopes; materials; mev range; nuclear reactions; nuclei; nucleon beams; nucleon reactions; nucleons; odd-odd nuclei; oxygen compounds; particle beams; radioisotopes; targets;
MQ: charged-particle **activation** an: charge-exchange reactions; steels: corrosion.

DOCUMENT NUMBER = INI16:024541

VVSS	= 1607	RN	= 16:024541	CTRY	= DD
YEAR	= 1985	TYPE	= J	CAT	= D2200
LVLS	= AS	ISSN	= 0021-1915		
AU	= EICHHORN,	SRCE	= ISOTOPENPRAXIS.		
TSRCE	= JISOTOPENPRAXIS.				

TI: Nuclide production functions for **thin layer activation** of iron in wear investigations. Nuklidproduktionsfunktionen bei der Duennschichtaktivierung von Eisen fuer Verschleissuntersuchungen.
AU: Eichhorn, K. (Zentralinstitut fuer Kernforschung, Rossendorf bei Dresden (German Democratic Republic)); Eifrig, C. (Akademie der Wissenschaften der DDR, Leipzig. Zentralinstitut fuer Isotopen- und Strahlenforschung).
LA: German
JR: Isotopenpraxis. ISSN 0021-1915. (Feb 1985). v. 21(2) p. 45-48.
CN: DD (German Democratic Republic) J (Journal Article)
CC: D2200 (Industrial Applications, Radiometric)
AB: For wear measurements with the aid of **thin layer activation**, information is needed about the nuclide depth distribution in the activated material. Therefore, nuclide production functions have been determined for iron **activation** by alpha particles, deuterons, or protons at the Rossendorf cyclotron using iron foil stacks. (author).
CT: (iad); alpha reactions; depth; deuteron reactions; gamma spectra; iron; proton reactions; radioactivation; radioisotopes; spatial distribution; **thin** films; wear; . (cad); baryon reactions; dimensions; distribution; elements; films; hadron

reactions; isotopes; metals; nuclear reactions; nucleon reactions; spectra; transition elements;
MQ: iron: radioactivation; wear: radioisotopes.

DOCUMENT NUMBER = INI16:020582

VVSS	= 1606	RN	= 16:020582	CTRY	= US
YEAR	= 1981	TYPE	= J	CAT	= B2260
LVLS	= AS	ISSN	= 0018-9499		
RP	= CONF801111	AU	= CONLON, T.		
SRCE	= IEEE TRANS. NUCL	TSRCE	= JIEEE TRANS. NUCL		

TI: Ion beam **activation** for materials analysis: Methods and application.
AU: Conlon, T.W. (AERE Harwell Lab., Oxon).
LA: English
RP: CONF-801111--.
JR: IEEE Trans. Nucl. Sci. ISSN 0018-9499. (Apr 1981). v. NS-28(2) p. 1816-1819.
CF: (6. conference on application of accelerators in research and industry. Denton, TX (USA). 3-5 Nov 1980.)
CN: US (USA) J (Journal Article)
LI: K (Conferences)
CC: B2260 (Physical radiation effects on all metals and alloys) B1110
AB: A number of ion beam methods for materials analysis have been developed using Harwell's high voltage accelerators and these are currently being exploited for applications 'in house' and in industry. Ion beam **activation** is a relatively new area which has exhibited exceptional growth over the last few years. **Activation** by ion beams to produce a single dominant radioisotope as a surface label (**thin layer activation** or TLA) is becoming a mature technology offering ever increasing sensitivity for surface loss measurement (currently better than 0.1 mu m or 10/sup -7/ cm/sup 3/ depending on the method of measurement) and remote monitoring of inaccessible components during studies of wear/erosion/ corrosion/sputtering and the like. With the increasingly established credibility of the method has come the realisation that: (i) more complex and even multiple **activation** profiles can be used to extract more information on the characteristics of the surface loss process, (ii) that an analogous method can be used even on radiation sensitive materials through the newly established indirect recoil implantation process. (iii) that there is scope for treatment of truly immovable objects through the implantation of fission fragments, (iv) there is vast potential in the area of **activation** analysis. The current state of development of these methods which greatly extend the scope of conventional TLA will be briefly reviewed. Current applications of these and TLA in industry are discussed.
CT: (iad); **activation** analysis; corrosion; erosion; fission fragments; ion beams; ion implantation; metals; radioisotopes; recoils; uses; wear; . (cad); beams; chemical analysis; chemical reactions; elements; isotopes; nuclear fragments;
MQ: ion beams: **activation** analysis; ion beams: uses; metals: **activation** analysis; metals: ion beams.

DOCUMENT NUMBER = INI15:067903

VVSS	= 1522	RN	= 15:067903	CTRY	= NL
YEAR	= 1984	TYPE	= J	CAT	= E1700
LVLS	= AS	ISSN	= 0167-5087		
AU	= ROTBERG, V	SRCE	= NUCL. INSTRUM. M		
TSRCE	= JNUCL. INSTRUM. M				

TI: **Thin layer activation** of zinc compounds.
AU: Rotberg, V.H.; Acquadro, J.C. (Sao Paulo Univ. (Brazil). Inst. de Fisica).
LA: English
JR: Nucl. Instrum. Methods Phys. Res., Sect. A. ISSN 0167-5087. (1 May 1984). v. 222(3) p. 608-609. CODEN: NIMRD.
CN: NL (Netherlands) J (Journal Article)
CC: E1700 (Materials Testing)

AB: A nuclear technique has been developed in order to label metallic surfaces which contain zinc. It can be applied to the study of corrosion produced by alcohol on carburetors of automobile engines. (orig.).

CT: (iad)· charged-particle **activation** an; corrosion; deuteron reactions; layers; mev range 10-100; nondestructive testing; one- nucleon transfer reactions; protons; zinc alloys; zinc compounds; zinc 64 target; zinc 65; . (cad); **activation** analysis; alloys; baryons; beta decay radioisotopes; beta-plus decay radioisotopes; cations; charged particles; chemical analysis; chemical reactions; days living radioisotopes; direct reactions; electron capture radioisotopes; elementary particles; energy range; even-odd nuclei; fermions; hadrons; hydrogen ions; hydrogen ions 1 plus; intermediate mass nuclei; ions; isotopes; materials testing; mev range; nuclear reactions; nuclei; nucleons; radioisotopes; targets; testing; transfer reactions; zinc isotopes;

MQ: nondestructive testing: charged-particle **activation** an.

DOCUMENT NUMBER = INI15:048776

VVSS	= 1516	RN	= 15.048776	CTRY	= GB
YEAR	= 1984	TYPE	= J	CAT	= B2250
LVLS	= AS	ISSN	= 0010-938X		
RP	= AERER10477	AU	= WILLIAMS,		
SRCE	= CORROS. SCI.	TSRCE	= JCORROS. SCI.		

TI: Measurement of low corrosion rates: comparison of a.c. impedance and **thin layer activation** methods.

AU: Williams, D.E.; Asher, J. (UKAEA Atomic Energy Research Establishment, Harwell. Materials Development Div.; UKAEA Atomic Energy Research Establishment, Harwell. Nuclear Physics Div.).

LA: English

RP: AERE-R--10477.

JR: Corros. Sci. ISSN 0010-938X. (1984). v. 24(3) p. 185-196.

CF: (Meeting on 'Electrochemical methods in corrosion testing and research'. Manchester (UK). 4-6 Jan 1982.)

CN: GB (UK) J (Journal Article)

LI: K (Conferences)

CC: B2250 (Corrosion and erosion) B1110

AB: The very low corrosion rate (0.05-1 mu m per year) of 18Cr-13Ni-1Nb stainless steel in 7.8 M HNO3 at room temperature was determined with some confidence in a period of a few days by the combination of a.c. impedance and a radiotracer technique, Thin-Layer **Activation**. Both techniques were taken to their limits. It is argued that the a.c. method gives an upper estimate for the corrosion rate whilst the tracer method gives a lower estimate. Application of the a.c. method requires an estimate of the Tafel parameter relating corrosion rate and polarization resistance: an approximate method, utilizing the variation of the apparent value of the polarization resistance with the amplitude of the a.c. signal, is given in this paper. The corrosion rate decreased steadily with time over the first few days of exposure of the polished steel surface to the acid. Comparison of the results of the two methods suggested that there was a burst of active dissolution within the first few seconds of exposure, and some speculation about causes and consequences of this phenomenon is made. (author).

CT: (iad); alternating current; chromium-nickel steels; comparative evaluations; corrosion; deuteron beams; electric conductivity; electric impedance; gamma spectroscopy; medium temperature; mev range 01-10; nitric acid; radioactivation; time dependence; tracer techniques; . (cad); alloys; beams; carbon additions; chemical reactions; chromium alloys; currents; electric currents; electrical properties; energy range; high alloy steels; hydrogen compounds; impedance; inorganic acids; ion beams; iron alloys; iron base alloys; isotope applications; mev range; nickel alloys; nitrogen compounds; oxygen compounds; physical properties; spectroscopy; stainless steels; steels;

MQ: chromium-nickel steels: corrosion.

DOCUMENT NUMBER = INI15:024336

VVSS	= 1507	RN	= 15 024336	CTRY	= US
YEAR	= 1981	TYPE	= J	CAT	= B2260
LVLS	= AS	ISSN	= 0018-9499		
RP	= CONF801111	AU	= NILER, A.		
SRCE	= IEEE TRANS. NUCL	TSRCE	= JIEEE TRANS NUCL		

TI: Ion beam methods applied to interior ballistic studies.
AU: Niler, A. (Ballistic Research Lab., ABRADCOM, Aberdeen Proving Ground, Maryland 21005).
LA: English
RP: CONF-801111--.
JR: IEEE Trans. Nucl. Sci. ISSN 0018-9499. (Apr 1981). v. NS-28(2) p. 1834-1837.
CF: (6. conference on application of accelerators in research and industry. Denton, TX (USA) 3-5 Nov 1980.)
CN: US (USA) J (Journal Article)
LI: K (Conferences)
CC: B2260 (Physical radiation effects on all metals and alloys)
AB: High temperature, pressure and velocity gases produced during the interior ballistic cycle of a gun firing are responsible for considerable damage to the steel surfaces of a gun bore. This damage is studied by exposing steel samples to the erosive flows of burning propellant gases in a modified 37mm gun chamber where pressures of 200 MPa and flame temperatures of 3000 deg K are typical. Ion beam methods are used to characterize the composition of the steel surfaces by combined nuclear reaction (NR) and elastic backscattering (EBS) analysis and **thin layer activation** (TLA) is used to measure surface wear rates. Combined fits to the EBS and NR distributions yield concentrations and depth profiles of carbon, nitrogen and oxygen as well as iron and other heavier elements. Hydrogen concentrations have also been measured on some of the samples. The results of these experiments show the presence of two different erosion mechanisms. In one, the surface is softened by thermo-chemical processes prior to removal by the shear forces of the gas flow while in the other surface layer melting occurs prior to removal. TLA using the /sup 56/Fe(p,n)/sup 56/Co reaction has been used to measure wear from a 20 mm barrel and is being instrumented for larger barrels. EBS is being used to characterize the interfaces between steel substrates and coatings designed to reduce erosion.
CT: (iad), backscattering; cobalt 56; combustion; elastic scattering; erosion, explosions; guns; ion beams; iron 56; projectiles; steels; surfaces; wear; . (cad); alloys; beams; beta decay radioisotopes; beta-plus decay radioisotopes; carbon additions; chemical reactions; cobalt isotopes; days living radioisotopes; electron capture radioisotopes; even-even nuclei; intermediate mass nuclei; iron alloys; iron base alloys; iron isotopes; isotopes; nuclei; odd-odd nuclei; oxidation; radioisotopes; scattering; stable isotopes;
MQ: ion beams: elastic scattering; steels: erosion.

DOCUMENT NUMBER = INI15:024322

VVSS	= 1507	RN	= 15:024322	CTRY	= GB
YEAR	= 1983	TYPE	= B	CAT	= B2250
LVLS	= AM	AU	= FOUNTAIN,		
SRCE	= WATER CHEMISTRY	TSRCE	= BWATER CHEMISTRY		

TI: Two-phase erosion-corrosion studies at CEGB, North Western Region.
AU: Fountain, M.J. (Central Electricity Generating Board, Stockport (UK) North Western Region).
LA: English
MS: Water chemistry of nuclear reactor systems 3 vol. 1. Proceedings of an international conference organised by the British Nuclear Energy Society and co-sponsored by the Institution of Chemical Engineers and the Royal Society of Chemistry, Bournemouth, 17-21 October, 1983. British Nuclear Energy Society, London. Includes 11 separately paginated papers.

IM: London (UK) British Nuclear Energy Society 1983 393 p p 385-386 ISBN 0-7277-0201-7
CF: (Water chemistry of nuclear reactor systems 3 Bournemouth (UK) 17-21 Oct 1983)
CN: GB (UK) B (Book)
LI: K (Conferences)
CC: B2250 (Corrosion and erosion)
AB: Studies of two-phase erosion-corrosion have been carried out on a full-scale single tube experimental boiler It has been shown that erosion-corrosion rates in mild steel tubing can be successfully monitored by the **thin layer activation** technique and that the rates can be reduced by dosing amines which are less volatile and more basic than ammonia Complementary laboratory tests have shown that neither the amines themselves nor their thermal decomposition products will have a deleterious effect on other parts of the steam-water circuit The possible role of oxygen as an erosion-corrosion inhibitor is discussed (author)
CT: (iad), amines, boilers, carbon steels, corrosion, corrosion inhibitors, erosion, functional models, mass transfer, monitoring, oxygen, radioactivation, tubes, two-phase flow, (cad), alloys, carbon additions, chemical reactions, elements, fluid flow, iron alloys, iron base alloys, nonmetals, organic compounds, steels,
MQ: carbon steels corrosion

DOCUMENT NUMBER = INI15 021607

VVSS	= 1506	RN	= 15 021607	CTRY	= DD
YEAR	= 1983	TYPE	= R	CAT	= D2200
LVLS	= AM	RP	= ZFIMITT71		
AU	= ZUKOWSKA-C	SRCE	= RADIOISOTOPE APP		
TSRCE	= RRADIOISOTOPE APP				

TI: The use of **thin layer activation** in tribological investigations
AU: Zukowska-Cwik, G , Kras, J (Institute of Nuclear Research, Warsaw (Poland))
LA: English
MS: Radioisotope application and radiation processing in industry Selected papers of the second working meeting at Leipzig, 28 Sep - 1 Oct 1982 Akademie der Wissenschaften der DDR Leipzig Zentralinstitut fuer Isotopen- und Strahlenforschung
RP: Zfl-Mitt--71
IM: Jun 1983 368 p p 235-251 Availability INIS
CF: (2 working meeting 'radioisotope application and radiation processing in industry Leipzig (German Democratic Republic) 28 Sep - 1 Oct 1982)
CN: DD (German Democratic Republic) R (Report)
LI: K (Conferences)
CC: D2200 (Industrial Applications Radiometric)
AB: A procedure for **thin layer activation** (TLA) of engine parts by 10-Mev protons from a linear accelerator is described including application of TLA to wear investigations of tappets piston rings and tooth wheels
CT: (iad), cast iron, cobalt 56, depth, diesel motors, gears layers, machine parts, proton beams, radioactivation, spatial distribution, surfaces, tracer techniques, wear, (cad), alloys, beams beta decay radioisotopes, beta-plus decay radioisotopes, carbon additions, cobalt isotopes, days living radioisotopes, dimensions, distribution, electron capture radioisotopes, intermediate mass nuclei, iron alloys, iron base alloys, isotope applications, isotopes, motors, nuclei, nucleon beams, odd-odd nuclei, particle beams, radioisotopes, silicon alloys,
MQ: machine parts wear, wear tracer techniques

DOCUMENT NUMBER = INI15-021603

VVSS	= 1506	RN	= 15 021603	CTRY	= DD
YEAR	= 1983	TYPE	= R	CAT	= D2200
LVLS	= AM	RP	= ZFIMITT71		
AU	= VARKONYI	SRCE	= RADIOISOTOPE APP		
TSRCE	= RRADIOISOTOPE APP				

TI: The **thin layer activation** for industry.
AU: Varkonyi, A. (Magyar Tudomanyos Akademia, Budapest. Izotopintezete).
LA: English
MS: Radioisotope application and radiation processing in industry. Selected papers of the second working meeting at Leipzig, 28 Sep - 1 Oct 1982. Akademie der Wissenschaften der DDR, Leipzig. Zentralinstitut fuer Isotopen- und Strahlenforschung.
RP: Zfl-Mitt--71.
IM: Jun 1983. 368 p. p. 184-191. Availability: INIS.
CF: (2. working meeting 'radioisotope application and radiation processing in industry'. Leipzig (German Democratic Republic). 28 Sep - 1 Oct 1982.)
CN: DD (German Democratic Republic) R (Report)
LI: K (Conferences)
CC: D2200 (Industrial Applications, Radiometric)
AB: **Thin layer activation** (TLA) by a cyclotron has been introduced to wear, corrosion, and erosion measurements in industry. Applying TLA the following side effects should be taken into consideration: thermal effects, hydrogen embrittlement, point defects and dislocations, and microalloying.
CT: (iad); aluminium; austenitic steels; dislocations; embrittlement; hydrogen generation; layers; molybdenum; physical radiation effects; proton beams; radiation heating; radioactivation; steel-cr17ni12mo3; tensile properties; titanium; wires; . (cad); alloys; beams; carbon additions; chromium alloys; chromium- nickel steels; chromium-nickel-molybdenum ste; corrosion resistant alloys; crystal defects; crystal structure; elements; heat resisting alloys; heating; high alloy steels; iron alloys; iron base alloys; line defects; mechanical properties; metals; molybdenum alloys; nickel alloys; nucleon beams; particle beams; radiation effects; stainless steels; steels; transition elements;
MQ: aluminium: physical radiation effects; molybdenum: physical radiation effects; radioactivation: proton beams; steel-cr17ni12mo3: physical radiation effects; titanium: physical radiation effects.

DOCUMENT NUMBER = INI15:018331

VVSS	= 1505	RN	= 15:018331	CTRY	= US
YEAR	= 1983	TYPE	= J	CAT	= E1700
LVLS	= AS	ISSN	= 0018-9499		
AU	= JEANNEAU,	SRCE	= IEEE TRANS. NUCL		
TSRCE	= JIEEE TRANS. NUCL				

TI: Use of **thin layer activation** techniques to assess mechanical parts wear; a survey of the industrial experience in France.
AU: Jeanneau, B. (C.E.A. Isotopes Applications Service, Saclay).
LA: English
JR: IEEE Trans. Nucl. Sci. ISSN 0018-9499. (Apr 1983). v. 30(2) p. 1614-1618.
CN: US (USA) J (Journal Article)
CC: E1700 (Materials Testing)
AB: **Thin layer activation** is being used by industry for measurements of wear, erosion and corrosion. Such an **activation** is produced by bombardment with charged particles. The total activity level can be accurately monitored and if the activity to depth relationship is known, the amount of material worn away can thus be determined. By bombarding a given material with protons, deuterons, /sup 3/He, /sup 4/He, different radioactive species can be produced. Active layers can be obtained in a variety of materials such as iron, copper, chromium, titanium. The total activity level is weak, from 5 to 100 Ci but it will allow to use this technique in accordance to standard "Radioactive Substances regulations" for industry. The active **layer** varies from 10 to 1000 m, the activated area from some square millimeters to 2 squares centimeters and the sample can stand still or be rotated or translated to get a band of activity. Total or worn away activity is measured. The irradiations are made with the Orleans Cyclotron and the development and applications at Saclay Laboratory. Exemples of uses in mechanical engineering in the french automobile or nuclear industry are given.
CT: (iad); **activation** analysis; alpha reactions; cea saclay; chromium; copper;

corrosion; cyclotrons; deuteron reactions; erosion; france; helium 3 reactions; iron; machine parts; proton reactions; testing; titanium; wear; . (cad); accelerators; baryon reactions; cea; chemical analysis; chemical reactions; cyclic accelerators; developed countries; elements; europe; french organizations; hadron reactions; metals; national organizations; nuclear reactions; nucleon reactions; transition elements;

MQ: machine parts: **activation** analysis; machine parts: wear.

DOCUMENT NUMBER = INI15:005151

VVSS	= 1502	RN	= 15:005151	CTRY	= GB
YEAR	= 1983	TYPE	= J	CAT	= B1110
LVLS	= AS	ISSN	= 0144-557X		
AU	= EVANS, R.	SRCE	= ANAL. PROC.		
TSRCE	= JANAL. PROC.				

TI: Thin-layer **activation** in the measurement of engine wear.
AU: Evans, R. (Shell Research Ltd., Chester (UK)).
LA: English
JR: Anal. Proc. ISSN 0144-557X. (Sep 1983). v. 20(9) p. 474-476.
CN: GB (UK) J (Journal Article)
CC: B1110 (Nuclear methods in chemical and isotopic analysis)
AB: A summary is given of methods of activating specimens for wear measurement. The principle of thin-layer **activation** (TLA) is described, and its advantages for wear measurement are listed. Details are presented of the use of TLA for engine test cam follower wear measurement. In this case a swept beam of deuterons was used to irradiate the cast iron cam follower, to produce Co-57 by (d,n) reaction. (U.K.).
CT: (iad); labelling; layers; machine parts; measuring methods; motors; radioactivation; radioactivity; surfaces; thickness; tracer techniques; wear; . (cad); dimensions; isotope applications;
MQ: wear: measuring methods.

DOCUMENT NUMBER = INI14:802924

VVSS	= 1423	RN	= 14:802924	CTRY	= US
YEAR	= 1983	TYPE	= J	CAT	= E36
LVLS	= AS	ISSN	= 0018-9499		
AU	= CONLON, T.	SRCE	= IEEE TRANS. NUCL		
TSRCE	= JIEEE TRANS. NUCL				

TI: Nuclear and materials studies with ion beams.
AU: Conlon, T.W. (AERE Harwell Lab., Oxon).
LA: English
JR: IEEE Trans. Nucl. Sci. ISSN 0018-9499. (Apr 1983). v. 30(2) p. 1209-1213.
CN: US (USA) J (Journal article)
CC: E36 (Research and Test Reactors, including Experimental Reactors (Zero-Power Reactors and Subcritical Assemblies) and Training Reactors) A10 A14
AB: The main role of the Harwell Laboratory is to develop technology for nuclear power. Broadly this means the elucidation of the nuclear physics underlying fission and fusion concepts and the study and development of suitable materials for all aspects of the fuel cycle. An important and growing part of the Nuclear Physics Division's (NPD) work is the development of programmes spanning both roles. This synergy is clearly apparent in the ion beam work based on the Harwell suite of charged particle accelerators. This report covers aspects of nuclear studies on the accelerators (viz. heavy ion reaction mechanisms; heavy ion range, energy loss and straggling) the associated development of techniques for materials analysis (viz. **thin layer activation**, microbeam analysis, multi-element profiling etc.) and the commercial exploitation of accelerators and techniques.
CT: (iad); accelerators; aere; fission; heavy ion fusion reactions; nuclear power; nuclear reactions; physical radiation effects; reactor materials; research programs; thermonuclear reactor material; . (cad); heavy ion reactions; materials; national organizations; nucleosynthesis; power; radiation effects; ukaea; united kingdom

organizations;
MQ: accelerators: research programs; reactor materials: physical radiation effects; thermonuclear reactor material: physical radiation effects.

DOCUMENT NUMBER = INI14:763908

VVSS	= 1413	RN	= 14:763908	CTRY	= GB
YEAR	= 1982	TYPE	= R	CAT	= B15
LVLS	= M	RP	= AERER10574		
AU	= ASHER, J.;	SRCE	= ASSESSMENT USING		
TSRCE	= RASSESSMENT USING				

TI: An assessment using **thin layer activation** of a corrosion inhibitor treatment.
AU: Asher, J.; Webb, J.W.; Wilkins, N.J.M.; Lawrence, P.F.
CO: UKAEA Atomic Energy Research Establishment, Harwell. Materials Development Div.; UKAEA Atomic Energy Research Establishment, Harwell. Nuclear Physics Div.
LA: English
RP: AERE-R--10574.
IM: Aug 1982. 13 p. Availability: Available from HMSO, London, price Pound2.00.
CN: GB (UK) R (Report)
LI: X (Not available from INIS)
CC: B15 (Corrosion) B11
AB: **Thin layer activation** has been used to measure the progress of aqueous corrosion in a chiller plant circuit at the Rutherford Appleton Laboratory before, during and after a chemical corrosion inhibitor treatment. A steady rate of corrosion of about 0.25 mu m/day was reduced by over an order of magnitude by the treatment. Comparison with standard coupon weight loss measurements was also made and revealed systematic differences attributed to edge effects on the coupon. (author).
CT: (iad); **activation** analysis; carbon steels; corrosion; corrosion inhibitors; iron; layers; . (cad); alloys; carbon additions; chemical analysis; chemical reactions; elements; iron alloys; iron base alloys; metals; steels; transition element alloys; transition elements;
MQ: **activation** analysis: corrosion.

DOCUMENT NUMBER = INI14:755641

VVSS	= 1410	RN	= 14:755641	CTRY	= FR
YEAR	= 1982	TYPE	= B	CAT	= D22
LVLS	= AM	AU	= BOLLMANN,		
SRCE	= 9. INTERNATIONAL	TSRCE	= B9. INTERNATIONAL		

TI: Irradiation technique of machine parts for wear measurements in mechanical engineering.
AU: Bollmann, E.; Fehsenfeld, P.; Kleinrahm, A. (Kernforschungszentrum Karlsruhe, Institut fuer Angewandte Kernphysik, Karlsruhe (Germany, F.R.)).
LA: English
MS: 9. International conference on cyclotrons and their applications. Gendreau, G. (ed.).
IM: Les Ulis (France). Les Editions de la Physique. 1982. 885 p. p. 723-724.
CF: (9. International conference on cyclotrons and their applications. Caen (France). 7 - 10 Sep 1981.)
CN: FR (France) B (Book) Related to 755809.
LI: K (Conference)
CC: D22 (Industrial Applications, Radiometric)
AB: **Thin layer activation** of machine components for wear studies have been performed at the Karlsruhe Isochronous Cyclotron for more than ten years. In response to industrial needs the technical equipment has been developed to an optimum of reliability and precision and an **activation** service including routine quality control is now established.
CT: (iad); **activation analysis; cyclotrons; irradiation procedures**; proton beams; uses; wear; . (cad); accelerators; beams; chemical analysis; cyclic accelerators; nucleon beams; particle beams;

MQ: cyclotrons uses

DOCUMENT NUMBER = INI14·738116

VVSS	= 1406	RN	= 14 738116	CTRY	= GB
YEAR	= 1982	TYPE	= J	CAT	= D22
LVLS	= AS	ISSN	= 0020-708X		
AU	= JETLEY, S	SRCE	= INT J APPL RA		
TSRCE	= JINT J APPL RA				

TI: Application of radioactive tools in machining
AU: Jetley, S.K (National Inst. for Higher Education, Limerick (Ireland) Dept of Mechanical and Production Engineering).
LA: English
JR: Int. J. Appl. Radiat. Isot. ISSN 0020-708X. (Sep 1982) v 33(9) p. 763-770
CN: GB (UK) J (Journal article)
CC: D22 (Industrial Applications, Radiometric)
AB: To study the wearing of cutting tools, /sup 3/He ions from a cyclotron were used in the thin-layer **activation** technique The method can discriminate wear areas and differentiate the wearing mode as either notch or flank wear. (author)
CT: (iad); angular correlation; cutting tools, helium 3 reactions; mev range 10-100, penetration depth; proton reactions; radiation hardening, radiometric gages, wear, (cad); baryon reactions; correlations; energy range, equipment; hadron reactions, hardening; measuring instruments; mev range; nuclear reactions; nucleon reactions, physical radiation effects; radiation effects; tools,
MQ: cutting tools· radiometric gages; helium 3 reactions radiometric gages; radiometric gages. wear

DOCUMENT NUMBER = IN114:736112

VVSS	= 1406	RN	= 14 736112	CTRY	= GB
YEAR	= 1981	TYPE	= B	CAT	= B11
LVLS	= AM	AU	= ASHER, J ,		
SRCE	= ON-LINE SURVEILL	TSRCE	= BON-LINE SURVEILL		

TI: On-line monitoring of plant integrity by thin-layer **activation.**
AU: Asher, J, Conlon, T W (UKAEA Atomic Energy Research Establishment, Harwell Nuclear Physics Div).
LA: English
MS: On-line surveillance and monitoring of plant reliability Society of Chemical Industry, London (UK).
IM: London (UK). Society of Chemical Industry. Apr 1981 249 p. p. 191-197 ISBN 090100 167 8 Available from the Society of Chemical Industry, 14 Belgrave Square, London SW1X 8PS.
CF: (Conference on on-line surveillance and monitoring of plant reliability London (UK) 23 - 25 Sep 1980)
CN: GB (UK) B (Book)
LI: K (Conference)
CC: B11 (Chemical and Isotopic Analysis) D22
AB: A problem frequently encountered within a wide span of industries is to establish the lifetime of plant components under various mechanisms of surface loss, for example mechanical wear in bearings, and erosion or corrosion in pipes carrying process streams. Without accurate prediction of component life, costly unscheduled down time results. Without accurate surface loss measurement prediction is unreliable. **Thin Layer Activation** (TLA), extensively developed at Harwell, provides an accurate and sensitive method of quantifying loss of material from surfaces by any mechanism, in situ, and is appropriate for widespread application as a plant condition monitor. (author).
CT: (iad); **activation** analysis; cobalt 57; corrosion; erosion; gamma radiation; layers, monitoring; surfaces; wear; . (cad); beta decay radioisotopes; chemical analysis; chemical reactions; cobalt isotopes; days living radioisotopes; electromagnetic radiation; electron capture radioisotopes; intermediate mass nuclei; ionizing

radiations; isotopes, nuclei; odd- even nuclei; radiations; radioisotopes;
MQ: corrosion· **activation** analysis; monitoring: **activation** analysis; surfaces· **activation** analysis; wear. **activation** analysis.

DOCUMENT NUMBER = INI14:730971

VVSS	= 1405	RN	= 14 730971	CTRY	= CH
YEAR	= 1982	TYPE	= J	CAT	= B11
LVLS	= AS	ISSN	= 0043-1648		
AU	= ASHER, J ,	SRCE	= WEAR.		
TSRCE	= JWEAR.				

TI: A study of disc wear on a pin-on-disc tester by **thin layer activation.**
AU: Asher, J.; Peacock, A.T. (UKAEA Atomic Energy Research Establishment, Harwell. Nuclear Physics Div)
LA: English
JR: Wear. ISSN 0043-1648. (1 Oct 1982). v 81(2) p. 275-284.
CN: CH (Switzerland) J (Journal article)
CC: B11 (Chemical and Isotopic Analysis)
AB: The wear rate of an iron disc in lubricated contact with an iron pin on a pin-on-disc wear tester was measured using **thin layer activation.** The ratio of disc wear to pin wear was shown to be lower than that predicted on the basis of equal volumetric wear and, under one set of conditions, to have systematic correlations with the conditions of load and sliding speed A temperature dependent mechanism is proposed to explain the phenomena observed (Auth)
CT: (iad), cobalt 56, counting rates, depth; friction, iron, labelling; proton beams, radioactivation, radioactivity, radiometric analysis, wear; . (cad); beams; beta decay radioisotopes; beta-plus decay radioisotopes, chemical analysis; cobalt isotopes; days living radioisotopes, dimensions, electron capture radioisotopes, elements; intermediate mass nuclei, isotopes; metals; nuclei; nucleon beams; odd-odd nuclei; particle beams; quantitative chemical analysis; radioisotopes; transition elements;
MQ: iron. radioactivation; iron wear, radiometric analysis: cobalt 56; radiometric analysis. wear.

DOCUMENT NUMBER = INI14.720011

VVSS	= 1402	RN	= 14 720011	CTRY	= CH
YEAR	= 1982	TYPE	= J	CAT	= D24
LVLS	= AS	ISSN	= 0043-1648		
AU	= JETLEY, S	SRCE	= WEAR		
TSRCE	= JWEAR				

TI: Choosing the basic system in the application of the **thin layer activation** technique to cutting tools.
AU: Jetley, S. (National Institute for Higher Education, Limerick (Ireland). Dept. of Mechanical and Production Engineering)
LA: English
JR: Wear. ISSN 0043-1648. (2 Aug 1982). v. 80(1) p. 125-127.
CN: CH (Switzerland) J (Journal article)
CC: D24 (Tracer Techniques)
AB: Cemented carbide tools made radioactive by irradiating them with /sup 3/He/sup 2+/ ions were used to measure tool wear. The detector used to monitor the radioactivity incorporated a sodium iodide scintillation counter. The use of /sup 3/He/sup 2+/ ions for irradiation is preferable to that of protons. Consideration of the characteristics of commercially available radiation detectors showed that the use of a scintillation counter was most appropriate for this application. (Auth.).
CT: (iad); cations; cermets; cutting tools; helium ions; helium 3; radioactivation; radioactivity; radiometric analysis; rhenium 184; vanadium 48; wear; . (cad); beta decay radioisotopes; beta-plus decay radioisotopes; charged particles; chemical analysis; composite materials; days living radioisotopes; electron capture radioisotopes; equipment; even-odd nuclei; heavy nuclei; helium isotopes;

intermediate mass nuclei, ions, isomeric transition isotopes, isotopes, light nuclei, materials, nuclei, odd-odd nuclei, quantitative chemical analysis, radioisotopes rhenium isotopes, stable isotopes,-tools, vanadium isotopes,
MQ: cutting tools wear, wear radiometric analysis

DOCUMENT NUMBER = INI13 714620

VVSS	= 1324	RN	= 13 714620	CTRY	= XA
YEAR	= 1982	TYPE	= B	CAT	= D22
LVLS	= AMS	ISSN	= EDINGS SE		
RP	= IAEACN4072P	AU	= CONLON, T		
SRCE	= INDUSTRIAL APPLI	TSRCE	= BINDUSTRIAL APPLI		

TI: Developments in thin-layer **activation** for measurements of wear, erosion and corrosion
AU: Conlon, T W, Asher, J (UKAEA Atomic Energy Research Establishment, Harwell Nuclear Physics Div)
LA: English
MS: Industrial application of radioisotopes and radiation technology Proceedings of an international conference organized by the IAEA and held in Grenoble, France, 28 September to 2 October 1981 International Atomic Energy Agency, Vienna (Austria)
RP: IAEA-CN--40/72P
IM: Vienna IAEA 1982 ISBN 92-0-060082-4 595 p p 472
SE: Proceedings series
NO: Abstract only
CF: (International conference on industrial application of radioisotopes and radiation technology Grenoble, France 28 Sep - 2 Oct 1981)
CN: XA (IAEA) B (Book)
LI: K (Conference) E (Short communication)
CC: D22 (Industrial Applications, Radiometric)
CT: (iad), charged-particle **activation** an, corrosion; erosion; heavy ion reactions, industry; ion beams, radioactivation, wear; (cad), **activation** analysis, beams, chemical analysis, chemical reactions, nuclear reactions,
MQ: corrosion heavy ion reactions erosion heavy ion reactions, wear heavy ion reactions

DOCUMENT NUMBER = INI13 707537

VVSS	= 1322	RN	= 13 707537	CTRY	= GB
YEAR	= 1982	TYPE	= J	CAT	= B15
LVLS	= AS	ISSN	= 0143-4020		
AU	= ASHER J	SRCE	= MEAS INSP TECH		
TSRCE	= JMEAS INSP TECH				

TI: **Thin layer activation** - the built-in micrometer
AU: Asher, J, Conlon, T W, Humphries, P (UKAEA Atomic Energy Research Establishment, Harwell Nuclear Physics Div)
LA: English
JR: Meas Insp Technol ISSN 0143-4020 (Jul 1982). v 4(7) p 29- 30
CN: GB (UK) J (Journal article)
CC: B15 (Corrosion) D22
AB: The technique of **thin layer activation** for measuring metal removal in process plant, through wear and corrosion, is described Having generated trace quantities of a radioactive isotope within a **thin layer** of the material under test, using high energy ion beams, the wear is measured either from a reduction in activity in the **layer** or from the activity in the debris. Advantages of the method are discussed and examples of its application are given. (U.K.).
CT: (iad), corrosion, in-service inspection; ion beams, materials testing, radioactivation; radiometric analysis; tracer techniques; uses; wear; . (cad), beams; chemical analysis; chemical reactions; inspection; isotope applications; quantitative chemical analysis; testing;
MQ: in-service inspection radiometric analysis; in-service inspection tracer

techniques; materials testing: radiometric analysis; materials testing: tracer techniques.

DOCUMENT NUMBER = INI13:698545

VVSS	= 1319	RN	= 13:698545	CTRY	= GB
YEAR	= 1980	TYPE	= B	CAT	= B11
LVLS	= AM	AU	= CAIRNS, J.		
SRCE	= CHARACTERISATION		TSRCE	= BCHARACTERISATION	

TI: Particle methods of characterising catalysts. Part 2. The application of ion beams to catalyst research.
AU: Cairns, J.A. (UKAEA Atomic Energy Research Establishment, Harwell. Metallurgy Div.).
LA: English
MS: Characterisation of catalysts. Thomas, J.M.; Lambert, R.M. (Cambridge Univ. (UK). Dept. of Physical Chemistry).
IM: Chichester. Wiley. 1980. 283 p. p. 185-213. ISBN 0 471 27874 2.
CN: GB (UK) B (Book)
CC: B11 (Chemical and Isotopic Analysis)
AB: The subject is discussed under the headings: introduction (summary of some current and diagnostic techniques using electron, photon or ion beams); the ion accelerator and target chamber; proton-induced X-ray emission (PIXE); detection of light elements by prompt nuclear reactions; Rutherford backscattering spectrometry; low energy ion scattering; ion-induced optical emission; **thin layer activation**. (U.K.).
CT: (iad); accelerators; backscattering; catalysts; ion beams; ion scattering analysis; nuclear reactions; pixe analysis; radioactivation; rutherford scattering; . (cad); beams; chemical analysis; elastic scattering; nondestructive analysis; scattering; x-ray emission analysis;
MQ: catalysts: ion beams.

DOCUMENT NUMBER = INI13:692550

VVSS	= 1317	RN	= 13:692550	CTRY	= GB
YEAR	= 1982	TYPE	= P	CAT	= D22
LVLS	= M	RP	= UK 2079949A		
AU	= CONLON, T.	SRCE	= IMPROVEMENTS IN		
TSRCE	= PIMPROVEMENTS IN				

TI: Improvements in or relating to the monitoring of corrosion.
AU: Conlon, T.W.; Edeleanu, C.
CO: UKAEA Headquarters, London.
LA: English
RP: UK patent document 2079949/A/.
IM: 27 Jan 1982. 4 p. Int. Cl. G01n17/00. Availability: INIS.
CN: GB (UK) P (Patent document)
CC: D22 (Industrial Applications, Radiometric) B11
AB: A method of and apparatus for the detection of pitting corrosion are described in which simultaneous measurements of the rate of loss of material from a body (a probe) under test are made by means of changes in the resistance of the body and **thin layer activation** analysis of a region which has been rendered radioactive (changes in the activity of the region or of a downstream station are detected). If the body is corroding uniformly, the rate of loss of material as measured by each technique is the same; if pitting corrosion is occurring, then the two measured rates of loss of material are different; the difference may be displayed, recorded, or used to operate an alarm. (author).
CT: (iad); **activation** analysis; electric conductivity; fluid flow; laboratory equipment; mass transfer; measuring methods; pitting corrosion; probes; radiation detection; radioactivation; radioactivity; . (cad); chemical analysis; chemical reactions; corrosion; electrical properties; physical properties;
MQ: pitting corrosion: measuring methods.

DOCUMENT NUMBER = INI13:677450

VVSS	= 1312	RN	= 13:677450	CTRY	= GB
YEAR	= 1981	TYPE	= R	CAT	= B15
LVLS	= M	RP	= AERER10391		
AU	= ASHER, J.;	SRCE	= DEMONSTRATION OF		
TSRCE	= RDEMONSTRATION OF				

TI: A demonstration of on-line plant corrosion monitoring using **thin layer activation.**
AU: Asher, J.; Webb, J.W.; Wilkins, N.J.M.; Lawrence, P.F. (UKAEA Atomic Energy Research Establishment, Harwell. Nuclear Physics Div.; UKAEA Atomic Energy Research Establishment, Harwell. Materials Development Div.).
CO: UKAEA Atomic Energy Research Establishment, Harwell.
LA: English
RP: AERE-R--10391.
IM: Dec 1981. 14 p. ISBN 0-7058-0505-0. Availability: INIS. Also available from H.M. Stationery Office, price Pound2.00.
CN: GB (UK) R (Report)
CC: B15 (Corrosion) B11
AB: The corrosion of a 1 inch water pipe in an evaporative cooling system has been monitored over three periods of plant operation using **thin layer activation** (TLA). The corrosion rate was followed at a sensitivity of about 1 mu m and clearly reflected changes in plant operation. Examination of the test section after removal, both by autoradiography and metallography revealed the extent of corrosion and pitting over the active area. (author).
CT: (iad); autoradiography; cobalt 57; corrosion; depth; deuteron beams; gamma detection; liquid flow; metallography; on-line measurement systems; pipes; pitting corrosion; radioactivation; sensitivity; spatial distribution; steels; surfaces; water; . (cad); alloys; beams; beta decay radioisotopes; carbon additions; chemical reactions; cobalt isotopes; days living radioisotopes; dimensions; distribution; electron capture radioisotopes; fluid flow; hydrogen compounds; intermediate mass nuclei; ion beams; iron alloys; iron base alloys; isotopes; nuclei; odd-even nuclei; on-line systems; oxygen compounds; radiation detection; radioisotopes; transition element alloys;
MQ: corrosion: on-line measurement systems; steels: corrosion.

DOCUMENT NUMBER = INI13:670956

VVSS	= 1310	RN	= 13:670956	CTRY	= GB
YEAR	= 1982	TYPE	= J	CAT	= B11
LVLS	= AS	ISSN	= 0036-8792		
AU	= CONLON, T.	SRCE	= IND. LUBR. TRIBO		
TSRCE	= JIND. LUBR. TRIBO				

TI: **Thin layer activation** for materials analysis.
AU: Conlon, T.W. (UKAEA Atomic Energy Research Establishment, Harwell).
LA: English
JR: Ind. Lubr. Tribol. ISSN 0036-8792. (Jan - Feb 1982). v. 34(7) p. 20-25.
CN: GB (UK) J (Journal article)
CC: B11 (Chemical and Isotopic Analysis)
AB: The basic physics underlying **thin layer activation**, and its relevance to industrial problems are briefly reviewed. The service component or test material is activated with an ion beam, e.g. of protons, to produce a minute quantity of radioactive atoms in a **thin** surface **layer.** In a typical example the wear of a cylinder liner, which has been activated, is followed by measuring the loss of activity. Other examples are given. Developments of the process are: (i) multiple **activation** profiles which can be used to extract more information on the characteristics of the surface loss process particularly when the loss is non-uniform; (ii) a newly-established process called non-elastic recoil implantation which can be used even on radiation sensitive materials; (iii) the possibility for **activation** of truly immovable objects through the implantation of fission fragments; and (iv) the application of ion beam

activation for the analysis and profiling of the light elements in the near surface. These developments are discussed. (U.K.).

CT: (iad); depth, doped materials; fission fragments; heavy ion reactions; industry; ion beams; ion implantation; quantitative chemical analysis; radioactivation; radioactivity; recoils; spatial distribution; trace amounts; wear; . (cad); beams; chemical analysis; dimensions; distribution; nuclear fragments; nuclear reactions;

MQ: ion implantation: wear.

DOCUMENT NUMBER = INI12:629649

VVSS	= 1220	RN	= 12:629649	CTRY	= CH
YEAR	= 1981	TYPE	= J	CAT	= D24
LVLS	= AS	ISSN	= 0043-1648		
AU	= CHILDS, T.	SRCE	= WEAR.		
TSRCE	= JWEAR.				

TI: A study of wear in the friction cutting of cast iron using **thin layer activation.**

AU: Childs, T.H.C.; Kinsella, F.H. (Bradford Univ. (UK)).

LA: English

JR: Wear. ISSN 0043-1648. (2 Feb 1981). v. 66(2) p. 241-255.

CN: CH (Switzerland) J (Journal article)

LI: N (Numerical data)

CC: D24 (Tracer Techniques)

AB: Cast iron may be slit by pressing it against a water-cooled toothless mild steel disc spinning at high speed. Material removal occurs by wear and, as with other wear processes, two states of slitting, mild and severe, can be established. In this paper the generation of slitting debris in mild and severe conditions is followed by radiotracer and other techniques and reasons for the transitions between mild and severe slitting are presented. In mild conditions, all material removed from the cast iron is transferred adhesively to the slitting disc; it oxidizes and the slitting debris is a mixture of oxide and metal flaked from the disc rim. At a critical load the protective oxide breaks down and severe wear occurs. Then only half of the slitting rate is accounted for by adhesive transfer to the rim. The transferred **layer** becomes hardened and abrasive; abrasion accounts for the other half of the slitting rate. The form of irradiation used in the radiotracer study was **thin layer activation.** This has proved, as expected, to be free from health and contamination hazards. (Auth.).

CT: (iad); cast iron; cobalt 57; cutting; deuteron beams; experimental data; friction, mev range 01-10; radioactivation; radioactivity; tracer techniques; wear; . (cad); alloys; beams; beta decay radioisotopes; carbon additions; cobalt isotopes; data; days living radioisotopes; electron capture radioisotopes; energy range; information; intermediate mass nuclei; ion beams; iron alloys; iron base alloys; isotope applications; isotopes; machining; mev range; nuclei; numerical data; odd-even nuclei; radioisotopes; silicon alloys; transition element alloys;

DF: (iadfd); cast iron; cobalt 57; experimental data; radioactivity; wear; . (cadfd); alloys; beta decay radioisotopes; carbon additions; cobalt isotopes; data; days living radioisotopes; electron capture radioisotopes; information; intermediate mass nuclei; iron alloys; iron base alloys; isotopes; nuclei; numerical data; odd-even nuclei; radioisotopes; silicon alloys; transition element alloys;

MQ: cast iron; cast iron: cutting; cast iron: wear; wear; wear: tracer techniques.

DOCUMENT NUMBER = INI12:605329

VVSS	= 1211	RN	= 12:605329	CTRY	= CH
YEAR	= 1980	TYPE	= J	CAT	= D24
LVLS	= AS	ISSN	= 0043-1648		
AU	= EVANS, R.	SRCE	= WEAR.		
TSRCE	= JWEAR.				

TI: Radioisotope methods for measuring engine wear: a **thin layer activation** method for the measurement of cam follower wear and its comparison with a neutron **activation** method.

AU: Evans, R. (Shell Research Ltd., Chester (UK)).
LA: English
JR: Wear. ISSN 0043-1648. (Nov 1980). v. 64(2) p. 311-325.
CN: CH (Switzerland) J (Journal article)
LI: N (Numerical data)
CC: D24 (Tracer Techniques)
AB: **Thin layer activation** (TLA) has been applied to improve an existing radiotracer test method for measuring cam follower wear in a gasoline engine. The **activation** involves irradiation of the follower bearing pad with a swept beam of deuterons to produce 10 mu Ci(370 kBq) of /sup 57/Co with an approximately linear distribution to 100 mu m depth. Eight such followers are used for the engine test. Results for the new method are compared with those obtained from measurement of /sup 59/Fe using thermal-neutron-activated followers. The application of TLA affords important advantages for measuring follower wear: one of these is that the measurement is restricted to the critical area and wear from other rubbing contacts is excluded. (Auth.).
CT: (iad); charged-particle **activation** an; cobalt 57; deuterons; diesel motors; experimental data; iron 59; neutron **activation** analysis; nondestructive analysis; radioactivation; radiometric analysis; tracer techniques; wear; . (cad); **activation** analysis; beta decay radioisotopes; beta-minus decay radioisotopes; charged particles; chemical analysis; cobalt isotopes; data; days living radioisotopes; electron capture radioisotopes; even-odd nuclei; information; intermediate mass nuclei; iron isotopes; isotope applications; isotopes; motors; nuclei; numerical data; odd-even nuclei; quantitative chemical analysis; radioisotopes;
DF: (iadfd); charged-particle **activation** an; cobalt 57; deuterons; diesel motors; experimental data; iron 59; neutron **activation** analysis; radioactivation; radiometric analysis; tracer techniques; wear; . (cadfd); **activation** analysis; beta decay radioisotopes; beta-minus decay radioisotopes; charged particles; chemical analysis; cobalt isotopes; data; days living radioisotopes; electron capture radioisotopes; even-odd nuclei; information; intermediate mass nuclei; iron isotopes; isotope applications; isotopes; motors; nuclei; numerical data; odd-even nuclei; quantitative chemical analysis; radioisotopes;
MQ: charged-particle **activation** an: tracer techniques; radiometric analysis: tracer techniques; wear: radiometric analysis; wear: charged-particle **activation** an; diesel motors: wear.

DOCUMENT NUMBER = INI12:592249

VVSS = 1207 RN = 12:592249 CTRY = DE
YEAR = 1980 TYPE = R CAT = D22
LVLS = AM RP = KFK3068
AU = BLANK, R.; SRCE = ANNUAL REPORT.
TSRCE = RANNUAL REPORT.

TI: Thin-layer **activation** technique for wear measurements in mechanical engineering.
AU: Blank, R.; Bollmann, E.; Dressen, R.; Fehsenfeld, P.; Gegenheimer, B.; Herrmann, P.; Kleinrahm, A.; Roth, H.; Schoellhammer, H.; Schuessler, B.
LA: English
MS: Annual report. Dickmann, F.; Hanser, A. (eds.). Kernforschungszentrum Karlsruhe G.m.b.H. (Germany, F.R.). Inst. fuer Angewandte Kernphysik 2.
RP: KFK--3068.
IM: Oct 1980. 148 p. p. 103-105. Availability: INIS. Availability: INIS.
NO: Published in summary form only.
CN: DE (Germany, F.R.) R (Report)
LI: E (Short communication)
CC: D22 (Industrial Applications, Radiometric)
CT: (iad); **activation** analysis; engineering; layers; machine parts; materials testing; proton reactions; wear; . (cad); baryon reactions; chemical analysis; hadron reactions; nuclear reactions; nucleon reactions; testing;
MQ: **activation** analysis: wear.

DOCUMENT NUMBER = INI12:577179

VVSS = 1203 RN = 12:577179 CTRY = GB
YEAR = 1980 TYPE = J CAT = B11
LVLS = AS ISSN = 0004-7015
AU = CONLON, T. SRCE = ATOM (LONDON).
TSRCE = JATOM (LONDON).

TI: **Thin layer activation** for materials analysis.
AU: Conlon, T.W. (UKAEA Atomic Energy Research Establishment, Harwell).
LA: English
JR: Atom (London). ISSN 0004-7015. (Sep 1980). (no.287) p. 233-237.
CN: GB (UK) J (Journal article)
CC: B11 (Chemical and Isotopic Analysis)
AB: The current uses and future prospects of **thin layer activation** (TLA) for materials analysis are discussed. The method, developed primarily for the nuclear power industry is now used in a wide spectrum of industrial applications. The basic physics underlying TLA is reviewed and its relevance to industrial problems considered indicating in which areas and to which materials it is applicable. More advanced versions of TLA currently under development are described which greatly increase the scope of the conventional process and include; multiple **activation** profiles, non-elastic recoil implantation, fission fragment implantation and ion beam **activation** analysis. (U.K.).
CT: (iad); charged-particle **activation** an; corrosion; doped materials; erosion; fission fragments; ion beams; layers; materials testing; recoils; research programs; sputtering; technology transfer; uses; wear; . (cad); **activation** analysis; beams; chemical analysis; chemical reactions; nuclear fragments; testing;
MQ: charged-particle **activation** an: research programs; charged-particle **activation** an: uses.

DOCUMENT NUMBER = INI10:476853

VVSS = 1018 RN = 10:476853 CTRY = GB
YEAR = 1979 TYPE = J CAT = D22
LVLS = AS ISSN = 0301-679X
AU = CONLON, T. SRCE = TRIBOL. INT.
TSRCE = JTRIBOL. INT.

TI: **Thin layer activation**. Current applications to wear and corrosion measurements and future potential in studies of surface treatment and sputtering.
AU: Conlon, T.W. (UKAEA, Harwell. Atomic Energy Research Establishment).
LA: English
JR: Tribol. Int. ISSN 0301-679X. (Apr 1979). v. 12(2) p. 60-64.
CN: GB (UK) J (Journal article)
CC: D22 (Industrial Applications, Radiometric)
AB: **Thin layer activation** consists of bombarding a material with a high energy ion beam from an accelerator to produce a **thin layer** of radioactive atoms. This **layer** may be used for wear measurements. In fluid circuits the debris may be collected and the radioactivity determined, or in other cases residual activity is monitored in situ. Details are given of the technique. Current applications to wear and corrosion measurements, and future potential in studies of surface treatment and sputtering are described. (U.K.).
CT: (iad); charged-particle **activation** an; corrosion; corrosion products; ion beams; measuring methods; radioactivity; sputtering; surface treatments; wear; . (cad); **activation** analysis; beams; chemical analysis; chemical reactions;
MQ: charged-particle **activation** an: corrosion; wear: measuring methods; charged-particle **activation** an: wear.

DOCUMENT NUMBER = INI10:463497

VVSS = 1014 RN = 10:463497 CTRY = DK
YEAR = 1979 TYPE = I CAT = D22
LVLS = M RP = INISMF5084
AU = MOERCH, E. SRCE = WEAR MEASUREMENT
TSRCE = IWEAR MEASUREMENT

TI: Wear measurement using radioisotopes. Slidmaaling ved hjaelp af radioaktive isotoper.
AU: Moerch, E.; Hede Kjeldgaard, J. (Isotopcentralen, Copenhagen (Denmark)).
LA: Danish
RP: INIS-mf--5084.
IM: 1979. 15 p. Availability: INIS.
CF: (Danish Metallurgical Society Winter Meeting. Ringsted, Denmark. 3 - 4 Jan 1979.)
CN: DK (Denmark) I (Miscellaneous)
LI: K (Conference)
CC: D22 (Industrial Applications, Radiometric)
AB: The article examines the methods which are normally used to measure wear with isotope techniques. The traditional procedure consists of labelling the portions undergoing wear with neutron radiation, and subsequently determining the emergent mass of particulates associated with wear by recording their radioactivity. In recent years, however, a new method was developed which provides greatly enhanced possibilities. It is a thin-layer **activation** and corresponding method, viewed largely as having eliminated the problems with radioactive materials and at the same time providing advantages in measurement technique with, for example, the measurement of wear on parts that are not enclosed by a specific supporting medium for wear particles. At the close of the article an example is given of the measurement of grinding objects in a bearing mill. (author).
CT: (iad); measuring methods; radioisotopes; wear; . (cad); isotopes;
MQ: wear: measuring methods.

DOCUMENT NUMBER = INI10:459804

VVSS = 1013 RN = 10:459804 CTRY = AT
YEAR = 1978 TYPE = J CAT = A13
LVLS = AS ISSN = 0001-6713
AU = HIGATSBERG SRCE = ACTA PHYS. AUSTR
TSRCE = JACTA PHYS. AUSTR

TI: Static and dynamic surface analysis with a secondary ion mass spectrometer, a Moessbauer spectrometer, and a pure germanium gamma spectrometer.
AU: Higatsberger, M.J. (Vienna Univ. (Austria). 1. Physikalisches Inst.).
LA: English
JR: Acta Phys. Austriaca. ISSN 0001-6713. (1978). v. 49(3-4) p. 181- 191.
CF: (International SIMS conference. Muenster, Germany, F.R. 1977.)
CN: AT (Austria) J (Journal article)
LI: K (Conference)
CC: A13 (Solid State and Fluid Physics)
AB: In addition to the well-known atomic excitation processes it is shown that nuclear excitation processes such as the Moessbauer effect, neutron **activation** analysis, **thin layer activation** techniques, gamma spectroscopy, and X-ray fluorescence analysis may well be suited for surface analysis. Experimental results of positive and negative secondary ion mass spectra of solid samples and biological probes are presented and supplemented by Moessbauer spectra. (Auth.).
CT: (iad); gamma spectroscopy; mass spectroscopy; moessbauer effect; neutron **activation** analysis; surfaces; x-ray fluorescence analysis; . (cad); **activation** analysis; chemical analysis; nondestructive analysis; spectroscopy; x-ray emission analysis;
MQ: moessbauer effect: surfaces; neutron **activation** analysis: surfaces; x-ray fluorescence analysis: surfaces.

DOCUMENT NUMBER = INI10:458219

VVSS = 1012 RN = 10:458219 CTRY = GB
YEAR = 1979 TYPE = J CAT = B15

LVLS = AS ISSN = 0306-526X
AU = CONLON, T SRCE = METALL MATER T
TSRCE = JMETALL MATER T

TI: The scope for TLA in corrosion and wear studies.
AU: Conlon, T.W. (UKAEA, Harwell. Atomic Energy Research Establishment).
LA: English
JR: Metall. Mater. Technol ISSN 0306-526X. (Mar 1979). v 11(3) p. 143-146.
CN: GB (UK) J (Journal article)
CC: B15 (Corrosion) E17
AB: A description is given of the technique of **thin layer activation** (TLA), which offers a basis for the routine study of a variety of industrial problems involving in situ measurement of very low levels of wear and corrosion. It has use also as a basic research tool in studies of surface treatments such as ion beam bombardment and plasma sputtering. (author).
CT: (iad); corrosion; erosion; ion beams; layers; materials testing; nuclear reactions; radioactivation; sensitivity; surface properties; thickness; tracer techniques; wear; . (cad); beams; chemical reactions; dimensions; isotope applications; testing;
MQ: erosion· materials testing; corrosion: materials testing; radioactivation: tracer techniques; wear· materials testing

DOCUMENT NUMBER = INI10:439173

VVSS = 1007 RN = 10·439173 CTRY = NL
YEAR = 1978 TYPE = J CAT = A14
LVLS = AS ISSN = 0022-3115
AU = GOODALL, D SRCE = J NUCL MATER
TSRCE = JJ NUCL MATER

TI: Investigations of arcing in the DITE tokamak.
AU: Goodall, D.H.J.; McCracken, G.M. (UKAEA, Abingdon. Culham Lab.); Conlon, T.W.; Sofield, C. (UKAEA, Harwell. Atomic Energy Research Establishment).
LA: English
JR: J Nucl. Mater. ISSN 0022-3115. (Sep - Oct 1978). v 76-77 p. 492-498.
CF: (3 international conference on plasma surface interactions in controlled fusion devices Abingdon, UK. 3 - 7 Apr 1978.)
CN: NL (Netherlands) J (Journal article)
LI: K (Conference)
CC: A14 (Plasma Physics and Thermonuclear Reactions)
AB: Unipolar arcing has been observed in the DITE tokamak. These arcs occur on the fixed limiter, on probes inserted in the plasma and on parts of the torus structure. The amount of material removed by arcing is consistent with the concentration of metal in the plasma A measurement of erosion of the divertor target by the arcing has been made by the **thin layer activation** technique A 25 mu m **layer** at the surface of a titamium sample is activated using the /sup 48/Ti(p, n)/sup 48/V reaction and the removal of this **layer** is monotored by measuring the reduction in gamma-rays emitted. Another form of surface erosion observed is the presence of craters and well defined cylindrical holes Large numbers of these holes are present near regions which have been locally melted by runaway electron beams (Auth)
CT: (iad); deposition, divertors; electric arcs; erosion, impurities, limiters, neutrons, proton reactions, surfaces; titanium, titanium 48 target, tokamak devices; vanadium 48; (cad); baryon reactions; baryons; beta decay radioisotopes, beta-plus decay radioisotopes; closed plasma devices; currents; days living radioisotopes; electric currents; electric discharges, electron capture radioisotopes, elementary particles; elements, fermions, hadron reactions; hadrons, intermediate mass nuclei, isotopes; metals, nuclear reactions, nuclei; nucleon reactions; nucleons; odd-odd nuclei; radioisotopes, targets; thermonuclear devices; transition elements; vanadium isotopes;
MQ: tokamak devices: electric arcs.

DOCUMENT NUMBER = INI09:376275

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VVSS     = 0911          RN       = 09:376275          CTRY     = GB
YEAR     = 1978          TYPE     = J          CAT      = D22
LVLS     = AS          ISSN     = 0368-2595
AU       = HUMPHRIES,          SRCE     = J. INST. NUCL. E
TSRCE    = JJ. INST. NUCL. E
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TI: The **thin layer activation** technique applied to the measurement of wear.
AU: Humphries, P. (UKAEA Research Group, Harwell. Atomic Energy Research Establishment).
LA: English
JR: J. Inst. Nucl. Eng. ISSN 0368-2595. (Jan - Feb 1978). v. 19(1) p. 23-25.
CN: GB (UK) J (Journal article)
CC: D22 (Industrial Applications, Radiometric)
AB: A **thin layer** of radioactive atoms is produced in the material by bombardment with charged particles, and as the material is worn away the total activity level is monitored. If the activity to depth relationship is then known the amount of material worn away can be determined. By a selective choice of the charged particle species and energy the depth of the active **layer**, its natural decay rate, and the energy of the emitted radiation can be pre-determined. The Harwell Tandem Electrostatic Generator has been found very suitable for the work. The total activity level can be made as little or as large as required, but a level around 5 to 10 microcuries is usually found to be adequate, and the active **layer** usually has a depth of 50 to 300 mu m. The activated area can be from < 1 mm/sup 2/ to 4 cm/sup 2/. Particular reference is made to the production of /sup 56/Co in Fe. Experimental arrangements for the irradiation of components are described. Some practical applications undertaken by Harwell for industry are briefly mentioned, including wear of diesel engine valve seatings and fuel injection equipment, engine testing of lubricants, surface loss of rails and railway wheels, wear of gears, wear of graphite bearing materials, and corrosion and erosion of materials. 4 references. (UK).
CT: (iad); **activation** analysis; cobalt 56; depth; iron 56 target; irradiation procedures; layers; proton reactions; radiometric gages; uses; wear; . (cad); baryon reactions; beta decay radioisotopes; beta-plus decay radioisotopes; chemical analysis; cobalt isotopes; days living radioisotopes; dimensions; electron capture radioisotopes; hadron reactions; intermediate mass nuclei; isotopes; measuring instruments; nuclear reactions; nuclei; nucleon reactions; odd-odd nuclei; radioisotopes; targets;
MQ: **activation** analysis: wear; wear: **activation** analysis.

DOCUMENT NUMBER = INIS08:301549

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VVSS     = 0808          RN       = 08:301549          CTRY     = DE
YEAR     = 1976          TYPE     = R          CAT      = D24
LVLS     = AM          RP       = AEDCONF76280
AU       = VOGG, H. (          SRCE     = RADIATION PROTEC
TSRCE    = RRADIATION PROTEC
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TI: The use of unsealed radioactive substances in technical processes. Verwendung offener radioaktiver Stoffe in der Technik.
AU: Vogg, H. (Kernforschungszentrum Karlsruhe (Germany, F.R.). Lab. fuer Isotopentechnik).
LA: German
MS: Radiation protection in nuclear facilities. Experience and consequences from a technical point of view. Betrieblicher Strahlenschutz. Erfahrungen und Konsequenzen aus technischer Sicht. Rausch, L. (ed.) (Giessen Univ. (Germany, F.R.). Abt. Strahlenbiologie und Strahlenschutz). Fachverband fuer Strahlenschutz e.V., Karlsruhe (Germany, F.R.).
RP: AED-Conf--76-280-000. FS--76-13-T. AED-Conf--76-280-009.
IM: Aug 1976. p. 75-79. Availability: Availability:
NO: 3 refs. Available from ZAED.
CF: (10. annual meeting of the Fachverband fuer Strahlenschutz e.V. and 17. annual meeting of the Vereinigung Deutscher Strahlenschutzaerzte e.V. Giessen, Germany, F.R. 9 Jun 1976.)
CN: DE (Germany, F.R.) R (Report)
LI: K (Conference) X (Not available from INIS)

CC: D24 (Tracer Techniques)
AB: Three different examples for the application of radiotracers in technical processes are illustrated (/sup 24/Na studies of motion behavior of raw phosphate in rotating ovens /sup 24/Na studies of deposition in sewage sludge pools, /sup 51/Cr thin-layer **activation** for measurement of piston ring wear of motors) Accurate safety considerations in connection with practical experience guarantee the feasibility of investigations without any risk Reliable cooperation between users and safety authorities is helpful (orig /HP)
CT: (iad), furnaces, industrial plants, phosphates, production, radiation protection, sodium 24, tracer techniques, (iad), industrial plants, radiation protection, sewage sludge; time dependence, tracer techniques, (iad), chromium 51, industrial plants; motors, radiation protection, tracer techniques, wear, (cad), beta decay radioisotopes, beta-minus decay radioisotopes, isomeric transition isotopes, isotope applications, isotopes, light nuclei, nuclei, odd-odd nuclei, oxygen compounds, phosphorus compounds, radioisotopes, seconds living radioisotopes, sodium isotopes, biological materials, biological wastes, wastes, chromium isotopes, electron capture radioisotopes, even-odd nuclei, intermediate mass nuclei
MQ: tracer techniques radiation protection

DOCUMENT NUMBER = INIO7 270908

VVSS	= 0721	RN	= 07 270908	CTRY	= HU
YEAR	= 1976	TYPE	= J	CAT	= D24
LVLS	= AS	AU	= TENDERA P		
SRCE	= RADIOCHEM RADIO		TSRCE	= JRADIOCHEM RADIO	

TI: Thin-layer **activation** by protons-application to measurement of the wear of gear wheels
AU: Tendera, P, Frynta, Z (Statni Vyzkumny Ustav Materialu Prague (Czechoslovakia))
LA: English
JR: Radiochem Radioanal Lett (1976) v 24(3) p 193-197
NO: 2 figs, 4 refs
CN: HU (Hungary) J (Journal article)
CC: D24 (Tracer Techniques) B11
AB: A technique is described for the determination of the rate of wear A small surface area of a tooth profile is irradiated by protons The concentration of radioactive wear debris in the lubricating oil is measured by means of gamma-ray spectroscopy This technique has been applied for the wear measurements of gear wheels of buses and lorries Every tooth profile was irradiated for ten minutes with 7 MeV protons The proton current was 1 5 mu A and the total irra-diated area was 10 cm/sup 2/ The irradiations were carried out in the cyclotron (T I)
CT: (iad), abrasion, **activation** analysis, gamma spectroscopy, proton reactions, surfaces, tracer techniques, uses, wear, (cad), baryon reactions, chemical analysis, hadron reactions, isotope applications, nuclear reactions nucleon reactions, spectroscopy,
MQ: **activation** analysis proton reactions, wear tracer techniques

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