269
7-6-73

14. 212

UCRL-51362

RESULTS OF THE 1972 SURVEY ON TRACK REGISTRATION

R. V. Griffith

March 15, 1973

Prepared for U.S. Atomic Energy Commission under contract No. W-7405-Eng-48

**LAWRENCE
LIVERMORE
LABORATORY**

University of California/Livermore

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED.

NOTICE

"This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately-owned rights."

Printed in the United States of America
Available from

National Technical Information Service
U. S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22151

Price: Printed Copy \$ ____*: Microfiche \$0.95

<u>* Pages</u>	<u>NTIS Selling Price</u>
1-50	\$4.00
51-150	\$5.45
151-325	\$7.60
326-500	\$10.60
501-1000	\$13.60

TID-4500, UC-41
Health and Safety

LAWRENCE LIVERMORE LABORATORY

University of California, Livermore, California, 94550

UCRL-51362

**RESULTS OF THE 1972 SURVEY
ON TRACK REGISTRATION**

R. V. Griffith

MS. date: March 15, 1973

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

104

Contents

Abstract	1
Introduction	1
Survey Summary	1
Conclusion	5
Acknowledgments	5
Survey Contributors	6
Appendix A—General Track Registration Survey Replies	11
United States	12
West Germany	38
France	46
Japan	50
England	53
Australia	55
Belgium	57
Canada	59
Italy	60
Switzerland	61
Hungary	63
Ireland	64
Netherlands	66
Austria	66
India	67
Israel	67
Poland	68
Romania	69
Sweden	69
Trinidad	70
Appendix B—Spark Counting Survey Replies	71

RESULTS OF THE 1972 SURVEY ON TRACK REGISTRATION

Abstract

The results of a survey of 118 laboratory groups in 20 countries on the registration of particles in dielectric materials is presented. The survey includes data on track registration applications, as well as materials

used, particles studied, analyses performed, and methods of data acquisition and track image enhancement. A section is also included which presents detailed replies by 39 laboratories on techniques of spark counting.

Introduction

The use of techniques for registration of nuclear particles in dielectric materials has increased dramatically in recent years and has found application in such widely diversified fields as particle dosimetry, geology, biology, radiography, and trace element analysis. Within the last two years, we decided that it would be useful to researchers involved in track registration to circulate a survey which would help define trends in the field, as well as encourage interchange of information on the personal level, particularly for those who are just becoming involved with these techniques.

In January 1972, questionnaires were sent to more than 550 researchers at approximately 220 laboratories where work in track registration had been reported. These laboratories represented 29 countries. By August, we had received 118 replies from laboratories in 20 countries.

We have briefly summarized the results. Information from the replies themselves appears in Appendix A, and the replies covering spark counting techniques appear in Appendix B. To add to the informative value of this survey, we have prepared an abstracted bibliography, including over 550 references, which will be published separately.

Survey Summary

The national distribution of survey replies is shown in Table 1, and it

certainly reflects the widespread geographical interest in track registration.

Table 1. Survey replies by country of origin.

United States	53	Hungary	2
West Germany	18	Ireland	2
France	8	Netherlands	2
Japan	6	Austria	1
England	5	India	1
Australia	3	Israel	1
Belgium	3	Poland	1
Canada	3	Romania	1
Italy	3	Sweden	1
Switzerland	3	Trinidad	1

Table 2 shows the distribution of interest as a function of registration materials used. Many researchers are interested in more than one material. The fact that polycarbonates, mica and cellulosic materials are most popular should surprise no one. It is obvious that there is interest in a wide variety of materials.

The distribution of interest by particles studied, shown in Table 3, indicates the abundance of work done with fission fragments and alpha particles, which is a result of the use of isotopic sources and fissionable radiators for neutron detection.

In Table 4 we see the wide variety of materials used as particle radiators.

Table 5 is of particular interest since it shows the very large number of applications that have been investigated for track registration work. The replies also indicated that 16 laboratories are now using track registration for personnel neutron dosimetry, either in fixed-area monitors or as personnel-worn dosimetry, and one laboratory is using track detection for alpha dosimetry.

Table 2. Registration materials by number of researchers.

Polycarbonates	83
Mica	58
Cellulose compounds	
Nitrate	38
Acetates	13
Acetate butyrate	3
Unspecified	13
Glasses	
Silicate	8
Phosphate	6
Soda lime	3
Borate	1
Quartz	6
Polyester	4
Tooth and bone	2
Polyimide	1
Polyvinyl	1
Silver chloride	1
Uranium oxide	1
Unspecified minerals and glasses	30

Table 3. Particles studied.

Fission fragments	101
Alpha particles	57
Protons	16
Heavy ions	11
Cosmic particles	9
Recoil nuclei	8
Tritons	3
Deuterons	2
Muons	2
Mesons	1
1-MeV electrons	1

The distribution of track analyses performed are shown in Table 6, and the methods for image enhancement and data

Table 4. Particle radiators and sources.

A. Radiation-induced			
^{235}U	41	Nitrogen	2
^{238}U	40	^{238}Pu	1
^{232}Th	28	^{241}Pu	1
^{239}Pu	12	^{230}Th	1
^{237}Np	11	Nat. La	1
^{10}B	9	^{252}Cf	1
^6Li	6	^{226}Ra	1
^{197}Au	6	^{227}Ac	1
Nat. Pb	5	Nat. Cd	1
Nat. Bi	5	^{244}Cm	1
Nat. Ta	3	^{240}Pu	1
Oxygen	3	^{231}Pa	1
^{241}Am	2	Nat. W	1
^{12}C	2	Nat. In	1
^{232}U	2	Nat. Cu	1
Accelerator-produced 16			
B. Natural radioactive decay			
^{252}Cf	24	^{232}Th	3
^{238}U	12	^{228}Th	3
^{241}Am	11	^{210}Pb	1
^{239}Pu	8	^{226}Ra	1
Radon	4	^{234}U	1
^{235}U	4	^{237}Np	1
^{210}Po	3	^{244}Cm	1

Table 5. Areas of interest.

Basic Research	47
Neutron dosimetry	46
Geological studies	36
Cosmic ray studies	25

Cross-section measurements

Neutron	22
Gamma	5
Alpha autoradiography	21
Radiography - neutron	15
Analytical applications	15
Radon dosimetry	13
Nuclear reaction studies	9
Reactor physics	7
Biological sample analysis	6
Dating studies	5
Metallurgy	3
Uranium assay in geological samples	3
Studies of meteorites	3
Archaeological studies	3
Ternary fission studies	2
Spontaneous fission studies	2
Environmental sample analysis	2
Search for superheavy elements	2
Beam profiles determination	2
Lunar studies	2
Measurement of environmental neutrons	2
Studies of solar system origin	1
Uptake of bone seekers	1
Implantation effects studies	1
Registration of single-crystal blocking patterns	1
Radiation damage in biological systems	1
Geochemistry of heavy elements	1
Proton dosimetry	1
Solar flare studies	1
Product development	1
Channeling and diffraction measurements	1
Effects of trace impurities on AgCl	1
Fission fragment irradiation research	1
Radiography - proton	1

Table 6. Track analyses performed.

Track densities	103
Track length	36
Track or pit diameter	11
Angular distribution	4
Cone angle	1
Angle between tracks	1

Table 7. Methods of image enhancement and data acquisition.

Optical microscopy (manual)	100
Spark counting	39
Automatic scanning devices	21
Optical density measurements	7
Photographic assessment	5
Ammonia imaging	4
Use of opaque coatings	4
Optical microscopes with television monitors	3
Electron microscopy	3
Flying spot scanners	2
Microphotometers	2
Electrochemical etching	2
Use of fluorescent dyes	2
Dark field microscopy	1
Infrared analysis	1
Bubble-point analysis	1
Flow measurement	1
Light scattering	1
Chemical analysis	1
Visual assessment	1
Reflection from silvered surfaces	1
X-ray analysis	1

acquisition appear in Table 7. The optical microscope remains the workhorse of the track registration researcher, but the use of spark counting for measuring track densities below about 5000 cm^{-2} is finding wide acceptance.

There are now at least four computer-based scanning systems available commercially for small particle or track counting. These systems, which use a light microscope with television display, generally cost over \$20,000; but a growing number of laboratories are using these systems for automatic track counting. Often the expense of such systems can be shared with other laboratory research groups.

Tables 8, 9, and 10 briefly summarize some of the data from the replies on spark counting found in Appendix B. Those interested in spark counting should review the individual replies. Therefore, a

Table 8. Spark counting applications.

Neutron dosimetry	24
Radiograph	4
Measurement of uranium in geological materials	3
General research	2
Radon dosimetry	2
Cross-section measurements	2
Environmental neutron measurements	2
Cosmic ray measurement	2
Isomeric fission studies	1
Fissionography	1
Alpha counting	1
Measurement of uranium in liquid and air	1
Metallurgy	1
Trace element analysis	1
Autoradiography	1

Table 9. Registration materials used for spark counting.

Polycarbonates	34
Cellulose nitrate	8
Polyester	1

great deal of interpretation is not provided here. However, two points are worth noting. The a.c. spark counter reported by Geisler, Philips and Walker from Washington University, St. Louis, Missouri was probably the most significant departure from conventional spark techniques and should be of interest for some applications. Also, the report by Cross at Chalk River Nuclear Laboratories, Chalk River, Ontario, that spark counter performance is dependent on electrode polarity is somewhat surprising and will be of interest to spark counter enthusiasts.

Table 10. Radiators used for spark counting.

^{235}U	18	^{210}Po	2
^{238}U	18	^{222}Rn	1
^{232}Th	13	^6Li	1
^{252}Cf	7	Nat. Pb	1
^{237}Np	7	Nat. Bi	1
^{239}Pu	6	Nat. Hg	1
Geological samples	3	Nat. Ta	1
^{241}Am	2	Nat. Po	1
		Nat. Au	1

Conclusions

The widespread interest in and use of track registration has been indicated through the replies to this survey. It is hoped that this report

will provide information contributing to this work, and will encourage increased communication between researchers.

Acknowledgments

I would like to thank each of those who contributed to the survey for the effort they expended providing us with this valuable information. I also wish to extend my appreciation to Dr. Goren Svensson at the Joint Center for Radiation

Therapy, Harvard Medical School, Boston, Massachusetts for suggesting the survey and for his help in preparing the questionnaire. I would also like to thank my wife, Donna, who helped with preparation of the mailing list and the bibliography.

Survey Contributors

UNITED STATES

	<u>Survey No.</u>		<u>Survey No.</u>
Argonne National Laboratory		H. D. Kosanke	18*
Edward W. Barts	1	J. E. Gingrich	18*
Roland J. Armani	2*	H. S. Rosenbaum	18*
Charles E. Cohn	2*	R. Caputi	19
Raymond Gold	2*	Hanford Engineering Development Laboratory	
Dale J. Henderson	3*	R. E. Dahl	20
Harold Berger	4*	H. H. Yoshikawa	20
N. P. Lapinski	4*	W. J. Gruber	21
David J. Simmons	5*	Iowa State University	
Battelle Memorial Institute		P. B. Hahn	22*
Pacific-Northwest Laboratories		M. A. Wechter	22*
L. W. Brackenbush	6	A. F. Voigt	22*
Carl M. Unruh	7	Johns Hopkins Hospital	
Brookhaven National Laboratory		R. C. Thompson	23
Seymour Katcoff	8	Knolls Atomic Power Laboratory	
Carl Distenfeld	9*	H. M. Eiland	24
California Institute of Technology		MacAlester College	
D. S. Burnett	10	James H. Roberts	25*
Carnegie Institution		Frank J. Congel	25*
Martin G. Seitz	11	National Aeronautics and Space Administration	
Case Western Reserve University		James A. Morley	26
Bruce E. Rippeteau	12	National Bureau of Standards	
Catholic University		B. Stephen Carpenter	27*
Hall Crannell	13	Nebraska Geological Survey	
Corning Museum of Glass		John Boellstorff	29
Robert H. Brill	14	Oak Ridge National Laboratory	
E.G. and G.		C. D. Bopp	30
William M. Quam	15*	W. W. Parkinson	31
Enrico Fermi Institute		K. Becker	32*
Laurel Wilkening	16	Plum Brook Reactor	
General Electric Research Laboratory		Lewis Research Center	
Robert L. Fleischer	17	Glenn C. Winters	26
General Electric Nucleonics Laboratories		Rensselaer Polytechnic Institute	
H. W. Alter	18*	Donald S. Miller	33
J. L. Carroll	18*	Willard G. Myers	34
D. B. Lovett	18*	Rosentiel School of Marine and Atmospheric Sciences	
		David Fisher	35

* Denotes contributor to spark counting portion of survey, Appendix B.

	<u>Survey No.</u>		<u>Survey No.</u>
Stanford Linear Accelerator		Washington University	
Goren Svensson	36*	F. H. Geisler	52*
Kenneth Kase	36*	P. R. Phillips	52*
Teledyne Isotopes		R. M. Walker	52*
David Lightbody	37	Westinghouse Research Laboratories	
Texas A&M University		K. H. Sun	53
J. Marvin Herndon	33		
U.S. Geological Survey		WEST GERMANY	
H. T. Millard	39*	Fachbereich Physikalische Chemie	
P. J. Aruscavage	39*	Kurt Starke	54
Charles W. Naeser	40	GSF-Institut für Strahlenschutz	
John R. Dooley, Jr.	41	Herwig G. Paretzke	55*
R. B. Taylor	41	Institut für Angewandte Reaktorphysik	
F. J. Jurceka	41	Kernforschungszentrum Karlsruhe	
U.S. Naval Research Laboratory		Experimenter not indicated	56
John P. Wefel	28*	Institut für Kernchemie	
Conrad H. Cheek	42	Alexander H. Boos	57
University of Arizona		Institute of Nuclear Chemistry Cologne	
Clarence Wendt	43	K. Thiel	58*
University of California		W. Herr	58*
P. B. Price	44	Institut für Physik	
University of California		Bundesanstalt für Milchforschung	
Lawrence Berkeley Laboratory		A. Wiechen	59
Harold Wollenberg	45	Institut für Radiochemie der	
Allan Smith	45	Technischen Universität München	
University of California		F. N. Flakus	60*
Lawrence Livermore Laboratory		J. M. Kesý	60*
Gurnam S. Sidhu	46	J. H. Born	60*
Richard V. Griffith	47*	Institut für Reine und Angewandte	
University of California		Kernphysik	
Los Alamos Scientific Laboratory		W. Enge	61
Dale E. Hankins	48*	K. P. Bartholoma	61
University of Michigan		R. Beaujean	61
David M. Gilliam	49	K. Fukui	61
Glenn F. Knoll	49	Karlsruhe Nuclear Research Center	
University of North Carolina		Ernst Piesch	62*
Charles B. Childs	50	Kernforschungsanlage Jülich	
Lawrence M. Slifkin	50	Maximilian Wald	63*
University of San Francisco		M. Heinzelmann	64*
Eugene V. Benton	51*		

	<u>Survey No.</u>		<u>Survey No.</u>
Max-Planck-Institut fur Kernphysik		J. Ralarosy	77*
Gunther A. Wagner	65	G. Remy	77*
W. Kratschmer	66*	R. Stein	77*
T. Plieninger	66*	J. Tripier	77*
R. Repnow	66*	Physique des Solides	
V. Metag	66*	Dartyge	78
Philipps Universitat		Universite de Clermont	
Reinhard Brandt	67	Laboratoire de Physique Corpusculaire	
Physikalisches Institut		Michael M. Monnin	79
F. Goennenwein	68		
Physikalisches Institut		JAPAN	
Gerhard Fiedler	69	Japan Atomic Energy Research Institute	
U. Hoppner	69	Takeo Kikuchi	80
H. Schreck-Kollner	69	Shoichi Nasu	80
J. Aschenbach	69	Ken-ichi Shiozawa	80
Staatliches Forschungsinstitut fur Geochemie		Kanazawa University	
Hans Meier	70	Takashi Nakanishi	81
Wolfgang Hecker	70	Masanobu Sakanoue	81
Technische Universitat Munchen		Kyoto University	
E. Konecny	71	Tetsuo Hashimoto	82
		Shiro Iwata	83
FRANCE		Takao Tsuruta	84
C. E. A. Steppa Dosimetrie Physique		Radiation Center of Osaka Prefecture	
A. M. Chapuis	72*	Yatsuka Matsuda	85
H. Francois	72*		
G. Soudain	72*	ENGLAND	
Centre de Recherches Kodak Pathe'		Atomic Energy Research Establishment	
J. F. Barbier	73	R. A. Loveridge	86
Centre de Spectrometrie de Masse Du CNRS		P. D. Holt	87*
Michel Maurette	74	Ron Matfield	88
College Scientifique Universitaire Chambery		Fast Reactor Physics Division, UKAEA	
Jean-Charles Carfantan	75	D. Jowitt	89
Institut de Physique Nucleaire		Rutherford High Energy Laboratory	
Claude J. Stephan	76	F. M. Russell	90
Laboratoire de Physique Corpusculaire Centre de Recherches Nucleaires		AUSTRALIA	
M. Debeauvais	77*	Australian Atomic Energy Commission	
J. C. Marsaudon	77*	N. F. Conway	91*
		Terence Wall	92

Survey No.Survey No.

Particle Track Laboratory

J. F. Lovering 93
D. A. Wark 93
J. W. Gleadow 93

BELGIUM

Euratom

B. J. Mijneer 94*
S.C.K. C.E.N.
Marcel de Coster 95
State University of Ghent
Renaat Gijbels 96

CANADA

Chalk River Nuclear Laboratories

G. R. Bellavance 97
William Cross 98*
George Cowper 98*
Dalhousie University
F. Aumento 99

ITALY

CISE

Marzio Mangialajo 100*
Laboratorio di Dosimetria E
Standardizzazione
L. Tommasino 101*
Universita di Napoli
F. Carbona 102

SWITZERLAND

CERN

J. R. Dutrannois 103
A. J. Herz 104
Jan W. H. Tuyn 106

Eidgenossisches Institut fur
Reaktorforschung

S. Pretre 105
R. Richmond 105*
B. Ruegger 105*

HUNGARY

Institute of Nuclear Research of the
Hungarian Academy of Sciences

L. Medveczky 107*
G. Somogyi 107*
B. Schlenk 107*
L. Mesko 107*
A. Valek 107*
I. Hunyady 107*
Kossuth University
M. Varnagy 108
S. Juhasz 108
S. Nagy 108
J. Csikai 108

IRELAND

Institute for Advanced Studies

Denis O'Sullivan 109
University College Dublin
James P. McLaughlin 110

NETHERLANDS

Philips
H. Pauw 111*
Reactor Centrum Nederland
Jan W. H. Tuyn 106*

AUSTRIA

Institut fur Atomphysik der
Universitat Innsbruck

M. Pahl 112
T. D. Mark 112
E. Mark 112

	<u>Survey No.</u>		<u>Survey No.</u>
INDIA		ROMANIA	
Tata Institute of Fundamental Research		Institute for Atomic Physics	
D. Lal	113	Marieta Nicolae	116
ISRAEL		SWEDEN	
Weizmann Institute of Science		AB Atomenergi	
David Samuel	114	Carl O. Widell	117*
POLAND		TRINIDAD	
Institute of Nuclear Research		University of the West Indies	
Krystyna Jozefowicz	115	E. Theodore Agard	118*

Appendix A **General Track Registration Survey Replies**

RESPONSES LISTED BY COUNTRY OF ORIGIN

<u>Country</u>	<u>Survey Number</u>
United States	1
West Germany	54
France	72
Japan	80
England	86
Australia	91
Belgium	94
Canada	97
Italy	100
Switzerland	103
Hungary	107
Ireland	109
Netherlands	111
Austria	112
India	113
Israel	114
Poland	115
Romania	116
Sweden	117
Trinidad	118

UNITED STATES

Survey No. 1

Laboratory: Argonne National Laboratory

Address: 9700 South Cass Avenue
Argonne, Illinois 60439

Researcher: Edward W. Barts

Registration Materials Studied: Mica
Polycarbonates
Cellulose Compounds - Kodak

Comments: Lexan preferred to Makrofol and polycarbonate is preferred to all other plastics.

Nuclear Particles Studied: Fission Fragments - ^{235}U

Area of Interest: Reactor Applications - We are interested in changes in fission density inside fuel elements.

Track Analyses Performed: Track Area Density - Of the order of 5×10^6 tracks/cm².

Methods of Data Acquisition: Manual Microscopic Analysis
Microphotometer - Used primarily

Survey No. 2

Laboratory: Argonne National Laboratory
Applied Physics Division

Address: Building 316
Argonne, Illinois 60439

Researchers: Roland J. Armani, Charles E. Cohn, and Raymond Gold

Registration Materials Studied: Mica
Polycarbonates
Cellulose Nitrate
Cellulose Acetate Butyrate

Comments: Our choice of track recorders depends upon the specific application.

Nuclear Particles Studied: Fission Fragments - See comments

Alpha Particles - ^{10}B (n, alpha) etc.

Comments: We have used track recorders with many actinide nuclei, e.g., ^{244}Cm , ^{241}Am , ^{239}Pu , ^{235}U , ^{238}U , ^{232}Th .

Areas of Interest: Basic Registration Research
Cosmic Ray Studies
Neutron Dosimetry
Cross-Section Measurements - Neutron

Comments: Additional interests include:

1. Precise fission-rate measurements (in reactor, critical facility, and accelerator measurements).
2. Environmental neutron measurements.
3. Spontaneous fission half-life measurements.
4. Fission yields and cross-section measurements.

Track Analyses Performed: Track Area Density - Up to 2×10^5 tracks/cm².
Track Length

Comments: Depending on the application, we have used track recorder areas ranging from roughly 1 cm^2 up to more than 100 cm^2 . Similarly track densities have varied from a few tracks/ cm^2 up to over 2×10^5 tracks/ cm^2 .

Methods of Data Acquisition: Manual Microscopic Analysis
Automatic Scanning Device - Argonne ATS System
Spark Counting

Applied Dosimetry: Type: Neutron
Occasion: Routinely
Use: Personnel work dosimeters
Number of Employees Monitored: 20 to 30

Comments: Fast neutron dosimetry service has been supplied to Zero Power Reactor (ZPR) personnel who work in and around plutonium-loaded critical facilities at the Illinois site. This service was instituted about $2\frac{1}{2}$ years ago.

Survey No. 3

Laboratory: Argonne National Laboratory
Chemistry Division

Address: 9700 S. Cass Avenue
Argonne, Illinois 60439

Researcher: Dale J. Henderson

Registration Materials Studied: Mica
Polycarbonates - Main effort
Glasses - Fused quartz

Comments: Work was done by Dr. J. Unik on mica and fused quartz. While the procedure progressed satisfactorily, a level was reached that proved to be too high for very low-level counting.

Nuclear Particles Studied: Fission Fragments - Californium

Comments: A Cf target was used to standardize etching techniques.
Goal - To find superheavy elements in targets radiated with very high-energy particles (protons and heavy ions).

Area of Interest: Search for New Superheavy Elements

Track Analyses Performed: Track Area Density

Comments: Number of events is very low. It is necessary to know the background and efficiency very well to set limits.

Methods of Data Acquisition: Manual Microscopic Analysis
Spark Counting

Comments: Manual microscopic analysis has only been used as an occasional check.

General Comments: I have tried KMnO_4 , KOH , and NaOH combinations and produced one film where the material became very uniformly colored and the holes were very clear and distinct under a microscope. I have not been able to duplicate the results, but do not need to since counting by sparking.

Survey No. 4

Laboratory: Argonne National Laboratory
Materials Science Division
Address: 9700 S. Cass Avenue
Argonne, Illinois 60439
Researchers: H. Berger and N. P. Lapinski

Registration Materials Studied: Polycarbonates
Cellulose Nitrate - Eastman Kodak, Kodak Pathe'

Nuclear Particles Studied: Fission Fragments - ^{235}U
Alpha Particles
Protons

Comments: Fission fragments and alphas used primarily in conjunction with
neutron radiography. Proton work also involved radiographic studies.

Areas of Interest: Neutron Radiography
Proton Radiography

Track Analyses Performed: Track Area Density - 10^5 to 10^7 tracks/cm².
Image Quality - Primary interest.

Methods of Data Acquisition: Visual Assessment
Photographic Assessment

Survey No. 5

Laboratory: Argonne National Laboratory
Radiological Physics Division
Address: 9700 S. Cass Avenue
Argonne, Illinois 60439
Researchers: David J. Simmons

Registration Materials Studied: Cellulose Nitrate - Hercules Powder Co., Wilmington
Delaware, CAT. R.S. 11.8-112.2%
N₂ 5-6 sec viscosity, 33% isopropyl
alcohol.

Nuclear Particles Studied: Alpha Particles - ^{239}Pu

Area of Interest: Alpha Autoradiography

Track Analyses Performed: Track Area Density

Comments: Resolution of films of various thicknesses for tissue location of ^{239}Pu
and ^{226}Ra .

Methods of Data Acquisition: Manual Microscopic Analysis
Spark Counting

Survey No. 6

Laboratory: Battelle Memorial Institute, Pacific-Northwest Laboratories

Address: P.O. Box 999
Richland, Washington 99352

Researcher: L. W. Brackenbush

Registration Materials Studied: Mica
Polycarbonates
Cellulose Nitrate
Cellulose Acetate

Comments: I have tried formvar and many other commercial plastics, but almost all were rejected because of uneven etching rates produced by plasticizers, especially in cellulose nitrate.

Nuclear Particles Studied: Fission Fragments - ^{237}Np , ^{238}U , ^{235}U , Pb, Bi, Au, Th, and W
Alpha Particles - ^{239}Pu and Uranium
Protons - 50 and 100 MeV from the cyclotron
Cosmic Ray Particles

Comments: The fission foils were used for neutron dosimetry, the alpha particles were used in alpha autoradiography with cellulose nitrate as the registration material, and the remaining heavy elements were used as threshold detectors in cosmic ray and solar flare dosimetry research.

Areas of Interest: Basic Registration Research
Cosmic Ray Studies
Neutron Radiography
Neutron Dosimetry
Alpha Autoradiography
Trace Analysis of Heavy Elements

Comments: We have used track registration for determination of trace amounts of fissile materials in plants and environmental samples through reactor irradiations. We were able to use this technique in urinalysis for plutonium, but it was necessary to adopt clean room techniques to eliminate uranium and thorium in dust particles.

Track Analyses Performed: Track Area Density - 1 to 3000 tracks/cm².
Track Length

Comments: In 1964 to 1966, we used track density under fissionable filters, and track shape and length in a prototype cosmic ray dosimeter.

Methods of Data Acquisition: Manual Microscopic Analysis
Etched Holes in Opaque Material

Comments: We developed a method for track reading by etching small holes in opaque material, but it was more difficult to use than spark counting.

Dosimetry Applications: We developed prototype neutron dosimeters in 1965. These have been used successfully for area dosimeters around plutonium production facilities. However, they were not used extensively for personnel because of the amount of fissionable material they contained ($^{237}\text{Np O}_2$).

Survey No. 7

Laboratory: Battelle-Northwest
Address: Box 999
Richland, Washington 99352
Researchers: Carl M. Unruh and Staff

Registration Materials Studied: Polycarbonates

Comments: Most of our work was done in 1964 to 1966.

Nuclear Particles Studied: Fission Fragments - ^{237}Np , ^{235}U , ^{238}U , Pb, Bi, Cu.
10 MeV to 50 MeV protons from the Lawrence Livermore Laboratory
88 in. cyclotron and the cyclotron at Uppsala, Sweden were used in an attempt to produce fission in Pb, Bi, and Cu.

Alpha Particles - Particles having energies of approximately 5 MeV from ^{239}Pu .

Area of Interest: Neutron Dosimetry

Track Analyses Performed: Track Area Density - Zero to 10^5 tracks/cm², depending on the materials and doses.

Methods of Data Acquisition: Manual Microscopic Analysis
Television Microscopic Display System

Survey No. 8

Laboratory: Brookhaven National Laboratory
Address: Upton, New York 11973
Researcher: Seymour Katcoff

Registration Materials Studied: Mica
Polycarbonates

Nuclear Particles Studied: Fission Fragments
Other Particles - Alpha recoil tracks; fragments of
 $6 \leq Z \leq 18$ at energies of 1 - 4 MeV/amu

Areas of Interest: Basic Registration Research
Other - Nuclear reaction studies, primarily fission.

Track Analysis Performed: Track Area Density - 10 to 10^3 tracks/cm².
Track Length

Method of Data Acquisition: Manual Microscopic Analysis

Survey No. 9

Laboratory: Brookhaven National Laboratory
Address: Upton, New York 11973
Researcher: Carl Distenfeld

Registration Materials Studied: Polycarbonates

Nuclear Particles Studied: Fission Fragments - ^{232}Th , ^{238}U

Area of Interest: Neutron Dosimetry - For accelerator use.

Track Analyses Performed: Track Area Density

Methods of Data Acquisition: Manual Microscopic Analyses
Spark Counting

Survey No. 10

Laboratory: California Institute of Technology
Division of Geological and Planetary Science

Address: Pasadena, California

Researcher: D. S. Burnett

Registration Materials Studied: Mica
Polycarbonates
Cellulose Triacetate - Bayer (TN), Kodak

Comments: Cellulose triacetate, particularly TN, is highly variable in its sensitivity for alpha registration. The sensitivity in vacuum differs from that in air.

Nuclear Particles Studied: Fission Fragments - ^{252}Cf
Alpha Particles - 0 to 5 MeV from the Van de Graff and
from the ^{10}B (n, alpha) reaction.
Protons - 0 to 1 MeV from the Van de Graff.

Areas of Interest: Basic Registration Research
Radon Dosimetry
Cosmic Ray Studies
Neutron Radiography
Neutron Dosimetry
Cross Section Measurements - Neutron
Geologic Studies

Track Analyses Performed: Track Area Density - $10^2 - 10^6$ tracks/cm².

Method of Data Acquisition: Manual Microscopic Analysis

Survey No. 11

Laboratory: Carnegie Institution
Geophysical Laboratory

Address: Washington, D.C. 20008

Researcher: Dr. Martin G. Seitz

Registration Materials Studied: Mica - Huse-Liberty IWI Division
Quartz
Fossilized Teeth
Apatite
Zircon
Sphene Minerals, etc.

Comments: Mica is unique in that it is not chemically attached on its basal plane. Therefore, track densities are not sensitively dependent on etching conditions or the direction of the incident track-forming particles.

Nuclear Particles Studied: Fission Fragments - Spontaneous fission of ^{235}U . Induced fission of thorium and uranium.

Alpha Particles - Alpha decay of alpha activated lead and neutron activated oxygen.

Areas of Interest: Geologic Studies
Geochemistry of Heavy Elements

Comments: Geological studies include fission and alpha recoil track dating and lead, thorium and uranium partitioning in basalts, eclogites and fossilized animal materials.

Track Analyses Performed: Track Area Density - 10^2 to 5×10^7 tracks/cm².

Method of Data Acquisition: Manual Microscopic Analysis
Other - See comments

Comments: For neutron dosimetry, tracks are counted from photographs of silvered surfaces. By eliminating the need for a track length criterion, this technique alleviates many problems of track counting. See bibliography (to be published).

Survey No. 12

Laboratory: Case Western Reserve University
Department of Anthropology

Address: Cleveland, Ohio 44106

Researcher: Bruce E. Rippeteau

Registration Materials Studied: Mica
Glasses - Geologic
Others - 1 Silicas such as chert
2 Tooth enamel (calcium phosphates)

Comments: I have been investigating fission track dating for archeology.
1. No results positive on mammalian tooth enamel.
2. No results positive on chert from fire spalls, etc.
3. Ambiguous results on obsidian (fired) (for example, Tabon cave in Israel, Neanderthal).
4. Some success on mica tempered pottery from the southwestern part of the United States (for example, Hohokam pottery).

Nuclear Particles Studied: Fission Fragments
Alpha Particles

Comments: The research is temporarily suspended at Case Western Reserve University; but I believe there to be possibilities yet for chert and enamel sized crystallites with suitable impregnation of the matrix before etching. All of these data refer to research done while I was at the University of Arizona.

Areas of Interest: Geologic Studies
Archeological Studies

Comments: 1. Mammalian enamel was used for study of human evolution in Pleistocene.
2. Heat altered cherts (lithics) were used to date late Pleistocene items.
3. Mica-tempered pottery is used for dating over the last 5 thousand years.

Track Analyses Performed: Track Area Density - Used for dating.

Method of Data Acquisition: Manual Microscopic Analysis

Survey No. 13

Laboratory: Catholic University
Physics Department

Address: Washington, D.C. 20017

Researcher: Hall Crannell

Registration Materials Studied: Polycarbonates
Cellulose Nitrate
Cellulose Butyrate

Nuclear Particles Studied: Fission Fragments - ^{235}U
Alpha Particles

Areas of Interest: Basic Registration Research
Cosmic Ray Studies

Track Analyses Performed: Track Area Density - Approximately 10^5 tracks/cm²
Enhancement Using Electric Fields

Method of Data Acquisition: Manual Microscopic Analysis

Survey No. 14

Laboratory: The Corning Museum of Glass

Address: Corning, New York 14830

Researcher: Dr. Robert H. Brill

Registration Materials Studied: Glasses - Historical or ancient from various museums.

Comments: Fission-track dating is useful for dating man-made glasses which contain about 1% uranium oxide. This includes several types of glasses made in the 19th and 20th centuries. More ancient glasses (3500 - 200 years old) cannot be dated accurately because the uranium contents are too low, but it is sometimes possible to decide if a glass is "ancient" or a modern forgery.

Nuclear Particles Studied: Fission Fragments

Area of Interest: Archeological Dating - Dating of early man-made glasses and dating or authentication of ancient man-made glasses.

Track Analyses Performed: Track Area Density

Method of Data Acquisition: Manual Microscopic Analysis

General Comment: The laboratory work was actually done by Fleischer, Price, and Walker.

Survey No. 15

Laboratory: E.G. and G.
Address: P.O. Box 98
Goleta, California 93017
Researcher: W. M. Quam

Registration Materials Studied: Polycarbonates - Lexan, General Electric; Kimfol

Nuclear Particles Studied: Fission Fragments - ^{232}Th , ^{235}U , ^{238}U

Comments: We use sputtered radiators made in our own facility. Generally they range from 0.01 to 2μ in thickness. They are in the oxide form on an aluminum substrate.

Areas of Interest: Cosmic Ray Studies
Neutron Dosimetry
Trace Element Analysis - ^{239}Pu tracing in animals.

Track Analyses Performed: Track Area Density - Up to 3×10^6 tracks/cm².

Methods of Data Acquisition: Manual Microscopic Analysis
Spark Counting

Survey No. 16

Laboratory: Enrico Fermi Institute
Address: 5630 Ellis Ave.
Chicago, Illinois 60637
Researcher: Laurel Wilkening

Registration Materials Studied: Glasses - Natural, impact, Tektite, Lunar
Silicate Minerals

Nuclear Particles Studied: Fission Fragments - ^{252}Cf , ^{235}U
Cosmic Ray Nuclei - >1 MeV/nucleon, mass >50 amu

Areas of Interest: Cosmic Ray Studies
Geologic Studies - Meteorite and Lunar studies.

Track Analyses Performed: Track Area Density - 10^4 to 10^9 tracks/cm²
Track Length
Angular Distributions

Method of Data Acquisition: Manual Microscopic Analysis

Survey No. 17

Laboratory: General Electric Research Laboratory
Address: Schenectady, New York
Researcher: Dr. Robert L. Fleischer

Registration Materials Studied: Mica
Polycarbonates
Various Glasses
Minerals
Assorted Cellulose Compounds

Nuclear Particles Studied: Fission Fragments
Alpha Particles - ^{252}Cf , ^{228}Th
Protons
Other Particles Including Cosmic Rays

Areas of Interest: Basic Registration Research
Radon Dosimetry
Cosmic Ray Studies
Neutron Radiography
Neutron Dosimetry
Cross Section Measurements
Geologic Studies
Alpha Autoradiography
A Number of Other Applications

Methods of Data Acquisition: Manual Microscopic Analysis
Spark Counting
Ozalid Imaging

Survey No. 18

Laboratory: General Electric
Nucleonics Laboratories

Address: Vallecitos Road
Pleasanton, California 94566

Researchers: H. W. Alter, J. L. Carroll, D. B. Lovett, H. D. Kosanke, J. E. Gingrich
and H. S. Rosenbaum

Registration Materials Studied: Mica
Polycarbonates
Glasses
Cellulose Compounds - Primarily cellulose nitrate;
from various commercial
sources. We produce our own
cellulose nitrate film coatings.
Other - Natural and synthetic quartz.

Nuclear Particles Studied: Fission Fragments - ^{252}Cf , ^{235}U , ^{238}U , ^{237}Np and ^{239}Pu .
Alpha Particles - 5 MeV from UO_2 and radon.
Protons - About 200 keV from n, p knock-on.
Other Particles - Tritons, about 600 keV.

Areas of Interest: Basic Registration Research
Radon Dosimetry
Neutron Radiography
Neutron Dosimetry
Alpha Autoradiography

Track Analyses Performed: Track Area Density = 0 to 5×10^6 tracks/cm².
Track Length
Fade Rates

Methods of Data Acquisition: Manual Microscopic Analysis
Spark Counting
Other - Aluminized coating - microscopic counting

Survey No. 19

Laboratory: General Electric Company
Vallecitos Nuclear Center

Address: Vallecitos Road
Pleasanton, California 94566

Researcher: Roger Caputi

Registration Materials Studied: Polycarbonates
Cellulose Nitrate
Polyimide

Comments: 6 N NaOH etchant is used for both polycarbonates and polyimides as well as cellulose nitrate.

Nuclear Particles Studied: Fission Fragments - ^{235}U fission plate and ^{252}Cf
Alpha Particles - UO_2 thick sources.

Areas of Interest: Basic Registration Research
Product Development

Track Analyses Performed: Track Area Density - 10^2 to 10^{10} tracks/cm²
Track Length
Cone Angle

Methods of Data Acquisition: Manual Microscopic Analysis - Both light and electron
scanning.
Other - Bubble point and flow measurements.

Survey No. 20

Laboratory: Hanford Engineering Development Laboratory

Address: P.O. Box 1970
Richland, Washington 99352

Researchers: R. E. Dahl and H. H. Yoshikawa

Registration Materials Studied: Mica

Source of Material: General Electric Lab.

Nuclear Particles Studied: Fission Fragments

Area of Interest: Neutron Dosimetry

Method of Data Acquisition: Manual Microscopic Analysis

Survey No. 21

Laboratory: Hanford Engineering Development Laboratory

Address: Westinghouse Hanford Company
P.O. Box 1970
Richland, Washington 99352

Researcher: William J. Gruber

Registration Materials Studied: Cellulose Nitrate - Eastman Kodak film type 106-01,
8-10 μ thick cellulose nitrate on
estar base.

Cellulose Acetate

Comments: Before Eastman manufactured 106-01 film, our recording media was made by dissolving reagent grade cellulose nitrate or acetate in a solvent, pouring the material into thin layers, and then evaporating the solvent to leave a thin recording film. Cellulose nitrate is used primarily for our work.

Nuclear Particles Studied: Alpha Particles

Areas of Interest: Basic Registration Research
Alpha Autoradiography

Comments: Alpha Autoradiography - Determination of distribution of plutonium of other transuranium elements in a matrix of U or Th in irradiated nuclear fuels.

Basic Registration Research - More precise determination of alpha particle registration in cellulose nitrate. Factors such as energy range for registration, path length for energy ranges ≤ 7 MeV, and absorbing characteristics of several candidate materials.

Track Analyses Performed: Track Area Density

Comments: Track area density is used to determine precise Pu distribution. Relative distribution is determined by photographing etched recording media.

Methods of Data Acquisition: Manual Microscopic Analysis

Automatic Scanning Device - A scanning microscope is now available for counting tracks.

Photographic - Low magnification (2X - 15X) photographs of the recording media.

Comments: Photography of recording material after etching gives relative distribution of plutonium in irradiated U-Pu oxide nuclear fuels and is an integral part of data recording during postirradiation examinations at this site.

Survey No. 22

Laboratory: Iowa State University
Ames Laboratory

Address: Ames, Iowa 50010

Researchers: P. B. Hahn, M. A. Wechter, and A. F. Voigt

Registration Materials Studied: Cellulose Nitrate - Self cast

Comments: Cellulose nitrate prepared according to NRDL-1 formula and cast to a thickness of 1.3-1.4 mg/cm².

Nuclear Particles Studied: Alpha Particles - 2.0 MeV

Comments: Source of 2 MeV alphas from ⁶Li(n, alpha)³H reaction surface analysis of lithium tungsten bronzes, film in contact with bronze surface. ²¹⁰Po alpha particles attenuated by 2.7 cm of air are also used.

Area of Interest: Neutron Dosimetry
Surface Analysis for Lithium in Tungsten Bronzes

Track Analyses Performed: Track Area Density - 500-3000 tracks/cm².

Method of Data Acquisition: Spark Counting

Survey No. 23

Laboratory: The Johns Hopkins Hospital
Orthopaedic Research Laboratory
Address: CMSC9713
601 N. Broadway
Baltimore, Maryland 21205
Researcher: R. C. Thompson, MD

Registration Materials Studied: Cellulose Nitrate - Collodion

Nuclear Particles Studied: Fission Fragments
Alpha Particles

Area of Interest: Biological Studies - Geometric localization of uptake of fissionable bone seeking isotopes.

Method of Data Acquisition: Manual Microscopic Analysis

Survey No. 24

Laboratory: Knolls Atomic Power Laboratory
Address: P.O. Box 1072
Schenectady, New York
Researcher: H. M. Eiland

Registration Materials Studied: Polycarbonates
Glasses - Fused silicon
Cellulose Nitrate - We cast our own

Nuclear Particles Studied: Fission Fragments
Alpha Particles

Areas of Interest: Cross Section Measurements - Neutron
Alpha Autoradiography

Comments: Much of our work is devoted to locating and characterizing low levels of alpha emitters on reactor structural materials. To this end we are developing a detector which chemically amplifies tracks to a size which can be detected with the unaided eye.

Track Analyses Performed: Track Area Density - Approximately 5×10^4 tracks/cm².

Method of Data Acquisition: Manual Microscopic Analysis - Digital Electronics, Inc.
Westbury, New York with
Leitz microscope.

Comments: We have a scanning machine, but the nature of our counting problems is so varied that we have not been able to apply it effectively.

General Comments: We are interested in the track sparking technique for possible application in measuring the angular distribution of alphas produced in n, alpha cross section measurements where the track density will be quite low.

Survey No. 25

Laboratory: Macalester College
Address: St. Paul, Minnesota 55105
Researchers: James H. Roberts and Frank J. Congel

Registration Materials Studied: Mica
Polycarbonates
Cellulose Nitrate - Diacel and Benton type USF#3
Nuclear Particles Studied: Fission Fragments - ^{235}U , and ^{244}Cm
Alpha Particles - 5.5 MeV from ^{241}Am and 5.8 MeV from ^{244}Cm
Areas of Interest: Basic Registration Research
Cosmic Ray Studies
Alpha Autoradiography
Track Analyses Performed: Track Area Density - 2 to 10^6 tracks/cm²
Methods of Data Acquisition: Manual Microscopic Analysis
Spark Counting

Survey No. 26

Laboratories: National Aeronautics and Space Administration* and
Plum Brook Reactor† Lewis Research Center
Address: Taylor Road
Sandusky, Ohio 44870
Researchers: Mr. James A. Morley* and Mr. Glenn C. Winters, Jr.†

Registration Materials Studied: Mica
Cellulose Diacetate - Cast from "Celanese" type 822,
AA grade.
Nuclear Particles Studied: Fission Fragments - ^{235}U foil, 92% enriched, ^{238}U foil
depleted in ^{235}U , and ^{232}Th foil.
Areas of Interest: Neutron Radiography
Fission Rate Measurements - For neutron spectra determination.
Track Analyses Performed: Track Area Density - 2×10^4 to 2×10^5 tracks/cm².
Other - Resolution of neutron radiographs and sensitivity
to different thicknesses of different materials.
Methods of Data Acquisition: Manual Microscopic Analysis
Photographic Imaging - See Comments
Comments: We are using photo copying using fluorescent dyes and ultraviolet
light. We are also using photocopying from a negative placed between
crossed polaroid filters. Both methods are used to enhance image
contrast.

Survey No. 27

Laboratory: National Bureau of Standards
Activation Analysis Section

Address: Washington, D.C. 20234

Researcher: B. Stephen Carpenter

Registration Materials Studied: Mica
Polycarbonates
Glasses
Cellulose Nitrate
Cellulose Acetate
Cellulose Acetate Butyrate

Nuclear Particles Studied: Fission Fragments
Alpha Particles
Protons

Comments: The above charged particles are used to determine the concentrations of elements that emit charged particles (boron, lithium, nitrogen, oxygen, uranium and thorium) in a wide variety of matrices. Usually the charged particles are produced from thermal neutron reactions, except thorium for which we use fast neutrons.

Areas of Interest: Basic Registration Research
Neutron Dosimetry
Geologic Studies
Analytical Applications

Track Analyses Performed: Track Area Density

Methods of Data Acquisition: Manual Microscopic Analysis
Automatic Scanning Device - QTM Quantimet
Spark Counting

Survey No. 28

Laboratory: Naval Research Laboratory

Address: Washington, D.C. 20390

Researcher: John P. Wefel, Code 7026

Registration Materials Studied: Polycarbonates
Cellulose Triacetate
Cellulose Acetate-Butyrate

Nuclear Particles Studied: Cosmic Rays
Artificially Accelerated Heavy Ions

Areas of Interest: Basic Registration Research
Cosmic Ray Studies
Cross Section Measurements - Fragmentation

Track Analyses Performed: Track Length
Track Diameters

Methods of Data Acquisition: Manual Microscopic Analysis
Automatic Scanning Device - d.c.spark locating device.

Survey No. 29

Laboratory: Nebraska Geological Survey
Address: Conservation and Survey Division
University of Nebraska
Lincoln, Nebraska
Researcher: John Boellstorff

Registration Materials Studied: Glasses - Volcanic ash, rhyolitic. Microscope slides
Shard size used - 80 to 150 μ .

Areas of Interest: Neutron Dosimetry
Geologic Studies

Comments: Our studies involved dating volcanic ash deposits, intercalibrated
with Pleistocene and Tertiary sediments in the mid-continent.

Track Analyses Performed: Track Area Density - 2 to 50×10^3 tracks/cm².
Track Length
Rate of Radial Enlargement

Method of Data Acquisition: Manual Microscopic Analysis

Survey No. 30

Laboratory: Oak Ridge National Laboratory
Address: P.O. Box Y
Oak Ridge, Tennessee 37830
Researcher: C. D. Bopp

Registration Materials Studied: Cellulose Compounds
Others

Comments: See D. R. Sears and C. D. Bopp, Oak Ridge National Laboratory
Rept. ORNL-4351 (1969).

Nuclear Particles Studied: Alpha Particles

Survey No. 31

Laboratory: Oak Ridge National Laboratory
Address: P.O. Box X
Oak Ridge, Tennessee 37830
Researcher: W. W. Parkinson

Registration Materials Studied: Cellulose Acetate - Tennessee Eastman

Nuclear Particles Studied: Alpha Particles

Area of Interest: Basic Registration Research

Methods of Data Acquisition: Manual Microscopic Analysis
Infrared and Chemical Analysis

Survey No. 32

Laboratory: Oak Ridge National Laboratory
Health Physics Division

Address: Oak Ridge, Tennessee 37830

Researcher: Dr. Klaus Becker

Registration Materials Studied: Polycarbonates
Glasses - Phosphate, silicate
Cellulose Compounds - Triafol B and T, cellulose
nitrate from various sources -
Bayer, Germany; Dai Nippon,
Japan; Hercules Powder Co. etc.

Nuclear Particles Studied: Fission Fragments - Uranium isotopes, thorium, ^{237}Np ,
 ^{239}Pu , ^{252}Cf , etc.
Alpha Particles - 0 to 5.5 MeV from uranium and ^{241}Am .
Protons - Accelerator produced.

Areas of Interest: Basic Registration Research
Radon Dosimetry
Neutron Radiography
Neutron Dosimetry
Alpha Autoradiography
Other - Neutron induced autoradiography (NIAR) analysis.

Track Analyses Performed: Track Area Density - 1 to 10^8 tracks/cm²
Etch Pit Diameter
Track Diameter

Methods of Data Acquisition: Manual Microscopic Analysis
Automatic Scanning Device - Flying spot electronic
analyzer (not used any more
after spark counting).
Spark Counting
Other - Optical density, light scattering, dark-field
microscopy etc.

Applied Dosimetry: Type - Neutron
Occasion - For special requirements
Use-Personnel Worn Dosimeters (Under development for badges,
but already worn in accident
belts)

Survey No. 33

Laboratory: Rensselaer Polytechnic Institute
Department of Geology

Address: Troy, New York 12181

Researcher: Donald S. Miller, Professor of Geochemistry

Registration Materials Studied: Mica
Polycarbonates

Nuclear Particles Studied: Fission Fragments - ^{252}Cf

Area of Interest: Geologic Studies

Track Analyses Performed: Track Area Density - 10^2 to 10^4 tracks/cm².

Method of Data Acquisition: Manual Microscopic Analysis

Survey No. 34

Laboratory: Rensselaer Polytechnic Institute
Department of Nuclear Science

Address: Troy, New York 12181

Researcher: Dr. Willard G. Myers

Registration Material Studied: Polycarbonates

Nuclear Particles Studied: Fission Fragments - ^{235}U , ^{252}Cf

Area of Interest: Analytical Studies on Uranium Concentrations in Environmental Media

Comment: Our fission track work has been primarily used to supplement isotopic analyses of uranium via mass spectrometry.

Track Analyses Performed: Track Area Density - 0 to 3,000 tracks/cm².

Method of Data Acquisition: Manual Microscopic Analysis

Survey No. 35

Laboratory: Rosenstiel School of Marine and Atmospheric Sciences

Address: 10 Rickenbacker Causeway
Miami, Florida 33149

Researcher: Dr. David Fisher

Registration Materials Studied: Polycarbonates
Glasses

Nuclear Particles Studied: Fission Fragments

Areas of Interest: Basic Registration Research
Geologic Studies

Track Analyses Performed: Track Area Density - 0 to 10⁴

Method of Data Acquisition: Manual Microscopic Analysis

Survey No. 36

Laboratory: Stanford Linear Accelerator Center

Address: P.O. Box 4349
Stanford, California 94305

Researchers: Dr. Goren Svensson* and Kenneth Kase

* Present Address: Joint Center for Radiation Therapy
Department of Physics
Harvard Medical School
50 Binney Street
Boston, Massachusetts 02115

Registration Materials Studied: Polycarbonates

Nuclear Particles Studied: Fission Fragments - Thorium

Areas of Interest: Neutron Dosimetry
Cross Section Measurements

Track Analyses Performed: Track Area Density

Methods of Data Acquisition: Manual Microscopic Analysis
Spark Counting

Survey No. 37

Laboratory: Teledyne Isotopes
Address: 50 Van Buren Ave.
Westwood, New Jersey 07675
Researcher: David Lightbody

Registration Materials Studied: Mica
Polycarbonates
Nuclear Particles Studied: Fission Fragments - ^{235}U , ^{238}U
Area of Interest: Neutron Dosimetry
Track Analyses Performed: Track Area Density - 10 to 1,000 tracks/cm²
Track Length
Method of Data Acquisition: Manual Microscopic Analysis

Survey No. 38

Laboratory: Texas A&M University Chemistry Department
Address: College Station, Texas 77843
Researcher: J. Marvin Herndon

Registration Materials Studied: Mica - "#2-India Clear," Essex International/I. W. I.
Division, 247 Lynnfield St., Peabody, Mass.
(Approximate uranium content - 25 - 100 ppb)
Polycarbonate - General Electric
Glasses - Types U-2 and U-3 Standard Glasses,
courtesy of Dr. Brill, Corning Glass Museum.
Various Minerals
Nuclear Particles Studied: Fission Fragments - ^{252}Cf , used for track efficiency studies
and ^{241}Pu (n, fission) used for fission
yield studies.
Areas of Interest: Cross Section Measurements - Neutron
Geologic Studies
Method of Data Acquisition: Manual Microscopic Analysis

Survey No. 39

Laboratory: U.S. Geological Survey
Address: Building 15
Denver Federal Center
Denver, Colorado 80225
Researchers: H. T. Millard and P. J. Aruscavage

Registration Materials Studied: Mica
Polycarbonates
Nuclear Particles Studied: Fission Fragments - From geological samples
Area of Interest: Geologic Studies
Track Analysis Performed: Track Area Density - Up to 10⁵ tracks/cm².
Methods of Data Acquisition: Manual Microscopic Analysis
Spark Counting

Survey No. 40

Laboratory: U.S. Geological Survey
Address: Branch of Isotope Geology
U.S. Geological Survey
Federal Center
Denver, Colorado 80225
Researcher: Dr. Charles W. Naeser

Registration Materials Studied: Mica
Polycarbonates

Nuclear Particles Studied: Fission Fragments - ^{252}Cf

Area of Interest: Geologic Studies

Track Analyses Performed: Track Area Density - 1 to 10^7 tracks/cm².

Method of Data Acquisition: Manual Microscopic Analysis

Survey No. 41

Laboratory: United States Geological Survey
Isotope Geology Branch

Address: Denver Federal Center
Denver, Colorado 80225

Researchers: John R. Dooley, Jr., R. B. Taylor and F. J. Jurceka

Registration Materials Studied: Mica
Polycarbonates

Comments: We use Lexan almost exclusively, 20, 40, and 62 mil. thickness. Etch in KOH (28%) @ 50°C and use hot plate with manual stirring. Vary the time around 5 minutes depending on irradiation and just develop one side of Lexan. Rinse in distilled water and use N-Butyl alcohol (1-butanol) for removing tape.

Nuclear Particles Studied: Fission Fragments - Induced fission of natural uranium and thorium using TRIGA Mark III reactor.

Area of Interest: Geological Studies

Comments: We study uranium distribution in geologic material. We have found uncovered thin sections and polished thin sections most useful, although we have used polished sections and just plane-sawed rock specimens. The sizes used are about 5 cm² for circles and 7 cm² for rectangles.

Track Analyses Performed: Track Area Density

Comments: The analysis calls for localization of uranium and thorium bearing mineral phases.

Method of Data Acquisition: Manual Microscopic Analysis

Comments: We developed a method and instrumentation for localizing each area of fission track registration with the corresponding uranium and thorium bearing phases. See bibliography (to be published).

Survey No. 42

Laboratory: U.S. Naval Research Laboratory

Address: Code 8330
Washington, D.C. 20390

Researcher: Dr. Conrad H. Cheek

Registration Materials Studied: Polycarbonates

Nuclear Particles Studied: Fission Fragments

Area of Interest: Trace Element Analysis - Analysis of trace uranium in biological materials.

Track Analyses Performed: Track Area Density

Method of Data Acquisition: Manual Microscopic Analysis

Survey No. 43

Laboratory: University of Arizona
Department of Geology

Address: Tucson, Arizona

Researcher: Clarence Wendt

Registration Materials Studied: Mica

Nuclear Particles Studied: Fission Fragments

Area of Interest: Geologic Studies - Age dating of micas and other materials.

Track Analyses Performed: Track Area Density

Method of Data Acquisition: Manual Microscopic Analysis

Survey No. 44

Laboratory: University of California
Department of Physics

Address: Berkeley, California 94720

Researcher: Dr. P. B. Price

Registration Materials Studied: Mica
Polycarbonates
Many Glasses
Various Cellulose Compounds

Comment: We have also studied many minerals, particularly those in meteorites and lunar samples.

Nuclear Particles Studied: Fission Fragments - Cf, U, Th, Au, etc.
Alpha Particles

Other Particles - Heavy ions up to Kr and at energies up to 10.4 MeV/nucleon.

Areas of Interest: Basic Registration Research
Cosmic Ray Studies
Geological Studies
Solar Flare Studies
Lunar Science
Meteorites
Origin of the Solar System
High Energy Heavy Ion Reaction From Berkeley Bevatron

Track Analyses Performed: Track Area Density - Less than 10^{-4} to more than 10^{11} tracks/cm².

Track Length

Other - Particle identification via etch rate vs residual range.

Methods of Data Acquisition: Manual Microscopic Analysis - Optical and electron Ammonia Scanning

Survey No. 45

Laboratory: Lawrence Berkeley Laboratory

Address: Berkeley, California 94720

Researchers: Harold Wollenberg and Allan Smith

Registration Materials Studied: Mica - Victory Mica Mfg. Co., Brooklyn, New York
Polycarbonate - General Electric, Trade Name "Lexan"

Comment: The tracks in mica are easier to identify than in polycarbonate, but mica has a background due to natural uranium.

Nuclear Particles Studied: Fission Fragments - ²³⁸U, Th, Au, Pb, Ta, ²³⁹Pu, and ²³⁵U.

Comments: The sources of fission for these radiators include thermal neutrons from the Livermore Pool-Type Reactor for ²³⁵U and ²³⁹Pu, a PuBe source for ²³⁸U and thorium, as well as 230-MeV neutrons and 740-MeV protons from the Berkeley 184-in. cyclotron and 5.5 GeV neutron from the Berkeley bevatron for the U, Au, Bi, Pb, and Ta. Fast neutrons in the exposure room at the TRIGA on the University of California Campus were used for thorium and ²³⁸U in thin sections.

Areas of Interest: Neutron Dosimetry - In-beam high-energy accelerator dosimetry.
Proton Dosimetry - In-beam high-energy accelerator dosimetry.
Geologic Studies

Track Analyses Performed: Track Area Density - 10^4 - 10^6 tracks/cm².

Methods of Data Acquisition: Manual Microscopic Analysis
Automatic Scanning Device - See comment

Comment: I have tried the Leitz TV scan system on mica with track densities about 10^5 tracks/cm². It worked well, providing closely spaced tracks are not badly superimposed. This can generally be controlled by regulating the etching conditions.

Survey No. 46

Laboratory: University of California
Lawrence Livermore Laboratory

Address: P.O. Box 808
Livermore, California 94550

Researcher: Gurnam S. Sidhu

Registration Materials Studied: Mica
Polycarbonates

Comments: Mica damage tracks have a distinctive diamond shape projection when observed through an optical microscope.
The Lexan polycarbonate tracks appeared more like "comets" and were easier to confuse with scratches, smears, etc.

Nuclear Particles Studied: Fission Fragments

Area of Interest: Fission Studies - Fission densities in ^{235}U as a result of exposure to neutrons.

Comments: The fission track densities observed were related to fission densities in ^{235}U by means of a constant K = fissions per gram of ^{235}U /track per mm^2 . This multiplicative constant was separately determined in a measurement where the fission density and the neutron fluence were known from independent measurements.

Track Analyses Performed: Track Area Density - 10^3 to 10^5 tracks/ cm^2 .

Method of Data Acquisition: Manual Microscopic Analysis

Comments: For manual microscopic analysis, mica or some other crystalline material would be preferable because the damage structure after etching shows the etch pit characteristic of the material. In the case of Lexan, the fission fragment tracks appeared like "comets" with one end of the track indicating high density of damage.

Survey No. 47

Laboratory: University of California
Lawrence Livermore Laboratory

Address: P.O. Box 808
Livermore, California 94550

Researcher: Richard V. Griffith

Registration Materials Studied: Polycarbonates - Lexan, General Electric, ; Kimfol,
Kimberly Clark
Cellulose Nitrate - Kodak Pathe' - LR115 & CA8015, &
NRDL-1 formula
Cellulose Acetate
Cellulose Acetate Butyrate
Phosphate Glass

Nuclear Particles Studied: Fission Fragments - ^{252}Cf , ^{235}U , ^{238}U , ^{239}Pu , and ^{237}Np
Alpha Particles - 0 to 2.0 MeV from ^{10}B n, alpha & ^6Li n, alpha.
Protons - From ^{14}N n, p and proton recoils in plastic.
Recoils - Carbon, nitrogen and oxygen in plastic from 15-MeV neutrons.

Areas of Interest: Neutron Dosimetry
Neutron Radiography
Neutron Beam Profile Determinations

Track Analyses Performed: Track Area Density - 0 to over 10^6 tracks/ cm^2 .

Methods of Data Acquisition: Manual Microscopic Analysis
Automatic Scanning Device - See comments
Spark Counting

Comments: We have investigated computer-type particle scanning systems made by Millipore Corp., Leitz, Zeiss, Quantimet, and Bausch and Lomb. All have systems that appear to be useful for certain aspects of track counting. Unfortunately, these systems are expensive, with prices beginning at \$20,000. This cost can sometimes be shared by different research groups in the same laboratory, making the cost much more bearable.

Applied Dosimetry: Type - Neutron
Occasion - Routine Use
Type - Fixed Area Stations

Comments: We have 15 fixed Nuclear Accident Dosimeter stations with fission foils and polycarbonate registration foils. We also use thick foils of enriched ^{235}U in rem meter shields for Laboratory perimeter monitoring. The registration material is thin (0.00025 in.) polycarbonate which is spark counted after 6 months in the field. The limit of sensitivity of these systems is less than 1 millirem for this period.

Survey No. 48

Laboratory: Los Alamos Scientific Laboratory
Group H-1

Address: Los Alamos, New Mexico

Researcher: Dale E. Hankins

Registration Materials Studied: Polycarbonates

Nuclear Particles Studied: Fission Fragments - ^{239}Pu , ^{237}Np , U, Pb, Ta, Bi, Au.

Areas of Interest: Neutron Dosimetry

Other - In the future we plan to determine the high-energy neutron flux in our Mason Accelerator beam.

Track Analyses Performed: Track Area Density

Method of Data Acquisition: Spark Counting

Survey No. 49

Laboratory: University of Michigan
Nuclear Engineering Department

Address: 300 Auto Lab
North Campus
Ann Arbor, Michigan 48105

Researchers: David M. Gilliam and Glenn F. Knoll

Registration Materials Studied: Polycarbonates - Lexan, General Electric
Cronar - DuPont (Graphic Arts Film)

Comments: The commercial polycarbonate films used were of poor optical quality and sometimes fogged up when etched. We have found that KOH produces less foggy etching than NaOH. The use of Dowfax surfactant with the NaOH also produces good results.

Nuclear Particles Studied: Fission Fragments - ^{252}Cf and ^{235}U , 1 mg/cm², with
2.5 cm of He gas intervening.

Area of Interest: Cross-Section Measurements - Neutron

Comments: We are doing neutron cross-section measurements using photo-neutrons. The track-etch detectors were selected because of their insensitivity to the intense gamma background, and their ability to discriminate between alpha particles and fission fragments.

Track Analyses Performed: Track Area Density - 1000 - 2000 tracks/cm².
Total Track Count on Sample - Active area determined by
an aperture.

Method of Data Acquisition: Manual Microscopic Analysis - Projection microscope.
700 mm² area counted
4 mm² at a time.

Survey No. 50

Laboratory: University of North Carolina
Department of Physics
Address: Chapel Hill, North Carolina 27514
Researchers: Charles B. Childs and Lawrence M. Slifkin

Registration Materials Studied: Silver Chloride Crystals - produced locally.

Comments: Tracks are made visible by sweeping photoelectron through the crystal. Metallic silver forms on the tracks.

Nuclear Particles Studied: Alpha Particles
Other Particles

Comments: We have looked at heavy primary cosmic rays and at particles produced from Ag and Cl nuclei by bombardment with protons, etc.

Areas of Interest: Basic Registration Research
Cosmic Ray Studies
Effect of Trace Impurities on Performance of AgCl Crystals

Track Analyses Performed:

Comments: Our main emphasis so far has been on elucidating and controlling the effect of trace impurities on track registration.

Method of Data Acquisition: Manual Microscopic Analysis

Survey No. 51

Laboratory: University of San Francisco
Physics Department
Address: San Francisco, California 94117
Researcher: Dr. E. V. Benton

Registration Materials Studied: Mica
Polycarbonates
Cellulose Nitrate
Cellulose Triacetate

Nuclear Particles Studied: Fission Fragments
Alpha Particles - ^{241}Am
Other Particles - $2 \leq Z \leq 26$ cosmic ray particles

Areas of Interest: Basic Registration Research
Radon Dosimetry
Cosmic Ray Studies
Neutron Dosimetry
High Z and Energy Particles Dosimetry

Track Analyses Performed: Track Length

Method of Data Acquisition: Manual Microscopic Analysis

Survey No. 52

Laboratory: Washington University
Laboratory for Space Physics
Address: St. Louis, Missouri 63130
Researchers: F. H. Geisler, P. R. Phillips, and R. M. Walker

Registration Materials Studied: Polycarbonates
Nuclear Particles Studied: Fission Fragments
Area of Interest: Cosmic Ray Studies - Cosmic ray μ -induced fission of thorium and lead.

Track Analyses Performed: Track Area Density - 1 per 10 m^2 .

Comments: Counting is ultra-low-level spontaneous fission and cosmic ray μ -induced fission of heavy elements. Area of each sample is 1 to 10 m^2 . Background rate is less than one track and efficiency from an infinitely thick target is about 15%. Two 3.5- μ Kimfol sheets are sparked in coincidence.

Methods of Data Acquisition: Automatic Scanning Device - Pulse sparker
Spark Counting

Author's Note: This reply represents a specific area of work performed by Dr. Geisler, Dr. Phillips, and Dr. Walker. A much more complete description of Dr. Walker's work and interests can be found through his contribution to the bibliography, to be published.

Survey No. 53

Laboratory: Westinghouse Research Laboratories
Address: Pittsburgh, Pennsylvania 15235
Researcher: K. H. Sun

Registration Materials Studied: Mica
Polycarbonates - General Electric
Cellulose Nitrate - Eastman Kodak

Nuclear Particles Studied: Fission Fragments - ^{252}Cf , ^{235}U in the reactor.
Alpha Particles - From isotopic sources with energies about 5 MeV.

Area of Interest: Casual Track Parameter Studies

Track Analyses Performed: Track Area Density - About 10^5 tracks/cm 2 .

Method of Data Acquisition: Manual Microscopic Analysis

WEST GERMANY

Survey No. 54

Laboratory: Fachbereich Physikalische Chemie (Kernchemie)
Address: D355 Marburg
Lahnberge J4, Germany
Researcher: Dr. Kurt Starke

Registration Materials Studied: Mica
Polycarbonates
Glasses

Nuclear Particles Studied: Fission Fragments

Area of Interest: Basic Registration Research
Geologic Studies
Alpha Autoradiography

Method of Data Acquisition: Manual Microscopic Analysis

Survey No. 55

Laboratory: GSF-Institut für Strahlenschutz
Address: D 8042 Neuherberg
Germany
Researcher: Herwig G. Paretzke

Registration Materials Studied: Polycarbonates
Cellulose Nitrate - Self-made
Cellulose Acetate
Cellulose Triacetate
Cellulose Acetate Butyrate

Comments: Plastics obtained from Bayer, Dynamit Nobel and Leverkusens

Nuclear Particles Studied: Fission Fragments - ^{238}U , ^{235}U , and ^{232}Th
Alpha Particles - 1 to 5.5 MeV from ^{241}Am and ^{210}Po
Other Particles - Heavy ions (Li, Br, Cl, Fe, Ca) from
Tandem - accelerator MPI - Heidelberg
up to 10 MeV - accelerator voltage.

Areas of Interest: Basic Registration Research
Neutron Dosimetry

Comments: Main interest: Track formation phenomena and registration models.

Track Analyses Performed: Track Area Density - About 10^6 tracks/cm².
Track Length
Track Diameters as a Function of Etching Time

Methods of Data Acquisition: Manual Microscopic Analysis
Automatic Scanning Device - Flying spot scanner and
television with on-line com-
puter, both constructed and
operated by W. Abmayr of
this lab. Computer analysis
of the input data.

Spark Counting

Survey No. 56

Laboratory: Institut für Angewandte Reaktorphysik
Kernforschungszentrum Karlsruhe

Address: 75 Karlsruhe
Postfach 3640
Germany

Researcher: Not Indicated in Submission of the Survey

Registration Materials Studied: Polycarbonates - "Lexan," General Electric and
Makrofol, Bayer.

Nuclear Particles Studied: Fission Fragments - ^{235}U , ^{238}U , ^{239}Pu $10\text{ }\mu\text{g}/\text{cm}^2$.

Area of Interest: Cross Section Studies - Neutron

Track Analyses Performed: Track Area Density - $5 \times 10^3\text{ tracks}/\text{cm}^2$

Method of Data Acquisition: Automatic Scanning Device - Own development, Integramat

Survey No. 57

Laboratory: Institut für Kernchemie

Address: D-355, Marburg
Lahnberge, W. Germany

Researcher: Alexander H. Boos

Registration Materials Studied: Mica
Other - ThSiO_4

Nuclear Particles Studied: Fission Fragments

Area of Interest: Study of Ternary Fission

Track Analyses Performed: Track Area Density
Track Length
Angular Distributions

Method of Data Acquisition: Manual Microscopic Analysis

Survey No. 58

Laboratory: Institute of Nuclear Chemistry, Cologne

Address: Institut für Kernchemie der Universität
5 Köln 1
Zülpicherstr. 47
West Germany

Researchers: K. Thiel and W. Herr

Registration Materials Studied: Mica
Polycarbonates - Bayer-Leverkusen, Germany
Glasses - Antique uranium glasses, Silica glasses,
NBS-Standard 610-616; Leybold-Heraeus,
NBS.

Nuclear Particles Studied: Fission Fragments - ^{238}U , ^{235}U , ^{252}Cf .

Areas of Interest: Basic Registration Research
Cosmic Ray Studies
Neutron Dosimetry
Geologic Studies
Alpha Autoradiography
Other - Uranium distributions in terrestrial and extraterrestrial material.

Track Analyses Performed: Track Area Density - 10^2 to 10^8 tracks/cm²
Track Diameter

Methods of Data Acquisition: Manual Microscopic Analysis
Automatic Scanning Device - Leitz Classimat, Zeiss
Micro-Videomat
Spark Counting

Comments: The Automatic scanning devices mentioned are at our disposal in Giessen/Germany (Classimat) and Oberkochen/Germany (Micro-Videomat).

Applied Dosimetry: Type - Neutron
Occasion - For test only

Survey No. 59

Laboratory: Institut für Physik
Bundesanstalt für Milchforschung

Address: 23 Kiel
Hermann-Weigmann - Str. 1-27
West Germany

Researcher: Dr. A. Wiechen

Registration Materials Studied: Polycarbonates - "Makrofol N"^R, Farbenfabriken
Bayer AG

Nuclear Particles Studied: Fission Fragments - ²³⁵U

Area of Interest: Trace Analysis of Uranium in Biological Materials and Soils

Track Analyses Performed: Track Area Density - 10 to 10^4 tracks/cm²

Method of Data Acquisition: Manual Microscopic Analysis

Survey No. 60

Laboratory: Institut für Radiochemie der
Technischen Universität München

Address: 8046 Garching
Germany

Researchers: F. N. Flakus and J. M. Kesy
Director: Professor Dr. H. J. Born

Registration Materials Studied: Mica

Nuclear Particles Studied: Fission Fragments - natural uranium

Area of Interest: Geologic Studies

Track Analyses Performed: Track Area Density

Method of Data Acquisition: Spark Counting

Survey No. 61

Laboratory: Institut für Reine und Angewandte Kernphysik

Address: 23 Kiel, Olshausen Str. 40-60
West Germany

Researchers: W. Enge, K. P. Bartholoma, R. Beaujean, and K. Fukui*

* On leave from AFCRL; Bedford, Massachusetts USA

Registration Materials Studied: Mica

Polycarbonates - "Lexan," "Zelux" General Electric,
USA, "Makrofol" Bayer, Germany.

Cellulose Nitrate - "Daicel" Japan, Kodak Pathe',
France

Cellulose Acetate - Bayer, Germany

Nuclear Particles Studied: Fission Fragments - ^{252}Cf

Alpha Particles - 5.4 MeV from ^{241}Am

Protons - 0.5 to 1.5 MeV produced by a Van de Graff
Accelerator.

Other Particles - Lithium to argon, from cosmic rays and
accelerators.

Comments: The accelerators used were at:

1. Yale University, New Haven, Connecticut, USA

2. Heidelberg, Germany

3. University of California, Berkeley, California, USA

Areas of Interest: Basic Registration Research

Radon Dosimetry

Cosmic Ray Studies

Biological Studies - Radiation damage in biological systems*

Comments: * Collaboration for "Biostack" in Apollo 16 (and 17?)

Track Analyses Performed: Track Length

Other - Track width, sheet geometries

Methods of Data Acquisition: Manual Microscopic Analysis

Automatic Scanning Device - A device for sensing X, Y,
and Z coordinates to be
punched on computer cards.

Ozolid Imaging

Survey No. 62

Laboratory: Karlsruhe Nuclear Research Center
Health Physics Division
Radiation Monitoring Service

Address: Karlsruhe, Germany

Researcher: Ernst Piesch

Registration Materials Studied: Mica

Polycarbonates

Glasses - Phosphate

Cellulose Compounds

Nuclear Particles Studied: Fission Fragments - Neptunium, thorium, uranium

Alpha Particles

Recoil Particles

Areas of Interest: Basic Registration Research
Neutron Radiography
Neutron Dosimetry
Alpha Autoradiography
Trace Analysis of Uranium

Track Analyses Performed: Track Area Density

Methods of Data Acquisition: Manual Microscopic Analysis
Automatic Scanning Device - Mikrovideomat, Carl Zeiss,
Germany
Spark Counting

Applied Dosimetry: Type - neutron
Occasion - for special requirements
Use - fixed area monitors

Survey No. 63

Laboratory: Kernforschungsanlage Julich, Analytical Division

Address: D-517, Julich, Postfach 363
Central Institute for Analytical Chemistry
Germany

Researcher: Maximilian Wald

Registration Materials Studied: Polycarbonates
Cellulose Compounds - Macrofol, Bayer

Nuclear Particles Studied: Fission Fragments - ^{235}U
Recoil Particles - From neutron irradiation

Area of Interest: Trace Analysis for Uranium - In the microgram and nanogram range

Track Analyses Performed: Track Area Density - 400 to 4000 tracks/cm²

Method of Data Acquisition: Spark Counting

Survey No. 64

Laboratory: Kernforschungsanlage Julich
Health Physics Division

Address: D-517 Julich, Postfach 365
Germany

Researcher: M. Heinzelmann

Registration Materials Studied: Polycarbonates
Cellulose Compounds - Triafol TN from Bayer

Nuclear Particles Studied: Fission Fragments - ^{232}Th , ^{238}U , Bi, Au.
Recoil Particles - From neutron irradiation.

Area of Interest: Neutron Dosimetry

Track Analyses Performed: Track Area Density - Low to 10⁵ tracks/cm²

Methods of Data Acquisition: Manual Microscopic Analysis
Spark Counting

Applied Dosimetry: Type - neutron
Use - personnel worn dosimeters

Comments: 20 persons wear fission track dosimeters with 24 cm² thorium as
well as photographic films for neutrons

Survey No. 65

Laboratory: Max-Planck-Institute für Kernphysik

Address: Heidelberg, Germany

Researcher: Gunther A. Wagner

Registration Materials Studied: Mica

Glasses - Volcanic glasses, tektites, uranium glasses.
Other - Apatite, epidote, zircon, sphene

Nuclear Particles Studied: Fission Fragments

Areas of Interest: Cosmic Ray Studies
Geological Studies

Track Analyses Performed: Track Area Density
Track Length

Method of Data Acquisition: Manual Microscopic Analysis

Survey No. 66

Laboratory: Max-Planck-Institut für Kernphysik

Address: 69 Heidelberg
P.O. Box 1248
West Germany

Researchers: W. Kratschmer, T. Plieninger, R. Repnow, and V. Metag

Registration Materials Studied: Polycarbonates
Glasses - SiO_2
Pyroxenes

Nuclear Particles Studied: Fission Fragments - Study of lifetimes of fission isomers
with polycarbonates and spark counting.
Other - Artificially accelerated chlorine, calcium, iron,
iodine and uranium. Energy range 10-100 MeV.
Tracks in SiO_2 glass and pyroxenes.

Areas of Interest: Basic Registration Research
Cosmic Ray Studies

Track Analyses Performed: Track Area Density - $10\text{-}100\text{ tracks/cm}^2$
Track Length - For fission isomer studies

Methods of Data Acquisition: Manual Microscopic Analysis
Spark Counting

Survey No. 67

Laboratory: Philipps Universität
Fachgebiet Kernchemie
Fachbereich Physikalische Chemie

Address: 355 - Marburg/Lahn
Germany

Researcher: Professor Reinhard Brandt

Registration Materials Studied: Mica

Nuclear Particles Studied: Fission Fragments

Area of Interest: Fission Studies - Ternary fission, spontaneous fission

Track Analyses Performed: Track Area Density
Track Length
Angle Between Tracks

Method of Data Acquisition: Manual Microscopic Analysis

Survey No. 68

Laboratory: Physikalisches Institut
Address: Gmelin Str. 6
D74 Tuebingen, West Germany
Researcher: F. Goennenwein

Registration Materials Studied: Polycarbonates
Cellulose Compounds - Film backing

Nuclear Particles Studied: Fission Fragments - ^{252}Cf , ^{232}Th , ^{238}U

Area of Interest: Cross Section Measurements - Neutron

Track Analyses Performed: Track Area Density - Approximately 10^4 tracks/cm²
Track Length

Method of Data Acquisition: Manual Microscopic Analysis

Survey No. 69

Laboratory: Physikalisches Institut
Justus Liebig-Universitat
Address: 63 Giessen
West Germany

Researchers: Dr. Gerhard Fiedler, U. Hoppner, H. Schreck-Kollner, and J. Aschenbach

Registration Materials Studied: Mica
Glasses - See Comments

Comments:	Types of Glasses	Etching Solutions
a)	Phosphate Glasses	n/10 HNO ₃ , 10n NaOH
b)	Silicate Glasses (Quartz)	n/10 HNO ₃ , 48% HF
c)	Borate Glasses	n/10 HNO ₃ , 48% HF
d)	Glasses of different materials	n/10 HNO ₃ , 48% HF
e)	Mica	48% HF

Nuclear Particles Studied: Fission Fragments - ^{252}Cf , ^{235}U , and ^{232}Th

Comments: ^{235}U Fission fragments with known mass and kinetic energy were separated using the Munich fission particle mass spectrograph. These fragments then passed through Au foils and various thicknesses were employed to cover a wide range of kinetic energies.

^{232}Th Electron-induced fission with an electron accelerator.

Areas of Interest: Basic Registration Research
Cross Section Measurements

Comments: a) Energy discriminating detectors for fission fragments.
b) Energy distributions of fission fragments.
c) Angular distributions of fission fragments.
d) Cross section measurements.

Track Analyses Performed: Track Area Density - Approximately 10^3 tracks/cm².
Track Diameter

Comments: The track diameter is proportional to the energy of the fission fragments.

Methods of Data Acquisition: Manual Microscopic Analysis
Automatic Scanning Device - Classimat, Leitz

Comments: To the microscopic analysis:
The diameters of the etch pits were scanned under a microscope by use of an ocular micrometer. The micrometer was mechanically coupled to the balance point of a precise potentiometer to which a certain fixed voltage was applied. The indicated voltages were registered by a digital voltmeter and punched on paper tape for evaluation in a computer.

Survey No. 70

Laboratory: Staatliches Forschungsinstitut für Geochemie

Address: 86 Bamberg, Concordiastr. 28
Germany

Researchers: Priv.-Doz. Dr. Hans Meier and Dr. Wolfgang Hecker

Registration Materials Studied: Mica - Natural occurring micas
Polycarbonates - Bayer-Leverkusen
Glasses - Lead glasses, made in our institute
Cellulose Compounds - "Triafol TN," Bayer-Leverkusen
Other - Div. minerals in Mn-nodules

Nuclear Particles Studied: Fission Fragments - Uranium for preliminary studies.
Alpha Particles - Uranium and thorium series, samarium;
for preliminary studies.

Areas of Interest: Neutron Radiography
Geologic Studies
Alpha Autoradiography

Track Analyses Performed: Track Area Density

Comments: Track length analyses may be necessary later.

Method of Data Acquisition: Manual Microscopic Analysis

General Comments: We are at the beginning of our studies.

Survey No. 71

Laboratory: Technische Universität München
Physik Department

Address: 8046 Garching, Forschungsgelände
Germany

Researcher: E. Konecny

Registration Materials Studied: Glasses
Cellulose Compounds

Nuclear Particles Studied: Fission Fragments - ²³⁵U n, fission; ²⁵²Cf; ²³²Th gamma, fission; ²²⁶Ra gamma, fission.

Comments: Fission fragments selected according to mass and kinetic energy using a fission particle mass spectrograph (energy range 20 - 160 MeV).

Area of Interest: Cross Section Measurements - Photonuclear

Comments: Determination of kinetic energy distributions of fission fragments from e^- and gamma induced fission reactions.

Track Analyses Performed: Diameter of Etch Pits

Methods of Data Acquisition: Manual Microscopic Analysis
Automatic Scanning Device - Self-made

FRANCE

Survey No. 72

Laboratory: C. E. A. Steppa Dosimetrie Physique

Address: Centre D'Etudes Nucleaires
BP n° 6 Fontenay-Aux-Roses 92
France

Researchers: A. M. Chapuis, H. Francois, and G. Soudain

Registration Materials Studied: Polycarbonates
Glasses - C. E. C. Metaphosphates
Cellulose Nitrate - Kodak-Pathe' CA80-15 and LR115

Comments: Our main interest is in nitrocellulose.

Nuclear Particles Studied: Fission Fragments - $^{235,238}\text{U}$ and ^{252}Cf
Alpha Particles - 0 to 7.7 MeV

Areas of Interest: Basic Registration Research
Radon Dosimetry
Neutron Dosimetry
Alpha Autoradiography

Track Analyses Performed: Track Area Density - 10^2 to 10^6 tracks/cm²
Etch Rates - Minimal etching time to get tracks $>0.5\text{-}1\mu$.

Comments: The typical track area densities for different counting methods are:

10^2 to 10^6 tracks/cm² by automatic counting,
 10^3 to 1.5×10^5 tracks/cm² by photometric system,
 10^2 to 5×10^4 tracks/cm² by spark counting.

Methods of Data Acquisition: Manual Microscopic Analysis^a
Automatic Scanning Device^b - Quantimet 720
Spark Counting^c
Other^d - Evaluation of mean density by light transmission.

Comments: a, b - Used for basic registration research.
c - Studied but not used yet.
d - Used for radon and neutron dosimetry.

Survey No. 73

Laboratory: Centre de Recherches Kodak Pathe'

Address: 26 Avenue du Petit Parc
94 Vincennes, France

Researcher: J. F. Barbier

Registration Materials Studied: Cellulose Nitrate - Kodak-Pathe'

Nuclear Particles Studied: Alpha Particles - 1.6 to 5 MeV from uranium, plutonium, and americium in addition to n, alpha reactions on ^{10}B and ^6Li .

Protons - 3 GeV from the cyclotrons at Saclay and Cern.
Cosmic Rays

Areas of Interest: Radon Dosimetry
Cosmic Ray Studies
Neutron Radiography
Neutron Dosimetry
Geologic Studies
Alpha Autoradiography
Plutonium and Uranium dosimetry
Mapping of Boron in Steel

Track Analyses Performed:

Comments: For each alpha particle, a hole is punched through the 10- μ cellulose nitrate film coat of Kodak LR115 film.
Plutonium sources as low as 0.001 pCi have been measured, almost without background noise.

Method of Data Acquisition: Automatic Scanning Device

Comments: Track counting or measurement of the transmitted light through the holes.

Survey No. 74

Laboratory: Centre de Spectrometrie de Masse du CNRS

Address: 91 Campus
Orsay, France

Researcher: Dr. Michel Maurette

Registration Materials Studied: Mica
Natural Minerals

Comments: We are intensively studying natural minerals such as quartz, feldspars, pyroxenes, and phosphates.

Nuclear Particles Studied: Fission Fragments
Alpha Particles
Protons
Other Particles

Comments: Detection techniques for ions with very low energy ($0.1 < E < 100 \text{ keV/amu}$) have been developed.

Areas of Interest: Basic Registration Research
Cosmic Ray Studies
Geologic Studies
Implantation Effects

Track Analyses Performed: Track Area Density - up to $10^{12} \text{ tracks/cm}^2$.
Track Length
Track Etching Rates
Track Annealing

Comments: For measuring track density in excess of $10^{12} \text{ tracks/cm}^2$, we use the lattice disorder appearing in electron diffraction patterns

Method of Data Acquisition: Manual Microscopic Analysis

Comments: We also use a microdensitometer to measure the intensity of the diffuse electron scattering appearing in electron diffraction patterns.

Survey No. 75

Laboratory: College Scientifique Universitaire Chambéry

Address: Jacob-Bellecombette
73 Chambéry, France

Researcher: Jean-Charles Carfantan

Registration Materials Studied: Mica - From Madagascar, the Ivory Coast, and
Central France

Nuclear Particles Studied: Fission Fragments - The pile at CENG, Grenoble

Area of Interest: Geologic Studies - Dating

Track Analyses Performed: Track Area Density - $5 \text{ to } 3 \times 10^4 \text{ tracks/cm}^2$

Method of Data Acquisition: Manual Microscopic Analysis

Survey No. 76

Laboratory: Institut de Physique Nucleaire

Address: B. P. n°1 91 Orsay
France

Researcher: Claude J. Stephan

Registration Materials Studied: Mica
Cristalline Quartz

Nuclear Particles Studied: Fission Fragments - 156-MeV protons on Ta, La, Cd, and
In. Reactor neutrons on super heavy
elements.

Areas of Interest: Cross Section Measurements
Search for Superheavy Elements in Nature

Track Analyses Performed: Track Area Density - 10^4 tracks/cm^2
Track Length - Track length of correlated fission fragments.

Method of Data Acquisition: Manual Microscopic Analysis

Survey No. 77

Laboratory: Laboratoire de Physique Corpusculaire
Centre de Recherches Nucleaires

Address: Rue de Loess
67 Strasbourg-Cronenbourg

Researchers: M. Debeauvais, J. C. Marsaudon, J. Ralarosy, G. Remy, R. Stein,
and J. Tripier

Registration Materials Studied: Mica
Polycarbonates
Cellulose Nitrate - Bergerac Kodak

Nuclear Particles Studied: Fission Fragments - Uranium, thorium, neptunium and
californium
Alpha Particles - $C^{12} (n, n')$ 3 alpha with 14-MeV neutrons.
Other Particles - Boron, carbon, nitrogen, oxygen, neon,
and argon.

Comments: Fission study of heavy targets (U, Th, Bi, Pb, Au) by various in-
coming particles; alpha (50-100 MeV), deuterons (2 GeV), protons
(0.6 to 23 MeV) and Ne (10 MeV/nucleon), with polycarbonate
detector and a sandwich technique.

Areas of Interest: Basic Registration Research
Neutron Dosimetry
Cross Section Measurements
High-Energy Fission Studies

Comments: Other interests include laying of a semi-experimental range-energy relation for all ions in a polycarbonate (Makrofol) detector, and application of mass and charge discrimination.

Track Analyses Performed: Track Area Density - 10 to 10^6 tracks/cm²
Track Length
Other - Study of various ions with electronic microscopy.

Methods of Data Acquisition: Manual Microscopic Analysis
Automatic Scanning Device
Spark Counting
Electron Microscopy

Comment: The basis is a density measurement.

Applied Dosimetry:

Comments: Used not for personnel dosimetry, but for neutron dosimetry near the accelerator.

Survey No. 78

Laboratory: Physique des Solides
Address: Batiment S10 Faculte des Sciences
Orsay 91, France
Researcher: Dartyge

Registration Materials Studied: Mica - Natural
Quartz - Synthetic

Comments: The purpose of the investigation is to study track formation mechanism. Dosimetry problems are not considered.

Nuclear Particles Studied: Alpha Particles - 4 to 13 MeV/amu Van de Graff produced
Other Particles - O^{5+} 5 MeV/amu to 5 MeV/amu
Kr⁸⁺ 1 MeV/amu
A 0.5 MeV/amu to 10 MeV/amu

Area of Interest: Basic Registration Research

Track Analyses Performed: Track Area Density - Up to 10^{12} tracks/cm²
Low-Angle Scattering of X Rays

Method of Data Acquisition: X-Ray Analysis

Survey No. 79

Laboratory: Universite de Clermont
Laboratoire de Physique Corpusculaire
Address: 34 Ave. Carnot
63 Clermont-Ferrand, France
Researcher: Dr. Michel M. Monnin

Registration Materials Studied: Polycarbonates
Cellulose Triacetate - Bayer GmbH
Cellulose Nitrate - Bayer GmbH
Other - Polyvinylchloride, and every kind of plastic.

Comments: We are seeking general rules for relating sensibility to micromolecular structure. For that purpose we need to perform experiments with different kinds of plastics.

Nuclear Particles Studied: Fission Fragments
Alpha Particles - 4 MeV from ^{210}Po .
Other Particles - Heavy ions up to 10 MeV/amu.

Areas of Interest: Basic Registration Research
Cosmic Ray Studies
Geologic Studies

Comments: Basically, we are interested in registration phenomenon. We are particularly trying to find any experimental evidence for the delta ray criterion that we proposed in 1966. We irradiate plastics with very high dose rate electrons (as high as 10^4 amperes) and then compare with heavy ion effects by means of IR, UV spectra, ESR and chemical analysis. On the other hand, we are interested in a collaboration with Dr. Walker about moon samples and cosmic ray experiments.

Track Analyses Performed: Track Area Density
Track Length
Other - Measurement of apparition times.

Methods of Data Acquisition: Manual Microscopic Analysis
Automatic Scanning Device - Fluorescence
Other - Stereoscan Cambridge Electron Microscope

Comments: We try to set up a device that might allow us to find automatically the tracks filled with fluorescent dyestuff illuminated by UV light. The fluorescent light is collected either in a photomultiplier or a photodiode.

General Comment: We are also interested in technological applications of track etching.

JAPAN

Survey No. 80

Laboratory: Japan Atomic Energy Research Institute

Address: Tokai-Mura, Ibaraki-Ken
Japan

Researchers: Takeo Kikuchi, Shoichi Nasu, and Ken-Ichi Shiozawa

Registration Materials Studied: Uranium Oxide - UO_2 as evaporated film, Epytaxy film, and sintered material.

Nuclear Particles Studied: Fission Fragments - ^{235}U irradiated in the reactor.

Area of Interest: Basic Registration Research - Fission fragment irradiation research.

Track Analyses Performed: Track Area Density - 10^8 tracks/cm².
Track Length

Method of Data Acquisition: Manual Microscopic Analysis

Survey No. 81

Laboratory: Kanazawa University
Radiochemistry Laboratory
Address: Faculty of Science
1-1 Marunouchi, Kanazawa-Shi 920
Japan
Researchers: Takashi Nakanishi and Masanobu Sakanoue

Registration Materials Studied: Mica - Muscovite - No. 4 clear and slightly stained
block from the province of Bihar,
India

Polycarbonates - 1 mm thick

Glasses - Soda-lime glass

Cellulose Nitrate - Daicell, 100 μ thick

Nuclear Particles Studied: Fission Fragments - ^{227}Ac , ^{230}Th , ^{232}Th , ^{231}Pa , ^{232}U ,
 ^{238}U , ^{235}U , ^{237}Np , ^{238}Pu , ^{239}Pu ,
 ^{240}Pu , ^{241}Am .

Alpha Particles - Particles with energies from 3.5 MeV to
7.7 MeV from ^{237}Np , ^{241}Am , ^{222}Rn
(including daughters), ^{238}U , ^{234}U , ^{239}Pu ,
and the $^{12}\text{C}(n, 3\alpha)$ reaction using
14-MeV neutrons.

Deuterons - Energies from 5 to about 14.76 MeV

Comments: Radiation damage of mica by a deuteron beam was studied in the cross
section measurements of the $^{231}\text{Pa}(d, \text{fission})$ reaction.

Areas of Interest: Basic Registration Research
Radon Dosimetry
Neutron Dosimetry
Cross Section Measurements - Neutron and photonuclear reactions
Geologic Studies - Uranium analysis
Alpha Autoradiography

Track Analyses Performed: Track Area Density - 10^3 to 10^6 tracks/cm²

Methods of Data Acquisition: Manual Microscopic Analysis - Microscopic photographs
were taken at 200X, and
hand counting was carried
out on photographs.

Comments: Semiquantitative determination of the track density was also carried
out by photometer in dark-field illumination.

Survey No. 82

Laboratory: Kyoto University
Research Reactor Institute
Address: Kumatori-Cho, Sennan-Gun
Osaka, Japan
Researcher: Tetsuo Hashimoto

Registration Materials Studied: Mica
Polycarbonates - "Panlite," Teijin Co.
Glasses - Microscope cover glasses
Cellulose Nitrate - Daicel, 100 micron thickness
Polyester Film - Lumirror, just like mylar

Nuclear Particles Studied: Fission Fragments - Reactor produced
Alpha Particles - Particles with energies 4 MeV from ²⁴¹Am and other alpha emitters

Areas of Interest: Basic Registration Research
Neutron Dosimetry
Cross Section Measurements - 2-MeV and 5-MeV neutrons,
Geologic Studies
Alpha Autoradiography

Track Analyses Performed: Track Area Density
Track Length

Method of Data Acquisition: Manual Microscopic Analysis

Survey No. 83

Laboratory: Kyoto University
Research Reactor Institute

Address: Kumatori-Cho, Sennan-Gun
Osaka-Fu, Japan

Researcher: Dr. Shiro Iwata

Registration Materials Studied: Mica
Polycarbonates
Cellulose Nitrate

Comments: The mica and polycarbonates were used for the registration of fission tracks, and the cellulose nitrate was used for alpha tracks.

Nuclear Particles Studied: Fission Fragments -
Alpha Particles - 4 to 6 MeV from natural radionuclides.

Areas of Interest: Basic Registration Research
Neutron Dosimetry
Cross Section Measurements - Neutron
Geologic Studies
Alpha Autoradiography

Track Analyses Performed: Track Area Density
Track Length

Methods of Data Acquisition: Manual Microscopic Analysis
Automatic Scanning Device

Survey No. 84

Laboratory: Kyoto University
Research Reactor Institute

Address: Kumatori-Cho, Sennan-Gun
Osaka-Fu, Japan

Researcher: Takao Tsuruta

Registration Materials Studied: Mica - Muscovite mica and synthetic fluor-phlogopite mica,
Polycarbonates
Glasses - Metaphosphate glass: FD-1, FD-3
(Toshiba Co. Ltd.)
Cellulose Nitrate
Cellulose Acetate
Cellulose Acetate Butyrate

Nuclear Particles Studied: Fission Fragments - ^{233}U , ^{235}U , ^{232}Th
Alpha Particles - 0 to 5.30 MeV from uranium, thorium,
RaD+E
Other Particles - Recoil carbon and oxygen due to fast
neutrons

Area of Interest: Neutron Dosimetry
Quantitative Analysis of Fissionable Material

Track Analyses Performed: Track Area Density

Methods of Data Acquisition: Manual Microscopic Analysis
Automatic Scanning Device - π MC particle measurement
computer system - Millipore

Survey No. 85

Laboratory: Radiation Center of Osaka Prefecture

Address: Shinke-Cho, Sakai
Osaka, Japan

Researcher: Yatsuka Matsuda

Registration Materials Studied: Mica
Polycarbonate
Cellulose Compounds

Comments: In counting fission tracks, mica plates were used simply because of
the clarity of the fission track etch pit images.

Nuclear Particles Studied: Fission Fragments - Uranium (bremstrahlung, fission)
Alpha Particles - 5.11 and 5.16 MeV alphas from ^{239}Pu

Areas of Interest: Basic Registration Research
Cross Section Measurements - neutron and photonuclear
Alpha Autoradiography

Track Analyses Performed: Track Area Density - Approximately 10^4 tracks/cm²
Track Length

Comment: For synthesized mica plates, the background can be neglected.

Method of Data Acquisition: Manual Microscopic Analysis

Comments: In a maker's demonstration, it could be seen to count our fission
track etch pits in a mica plate very quickly by a device composed of
microscope, television camera and minicomputer.

ENGLAND

Survey No. 86

Laboratory: Atomic Energy Research Establishment
Analytical Chemistry Division

Address: Harwell, Didcot
Berkshire, England

Researcher: Dr. B. A. Loveridge

Registration Materials Studied: Cellulose Acetate

Nuclear Particles Studied: Alpha Particles - 1.47 MeV from the $^{10}\text{B}(n, \alpha)^7\text{Li}$
reaction.

Area of Interest: Measurement of Boron Concentrations

Track Analyses Performed: Track Area Density - 10^6 to 4×10^6 tracks/cm².

Method of Data Acquisition: Automatic Scanning Device - Quantimet Image Analysing Microscope (Metals Research Ltd., Royston, Herts., England)

Survey No. 87

Laboratory: Atomic Energy Research Establishment
Health Physics and Medical Division

Address: Harwell Didcot
Berkshire, England

Researcher: P. D. Holt

Registration Materials Studied: Polycarbonates - Makrofol N, 200 μ - Bayer

Nuclear Particles Studied: Fission Fragments - Thorium, ²³⁵U, ²³⁷Np, ²³⁸U

Area of Interest: Neutron Dosimetry

Comments: This method is used in "experimental" dosimetry, e.g. in connection with tests of the criticality locket, rather than routine dosimetry.

Track Analyses Performed: Track Area Density

Methods of Data Acquisition: Manual Microscopic Analysis
Spark Counting

Survey No. 88

Laboratory: Atomic Energy Research Establishment
Research Reactor Division

Address: Harwell, Berkshire
England

Researcher: Ron Matfield

Registration Materials Studied: Glasses - Sodium
Cellulose Acetate

Nuclear Particles Studied: Fission Fragments - ²³⁵U
Alpha Particles - Boron

Area of Interest: Neutron Radiography

Comments: Application - Measurement of fuel pin diameter
Potential Advantage - High resolution
Disadvantage - Lack of contrast

Survey No. 89

Laboratory: Fast Reactor Physics Division, UKAEA

Address: Atomic Energy Establishment
Winfrith, Dorchester
Dorset, England

Researcher: D. Jowitt

Registration Materials Studied: Polycarbonates - Bayer Chemicals Ltd.

Nuclear Particles Studied: Fission Fragments - ²³⁵U, ²³⁸U, ²³⁹Pu

Area of Interest: Cross Section Measurements - Neutron

Track Analyses Performed: Track Area Density - 10^4 to 6×10^4 tracks/cm²
Methods of Data Acquisition: Manual Microscopic Analysis
Automatic Scanning Device - Quantimet 'B'

Survey No. 90

Laboratory: Rutherford High Energy Laboratory
Address: Chilton, Didcot
Berkshire, England
Researcher: Dr. F. M. Russell

Registration Materials Studied: Mica - Muscovite

Nuclear Particles Studied: Fission Fragments
Alpha Particles - Having energies of a few MeV from the
uranium and thorium series isotopes.
Protons - Having energies of a few BeV from cosmic rays
Electrons - 1 MeV
Muons - BeV

Comments: Muons and electrons studied in detail.

Areas of Interest: Basic Registration Research
Cosmic Ray Studies
Geologic Studies
Channeling and Diffraction

Comments: We have examined beta tracks from ⁴⁰K in detail, also electron showers and muon tracks. The track recording is by decoration with iron impurity.

Track Analyses Performed: Track Area Density - Of the order of 1 track/cm²
Track Length - 0.5 cm for ⁴⁰K betas and 5 to 10 cm for
muons.
Angular, Length and Width Distributions

Comments: The parameters studied include:
Momentum determination from multiple scattering.
Angular distribution of beta tracks correlated to lattice.
Rutherford scattering of ⁴⁰K betas.
Energy loss rates.

Method of Data Acquisition: Manual Microscopic Analysis

Dosimetry Applications: Type - Neutron
Occasion - Routinely
Use - Personnel worn dosimeters
Employees monitored - 200

AUSTRALIA

Survey No. 91

Laboratory: Australian Atomic Energy Commission
Address: Lucas Heights
Sydney, Australia
Researcher: N. F. Conway

Registration Materials Studied: Polycarbonates
Cellulose Nitrate

Comments: Material fabricated in laboratory from I.C.I. nitrocellulose type HL 30/40, plus solvents and plasticizers. NRDL-1 recipe.

Nuclear Particles Studied: Alpha Particles - 0-5.49 MeV from ^{238}U , ^{222}Rn , ^{241}Am thick sources.

Areas of Interest: Basic Registration Research
Radon Dosimetry
Geologic Studies

Track Analyses Performed: Track Area Density - 100-1000 tracks/cm².

Methods of Data Acquisition: Manual Microscopic Analysis
Spark Counting

Survey No. 92

Laboratory: Australian Atomic Energy Commission

Address: A.A.E.C. Private Mailbag
Sutherland
NSW 2232
Australia

Researcher: Terence Wall

Registration Materials Studied: Mica - Plessey-Ducon Mica Products Dept.,
Villawood NSW.

Comments: Clear mica, about 0.003 cm thick showed negligible fossil track density upon etching in HF - that is negligible compared to the track densities obtained in neutron flux measurements using the track recorder technique.

Nuclear Particles Studied: Fission Fragments

Comments: Used in the Physics Division for reactor beam neutron flux measurements and for fission rate measurements in reactor fuel pins.

Method of Data Acquisition: Manual Microscopic Analysis

Comments: For a flux measurement, not more than 1000 tracks are recorded. The resulting estimate of the neutron flux is usually accurate enough for experimental requirements.

Survey No. 93

Laboratory: Particle Track Laboratory

Address: School of Geology
University of Melbourne

Researchers: Dr. J. F. Lovering, D. A. Wark, and A. J. W. Gleadow

Registration Materials Studied: Mica
Polycarbonates
Glasses - Soda-lime
Cellulose Compounds - Melinex, Cellulose acetate
butyrate I.C.I. Bayer
Other - Natural silicate, impact glasses.

Comments: The polycarbonate used in General Electric "Lexan," Sometimes suffers slight annealing. Mica is used only for very high neutron doses (e.g., 10^{18} neutrons/cm²) or for very accurate neutron dosimetry or uranium concentration measurement where no annealing could be tolerated. Soda-lime (microscope slide) glasses are also used for dosimetry in dating.

Nuclear Particles Studied: Fission Fragments - ^{252}Cf and fragments from reactor fast neutron and photofission of thorium.
Alpha Particles - From $^{10}\text{B}(n, \alpha)^7\text{Li}$ and $^6\text{Li}(n, \alpha)^3\text{H}$.
Other Particles - From the ^{10}B and ^6Li reactions above.

Area of Interest: Geologic Studies

Trace Analysis - Micro analysis of lithium and boron and thorium.

Comments: Geological studies including dating and concentration and distribution of U, Th, B, and Li in rocks. We are also interested in dating manmade glasses and in fission fragment range correction factors for various minerals.

Track Analyses Performed: Track Area Density - 10^3 to 10^7 tracks/cm².

Other - Track distribution and total numbers of tracks from point sources.

Method of Data Acquisition: Manual Microscopic Analysis

Comments: Fission tracks in plastic and mica are counted optically at 1680X magnifica. Fission tracks in glasses and mica are counted optically at lower magnifica. Alpha and recoil ion tracks are counted with a scanning electron microscope.

BELGIUM

Survey No. 94

Laboratory: Euratom
Central Bureau for Nuclear Measurements

Address: Steenweg Naar Retie,
2440 Geel, Belgium

Researcher: B. J. Mijnheer

Registration Materials Studied: Polycarbonates - Makrofol KG, thickness - 12 μ

Nuclear Particles Studied: Fission Fragments - ^{232}Th , ^{235}U (enriched)

Comments: Thick thorium and uranium sheets (100 resp. 200 μ).
Thin natural uranium and plutonium of about 0.1 mgm/cm².

Area of Interest: Neutron Dosimetry
Neutron Fluence Measurements

Track Analyses Performed: Track Area Density - 10-1000 tracks/cm².

Method of Data Acquisition: Spark Counting

Applied Dosimetry: Type - Neutron
Use - Personnel worn dosimeters

Comments: Finger and hand dosimeter for use in water-shielded gloveboxes during ^{252}Cf handling.

General Comments: A dependence was observed between the sensitivity of the detector and the angle between the impinging neutrons and the radiator-foil combination, e.g. for ^{252}Cf neutrons and a thorium radiator an increase in sensitivity occurs, if the radiator-foil combination is turned perpendicular to the neutron field. Also in the perpendicular position it makes a difference whether the radiator or the foil is placed toward the neutron source.

Survey No. 95

Laboratory: S.C.K. C.E.N.

Address: B 2400 - Mol
Belgium

Researcher: Marcel de Coster

Registration Materials Studied: Mica
Polycarbonates

Nuclear Particles Studied: Fission Fragments - ^{235}U , ^{238}U , ^{239}Pu

Areas of Interest: Neutron Dosimetry
Cross-Section Measurements - Neutron

Track Analyses Performed: Track Area Density - 10^5 tracks/cm²

Methods of Data Acquisition: Manual Microscopic Analysis
Automatic Scanning Device - Quantimet 720

Survey No. 96

Laboratory: State University of Ghent
Institute for Nuclear Sciences

Address: Proeftuinstraat
B-9000 Ghent
Belgium

Researcher: Renaat Gijbels

Registration Materials Studied: Mica - Phlogopite, low uranium content
Polycarbonates

Nuclear Particles Studied: Fission Fragments - ^{235}U

Areas of Interest: Geologic Studies
Trace Materials Analysis

Comments: We are using the technique for determination of uranium, especially in geological samples. The analysis is used particularly for contents below 0.5 ppm, where instrumental neutron activation analysis becomes difficult, or even impossible. Our instrumental technique involves measuring the 106-keV gamma ray of ^{237}Np with a Low Energy Photon Detector to separate the 106-keV gamma of ^{237}Np from the 103-keV gamma of ^{153}Sm and others. The lowest content we have determined so far is about 5 ppb uranium (in cooperation with H.T. Millard, U.S. Geological Survey, Denver, Colo.).

Track Analyses Performed: Track Area Density - 3,000 to 10^5 tracks/cm²

Method of Data Acquisition: Manual Microscopic Analysis

General Comment: Since we use the method primarily for uranium determination at low levels, track detectors of low uranium content must be used. For mica this is more difficult than for polycarbonate ("Lexan" or "Makrofol"). Annealing of the tracks and etching conditions are not too much of a problem, since the rock powder is accompanied by an analyzed rock sample ("standard rock," checked by isotope dilution - mass spec.), pressed against a similar foil.

CANADA

Survey No. 97

Laboratory: Atomic Energy of Canada Limited
Chalk River Nuclear Laboratories

Address: Chalk River, Ontario
Canada

Researcher: G. R. Bellavance

Registration Materials Studied: Cellulose Nitrate - B.X. Plastics, 134 Sunrise Ave.,
Toronto, Ontario

Comments: We have been using cellulose nitrate to register blocking patterns from single crystals using 1 to 2 MeV He⁺ beam. These are used as an aid in alignment of the single crystal. At the present, we have no major programs to use this method for making quantitative measurements. We would of course be interested to hear of any development in the field.

Survey No. 98

Laboratory: Chalk River Nuclear Laboratories

Address: Chalk River, Ontario
Canada

Researchers: Dr. William Cross and Dr. George Cowper

Registration Materials Studied: Polycarbonates
Cellulose Nitrate

Nuclear Particles Studied: Fission Fragments
Alpha Particles

Area of Interest: Neutron Dosimetry

Track Analyses Performed: Track Area Density

Methods of Data Acquisition: Manual Microscopic Analysis
Spark Counting

Survey No. 99

Laboratory: Dalhousie University
Department of Oceanography

Address: Halifax, Nova Scotia
Canada

Researcher: Dr. F. Aumento

Registration Materials Studied: Polycarbonates
Glasses - Natural and silica from volcanoes

Nuclear Particles Studied: Fission Fragments

Areas of Interest: Neutron Dosimetry
Geologic Studies
Uranium Mapping

Track Analyses Performed: Track Area Density - 3×10^4 to 5×10^5 tracks/cm²

Methods of Data Acquisition: Manual Microscopic Analysis
Photographic Mosaics of Track Densities

ITALY

Survey No. 100

Laboratory: CISE
Address: C. P. 3986
20100-Milan, Italy
Researcher: Marzio Mangialajo

Registration Materials Studied: Polycarbonates - Makrofol KG, Bayer

Nuclear Particles Studied: Fission Fragments - Uranium oxide*

Comments: *We use uranium oxide in the form of sinterized chips in order to have constant ranges for fission fragments. Natural uranium, depleted uranium (350 ppm ^{235}U) and enriched uranium (up to 1.1% ^{235}U) are used.

Areas of Interest: Neutron Dosimetry
Cross Section Measurements - Neutron

Track Analyses Performed: Track Area Density - Up to 3000 tracks/cm², for spark counting; for manual microscopic analysis, up to 10⁵ tracks/cm².

Methods of Data Acquisition: Manual Microscopic Analysis
Spark Counting

Applied Dosimetry: Type - Neutron
Occasion - For special requirements

Survey No. 101

Laboratory: Laboratorio di Dosimetria E Standardizzazione
Address: CSN, Casaccia
Roma, Italy
Researcher: L. Tommasino

Registration Materials Studied: Mica
Polycarbonates
Cellulose Nitrate - Bayer
Cellulose Acetate - Bayer
Cellulose Aceto-Butyrate - Bayer

Comments: Polycarbonate best for fission fragment registration. Cellulose triacetate and aceto-butyrate as sensitive as cellulose nitrate.

Nuclear Particles Studied: Fission Fragments - ^{252}Cf , metallic uranium, thorium
Alpha Particles - About 4.2 MeV from thick uranium

Areas of Interest: Basic Registration Research
Neutron Radiography
Neutron Dosimetry

Track Analyses Performed: Track Area Density 0 to 2000 tracks/cm²

Methods of Data Acquisition: Manual Microscopic Analysis
Spark Counting

Survey No. 102

Laboratory: Universita di Napoli
Inf. Sezione di Napoli
Address: Via Tari 3
80138 Napoli, Italy
Researcher: F. Carbona

Registration Materials Studied: Mica - Natural
Glasses

Nuclear Particles Studied: Fission Fragments

Areas of Interest: Basic Registration Research
Cross Section Measurements - Photonuclear

Track Analyses Performed: Track Area Density - 10^3 to 10^4 tracks/cm²
Track Length
Track Angle

Method of Data Acquisition: Manual Microscopic Analysis

SWITZERLAND

Survey No. 103

Laboratory: CERN
Address: CH-1211
Geneve 23, Switzerland
Researcher: J. R. Dutrannois

Registration Materials Studied: Polycarbonates - Commercial Makrofol

Nuclear Particles Studied: Protons - Up to 30 GeV from a proton synchrotron
Other Particles - μ , π , K up to GeV

Areas of Interest: Neutron Dosimetry
High-Energy Particle Dosimetry - With discrimination for spallation
interaction.

Track Analyses Performed: Track Area Density - From 100 tracks/cm²

Method of Data Acquisition: Manual Microscopic Analysis

Applied Dosimetry: Type - High energy particles
Use - Personnel worn dosimeters
Employees Monitored - 2000

Comments: This is an attempt to use track registration for special study, in
addition to the standard gamma and neutron film dosimeters.

Survey No. 104

Laboratory: CERN
Address: 1211 Geneva 23
Switzerland
Researcher: A. J. Herz

Registration Materials Studied: Polycarbonates
Cellulose Nitrate - Kodak

Nuclear Particles Studied: Protons - 600 MeV and about 22 GeV from the CERN accelerators.
Other Particles - Very heavy nuclei, 10 MeV/nucleon.

Areas of Interest: Basic Registration Research
Determination of High-Energy Beam Profiles
Fragmentation Studies

Track Analyses Performed: Track Area Density
Track Length

Methods of Data Acquisition: Manual Microscopic Analysis
Automatic Scanning Device - Microdensitometer

Survey No. 105

Laboratory: Eidgenossisches Institut für Reaktorforschung
Address: 5303 Würenlingen
Switzerland
Researchers: R. Richmond, B. Ruegger and S. Pretre

Registration Materials Studied: Polycarbonates - Bayer AG, 4047 Dormagen, Germany
Nuclear Particles Studied: Fission Fragments - Uranium metal (0.1 mm) plus thin deposits of fissile material.

Area of Interest: Other - Measurement of fission rate ratios in reactor lattices

Track Analyses Performed: Track Density - 10^4 to 2×10^5 tracks/cm²

Comments: The density limits are chosen to be consistent with an overall error of 1% in the measurement of the ratio of track densities on two track recorders.

Method of Data Acquisition: Automatic Scanning Device - Quantimet 720

Applied Dosimetry: Type - Neutron
Occasion - Routinely
Use - Personnel worn dosimeters
Number of Employees Monitored - About 100

Comment: Spark counting used.

Survey No. 106

Laboratory: Reactor Centrum Nederland
Address: Petten (N.H.), The Netherlands
Present Address: CERN, Geneva, Switzerland
Researcher: Jan W. H. Tuyn

Registration Materials Studied: Polycarbonates
Glasses - Phosphate
Cellulose Nitrate - 1. Bayer 2. LR115 from Kodak

Comments: Phosphate glass special made by Schott, Germany. Composition - 50.6% LiPO₃, 41.7% Al(PO₃)₃ and 7.7% AgPO₃.

Nuclear Particles Studied: Fission Fragments - ²³⁵U, ²³⁸U, and ²³²Th
Alpha Particles - LiF, Boron, phosphate glass, ²³⁹Pu, ²³⁵U

Other Particles - Recoils produced by fast neutrons in Makrofol polycarbonate.

Areas of Interest: Basic Registration Research

Neutron Radiography

Neutron Dosimetry

Alpha Autoradiography

Experimental Reactor Physics - See comments

Comments: Intracell fission density distributions, intracell fast neutron flux distributions, $^{238}\text{U}/^{235}\text{U}$ fission ratio measurements, etc.

Track Analyses Performed: Track Area Density - Up to 10^8 tracks/cm²
Track Length

Comments: Especially analysis of etch pit dimensions of recoil tracks in Makrofol after fast neutron exposure.

Methods of Data Acquisition: Manual Microscopic Analysis

Spark Counting

Microdensitometer

Comments: For relative measurements, a microdensitometer or a microscope photometer were used.

For absolute measurements like fission rates and ratios, manual counting with a microscope was preferred.

HUNGARY

Survey No. 107

Laboratory: Institute of Nuclear Research of the Hungarian Academy of Sciences

Address: 18/c Bem ter, Debrecen, 1, P.O.B. 51
Hungary

Researchers: Drs. L. Medveczky, G. Somogyi, B. Schlenk, L. Mesko, A. Valek,
and I. Hunyady

Registration Materials Studied: Micas

Polycarbonates

Glasses - Na-Ca, obsidian

Cellulose Nitrate

Cellulose Acetate

Polyesters

Nuclear Particles Studied: Fission Fragments - ^{232}Th , ^{238}U , ^{239}Pu
Alpha Particles - 0.5 to 10 MeV from ^{239}Pu , ^{241}Am and
nuclear reactions

Protons - Less than 1 MeV accelerator produced and from
nuclear reactions

Other Particles - ^3He and ^6Li (<2 MeV). Heavy ions: ^{16}O ,
 ^{20}Ne , ^{32}S , ^{40}Ar , (about 8 MeV/nucleon)

Areas of Interest: Basic Registration Research

Geologic Studies

Alpha Autoradiography

Investigation of Nuclear Reactions

Track Analyses Performed: Track Area Density - 10 to 10^6 tracks/cm²
Track Length
Track Diameter

Methods of Data Acquisition: Manual Microscopic Analysis

Spark Counting

Optical Density Measurements

Survey No. 108

Laboratory: Kossuth University
Institute of Experimental Physics

Address: Bem ter 18/a Debrecen
Hungary

Researchers: M. Varnagy, S. Juhasz, S. Nagy, and J. Csikai

Registration Materials Studied: Cellulose Compounds - T-Cellit from Veb-Filmfabrik
Wolfen

Nuclear Particles Studied: Fission Fragments - ^{238}U , ^{232}U
Alpha Particles - 5.15 MeV from ^{239}Pu
Protons - 300-700 keV from a Van de Graff generator.
Other Particles - Deuterons, tritons and ^3He from D/d, p/T,
D/d and n/ ^3He reactions

Areas of Interest: Basic Registration Research
Neutron Dosimetry
Cross Section Measurements - n, fission; gamma, fission; n, alpha;
and gamma, alpha reactions
Other - Angular distribution measurements

Track Analyses Performed: Track Area Density - 10^3 to 10^6
Track Length
Track Diameter

Method of Data Acquisition: Manual Microscopic Analysis

IRELAND

Survey No. 109

Laboratory: Institute for Advanced Studies

Address: 5 Merrion Square
Dublin 2, Ireland

Researcher: Denis O'Sullivan

Registration Materials Studied: Polycarbonates - "Lexan," General Electric. This was
was used for cosmic ray studies with
cooperation from G. E. in Dublin.
Cellulose Nitrate - Nixon-Baldwin Company
Lunar Materials

Nuclear Particles Studied: Cosmic Rays - $Z = 10$ to 92, from 40 MeV/nucleon to
10 GeV/nucleon.

Comments: The Lexan polycarbonate sheets were flown in balloons (~30 million
ft³) at the top of the atmosphere. We were studying the charge and
energy spectrum of very heavy elements, $Z = 26$ to transuranic.

Areas of Interest: Basic Registration Research - Carried on in conjunction with cosmic
ray research.
Cosmic Ray Studies

Track Analyses Performed: Track Area Density - 0 to 10^7 tracks/cm²
Track Length

Comments: The nuclei are identified mainly by measuring etching rates at
different points along the trajectory and residual range of the nucleus
from these points.

Methods of Data Acquisition: Manual Microscopic Analysis
Ozalid Imaging Process

Comments: The scanning for heavy nuclei is carried out by etching each tenth sheet in a stack for a predetermined time at a well controlled temperature so that sheet is completely etched through. The sheets are then exposed to ammonia gas in contact with ozalid paper and coincidences are sought between different sheets. The method is extremely successful!

Survey No. 110

Laboratory:

University College Dublin
Physics Department
Atmospheric Physics Lab.
Belfield Dublin 4
Ireland

Address:

Researcher: Dr. James P. McLaughlin

Registration Materials Studied: Cellulose Nitrate - "Daicel," Dai - Nippon Company, Japan.

Comments: The plastic used was 110 μ thick and clear. Etching is mainly performed at 20°C in 6.25N NaOH for 3½ hr. Attempts were made to make thin sheets of plastic 10 to 20 μ thick by dissolving the plastic sheet in a suitable solvent and pouring onto glass sheets. This was followed by slow evaporation and final annealing. Results were not very successful. Partial success was achieved by "casting" a thin sheet of cellulose nitrate on the aluminized side of a mylar sheet. By exposing this to alpha particles and etching the etchant produced large holes in the aluminum below the cellulose nitrate which were visible under low magnification. Unfortunately, these holes in the aluminum often "ran" together.

Nuclear Particles Studied: Alpha Particles - 5.99-MeV and 7.68-MeV radon daughter attached to aerosols.

Area of Interest: Radon Dosimetry - See Comments

Comments: The studies involve determination of the attachment ratio, etc. of radon daughters in the atmosphere to aerosols (condensation nuclei). The attachment of RaA and RaC' to condensation nuclei was performed on air containing these aerosols and a high concentration of radon gas (about 10⁻⁹ Ci/liter) in a large vessel in the laboratory. Samples were collected in millipore filters before and after various diffusion boxes. These were counted for alpha activity and energies using a surface barrier detector in conjunction with a multichannel analyzer. Some attempts were made to use plastics for this purpose but they proved to be unsuitable where one wanted energy resolution of the alphas.

Track Analyses Performed: Track Area Density - Approximately 200 to 2,000 tracks/cm². 4.5 cm² exposed area.

Method of Data Acquisition: Manual Microscopic Analysis "Unfortunately"

Comments: The manual microscopic analysis (counting mainly) of alpha tracks of density approximately 200 to 2000 tracks/cm² for one observer proved to be inaccurate and tedious. Because of this, as explained earlier, I attempted to improve track visualization by casting a thin layer of cellulose nitrate on the aluminized surface of a mylar sheet so that the NaOH would produce large holes in the aluminum. I would be interested in hearing of a commercially available plastic in thin sheets which could be used for the spark counting dosimetry of airborne alpha emitters.

NETHERLANDS

Survey No. 111

Laboratory: Philips
Address: Jacob Marisstraat 1
Son (N.Br.)
The Netherlands
Researcher: Dr. H. Pauw

Registration Materials Studied: Polycarbonates - Makrofol KG
Nuclear Particles Studied: Fission Fragments
Areas of Interest: Neutron Dosimetry
Cross Section Measurements
Neutron Spectroscopy
Track Analyses Performed: Track Area Density
Method of Data Acquisition: Spark Counting

AUSTRIA

Survey No. 112

Laboratory: Institut für Atomphysik der Universität Innsbruck
Address: Muellerstr. 23/I;
A-6020 Innsbruck, Austria
Researchers: Univ. Prof. Dr. M. Pahl; H. Ass. Dr. T. D. Mark; Ak Ass. E. Mark

Registration Materials Studied: Mica
Polycarbonates
Apatite
Nuclear Particles Studied: Fission Fragments - ^{235}U and ^{238}U
Area of Interest: Basic Registration Research
Geologic Studies
Other - Determination of uranium contents and of λ fission
Track Analyses Performed: Track Area Density - 10 to 10^6 tracks/cm²
Track Length
Fission Track Distribution
Method of Data Acquisition: Manual Microscopic Analysis

INDIA

Survey No. 113

Laboratory: Tata Institute of Fundamental Research

Address: Homi Bhabha, Colaba
Bombay -5, India

Researcher: D. Lal

Registration Materials Studied: Glasses - Natural
Polycarbonates - Lexan
Cellulose Nitrate - Japan
Silicates

Comments: Most of our studies concern observations in natural silicates—both terrestrial and extraterrestrial. The extraterrestrial samples include lunar materials.

Nuclear Particles Studied: Fission Fragments - ^{252}Cf , and other neutron-induced fissions

Areas of Interest: Basic Registration Research
Cosmic Ray Studies
Geologic Studies

Track Analyses Performed: Track Area Density - 10^4 to 10^{10} tracks/cm²

Method of Data Acquisition: Manual Microscopic Analysis

ISRAEL

Survey No. 114

Laboratory: The Weizmann Institute of Science
Isotope Department

Address: Rehovot, Israel

Researcher: David Samuel

Registration Materials Studied: Polycarbonates
Cellulose Acetate
Others

Nuclear Particles Studied: Alpha Particles - $^{17}\text{O}(n, \alpha)^{14}\text{C}$

Area of Interest: Isotopic Analysis - Analysis and localization of ^{17}O labeled compounds, particularly in biological materials.

General Comments: Research just beginning

POLAND

Survey No. 115

Laboratory: Institute of Nuclear Research
Reactor Physics Department

Address: Swierk post Otwock
Poland

Researcher: Krystyna Jozefowicz

Registration Materials Studied: Polycarbonates - "Makrofol E," Bayer
Cellulose Acetate

Comments: Makrofol E 0.2-mm-thick foil is basic material for track detectors used in reactor physics and health physics experiments. The nuclear particle registration in cellulose acetate is now under investigation.

Nuclear Particles Studied: Fission Fragments - Th, natural uranium and depleted uranium.

Alpha Particles - 0 to 4.7 MeV from thick natural uranium.
Other Particles - Carbon and oxygen recoils from neutron interactions with polymer foil constituents, neutron energy up to 14 MeV.

Comments: Dielectric track detectors are developed in our laboratory mainly for neutron fluence measurements; thus the nuclear particles of interest for this purpose are studied.

Areas of Interest: Basic Registration Research
Neutron Dosimetry
Alpha Autoradiography
Reactor Studies - Fission rate measurements

Comments: Basic registration research concerns the estimation of the energy threshold for neutron registration using recoil atom track recording. Neutron dosimetry covers neutron fluence measurements for reactor physics and health physics purposes. Alpha autoradiography is used occasionally to check the uniformity of fissionable deposits.

Track Analyses Performed: Track Area Density - 10^4 to 10^6 tracks/cm²
Track Length
Track Diameter

Methods of Data Acquisition: Manual Microscopic Analysis
Optical Density Measurements

Applied Dosimetry: Type - Neutron
Occasion - For special requirements
Use - Personnel worn dosimeters and fixed area stations
Number of Employees Monitored - 10

Comments: The fission track detectors are included in an experimental set of nuclear accident dosimeters.

ROMANIA

Survey No. 116

Laboratory: Institute for Atomic Physics
Of. Nuclear Photography

Address: P.O. Box 35
Bucharest, Romania

Researcher: Dr. Marieta Nicolae

Registration Materials Studied: Mica
Polycarbonates
Cellulose Nitrate - The detector foils are prepared
from collodium of commercial type
(firma Riedelhehaen)

Nuclear Particles Studied: Fission Fragments - Uranium deposited by evaporation.
Alpha Particles - 2 to 6 MeV from ^{241}Am and radium.
Heavy Ions - Carbon, argon, neon, sulfur, and oxygen,
6 to 8 MeV/nucleon

Areas of Interest: Basic Registration Research
Radon Dosimetry
Cosmic Ray Studies
Neutron Dosimetry

Track Analyses Performed: Track Area Density - 10 to 10^5 tracks/cm²
Track Length
Track Width

Comments: The track area density is performed for dosimetry purposes. The track length or width measurements are used for basic registration research or cosmic ray studies.

Methods of Data Acquisition: Manual Microscopic Analysis
Automatic Scanning Device

Applied Dosimetry: Type - Neutron
Use - Personnel worn dosimeters
Number of Employees Monitored - About 350 monthly
Type - Air borne alpha emitters, Radon dosimetry
Use - Personnel worn dosimeters
Number of Employees Monitored - About 200

SWEDEN

Survey No. 117

Laboratory: AB Atomenergi

Address: Studsvik
S-61101 Nyköping
Sweden

Researcher: Carl O. Widell

Registration Materials Studied: Mica
Polycarbonates

Nuclear Particles Studied: Fission Fragments - Plutonium, uranium, and neptunium

Areas of Interest: Neutron Radiography
Neutron Dosimetry

Track Analyses Performed: Track Area Density - Of the order of 100 tracks/cm²

Methods of Data Acquisition: Manual Microscopic Analysis
Spark Counting

Applied Dosimetry: Type - Neutron
Use - Fixed area monitors

TRINIDAD

Survey No. 118

Laboratory: University of The West Indies
Physics Department

Address St. Augustine, Trinidad

Researcher: Dr. E. Theodore Agard

Registration Materials Studied: Polycarbonates - Bayer Farben-Fabriken A.G., Germany

Nuclear Particles Studied: Fission Fragments

Area of Interest: Neutron Dosimetry

Track Analyses Performed: Track Area Density

Method of Data Acquisition: Spark Counting

General Comments: This work was really carried out at the University of Toronto in
Canada and I am just about to resume it here.

Appendix B

Spark Counting Survey Replies

Survey No. 2

Laboratory: Argonne National Laboratory
Applied Physics Division

Address: Building 316
Argonne, Illinois 60439

Researchers: Roland J. Armani, Charles E. Cohn, and Raymond Gold

Application: Neutron Dosimetry
Environmental Neutron Measurements

Registration Material Data: Plastic: Polycarbonate Thickness: 5 and 10 μ
Trade Name: Kimfol

General Comments: See survey submitted by MacAlester College for responses to the
the remaining questions.

Survey No. 3

Laboratory: Argonne National Laboratory
Chemistry Division

Address: 9700 S. Cass Avenue
Argonne, Illinois 60439

Researcher: Dale J. Henderson

Application: Radiography

Registration Material Data: Plastic: Polycarbonate Thickness: 10 μ
Trade Name: Kimfol

Exposure Conditions:

- Radiators Used: Californium, mercury, and polonium
- Radiator Exposed Area: 100 cm²
- Method of Handling or Supporting the Registration Material: Unsupported
- Radiator-Registration Material Separation Distance: Contact

Etching Conditions:

- Etchant: NaOH Concentration: 6N Temperature: 58.6°C Volume: 1800 ml
- Etching Time: 150 min Stirring Used?: No Wetting Agent Used?: No
- Heat Source: Constant temperature bath
- Material Pre-Treatment: None
- Rinse Conditions: Rinsed several times in distilled water, soaked 1-2 hr and
rinsed again.
- Drying Conditions: Air dried on a plexiglass sheet.

Comments: Since the foil is floated on the surface of the etchant, it is only etched
on one side by convection currents in the solution. The time of etching
is very dependent on the difference in temperature between the top and
bottom of the solution, making the use of a constant-temperature bath
more desirable than a hot plate as a heat source.

Counting Conditions:

- Solid Electrode Material: Highly polished stainless steel. Polarity: Positive
- Metallized Plastic Electrode: Aluminized mylar. Plastic Thickness: 0.004 in.
- Pressure Applied to Film During Counting: 50-100 g/cm²
- Count Termination Criterion: Usually counting 1½-2 min at each voltage.
- Is the Film Repositioned Between Counts: No, but the solid electrode is removed
several times during counting to view the
foil.
- Is the Film Cleaned Between Counts?: No

Comments: Since we count very few counts, we record all events visually. A
plateau is run and its shape is compared with a known standard shape
and efficiency.

System Performance:

Estimate of Efficiency in Counts per Etchable Track: 57%

Reproducibility: Very good

Experienced Difficulty with "Stuck" Count or Foil That Will Not Count?: Yes, in early work occasionally I would have a hole caused by some mechanical damage or chemical damage that was large enough to act as a short.

Comments: Because many investigators want to register a very large number of tracks per unit area, they choose an RC time constant that will give small holes. They are therefore more troubled by shorts.

General Comments: I began using KOH, but switched to NaOH when KOH was not available. I noticed no difference in performance except that I had to etch about twice as long. Different weights were tried on the counting foils. No difference was noticed in efficiency, although there was an increase in spurious holes at the edge of the counting disc as weight increased. It is my feeling that the use of a thin layer of rubber to give uniform pressure while counting may be OK, but a better approach is to try to have both the counting electrode and the material backing the Al-mylar foil as flat as possible, possibly two plates lapped against each other. Every effort should be used to keep the foil itself from wrinkling.

Survey No. 4

Laboratory: Argonne National Laboratory
Materials Science Division

Address: Argonne, Illinois 60439

Researchers: H. Berger and N. P. Lapinski

Application: Radiography

Registration Material Data: Plastic: Polycarbonate Thickness: 10 μ

Exposure Conditions:

Radiators Used: 235U

Radiator Thickness: 0.001 in. Exposed Area: 4 in.²

Method of Handling or Supporting the Registration Material: No special support

Radiator-Registration Material Separation Distance: Contact

Etching Conditions:

Etchant: NaOH Concentration: 6.5N Temperature: Room Etching Time: 18 hr

Stirring Used?: No

Material Pre-Treatment: None

Counting Conditions:

Solid Electrode Material: Brass Polarity: Positive

Metallized Plastic Electrode: Mylar

Pre-Spark Voltage: 800 V

Record Count Voltage: 500 V

System Performance:

Comments: Poor results for displaying radiographic images other than mere outlines of objects.

Survey No. 5

Laboratory: Argonne National Laboratory
Radiological Physics Division

Address: 9700 South Cass Avenue
Argonne, Illinois 60439

Researcher: David J. Simmons

Application: Autoradiography

Registration Material Data: Plastic: Cellulose nitrate Thickness: 5-30 μ
Source: Hercules Powder Co.

Exposure Conditions:

Radiator-Registration Material Separation Distance: Contact (air space only)

Etching Conditions:

Etchant: NaOH Concentration: 6.5N Temperature: Room Volu e: 100 ml
Etching Time: 2 hr Stirring Used?: Yes Wetting Agent Used: No
Material Pre-Treatment: None
Rinse Conditions: Distilled water
Drying Conditions: Room air

System Performance:

Estimate of Efficiency in Counts per Etchable Track: 100%
Reproducibility: 10%

Survey No. 9

Laboratory: Brookhaven National Laboratory

Address: Upton, New York 11973

Researcher: Carl Distenfeld

Application: Neutron Dosimetry:

Registration Material Data: Plastic: Polycarbonate Thickness: 10 μ
Trade Name: Kimfol

Exposure Conditions:

Radiators: ^{232}Th , ^{238}U

Exposed Area: Greater than 4.46 cm^2

Method of Handling or Supporting Registration Material: Concentric plastic rings
Radiator-Registration Material Separation Distance: Contact

Etching Conditions:

Etchant: KOH Concentration: 6N Temperature: 65°C Volume: 400 ml
Etching Time: 75 min Stirring Used?: No
Heat Source: Constant-temperature water bath
Material Pre-Treatment: Water plus detergent wash
Rinse Conditions: 5 min at room temperature
Drying Conditions: Oven dry at 100°C

Count Conditions:

Solid Electrode Material: Stainless steel Polarity: Positive

Counter Capacitance: 3000 pF

Pressure Applied to Film During Counting: 100 g/4.46 cm^2

Pre-Spark Voltage: 1060V Number of Pre-Spark Counts: 1

Record Count Voltage: 560 V Number of Counts for Measurement: 1

Count Termination Criterion: 5 sec after last spark

Is the Film Repositioned Between Counts?: Yes

Is the Film Cleaned Between Counts?: No

System Performance:

Reproducibility: 10%

Maximum Countable Track Density: Over 1000 sparks/4.46 cm²

Experienced Difficulty with "Stuck" Count or Foil That Will Not Count?: No

General Comments: Physical properties of spark counting are good for accelerator spectra.

Survey No. 15

Laboratory: E.G. and G.

Address: P.O. Box 98
Goleta, California 93017

Researcher: W. M. Quam

Applications: Neutron Dosimetry
Trace Element Analysis - ²³⁹Pu

Registration Material Data: Plastic: Polycarbonate Thickness: 0.0005" and 0.00025"
Trade Name: Kimfol Source: Kimberly Clark

Exposure Conditions: ²³²Th, ²³⁵U, ²³⁸U, and ²³⁹Pu (in tissue matrix)
Radiators Used: ²³²Th, ²³⁵U, ²³⁸U, and ²³⁹Pu (in tissue matrix)
Radiator Thickness: 0.01 to 2. μ Exposed Area: About 2 cm²
Method of Handling or Supporting the Registration Material: Supported on edges or directly on radiator surface.
Radiator-Registration Material Separation Distance: 0 to 0.010 in.

Etching Conditions:

Etchant: KOH Concentration: About 20% Temperature: 60°C Volume: 100 ml
Etching Time: 90 min Stirring Used?: Mechanical agitation
Wetting Agent Used?: No
Heat Source: Water bath
Material Pre-Treatment: Foils washed in detergent before irradiation
Rinse Condition: Tap water
Drying Conditions: Room air
Comments: It is important to have foils in a stress free mechanical condition during etching.

Count Conditions:

Solid Electrode Material: Brass Polarity: Positive
Metallized Plastic Electrode: Mylar Plastic Thickness: 0.003 in.
Counter Capacitance: 200 pF
Pressure Applied to Film During Counting: 3 lb over 2 cm²
Pre-Spark Voltage: 1200 V
Record Count Voltage: 500 V
Count Termination Criterion: 4 min
Is the Film Repositioned Between Counts?: No
Is the Film Cleaned Between Counts?: No

System Performance:

Estimate of Efficiency in Counts per Etchable Track: >90%
Reproducibility: σ = 3% at 10^9 nvt with 1 μ ²³⁸U, and fast neutrons
 σ = 3% at 4×10^8 nvt with 1 μ ²³⁵U and thermal neutrons
Maximum Countable Track Density: About 7×10^9 nvt with 2 μ ²³⁸U

Survey No. 18

Laboratory: General Electric
Nucleonics Laboratories

Address: Vallecitos Road
Pleasanton, California 94566

Researchers: H. W. Alter, J. L. Carroll, D. B. Lovett, H. D. Kosanke,
J. E. Gingrich, and H. S. Rosenbaum

Application: Research Only

Registration Material Data: Plastic: Polycarbonate Thickness: 0.0005 in.
Trade Name: Makrofol
Plastic: Cellulose Nitrate
Source: Laboratory Construction

Exposure Conditions:
Radiators Used: ^{235}U , ^{252}Cf collimated
Radiator Thickness: Thin fission plates Exposed Area: 1 cm^2
Radiator-Registration Material Separation Distance: $1/16$ to $1/8$ in.

Etching Conditions:
Etchant: NaOH Concentration: 6N Temperature: 60°C Stirring Used?: Yes
Wetting Agent Used?: Yes Type: Dowfax Concentration: 0.10%
Heat Source: Hot plate
Material Pre-Treatment: None
Rinse Conditions: Distilled water
Drying Conditions: Clean air

Counting Conditions:
Solid Electrode Material: Aluminum
Metallized Plastic Electrode: Aluminized mylar Plastic Thickness: 0.005 in.
Counter Capacitance: Variable
Pre-Spark Voltage: 0-2000 V
Record Count Voltage: 500-1500 V
Count Termination Criterion: When counts no longer occur
Is the Film Repositioned Between Counts?: Yes
Is the Film Cleaned Between Counts?: No

System Performance:
Estimate of Efficiency in Counts Per Etchable Track: Variable
Reproducibility: We experienced considerable non-reproducibility thus limited
our testing with spark counting.
Maximum Countable Track Density: 1000 to 3000
Experienced Difficulty with "Stuck" Count or Foil That Will Not Count?: Yes, with
our technique we had to reposition the films.

Survey No. 22

Laboratory: Iowa State University
Ames Laboratory

Address: Ames, Iowa 50010

Researchers: P. B. Hahn, M. A. Wechter, and A. F. Voigt

Applications: Alpha Counting
Lithium Surface Analysis by $^6\text{Li}(n, \alpha)^3\text{H}$ Reaction

Registration Material Data: Plastic: Cellulose Nitrate Thickness: 1.3-1.4 mg/cm²
Source: NRDL-1 Self-cast

Exposure Conditions:

Radiators Used: (1) ^{210}Po electroplated ^{210}Po (2) Lithium tungsten bronze crystal
Radiator Thickness: (1) Weightless on infinite backing Exposed Area: (1) 1 cm^2
(2) Infinite (2) 0.3 cm^2

Method of Handling or Supporting the Registration Material: Concentric rings

Radiator-Registration Material Separation Distance: ^{210}Po - 2.7 cm;

Bronze: contact

Etching Conditions:

Etchant: KOH Concentration: 28% Temperature: $40^\circ\text{--}43^\circ\text{C}$ Volume: 300 ml

Etching Time: 60-90 min Stirring Used?: See Comments

Wetting Agent Used?: No

Heat Source: Hot plate

Material Pre-Treatment: None

Rinse Conditions: Water rinse, 30 sec in 1% acetic acid, 20 min water rinse

Comments: Agitation consisted of shaking the mounted film in an up and down motion through an arc of approximately 2-3 mm at 4 cycles/sec (surface of film parallel to shaking motion). Etching in 6.5N NaOH for 300-350 min also gave satisfactory results.

Counting Conditions:

Solid Electrode Material: Brass Polarity: Positive

Metallized Plastic Electrode: Mylar Plastic Thickness: 1.75 mg/cm^2

Counter Capacitance: 50 pF

Pressure Applied to Film During Counting: Rubber stopper "finger pressure"
(Variations did not appear critical)

Pre-Spark Voltage: 600 V Number of Pre-Spark Counts: Alternate between counts

Record Count Voltage: 500 V Number of Counts for Measurement: 3-4

Count Termination Criterion: When no additional counts were recorded in 5-10 sec period.

Is Film Repositioned Between Counts: No

Is Film Cleaned Between Counts?: No

System Performance:

Reproducibility: Approached counting statistics for samples from same casting which were similarly exposed to 2.0-MeV alpha particles perpendicular to film surface and etched simultaneously.

Maximum Countable Track Density: $2500\text{--}3000/\text{cm}^2$

Experienced Difficulty with "Stuck" Count or Foil That Will Not Count?: No

Comments: Surface analysis by n, alpha reaction appears feasible. Count ratios between samples similarly exposed (film in contact with the surface) appear to be consistent within counting statistics if films from the same casting are employed and etching performed simultaneously.

Survey No. 25

Laboratory: MacAlester College

Address: St. Paul, Minnesota

Researchers: James H. Roberts and Frank J. Congel

Application: Neutron Dosimetry

Registration Material Data: Plastic: Polycarbonate Thickness: $10\text{ }\mu$

Trade Name: Kimfol

Plastic: Cellulose Nitrate Thickness: Variable

Source: Benton Type USF #3

Comments: The cellulose nitrate is still under investigation as a suitable recorder of alpha particles, to be studied using spark counting.

Exposure Conditions:

Radiators Used: ^{235}U

Radiator Thickness: $100\text{ }\mu\text{g/cm}^2$ Exposed Area: 100 cm^2

Radiator-Registration Material Separation Distance: Contact

Etching Conditions:

Etchant: KOH Concentration: 6.25N Temperature: Room
Etching Time: 22 hr Stirring Used?: No Wetting Agent Used?: No
Material Pre-Treatment: None
Rinse Conditions: Tap water for 15-20 min, then distilled water
Drying Conditions: Placed on paper towels until dry

Counting Conditions:

Solid Electrode Material: Brass Polarity: Positive
Metallized Electrode: Mylar Plastic Thickness: 100 gauge
Pressure Applied to Film During Counting: About 4 kg/100 cm² through foam rubber.
Pre-Spark Voltage: 1000 V Number of Pre-Spark Counts: 2
Record Count Voltage: 550 V Number of Counts for Measurement: 4 to 5
Count Termination Criterion: Counting stops.
Is the Film Repositioned Between Counts?: Only if wrinkled
Is the Film Cleaned Between Counts?: No

System Performance:

Estimate of Efficiency in Counts per Etchable Track: 70 to 90%
Reproducibility: $\pm 10\%$ (Outside of statistical uncertainty)
Maximum Countable Track Density: About 100 tracks/cm²
Experienced Difficulty with "Stuck" Count or Foil That Will Not Count?: Yes. The current meter indicates a short circuit across the foil when this condition appears. Apparently repositioning eliminates the dirt speck or whatever is causing the problem.

Survey No. 27

Laboratory: National Bureau of Standards
Activation Analysis Section

Address: Washington, D.C. 20284

Researcher: B. Stephen Carpenter

Application: Research Only

Registration Material Data: Plastic: Polycarbonate Thickness: 0.0005 in.

Exposure Conditions:

Radiators Used: Uranium-doped glasses

Survey No. 28

Laboratory: Naval Research Laboratory

Address: Washington, D.C. 20390

Researcher: John P. Wefel, Code 7026

Application:

Comments: Spark counting used to locate cosmic ray events (positions recorded by hand) in a stack of plastic detectors. We have not done any spark "counting."

Survey No. 32

Laboratory: Oak Ridge National Laboratory
Health Physics Division

Address: Oak Ridge, Tennessee 37830

Researcher: Dr. Klaus Becker

Applications: Neutron Dosimetry
Radiography
Radon Dosimetry

Registration Material Data: Plastic: Polycarbonate Thickness: 10 μ
Trade Name: Kimfol

Plastic: Cellulose Nitrate Thickness: About 15 μ
Source: Hercules material. Films lab. made.

Exposure Conditions:

Radiators Used: ^{241}Am , uranium, thorium, ^{237}Np , ^{239}Pu , ^{252}Cf

Radiator Thickness: Varies Exposed Area: Usually 2 to 3 cm^2

Method of Handling or Supporting the Registration Material: Retainer rings (nylon or polyethylene).

Radiator-Registration Material Separation Distance: Varies

Etching Conditions:

Etchant: KOH Concentration: 28% Temperature: 60°C Volume: $\frac{1}{2}$ liter

Etching Time: 2 hr Stirring Used?: Yes

Heat Source: Laboratory oven

Material Pre-Treatment: Normally none

Rinse Conditions: Laboratory water

Counting Conditions:

Solid Electrode Material: Brass or nickel Polarity: Negative

Pressure Applied to Film During Counting: 500 g, 150 g/cm^2

Pre-Spark Voltage: 600 V Number of Pre-Spark Counts: 1

Record Count Voltage: 500 V Number of Counts for Measurement: 2 to 5

Capacitance: 100 pF

Is the Film Repositioned Between Counts?: Sometimes

Is the Film Cleaned Between Counts?: Yes

System Performance:

Estimate of Efficiency in Counts per Etchable Track: Usually 90-98%, for alphas frequently less.

Reproducibility: Around 3-5% unless limited by counting statistics

Maximum Countable Track Density: 3000-5000 tracks/ cm^2

Experienced Difficulty with "Stuck" Count or Foil That Will Not Count?: Occasionally

Survey No. 36

Laboratory: Stanford Linear Accelerator

Address: P.O. Box 4349
Stanford, California 94305

Researchers: Dr. Goren Svensson* and Kenneth Kase

Application: Neutron Dosimetry
Cross Section Measurements

Registration Material Data: Plastic: Polycarbonate Thickness: 10 μ
Trade Name: Kimfol

* Present Address: Joint Center for Radiation Therapy, Department of Physics,
Harvard Medical School, 50 Binney Street, Boston, Mass. 02115.

Exposure Conditions:

Radiators: Thick radiators, primarily thorium Exposed Area: 1 cm²
Method of Handling or Supporting Registration Material: Concentric plastic rings
Radiator-Registration Material Separation Distance: Contact

Etching Conditions:

Etchant: KOH Temperature: 60°C Concentration: 5N Volume: 400 ml
Etching Time: 60 min Stirring Used?: Yes
Heat Source: Constant temperature water bath
Material Pre-Treatment: Foils tested at 1500 V for pinholes before use.
Rinse Conditions: Water and low concentration weak acid.

Count Conditions:

Solid Electrode Material: Stainless steel Polarity: Negative
Metallized Plastic Electrode: Mylar
Counter Capacitance: 2000 pF
Pressure Applied to Film During Counting: 1 lb, 14 oz lucite lid
Pre-Spark Voltage: 1500 V Number of Pre-Spark Counts: 1
Record Count Voltage: 485 V Number of Counts for Measurement: ≤5
Is the Film Repositioned Between Counts?: No
Is the Film Cleaned Between Counts?: No

System Performance:

Reproducibility: About 5%
Maximum Countable Track Density: Less than 900 tracks/cm².
Experienced Difficulty with "Stuck" Count or Foil That Will Not Count?: Yes. If the passive R-C circuitry is OK, I always get holes in the Al mylar. However, sometimes the scaler does not record without repositioning. I believe that the pulse train may be too fast under certain circumstances.

Survey No. 39

Laboratory: U.S. Geological Survey

Address: Building 15
Denver Federal Center
Denver, Colorado 80225

Researchers: H. T. Millard and P. J. Aruscavage

Application: Determination of Uranium Concentrations in Geologic Material.

Registration Material Data: Plastic: Polycarbonate Thickness: 10 μ
Trade Name: Kimfol

Exposure Conditions:

Radiators Used: Rock powders pelletized with cellulose
Radiator Thickness: 1-3 mm Exposed Area: 1 cm²
Method of Handling or Supporting the Registration Material: Mounted on polyethylene sheet.
Radiator-Registration Material Separation Distance: Contact

Etching Conditions:

Etchant: NaOH Concentration: 7N Temperature: 60°C Volume: 150 ml
Etching Time: 30 min Stirring Used?: Yes Wetting Agent Used?: No
Heat Source: Water bath
Material Pre-Treatment: None
Rinse Conditions: Distilled water
Drying Conditions: Air-dried 15 min

Counting Conditions:

Solid Electrode Material: Brass Polarity: Positive
Metallized Plastic Electrode: Aluminized mylar Plastic Thickness: 0.0005 in.
Counter Capacitance: 50,000 pF
Pressure Applied to Film During Counting: 10 g

Pre-Spark Voltage: 800 V Number of Pre-Spark Counts: 1
Record Count Voltage: up to 500 V
Is the Film Repositioned Between Counts?: Yes
Is the Film Cleaned Between Counts?: No
Comments: We are still experimenting to find the best conditions. We are worried that the altitude and dry air conditions for Denver may require modification of the procedures given in the literature.

System Performance:

Estimate of Efficiency in Counts per Etchable Track: About 0.6
Reproducibility: Not good under present conditions.
Maximum Countable Track Density: About 3000/cm²
Experienced Difficulty with "Stuck" Count or Foil That Will Not Count?: Yes. At present, we believe it is due to surface irregularities in the plate behind the mylar and wrinkles in the Kimfol.

General Comments: We are trying to improve our apparatus and procedure to achieve reproducibility.

Survey No. 47

Laboratory: University of California
Lawrence Livermore Laboratory
Address: P. O. Box 808
Livermore, California 94550
Researcher: Richard Griffith

Application: Neutron Dosimetry

Registration Material Data: Plastic: Polycarbonate Thickness: 6 to 12 μ
Trade Name: Kimfol

Exposure Conditions:

Radiators: ²⁵²Cf, ²³⁵U, ²³⁸U, ²³⁷Np, ²³⁹Pu
Radiator Thickness: Electroplated to 6 mgm/cm² Exposed Area: 3 cm²
Method of Handling or Supporting the Registration Material: Concentric rings -
outer ring of stainless steel, inner ring of Lexan.
Radiator-Registration Material Separation Distance: Contact to 0.040 in.

Etching Conditions:

Etchant: NaOH and KOH Concentration: 6N Temperature: 40°C Volume: 500 ml
Etching Time: 2 hr Stirring Used?: No Wetting Agent Used?: No
Heat Source: Constant temperature oil bath (eliminates concern about water evaporation).

Material Pre-Treatment: None
Rinse Conditions: 30 min in demineralized water (running).
Drying Conditions: 1 to 2 hr at 80°C.
Comments: Above conditions for 6- μ material.

Count Conditions:

Solid Electrode Material: Gold-plated copper. Polarity: Negative
Metallized Plastic Electrode: Mylar Plastic Thickness: 0.00025 in.
Counter Capacitance: 100 pF
Pressure Applied to Film During Counting: About 350 g/cm²
Pre-Spark Voltage: 800 V Number of Pre-Spark Counts: 2
Record Count Voltage: 500 V Number of Counts for Measurement: 3 to 5
Count Termination Criterion: 30-sec count time
Is the Film Repositioned Between Counts?: Not usually
Is the Film Cleaned Between Counts?: No

System Performance:

Estimate of Efficiency in Counts per Etchable Track: About 0.25
Reproducibility: σ = about 5%

Maximum Countable Track Density: 2000 counts/cm²
Experienced Difficulty with "Stuck" Count or Foil That Will Not Count?: Yes.
Seems to be a short resulting for debris in tracks.

Survey No. 48

Laboratory: Los Alamos Scientific Laboratory
Group H-1

Address: Los Alamos, New Mexico

Researcher: Dale E. Hankins

Application: Neutron Dosimetry

Registration Material Data: Plastic: Polycarbonate Thickness: 10 μ
Trade Name: Kimfol

Exposure Conditions:

Radiators Used: ²³⁹Pu, ²³⁷Np, ²³⁸U, Pb, Ta, Au, Bi

Radiator Thickness: Evaporated and up to 1/8-in.

Exposed Area: About 3 cm².

Method of Handling or Supporting the Registration Material: Foil wrapped around radiator or foil placed between concentric rings.

Radiator-Registration Material Separation Distance: None or at most the curvature of the radiator.

Comments: We use two techniques. One for the evaporated foils of Pu, Np, and U, and another method for the Pb, Au, Ta, Bi, and ²³⁸U with high-energy neutrons.

Etching Conditions:

Etchant: KOH Concentration: 5N Temperature: 70°C Volume: 1½ liters

Etching Time: 40 min Stirring Used?: Yes Wetting Agent Used?: No

Heat Source: Hot plate Material Pre-Treatment: None

Rinse Conditions: Acetic acid followed by tap water followed by distilled water.

Drying Conditions: Low temperature oven for about an hour.

Counting Conditions:

Solid Electrode Material: Copper Polarity: Negative

Counter Capacitance: 110 pF

Pressure Applied to Film During Counting: Plastic block, 2 in. X 4 in. diameter

Pre-Spark Data:

Pre-Spark Voltage: 600 V Number of Pre-Spark Counts: 3 plus one for each
500 sparks above 1500

Record Count Data:

Counting Voltage: 500 V Number of Counts for Measurement: Usually 4

Count Termination Criterion: 5 min or at least 1 min after the rapid sparking has stopped

Is the Film Repositioned Between Counts?: Yes, lifted and rotated.

Is the Film Cleaned Between Counts?: No, except to brush off any foreign material with a horsehair brush

System Performance:

Reproducibility: σ is 2% or maximum spread ± 4 to 5%, below 5000 counts.

Maximum Countable Track Density: 5000 sparks in a 3/4-in.-diam exposed area.

At 5000 it is 4% low. Above 6000 counts, not reproducible.

Experienced Difficulty with "Stuck" Count or Foil That Will Not Count?: Yes, sometimes due to moisture or traces of KOH. At other times, no explanation.

General Comments: The Kimfol has a shiny and a dull side. We find that the dull side up during counting gives us 10% more sparks than with the shiny side up. Care must be taken to expose and count the foil with the same side up.

Survey No. 51

Laboratory: University of San Francisco
Physics Department
Address: San Francisco, California 94117
Researcher: Dr. E. V. Benton

Application: Neutron Dosimetry

Registration Material Data: Plastic: Polycarbonate
Trade Name: Lexan, Makrofol
Plastic: Cellulose Nitrate
Source: Made in the lab.

Etching Conditions:

Etchant: NaOH Concentration: 6.25N Temperature: 40°C
Etching Time: 0.1 to 20 hr Stirring Used?: Yes
Wetting Agent Used?: Yes Type: Benax, 2A-1 Concentration: 0.1%
Material Pre-Treatment: Ultraviolet irradiated

Survey No. 52

Laboratory: Washington University
Laboratory for Space Physics
Address: St. Louis, Missouri 63130
Researchers: F. H. Geisler, P. R. Philips, and R. M. Walker

Application: Ultra-Low Level Fission Counting

Registration Material Data: Plastic: Polycarbonate Thickness: 3.5 μ
Trade Name: Kimfol

Exposure Conditions:

Radiators Used: Natural ores
Radiator Thickness: Infinitely thick for fission fragments Exposed Area: 10 m²
Method of Handling or Supporting the Registration Material: Plexiglass frames
Radiator-Registration Material Separation Distance: Contact

Etching Conditions:

Etchant: NaOH Concentration: 6.25N Temperature: 40.00°C Volume: 17 gal
Etching Time: 2-2.5 hr Stirring Used?: Yes
Wetting Agent Used?: Beuax Concentration: 0.05%
Heat Source: Glow quartz heater
Material Pre-Treatment: None
Rinse Conditions: Double deionized water after acid rinse.
Drying Conditions: Laminar flow clean room.

Counting Conditions:

Solid Electrode Material: Tool steel Polarity: Positive
Metallized Plastic Electrode: Mylar Plastic Thickness: 0.0005 in.
Pressure Applied to Film During Counting: Zero
Count Termination Criterion: One automatic pass

System Performance:

Estimate of Efficiency in Counts per Etchable Track: 85 $\pm$ 4%
Reproducibility: 100%

Maximum Countable Track Density: About $10/\text{cm}^2$

Experienced Difficulty with "Stuck" Count or Foil That Will Not Count?: Not relevant to our set-up

General Comments: We developed the pulse modification to overcome the difficulties of d.c. sparking. The pulse method has none of the problems of d.c. sparking. Counter capacitance is not important because the amount of energy in a spark is supplied by a charged line in the pulser. Also, there is no ambiguity as to when to stop counting. We use one automatic pass. Also background is low, 10-20 spurious counts/ ft^2 , with 3.5μ Kimfol and much lower at $6\text{-}\mu$ and $8\text{-}\mu$ material. We believe the pulse modification to be significantly better than the d.c. method in every respect.

Survey No. 55

Laboratory: GSF-Institut für Strahlenschutz

Address: D 8042 Neuherberg
Germany

Researcher: Herwig G. Paretzke

Application: Neutron Dosimetry

Registration Material Data: Plastic: Polycarbonate Thickness: 10μ
Trade Name: Makrofol KG, E

Exposure Conditions:

Radiators Used: Uranium and thorium sheets

Radiator Thickness: Thick compared to fission fragment ranges.

Exposed Area: $10\text{-}15 \text{ cm}^2$

Method of Handling or Supporting the Registration Material: Special frame

Radiator-Registration Material Separation Distance: Contact

Etching Conditions:

Etchant: KOH Concentration: 6N Temperature: 40°C Volume: 1 liter
NaOH 6.25N

Etching Time: 1 hr for most Stirring Used?: Yes

Wetting Agent Used?: Yes, Dowfax 2A1 Concentration: 0.05%

Heat Source: Constant temperature bath, $\pm 0.05^\circ\text{C}$

Material Pre-Treatment: Storage in the dark at room temperature.

Rinse Conditions: Washing in running water with finger tips to clean the etchant,
the rinsing in distilled water for $\frac{1}{2}$ hr.

Drying Conditions: $\frac{1}{2}$ hr at 80°C

Comments: Acid washing is preferred. Washing in normal water or distilled water only gives different counts.

Counting Conditions:

Solid Electrode Material: Nickel Polarity: Positive

Metallized Plastic Electrode: Steiner-Film^R Plastic Thickness: About $5\text{-}10 \mu$

Pressure Applied to Film During Counting: Pressed with some foam rubber,
pressure greater than 100 g/cm^2 .

Pre-Spark Voltage: 2000 V Number of Pre-Spark Counts: 1-5, depending on the
experiment.

Record Count Voltage: 600 V Number of Counts for Measurement: 5-10, some-
times only 1.

Count Termination Criterion: The count process is terminated after some time
waiting for additional pulses (about $\frac{1}{2}$ min since last
pulse).

Is the Film Repositioned Between Counts: No

Is the Film Cleaned Between Counts?: Most cases, no.

System Performance:

Estimate of Efficiency in Counts per Etchable Track: Depends strongly on etching
Reproducibility: Sometimes better than 1%, most cases better than 5% depending
on track density, etching etc.

Maximum Countable Track Density: Depends on thickness of the aluminum layer;
and area of electrode.

Experienced Difficulty with "Stuck" Count or Foil That Will Not Count: I had a
similar problem after marking the tracks with a pencil (for comparison between
visible tracks and count) the foil could not be counted again. The reason was
that the graphite of the pencil in the holes had enough conductivity to prevent
charging of the capacitor. I use a pre-resistor of 10 M Ω . After cleaning the
graphite, the foil could be counted again. Replace "graphite" by "aluminum
oxide" from the sparks and you may have the explanation for the mentioned
problem. If the "aluminum oxide" is connected with the solid electrode, as
observed with some electrode materials, this "counting poison" is removed by
repositioning the foil.

Survey No. 58

Laboratory: Institute of Nuclear Chemistry, Cologne

Address: Institut für Kernchemie der Universität
5 Köln 1
Zuelpicherstr. 47
West Germany

Researchers: K. Thiel and W. Herr

Application: Neutron Dosimetry - For test purposes only

Registration Material Data: Plastic: Polycarbonate Thickness: 10 μ
Trade Name: Makrofol KG

Exposure Conditions:

Radiators Used: 252Cf source, 210Po source

Radiator Thickness: Electroplated Exposed Area: About 1 cm²

Method of Handling or Supporting the Registration Material: Two concentric
plexiglass rings.

Radiator-Registration Material Separation Distance: 0.5 mm to 10 cm

Comments: Various separation distances (evacuated chamber) were used to
investigate the influence of different fission fragment incident angles.

Etching Conditions:

Etchant: KOH Concentration: 5N Temperature: 60°C Volume: 200 ml

Etching Time: 2 hr Stirring Used?: Yes Wetting Agent Used?: No

Heat Source: Water bath

Material Pre-Treatment: None

Rinse Conditions: Distilled water

Drying Conditions: Several hours at about 30°C.

Counting Conditions:

Solid Electrode Material: Brass Polarity: Positive

Metallized Plastic Electrode: Makrofol Plastic Thickness: 40 μ

Counter Capacitance: 100 pF to 5000 pF

Pressure Applied to Film During Counting: 200 g

Pre-Spark Voltage: 1000 V Number of Pre-Spark Counts: 1 to 5

Record Count Voltage: 460 V Number of Counts for Measurement: 3

Count Termination Criterion: Sparking rate becoming smaller than 1 spark/sec

Is the Film Repositioned Between Counts?: No

Is the Film Cleaned Between Counts?: Yes

System Performance:

Reproducibility: Within statistical error for about the next 3 counts, then increasing
number of sparks per track.

Maximum Countable Track Density: About 2000/cm²

Experienced Difficulty with "Stuck" Count or Foil That Will Not Count?: No

General Comments: Our main efforts at the moment concern uranium distribution in lunar material. The development of neutron dosimeters based on particle tracks is done in cooperation with the University of Giessen (G.L. Fangewisch, 1. Physikalisches Institut der Universität 63 Giessen, Leihgesterner Weg.).

Survey No. 60

Laboratory: Institut für Radiochemie der
Technischen Universität München

Address: 8046 Garching
Germany

Researchers: F. N. Flakus and J. M. Keszy
Director: Professor Dr. H.J. Born

Application: Determination of Uranium Content

Registration Material Data: Plastic: Polycarbonate Thickness: 10 μ
Trade Name: Makrofol KG

Exposure Conditions:

Radiators Used: Geological sample

Radiator Thickness: 1 mm Exposed Area: 28 mm diam

Radiator-Registration Material Separation Distance: Close

Comments: Irradiation of 8 samples is made by means of a rotating disc in reactor neutron flux

Etching Conditions:

Etchant: K₂H₂ Concentration: 6.25N Temperature: 40°C Volume: 0.3 liters

Etching Time: 60 min Stirring Used?: No Wetting Agent Used?: No

Heat Source: Constant temperature water bath

Material Pre-Treatment: None

Rinse Conditions: Distilled water

Drying Conditions: On filter paper at room temperature.

Counting Conditions:

Solid Electrode Material: Copper (Chromium plated) Polarity: Negative

Counter Capacitance: Variable

Pressure Applied to Film During Counting: About 0.01 kg/cm²

Pre-Spark Voltage: 2000 V

Record Count Voltage: 600 V

Is the Film Cleaned Between Counts?: No

Survey No. 62

Laboratory: Karlsruhe Nuclear Research Center
Health Physics Division
Radiation Monitoring Service

Address: Karlsruhe, Germany

Researcher: Ernst Piesch

Applications: Neutron Dosimetry

Radiography

Other - Determination of low-level uranium concentration in liquids and air samples.

Registration Materials Data: Plastic: Polycarbonate Thickness: 12 μ
Trade Name: Makrofol E

Exposure Conditions:

Radiators Used: Neptunium, uranium, and thorium

Radiator Thickness: About 40 $\mu\text{g}/\text{cm}^2$

Exposed Area: 1 and 2 cm^2

Method of Handling or Supporting the Registration Material: Two concentric plastic rings.

Radiator-Registration Material Separation Distance: Contact

Etching Conditions:

Etchant: KOH Concentration: 34% Temperature: 60°C Volume: 100 ml

Etching Time: 60 min Stirring Used?: No Wetting Agent Used?: No

Heat Source: Constant temperature bath

Material Pre-Treatment: Cleaning in ultrasonic

Rinse Conditions: Distilled water

Drying Conditions: Tissue, free air

Counting Conditions:

Solid Electrode Material: Stainless steel Polarity: Either

Metallized Plastic Electrode: Mylar foil Plastic Thickness: About 6 μ

Counter Capacitance: 110/170 pF

Pressure Applied to Film During Counting: 200 g

Pre-Spark Voltage: 1200 V Number of Pre-Spark Counts: 1

Record Count Voltage: 600 V Number of Counts for Measurement: 2

Count Termination Criterion: Counting time is about 2 min for high-density foils, down to 2 sec

Is the Film Repositioned Between Counts?: Yes

Is the Film Cleaned Between Counts?: Yes

System Performance:

Estimate of Efficiency in Counts per Etchable Track: 50% for thick foil, 70% for electroplated source.

Reproducibility: $\pm 10\%$ standard deviation

Maximum Countable Track Density: 5000 tracks/ cm^2

Experienced Difficulty with "Stuck" Count or Foil That Will Not Count?: Foils not clean, finger tips on mylar or detector foil.

Survey No. 63

Laboratory: Kernforschungsanlage Julich
Analytical Division

Address: D-517, Julich, Postfach 363
Central Institute for Analytical Chemistry
Germany

Researcher: Maximilian Wald

Application: Uranium Concentration

Registration Material Data: Plastic: Polycarbonate Thickness: 12 μ
Trade Name: Makrofol KG

Exposure Conditions:

Radiators Used: ^{235}U in natural uranium

Radiator Thickness: 8×10^{-9} to 3×10^{-7} g uranium/ cm^2 Exposed Area: 16 cm^2

Method of Handling or Supporting the Registration Material: After irradiation, the foils are fastened in a frame for etching.

Radiator-Registration Material Separation Distance: Contact

Etching Conditions:

Etchant: KOH Concentration: 35% Temperature: 50°C Volume: 1 liter

Etching Time: 40 min Stirring Used?: Yes Wetting Agent Used?: No

Heat Source: Constant temperature bath
Material Pre-Treatment: Water wash
Rinse Conditions: Tap water, followed by deionized water - 1 hr.
Drying Conditions: 1 hr in air

Counting Conditions:

Solid Electrode Material: Brass, surface gilded. Polarity: Negative
Metallized Plastic Electrode: Polyester Plastic Thickness: 25 μ
Pressure Applied to Film During Counting: 600 g
Pre-Spark Voltage: 700 V Number of Pre-Spark Counts: 1
Record Count Voltage: 500 V Number of Counts for Measurement: 5
Count Termination Criterion: First decrease in number of counts
Is the Film Repositioned Between Counts?: Yes
Is the Film Cleaned Between Counts?: Yes

System Performance:

Reproducibility: 10%
Maximum Countable Track Density: 250 counts (sparks)/cm² provided reproducibility.
Experienced Difficulty with "Stuck" Count or Foil That Will Not Count?: Short circuit Al-brass through the track-pores.

Survey No. 64

Laboratory: Kernforschungsanlage Julich
Health Physics Division

Address: D-517 Julich, Postfach 365
Germany

Researcher: M. Heinzelmann

Application: Neutron Dosimetry

Registration Material Data: Plastic: Polycarbonate Thickness: 10 to 12 μ
Trade Name: Makrofol KG

Exposure Conditions:

Radiators Used: Thorium (see comments)
Radiator Thickness: About 4 mg/cm² (electroplated) Exposed Area: 24 cm²
Method of Handling or Supporting the Registration Material: The registration foil is in a "film badge" on the radiator. After irradiation the foils are fastened in a Lucite frame for etching, (The foil is larger than the radiator).
Radiator-Registration Material Separation Distance: Contact
Comments: Some experiments have also been done with gold and bismuth radiators for dosimetry of high energy neutrons.

Etching Conditions:

Etchant: KOH Concentration: 35% Temperature: 40°C (see comments)
Volume: 1 liter Etching Time: See comments Stirring Used?: No
Wetting Agent Used?: No
Heat Source: Constant temperature bath
Material Pre-Treatment: None
Rinse Conditions: 1 hr with water
Drying Conditions: 3-5 hr in air
Comments: 1) Etching time - 1.3 hr for 10- μ Makrofol; 2.25 hr for 12- μ Makrofol.
In experiments with high-energy neutrons the etching time must be less (1.0 hr for the 12- μ foil), because the tracks of recoils appear faster.
2) With higher etching temperature, the results are not good.

Counting Conditions:

Solid Electrode Material: Stainless steel Polarity: Positive
Metallized Plastic Electrode: Polyester
Pressure Applied to Film During Counting: No

Pre-Spark Voltage: 1100 V Number of Pre-Spark Counts: 1
Record Count Voltage: 600 V Number of Counts for Measurement: 2 or more
Count Termination Criterion: About $\frac{1}{2}$ min. No difficulties because the number of tracks is small.

Is the Film Repositioned Between Counts?: No

Is the Film Cleaned Between Counts?: No

System Performance:

Reproducibility: 10%

Maximum Countable Track Density: 25 tracks/cm²

Experienced Difficulty with "Stuck" Count or Foil That Will Not Count?: No

Survey No. 66

Laboratory: Max-Planck-Institut für Kernphysik

Address: 69 Heidelberg
P.O. Box 1248
West Germany

Researchers: W. Kratschmer, T. Plieninger, R. Repnow, and V. Metag

Application: Registration of Fission Fragments from Isomeric Fission

Registration Material Data: Plastic: Polycarbonate Thickness: 10-15 μ
Trade Name: Makrofol

Exposure Conditions:

Radiators Used: Fission fragments (isomeric fission) Exposed Area: 100-500 cm²

Method of Handling or Supporting the Registration Material: Glass or plexiglass plates.

Radiator-Registration Material Separation Distance: About 5 cm

Etching Conditions:

Etchant: NaOH Concentration: 2N Temperature: 70°C Volume: 10 liters

Etching Time: 20 min Stirring Used?: Yes Wetting Agent Used?: No

Heat Source: Electrical plate

Material Pre-Treatment: None

Rinse Conditions: Washed in distilled water and alcohol

Drying Conditions: Air

Counting Conditions:

Solid Electrode Material: Copper plate Polarity: Positive

Metallized Plastic Electrode: Hostafan Plastic Thickness: 25 μ

Pressure Applied to Film During Counting: No

Pre-Spark Voltage: 1500 V

Record Count Voltage: 600 V

Is the Film Repositioned Between Counts?: No

Is the Film Cleaned Between Counts?: No

System Performance:

Estimate of Efficiency in Counts per Etchable Track: 80%

Reproducibility: $<\pm 10\%$

Maximum Countable Track Density: Over 200 cm⁻²

Experienced Difficulty with "Stuck" Count or Foil That Will Not Count?: Burn out of contact on metal film.

Survey No. 72

Laboratory: C. E. A. Steppa Dosimetrie Physique

Address: Centre D'Etudes Nucleaires
BP n° 6 Fontenay-Aux-Roses 92
France

Researchers: A. M. Chapuis, H. Francois, and G. Soudain

Application: Studied But Not Used

Registration Material Data: Plastic: Cellulose Nitrate Thickness: 8 μ
Source of Plastic: Kodak LR115

Exposure Conditions:

Radiator Used: Natural uranium

Radiator Thickness: $>100 \mu$ Exposed Area: 20 cm²

Method of Handling or Supporting the Registration Material: Coated on mylar film,
100 μ

Radiator-Registration Material Separation Distance: Contact

Comments: The cellulose nitrate is coated on the film by the manufacturer.
Handling, irradiation and etching are made before stripping the
cellulose nitrate from the mylar film.

Etching Conditions:

Etchant: NaOH Concentration: 6.25N Temperature: 60°C Volume: 1000 cm³

Etching Time: 15 min Stirring Used?: Yes Wetting Agent Used?: No

Heat Source: Constant temperature bath

Rinse Conditions: Deionized water at 60°C

Drying Conditions: Ambient air

Counting Conditions:

Solid Electrode Material: Brass Polarity: Negative

Metallized Plastic Electrode: Mylar Plastic Thickness: 6 μ . Al $< 300 \text{ \AA}$

Pressure Applied to Film During Counting: 40 g/cm²

Pre-Spark Voltage: 1000 V Number of Pre-Spark Counts: 1

Record Count Voltage: 500 V Number of Counts for Measurement: 1-10

Is the Film Repositioned Between Counts?: Yes

Is the Film Cleaned Between Counts?: No

System Performance:

Estimate of Efficiency in Counts per Etchable Track: 9% (for thick source of ²³⁵U)

Reproducibility: $2\sigma = 10\%$ for 1000 tracks/cm² and materials coming from the same
coating.

Maximum Countable Track Density: 4000/cm²

General Comments: The main difficulties for alpha counting are due to the use of
cellulose nitrate which is not easy to get with low and constant
thickness.

Survey No. 77

Laboratory: Laboratoire de Physique Corpusculaire
Centre de Recherches Nucleaires

Address: Rue Du Loess
67 - Strasbourg-Cronenbourg, France

Researchers: M. Debeauvais, J. C. Marsaudon, J. Ralarosy, G. Remy, R. Stein,
and J. Tripier

Application: Neutron Dosimetry

Registration Material Data: Plastic: Polycarbonate Thickness: 10 μ
Trade Name: Makrofol

Exposure Conditions:

Radiators Used: 238U
Radiator Thickness: Very thin or 2 mm Exposed Area: 1 cm²
Method of Handling or Supporting the Registration Material: Plastic rings
Radiator-Registration Material Separation Distance: Contact

Etching Conditions:

Etchant: KOH Concentration: 35% Temperature: 60°C Etching Time: 1 hr
Stirring Used?: No Wetting Agent Used?: No
Heat Source Used: Constant temperature baths
Material Pre-Treatment: None
Rinse Conditions: Distilled water
Drying Conditions: Air

Counting Conditions:

Solid Electrode Material: Brass Polarity: Positive
Metallized Plastic Electrode: Claryl Plastic Thickness: 13 μ
Counter Capacitance: 1000 pF
Pressure Applied to Film During Counting: 200 g/cm²
Pre-Spark Voltage: 1500 V
Record Count Voltage: 600 V Number of Counts for Measurement: 10
Count Termination Criterion: When count stops or becomes very slow.
Is the Film Repositioned Between Counts?: Yes
Is the Film Cleaned Between Counts?: Yes, for more than 10 counts.

System Performance:

Estimate of Efficiency in Counts per Etchable Track: 40 to 60%
Maximum Countable Track Density: 2000 to 2500/cm²
Experienced Difficulty with "Stuck" Count or Foil That Will Not Count?: No

Survey No. 87

Laboratory: Atomic Energy Research Establishment
Health Physics and Medical Division

Address: Harwell Didcot
Berkshire, England

Researcher: P. D. Holt

Application: Neutron Dosimetry

Registration Material Data: Plastic: Polycarbonate Thickness: 10 μ
Trade Name: Makrofol KG

Exposure Conditions:

Radiators Used: 0.002-in. thorium Exposed Area: 10 cm²
Comments: We have mostly done laboratory experiments where a piece of the registration material was used loose. The foils were pressed together with sponge rubber between two pieces of Perspex. However we are now trying a method of supporting the registration material in an annular plastic chip.

Etching Conditions:

Etchant: KOH Concentration: 400 g/liter Temperature: 60°C
Etching Time: 25 min Stirring Used?: Yes Wetting Agent Used?: No
Heat Source: Tempette heater/stirrer in water bath
Material Pre-Treatment: None
Rinse Conditions: About 15 min under tap water.
Drying Conditions: Dessicator
Comments: The KOH is in a stainless steel beaker which sits in the water bath. It has a separate stirrer from the Tempette.

Counting Conditions:

Solid Electrode Material: Brass Polarity: Negative
Metallized Plastic Electrode: Melinex Plastic Thickness: 0.001 in.
Pressure Applied to Film During Counting: Sponge rubber
Pre-Spark Voltage: 1000 V Number of Pre-Spark Counts: 1
Record Count Voltage: 450 V Number of Counts for Measurement: About 5
Count Termination Criterion: The count is always stopped after 30 sec.
Is the Film Repositioned Between Counts?: No

System Performance:

Estimate of Efficiency in Counts per Etchable Track: Spark count is about 70% of optical count on thick foil.
Reproducibility: 1% on repeated counts on one foil.
Maximum Countable Track Density: Not fully investigated but linear to 2000 counts/cm².
Experienced Difficulty with "Stuck" Count or Foil That Will Not Count?: No

Survey No. 91

Laboratory: Australian Atomic Energy Commission

Address: Lucas Heights
Sydney, Australia

Researcher: N. F. Conway

Application: Radon Dosimetry

Registration Material Data: Plastic: Cellulose nitrate Thickness: 15-20 μ
Source: Laboratory fabricated

Comments: Manufactured ex I.C.I. HL 30/40 nitrocellulose NRDL-1 recipe

Exposure Conditions:

Radiators Used: 238U, 222Rn, 241Am thick sources

Radiator Thickness: Thick sources Exposed Area: 259 in

Method of Handling or Supporting the Registration Material: Concentric perspex clamping rings.

Radiator-Registration Material Separation Distance: 0-5 cm

Etching Conditions:

Etchant: KOH Concentration: 28% Temperature: 40°C Volume: 500 ml
Etching Time: 180 min Stirring Used?: Yes Wetting Agent Used?: No
Heat Source: Oven and hot plate
Material Pre-Treatment: Annealed 80°C 16 hr
Rinse Conditions: Water. Cold tap water.
Drying Conditions: 40°C until dry

Counting Conditions:

Solid Electrode Material: Brass Polarity: Positive
Metallized Plastic Electrode: Cellulose acetate Plastic Thickness: 0.007 in +
0.0005 in Al

Counter Capacitance: 1000 pF

Pressure Applied to Film During Counting: Yes, by spring. Amount unknown.

Pre-Spark Voltage: 800 V Number of Pre-Spark Counts: 1

Record Count Voltage: 550 V Number of Counts for Measurement: 2

Count Termination Criterion: No counts after 30 sec

Is the Film Repositioned Between Counts?: No

Is the Film Cleaned Between Counts?: No

System Performance:

Estimate of Efficiency in Counts per Etchable Track: 50%

Reproducibility: $\pm 5\%$

Maximum Countable Track Density: Not determined.

Experienced Difficulty with "Stuck" Count or Foil That Will Not Count?: Yes.

Repositioning and cleaning the foil and electrode and increasing electrode pressure appears to cure problem. Therefore have assumed dirty foil or electrode, debris or lack of good contact as cause of problem.

Survey No. 94

Laboratory: Euratom
Central Bureau for Nuclear Measurements

Address: Steenweg Naar Retie
2440 Geel, Belgium

Researcher: B. J. Mijheer

Application: Neutron Dosimetry

Registration Material Data: Plastic: Polycarbonate Thickness: $12\ \mu$
Trade Name: Makrofol KG

Exposure Conditions:

Radiators Used: Thorium, ^{235}U (93.5%)

Radiator Thickness: $0.105 \pm 0.005\ \text{mm}$ Exposed Area: $3.14\ \text{cm}^2$

Method of Handling or Supporting the Registration Material: Makrofol foil is resistance welded on several points between two steel rings.

Radiator-Registration Material Separation Distance: Contact

Etching Conditions:

Etchant: NaOH/KOH Concentration: 6N Temperature: 60°C Volume: 400 ml

Etching Time: 60 min Stirring Used?: Yes

Heat Source: Constant temperature water bath.

Material Pre-Treatment: None

Rinse Conditions: Rinsing in demineralized water.

Drying Conditions: Drying with filter paper and at least 1 hr on the radiator of the central heating system.

Counting Conditions:

Solid Electrode Material: Nickel electroplated on copper. Polarity: Positive

Metallized Plastic Electrode: Mylar; Helladur MB (Westfälische Metall Industrie KG, Lippstadt/Germany).

Plastic Thickness: $25\ \mu$

Counter Capacitance: 1000 pF

Pressure Applied to Film During Counting: Yes, but not measured.

Pre-Spark Voltage: 1100 V Number of Pre-Spark Counts: 4

Record Count Voltage: 550 V Number of Counts for Measurement: 3-5

Count Termination Criterion: 30 sec counting time

Is the Film Repositioned Between Counts?: Turned after each count.

Is the Film Cleaned Between Counts?: No

System Performance:

Reproducibility: Track density less than $500\ \text{cm}^{-2}$; 1-2%

Track density less than $1000\ \text{cm}^{-2}$; 2-4%

Track density more than $1000\ \text{cm}^{-2}$; Over 4%

Maximum Countable Track Density: Not yet measured.

Experienced Difficulty with "Stuck" Count or Foil That Will Not Count?: Sometimes,
No explanation.

General Comments: Another important quantity is the maximum track density that does not yet give a deviation from the linearity between the track density versus the neutron fluence (number of fission fragments). This amounts in our case to about $500\ \text{cm}^{-2}$. The reproducibility becomes less than satisfactory above this track density.

Survey No. 98

Laboratory: Chalk River Nuclear Laboratories

Address: Chalk River, Ontario
Canada

Researchers: Dr. William Cross and George Cowper

Application: Neutron Dosimetry

Registration Materials Data: Plastic: Polycarbonate Thickness: 10 μ
Trade Name: Makrofol KG

Exposure Conditions:

Radiators: ^{232}Th , $^{237}\text{Np-Al}$

Exposed Area: 5 cm^2

Radiator-Registration Material Separation Distance: Contact

Etching Conditions:

Etchant: KOH Concentration: 28% Temperature: 40°C Volume: 1 liter

Etching Time: 3 hr Stirring Used?: Yes

Heat Source: Constant temperature water bath.

Material Pre-Treatment: None

Rinse Conditions: Running, cold water about 10 min

Count Conditions:

Solid Electrode Material: Nickel or brass Polarity: Negative

Counter Capacitance: 100 pF

Pressure Applied to Film During Counting: 100 to 500 g/cm^2 (not critical to reproducibility).

Pre-Spark Voltage: 1500 V Number of Pre-Spark Counts: 2 or 3

Record Count Voltage: 500 V Number of Counts for Measurement: 2

Is the Film Repositioned Between Counts?: No

Is the Film Cleaned Between Counts?: Only between prespark and record counts.
Washed with dilute KOH, and rinsed in water.

System Performance:

Reproducibility: Repeated counts of same Makrofol - $\sigma \leq \pm 1\%$. Reproducibility of many Makrofol foils exposed to same neutron flux $\sigma \leq \pm 2\%$ after statistical variations (2%) subtracted in quadrature.

Maximum Countable Track Density: 3000/ cm^2 for 10% counting loss.

Experienced Difficulty with "Stuck" Count or Foil That Will Not Count?: Yes, occasionally. Short circuit through Makrofol from evaporated aluminum, so voltage cannot build up. Does not occur when foil is cleaned as above after precount sparking.

Survey No. 100

Laboratory: CISE

Address: C.P. 3986
20100-Milan, Italy

Researcher: Marzio Mangialajo

Applications: Neutron Dosimetry

Registration Material Data: Plastic: Polycarbonate Thickness: 8 μ
Trade Name: Makrofol KG

Exposure Conditions:

Radiators Used: UO_2 sinterized or vacuum deposited.

Radiator Thickness: Variable Exposed Area: About 3 cm^2

Method of Handling or Supporting the Registration Material: By vacuum or teflon tweezers - no supporting material.

Radiator-Registration Material Separation Distance: Contact

Etching Conditions:

Etchant: NaOH Concentration: 30% Temperature: 60°C Volume: 100 ml
Etching Time: 45 min Stirring Used?: Yes* Wetting Agent Used?: No
Heat Source: Hot plate with magnetic agitator.
Material Pre-Treatment: None
Rinse Conditions: Distilled water with ultrasonics
Drying Conditions: Between Tex-wipe R cloths.
Comments: *Each plastic sample has a container with magnetic ball for stirring.
Many containers on the same hot plate for etching.

Counting Conditions:

Solid Electrode Material: Inox Polarity: Negative
Metallized Plastic Electrode: Makrofol KG Plastic Thickness: 10 μ
Counter Capacitance: 500 pF
Pressure Applied to Film During Counting: About 100 g/cm²
Pre-Spark Voltage: About 1000 V Number of Pre-Spark Counts: 1
Record Count Voltage: 550 V Number of Counts for Measurement: 5 to 6
Count Termination Criterion: Time depending on track density.
Is the Film Repositioned Between Counts?: No
Is the Film Cleaned Between Counts?: No

System Performance:

Estimate of Efficiency in Counts per Etchable Track: Not measured
Reproducibility: Good for the first 10 counts on the same sample. 10% between
two samples irradiated and etched in the same conditions.
Maximum Countable Track Density: About 3000 tracks/cm²
Experienced Difficulty with "Stuck" Count or Foil That Will Not Count?: No
problems at all!

Survey No. 101

Laboratory: Laboratorio di Dosimetria E Standardizzazione

Address: CSN, Casaccia
Roma, Italy

Researcher: L. Tommasino

Application: Neutron Dosimetry

Registration Material Data: Plastic: Polycarbonate Thickness: 10 and 6 μ
Trade Name: Makrofol

Exposure Conditions:

Radiators Used: ²⁵²Cf, thick natural uranium, thorium
Radiator Thickness: Infinite thickness Exposed Area: 3 cm²
Radiator-Registration Material Separation Distance: Contact

Etching Conditions:

Etchant: KOH Concentration: 30% Temperature: 40°C Volume: 1 liter
Etching Time: 3 hr Stirring Used?: No Wetting Agent Used?: No
Heat Source: Ultrathermostat
Material Pre-Treatment: Yes
Rinse Conditions: Freon and ultrasonic

Counting Conditions:

Solid Electrode Material: Brass Polarity: Positive
Metallized Plastics Electrode Thickness: About 30 μ
Counter Capacitance: 500 pF
Pressure Applied to Film During Counting: 500 g/cm²
Pre-Spark Voltage: 1500 V in steps of 100 Number of Pre-Spark Counts: 10 μ - 3
6 μ - 1
Record Count Voltage: 500 V Number of Counts for Measurement: 1
Count Termination Criterion: Complete stop

Is the Film Repositioned Between Counts?: No

Is the Film Cleaned Between Counts?: No

System Performance:

Reproducibility: Reproducibility on the same foil better than 1% for thicknesses down to 4 μ .

Maximum Countable Track Density: 2000 tracks/cm²

Survey No. 105

Laboratory: Eidgenossisches Institut für Reaktorforschung

Address: 5303 Würenningen
Switzerland

Researchers: S. Pretre, R. Richmond, and B. Ruegger

Application: Neutron Dosimetry

Registration Material Data: Plastic: Polycarbonate Thickness: 10 μ
Trade Name: Makrofol KG

Exposure Conditions:

Radiators Used: ²³²Th and ²³⁵U-Al Alloy

Radiator Thickness: 0.2 mm Exposed Area: 2.5 cm²

Method of Handling or Supporting the Registration Material: Makrofol frame
0.4 mm thick

Radiator-Registration Material Separation Distance: Contact

Etching Conditions:

Etchant: KOH Concentration: 28% Temperature: 60°C Volume: 3 liters

Etching Time: 30 min

Heat Source: Water bath

Material Pre-Treatment: None

Rinse Conditions: Water

Drying Conditions: Warm air flow 50°C

Counting Conditions:

Solid Electrode Material: Steel

Metallized Plastic Electrode: Mylar Plastic Thickness: 25 μ

Counter Capacitance: 1000 pF

Pressure Applied to Film During Counting: Not measured, but low

Pre-Spark Voltage: 900 V

Record Spark Voltage: 550 V

Count Termination Criterion: Time Δt between sparks

Is the Film Repositioned Between Counts?: No

Is the Film Cleaned Between Counts?: No

System Performance:

Estimate of Efficiency in Counts per Etchable Track: About 35%

Reproducibility: $\pm 2\%$

Maximum Countable Track Density: 1000-2000 sparks/cm²

Experienced Difficulty with "Stuck" Count or Foil That Will Not Count?: Yes. Reduce the pressure applied from the electrode on the film.

Survey No. 106

Laboratory: Reactor Centrum Nederland
Address: Petten (N.H.), The Netherlands
Present Address: CERN, Geneva Switzerland
Researcher: Jan W. H. Tuyn

Application: Neutron Dosimetry

Comments: The development of the spark counting technique in Petten was in a rather preliminary stage at the time I left.

Registration Material Data: Plastic: Polycarbonate Thickness: 10 μ
Trade Name: Makrofol

Exposure Conditions:

Radiators Used: Natural uranium alloys, ^{238}U , ^{235}U

Radiator Thickness: 0.1 mm to 100 $\mu\text{g}/\text{cm}^2$

Exposed Area: 6 cm^2

Method of Handling or Supporting the Registration Material: Concentric plastic rings

Radiator-Registration Material Separation Distance: Zero

Etching Conditions:

Etchant: KOH Concentration: 6.25N Temperature: 60°C Volume: 0.5 liters

Etching Time: 1 hr Stirring Used?: Yes Wetting Agent Used?: Yes, Dowfax

Concentration: $\frac{1}{2}$ vol%

Heat Source: Hot plates, constant temperature bath.

Material Pre-Treatment: None

Rinse Conditions: Distilled water and acetic acid

Drying Conditions: Oven at 50°C

Counting Conditions:

Solid Electrode Material: Nickel, gold Polarity: Negative

Metallized Plastic Electrode: Aluminum or gold covered mylar

Counter Capacitance: Variable

Pressure Applied to Film During Counting: 1 kg.

Pre-Spark Data:

Pre-Spark Voltage: 1200 V

Record Count Data:

Counting Voltage: 500 V

Count Termination Criterion: Termination of sparking

Is the Film Repositioned Between Counts?: No

Is the Film Cleaned Between Counts?: No

Comments: The counting circuits of Cross and Tommassino, and Congel were used with variable capacitances and resistances.

System Performance:

Reproducibility: Rather poor

Survey No. 107

Laboratory: Institute of Nuclear Research of the Hungarian Academy of Sciences
Address: 18/c Bem ter, Debrecen, 1, P.O.B. 51
Hungary
Researchers: Drs. L. Medveczky, G. Somogyi, B. Schlenk, L. Mesko, A. Valek,
and I. Hunyady

Applications: Radiography
Fissionography

Registration Material Data: Plastic: Polycarbonate Thickness: 10 μ
Trade Name: Makrofol KG
Other: Melinex O Thickness: 12 μ
Source: Imperial Chemical Industries Limited, Great Britain

Exposure Conditions:

Radiators Used: U_3O_8 or uranium contamination
Radiator Thickness: Varied, less than 10 mg/cm² Exposed Area: 1.2 cm²
Method of Handling or Supporting the Registration Material: Two concentric plastic rings.

Radiator-Registration Material Separation Distance: Contact

Etching Conditions:

Etchant: KOH Concentration: 30% Temperature: 60°C Volume: 200 cm³
Etching Time: 1.5 hr Stirring Used?: No Wetting Agent Used?: No
Heat Source: Thermostat
Material Pre-Treatment: None
Rinse Conditions: 10% HCl + distilled water
Drying Conditions: Room temperature

Counting Conditions:

Solid Electrode Material: Brass Polarity: Positive
Metallized Plastic Electrode: Mylar Plastic Thickness: 40 μ
Counter Capacitance: 680 pF
Pressure Applied to Film During Counting: 200 g/cm²
Pre-Spark Voltage: 1000 V Number of Pre-Spark Counts: 2
Record Count Voltage: 500 V Number of Record Counts: 5
Count Termination Criterion: 5 sec waiting time between starting and stopping
Is the Film Repositioned Between Counts?: Yes
Is the Film Cleaned Between Counts?: No

System Performance:

Reproducibility: About 5%
Maximum Countable Track Density: About 3000/cm²
Experienced Difficulty with "Stuck" Count or Foil That Will Not Count?: No

General Comment: Only Dr. L. Medveczky and Dr. G. Somogyi are interested in spark counting.

Survey No. 111

Laboratory: Philips

Address: Jacob Marisstraat 1
Son (N. Br.)
The Netherlands

Researcher: Dr. H. Pauw

Applications: Neutron Dosimetry
Neutron Spectroscopy
Neutron Cross Section Measurements

Registration Material Data: Plastic: Polycarbonate Thickness: 12 μ
Trade Name: Makrofol KG

Exposure Conditions:

Radiators Used: Natural uranium, ²³⁹Pu, ²³⁷Np, and ²⁵²Cf
Radiator Thickness: About 0.1 mg total material Exposed Area: 12 mm diam
Method of Handling or Supporting the Registration Material: Nickel discs of 19 mm diam
Radiator-Registration Material Separation Distance: Contact

Etching Conditions:

Etchant: NaOH Concentration: 6N Temperature: $64^{\circ} \pm 1^{\circ}\text{C}$ Volume: About 20 ml
Etching Time: 1 hr Stirring Used?: Yes Wetting Agent Used?: No
Heat Source: Boiling methanol: methanol vapor refluxes around the etchant (double wall vessel).

Material Pre-Treatment: None

Rinse Conditions: Distilled water

Drying Conditions: Between tissues

Counting Conditions:

Solid Electrode Material: Thin layer of nickel electroplated on copper.

Metallized Plastic Electrode: Mylar Plastic Thickness: $25\ \mu$

Counter Capacitance: 1000 pF

Pre-Spark Voltage: 1150 V

Record Count Voltage: 560 V Number of Counts for Measurement: 3

Is Film Repositioned Between Counts?: Yes

Is Film Cleaned Between Counts?: No

System Performance:

Estimate of Efficiency in Counts per Etchable Track: About 70%

Reproducibility: Below 500 sparks/cm² the reproducibility is within 1%. At higher densities the reproducibility becomes worse and deviations of up to maximum 10% are normal for duplicate measurements.

Maximum Countable Track Density: About 2000 sparks/cm²

Experienced Difficulty with "Stuck" Count or Foil That Will Not Count?: We have had this problem. After counting the film once, the aluminum of the opposite electrode evaporates and precipitates into the holes in the plastic film. At that time we have a short circuit, which happens sometimes at the moment of counting. After repositioning or etching the film again, the problem was all over.

Survey No. 117

Laboratory: AB Atomenergi

Address: Studsvik
S-61101 Nyköping
Sweden

Researcher: Carl O. Widell

Application: Neutron Dosimetry

Registration Material Data: Plastic: Polycarbonate Thickness: $10\ \mu$
Trade Name: Makrofol

Exposure Conditions:

Radiators Used: Neptunium, uranium, and plutonium

Radiator Thickness: Zero to infinite Exposed Area: $1\text{--}20\ \text{cm}^2$

Method of Handling or Supporting the Registration Material: Stainless screen

Radiator-Registration Material Separation Distance: Contact

Etching Conditions:

Etchant: KOH Concentration: 28% Temperature: 70°C Volume: $1000\ \text{cm}^2$

Etching Time: 2 hr Stirring Used?: No Wetting Agent Used?: No

Heat Source: Hot plate

Material Pre-Treatment: None

Rinse Conditions: Water

Drying Conditions: Air

Counting Conditions:

Solid Electrode Material: Stainless steel Polarity: Positive
Metallized Plastic Electrode: Melinex
Counter Capacitance: 100 pF
Pressure Applied to Film During Counting: 0.5 kgm/cm²
Pre-Spark Voltage: 1000 V
Record Count Voltage: 500 V
Is the Film Repositioned Between Counts?: No
Is the Film Cleaned Between Counts?: No

Survey No. 118

Laboratory: University of the West Indies
Physics Department
Address: St. Augustine, Trinidad
Researcher: Dr. E. Theodore Agard

Application: Neutron Dosimetry

Registration Material Data: Plastic: Polycarbonate Thickness: 10 μ
Trade Name: Makrofol

Exposure Conditions:

Radiators Used: ²³²Th and natural uranium foil
Radiator Thickness: About 0.002 in.
Method of Handling or Supporting the Registration Material: Use of standard all plastic 35 mm film mounts.

Radiator-Registration Material Separation Distance: Contact
Comments: Radiator sandwiched between registration material.

Etching Conditions:

Etchant: NaOH Concentration: 6N Temperature: Room, about 22°C
Etching Time: 24 hr Stirring Used?: Yes Wetting Agent Used?: No
Material Pre-Treatment: None
Rinse Conditions: Running water
Drying Conditions: Plastic films sandwiched between absorbing paper.
Comments: After exposure, registration material placed in 35-mm film mounts, which are placed in standard slide tray and the tray is immersed in etching solution. After etching, tray placed in container under running water for washing.

Counting Conditions:

Solid Electrode Material: Brass Polarity: Negative
Metallized Plastic Electrode: Mylar Plastic Thickness: About 0.0005 in.
Pressure Applied to Film During Counting: 7250 dynes/cm²
Pre-Spark Voltage: 1200 V
Record Count Voltage: 500 V
Is the Film Repositioned Between Counts?: Yes
Is the Film Cleaned Between Counts?: No

System Performance:

Reproducibility: Better than 10%
Maximum Countable Track Density: About 500 tracks/cm²
Experienced Difficulty with "Stuck" Count or Foil That Will Not Count?: Have not had this problem.