AN EVALUATION
OF THE KSU MULTI-MILLIGRAM ^{252}CF FACILITY

by

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Dedicated to

my wife, Karen, and my son, Greg

TABLE OF CONTENTS

NOMENCLATURE v

LIST OF FIGURES vi

LIST OF TABLES ix

1.0 INTRODUCTION 1

2.0 CONSTRUCTION OF FACILITY 3

2.1 Materials 3

2.2 Circulation System 6

2.3 ^{252}Cf Source Holder 8

2.4 ^{252}Cf Source Accessibility 10

3.0 LICENSING THE KSU ^{252}Cf FACILITY FOR USE 15

3.1 License Application 15

3.2 License Amendments 17

3.3 KSU ^{252}Cf Facility Monitoring Procedures 18

4.0 TRANSPORTATION AND UNLOADING 21

4.1 Transportation Arrangements 21

4.2 Unloading Arrangements 22

4.3 ^{252}Cf Source Unloading 26

5.0 FLUX MEASUREMENTS 39

5.1 Cadmium Ratio and Thermal Neutron Flux Measurements by Indium Foils 39

5.2 Neutron Flux Measurements with Scandium Oxide 39

6.0 SECURITY AUTHENTICATION BY USE OF NAA 47

6.1 Purpose of Experimental Work 47

6.2 Sample Preparation and Procedure 47

6.3 Results 48

TABLE OF CONTENTS (cont'd)

7.0 PROTEIN DETERMINATION OF WHEAT BY CAPTURE GAMMA-RAY ANALYSIS 60

7.1 Introduction 60

7.2 Experimental Work with the KSU ^{252}Cf Facility 63

7.3 Experimental Work with the Bureau of Mines 64

7.4 Results 72

8.0 RADIATION-INDUCED CONDUCTIVITY IN POLYETHYLENE 84

8.1 Introduction 84

8.2 Methods and Materials 85

8.3 Experimental Data and Results 91

9.0 CONCLUSIONS 95

9.1 Introduction 95

9.2 Primary Contract Obligations 96

9.3 Secondary Contract Obligations 98

9.4 Additional Contract Obligations 99

10.0 SUGGESTIONS FOR FURTHER STUDY 101

10.1 Security Authentication by Use of NAA 101

10.2 Protein Determination of Wheat by Capture Gamma-Ray Analysis 102

10.3 Radiation Effect Studies 104

10.4 Miscellaneous Projects 104

11.0 ACKNOWLEDGEMENTS 105

12.0 LITERATURE CITED 107

13.0 APPENDIX 109

13.1 USAEC ^{252}Cf Market Evaluation Program Contract 110

13.2 Licensing 127

13.2.1 Formal License Applications--October, 1970 128

13.2.2 Application for Amendment No. 22 131

TABLES OF CONTENTS (cont'd)

13.2.3 Additional Information--December, 1970 134

13.2.4 Additional Information--January, 1971 143

13.2.5 Application for Amendment No. 23 150

13.2.6 Application for Amendment No. 25 152

13.3 KSU ^{252}Cf Facility License 156

13.4 ^{252}Cf Source Information Sheets 161

13.5 KSU Application for ETA 168

13.6 Working Drawings for the AECACSSC 171

NOMENCLATURE

Symbol	Explanation
KSU	Kansas State University
AEC	Atomic Energy Commission
SRO	Savannah River Operations
DNE	Department of Nuclear Engineering
KSUTMIINR	KSU Triga Mark II Nuclear Reactor
PVC	polyvinyl chloride
ABS	acrytonitrile butadiene styrene
RSO	Radiation Safety Officer
KSDH	State of Kansas Department of Health
RSC	Radiation Safety Committee
PT-CS	Packard Tri-Carb Model 3375 Liquid Scintillation Spectrometer
NAA	Neutron Activation Analysis
AECACSSC	AEC Americium-Curium U(D38) Shielded Shipping Carrier
ETA	Emergency Temporary Authority
DOT	Department of Transportation
INGT	internal geometry technique
EXGT	external geometry technique
BOM	United States Bureau of Mines
KSGID	Kansas State Grain Inspection Department
σ	electrical conductivity, $(\text{ohm-cm})^{-1}$

LIST OF FIGURES

1. Completed ^{252}Cf Facility with 8 feet of stainless steel pipe attached 5
2. Plan view of the KSUTMIINR Bay 5
3. ^{252}Cf Facility water circulation system 7
4. Plexiglass ^{252}Cf source holder 9
5. Radiation damaged source holder 9
6. New plexiglass ^{252}Cf source holder with fewer source locations . . . 9
7. Cross section view of KSU ^{252}Cf Facility 11
8. Electrical traversing mechanism 12
9. Sample entry remote control device 14
10. Underwater high intensity lamp 14
11. Transparent plexiglass boat 14
12. ^{252}Cf source magnetic eyelet 23
13. Bamboo ^{252}Cf source carrying pole 24
14. ^{252}Cf source unloading holding device and cutting tool 25
15. Magnetic pickup tool 25
16. ^{252}Cf adaptation to AECACSSC inner plug 304L SST flange 27
17. ^{252}Cf adaptation to AECACSSC polyethylene inner plug 28
18. ^{252}Cf adaptation to AECACSSC polyethylene well plug 29
19. AECACSSC and Tri-State motor transit carrier 32
20. Top view of AECACSSC with cover plates removed 32
21. Wipe test of AECACSSC polyethylene shielding plug 32
22. Lifting ^{252}Cf source from AECACSSC 32
23. ^{252}Cf source carry 32
24. ^{252}Cf source drop into tank 32

LIST OF FIGURES (cont'd)

25. Cutting of string and placement of ^{252}Cf source into holder 32

26. Polystyrene vials used for Indium-foil positioning 40

27. Cadmium ratio versus foil height for configurations 1 and 4 41

28. Thermal flux versus foil height for configurations 1 and 4 42

29. Plot of neutron flux versus time for scandium oxide and cadmium ratio 45

30. Normalized spectrum of ^{24}Na 49

31. Normalized spectrum of ^{27}Mg 50

32. Normalized spectrum of ^{28}Al 51

33. Normalized spectrum of ^{38}Cl 52

34. Normalized spectrum of ^{49}Ca 53

35. Normalized spectrum of ^{51}Ti 54

36. Normalized spectrum of ^{56}Mn 55

37. Normalized spectrum of ^{64}Cu 56

38. Normalized spectrum of ^{122}Sb 57

39. Normalized spectrum of ^{165}DY 58

40. Normalized spectrum of ^{180}Hf 59

41. Internal geometry configuration 62

42. External geometry configuration 62

43. System block diagram for BOM electronic equipment 69

44. BOM NaI(Tl) detector and shield 71

45. BOM aluminum container 71

46. Low protein spectrum run No. 2 73

47. Low protein region of interest No. 1 74

48. Low protein region of interest No. 2 75

49. Low protein region of interest No. 3 76

LIST OF FIGURES (cont'd)

50. Medium protein region of interest No. 1 77

51. Medium protein region of interest No. 2 78

52. Medium protein region of interest No. 3 79

53. High protein region of interest No. 1 80

54. High protein region of interest No. 2 81

55. Two techniques for current flow measurements 86

56. Sample holder for polyethylene exposed to ^{252}Cf neutrons and gamma rays 89

57. Water-tight container for the polyethylene sample holder 90

58. I-V characteristics for irradiation at 3 minute intervals 5.2 cm . . 92

59. I-V characteristics for irradiation at 3 minute intervals 37.7 cm 93

1.0 INTRODUCTION

The purpose of this work was to evaluate the Kansas State University (KSU) multi-milligram ^{252}Cf Facility, which is a part of the Atomic Energy Commission's (AEC) ^{252}Cf Market Evaluation Program. This thesis is a compilation of pertinent information concerning construction, licensing, and source handling; also an evaluation of special research projects is presented.

Plans for participation in the Market Evaluation Program commenced in the spring, 1970. Contract preparation and detailed proposals were prepared during the summer, 1970, with the final contract approved in October, 1970. The final contract is shown in the Appendix.

The scope of work of the contract included three primary objectives and three secondary objectives. These objectives were:

1. Primary Objectives
    a. Protein Analysis of Cereal Grains by Neutron Activation Analysis
    b. Cohesive Study of Electronic Materials and Components in Nuclear-Radiation Environments
    c. Quantitative Analysis of Mercury and Selected Additional Toxic Material in Commercially Processed Foods for Humans
2. Secondary Objectives
    a. Security Authentication by Neutron Activation Analysis
    b. Educational Uses
    c. Feed-lot Run-Off Analysis

The contract agreed to the loan of 50 milligrams of ^{252}Cf, at an estimated value of $500,000. This was the largest quantity of ^{252}Cf to be loaned in the

program and is the largest concentration of ^{252}Cf in the world, outside the AEC production centers at Oak Ridge National Laboratories and Savannah River Operations (SRO).

Unloading, storage, and licensing of such a facility had never been accomplished. Most of the material presented in the following pages is derived from our own experiences, with limited literature and experience as a guide.

2.0 CONSTRUCTION

Construction of the KSU ^{252}Cf Facility required the careful consideration of many constraints. Uses as outlined by the contract, monetary expenditures, radiation characteristics, and source packaging were the primary considerations. The goal in construction of the facility was to provide maximum flexibility for source use, to make it inexpensive, and to insure the safety of the operating and non-operating personnel.

2.1 Materials

The basic design characteristics were not so much theoretical, as practical in nature. Water provided the best possibilities for shielding, yet allowing maximum flexibility in the movement and placement of the sources. Supplementary shielding of paraffin and lead easily could be added to the outside of many water containing structures. The Department of Nuclear Engineering (DNE) at KSU possessed an unused water moderator subcritical assembly container. This assembly included a 5 feet high x 4 feet in diameter stainless steel tank 0.25 inches thick and a platform. Use of the tank satisfied the first and second criteria: source handling and expense.

The third consideration of safety was still in question. Shielding calculations indicated that safety could be insured for short periods of time, but long term storage of the sources at the bottom of the tank was questionable. Apparently, the sources needed to be stored away from personnel at a distance greater than the perimeter of the tank and platform. Two options were considered.

The first required the permanent placement of supplementary shielding around the tank. This would create the need for a large area to locate the

facility and would require the expense of buying or casting a great number of paraffin blocks. The second option was to alter the tank and increase the water depth. This option required the expense of additional stainless steel pipe and welding expertise. The second option was chosen.

A five-inch diameter stainless steel pipe eight feet long, 1/16 inch thick was welded to the bottom of the tank, Fig. 1. The storage of the sources at the bottom of the pipe placed nearly 15 feet of water or 9 feet of soil and 4 inches of concrete floor between the sources and personnel. The addition of the 5-inch pipe required alteration of the KSU Triga Mark II Nuclear Reactor (KSUTMIINR) bay floor. Checks were made for electrical conduit and other underground structures that might interfere with the placement of the tank. No obstacles were shown on the construction drawings and no obstacles were found when the hole was dug. An 8-inch hole was drilled in the southwest corner of the reactor bay floor. The hole was nine feet deep and lined with 8 1/2 feet of 1/4 inch x 7 inch diameter steel pipe. Concrete was poured around the lining to prevent settling or movement of the pipe.

Possible contamination of the underground water supply was considered. Construction drawings were consulted and the KSUTMIINR was shown to be located on high terrain several hundred feet from an underwater stream. Contamination possibilities were considered nil.

The ^{252}Cf tank was tested for leaks in the bulk shielding experimental tank of the KSUTMIINR. After the leak test the tank was lowered into position, Fig. 2. Placement of the tank in this location provided easy access to the control room and to other research facilities of the DNE. The platform was sand-blasted, primed, painted, and placed around the tank.

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Figure 1. Completed ^{252}Cf Facility with 8 feet of stainless steel pipe attached.

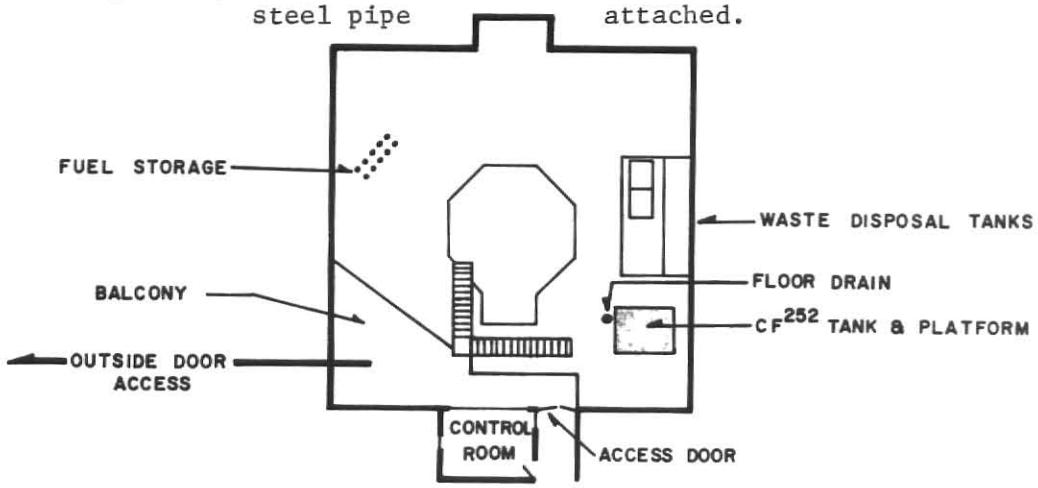

Figure 2. Plan view of the KSUTMIINR bay.

2.2 Circulation System

The use of water for shielding required a circulation system to keep the water deionized and clean. The bulk shielding tank of the KSUTMIINR contained such a system and it was concluded that the system could be altered for use with the ^{252}Cf Facility. The circulation pump was moved to the ground level because of efficiency. New 3/4-inch polyvinyl chloride (PVC) plastic pipe was added to join the systems. During operation, the water circulated either from the pump to the bulk shielding tank or from the pump to the ^{252}Cf Facility. A schematic of the combined system is shown in Fig. 3.

The water moderator subcritical assembly container had been constructed for water circulation. The inlet and outlet circulation fittings were already welded to the container. The outlet fitting was located at the bottom of the tank to allow complete drainage for special occasions. The outlet was extended vertically to the upper water level and a swimming pool skimmer was attached for normal circulation. Additions were made to the container inlet so that water entered at the floor level to improve circulation. Provisions were made for the circulation of water to the bottom of the 5 inch x 8 foot pipe to prevent the collection of impurities at the bottom. Water can be forced to the bottom through 3/8 inch diameter stainless steel pipe. This pipe also serves as a guide rod for the source holder.

There are four sets of valves (1, 2, 3, and 4), Fig. 3, that are located within the circulation system. Sets 1 and 2 contain two valves each (a_1b_1 and a_2b_2) which control the flow to and from the ^{252}Cf Facility. Sets 3 and 4 contain two valves each (c_1c_2 and d_1d_2) which control the flow to and from the KSUTMIINR bulk shielding tank. For drainage of the ^{252}Cf Facility, valves b_1, b_2, and c_1c_2 must be open with valves a_1, a_2, and d_1, d_2 closed. Drainage

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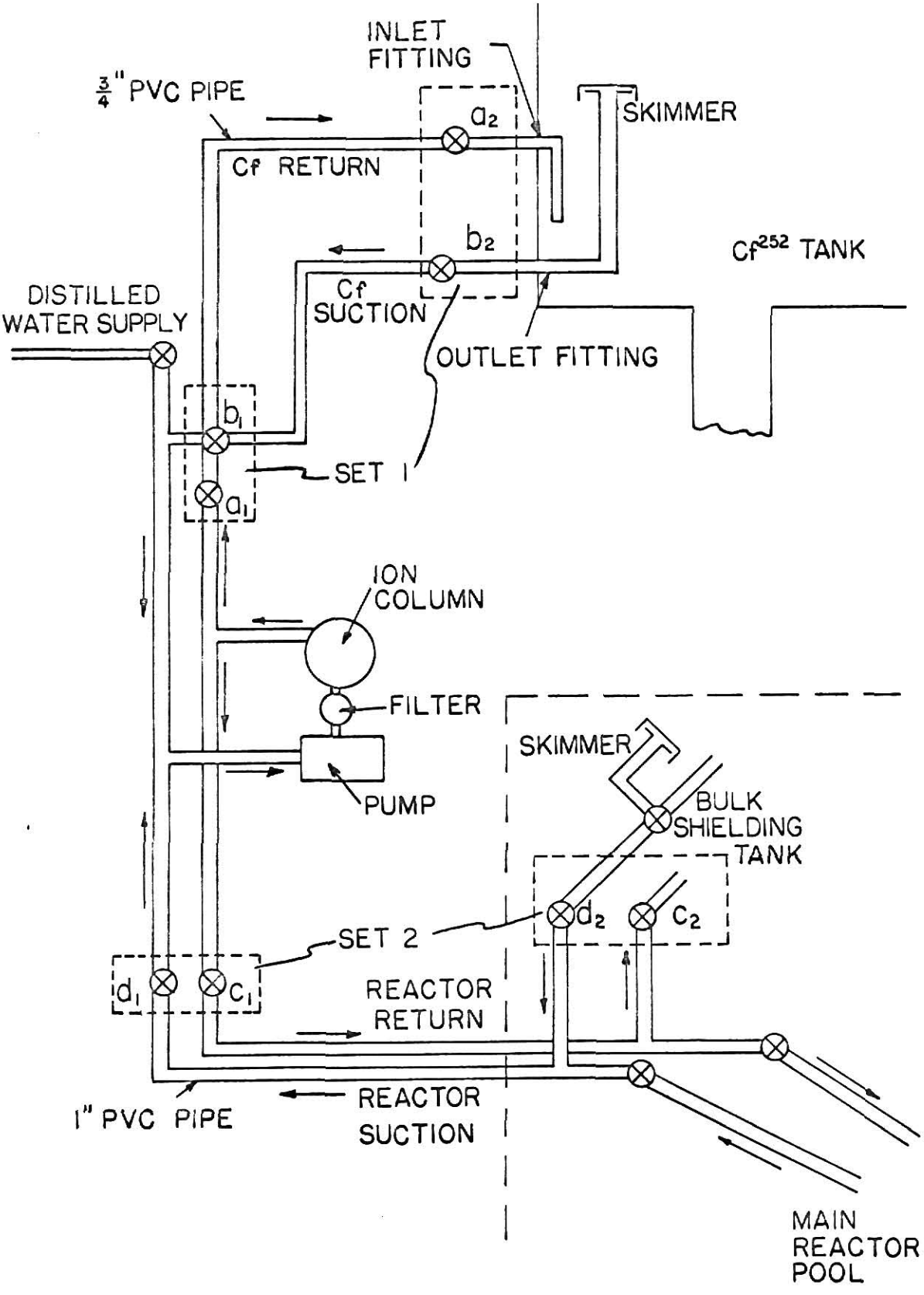


Figure 3. ^{252}Cf Facility water circulation system.

of the bulk shielding tank required that valves a_1, a_2 and d_1, d_2 be open with valves b_1, b_2, and c_1, c_2 closed. Either arrangement is a special case and must be purposely set up to cause the drainage of either tank.

If the valves are set to drain the bulk shielding tank: 1) a siphon break is located about six inches below the water line and the drain line itself is only 2 feet long, and 2) the skimmer is in the normal path of water flow and the water level can drop only four to eight inches before the system draws air.

If the ^{252}Cf Facility is drained, the tank will drain only six inches maximum before the skimmer drains air, however, by removing the pipe connecting the filter to the outlet at the bottom of the tank (a special case), the tank can be drained to floor level. The bulk shielding tank may overflow before drainage is completed. The drainage of the ^{252}Cf Facility to floor level still leaves 7-1/2 feet of water in the 5 inch diameter stainless steel pipe. This remaining water will provide adequate shielding from the sources.

All valves in the circulation system are easily determined as to whether they are opened or closed. The valves are open if the handles point in the direction of flow or are secured in an upward position. The valves are closed if the handles are perpendicular to the direction of flow or are secured in a downward position. AEC Compliance Division was notified of the intent to interconnect the two tanks.

2.3 ^{252}Cf Source Holder

A 1-inch thick plexiglass holder was constructed for the storage of the sources, Fig. 4. Holes were drilled 5/16 inch deep x 3/8 inch in diameter in the plexiglass to allow freedom of placement of the sources in differing configurations. Pilot holes of 1/8 inch were extended through the holder at

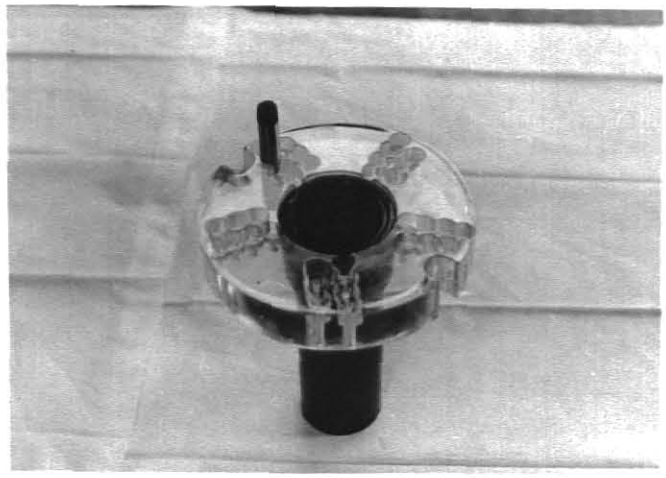


Figure 4. Plexiglass ^{252}Cf source holder.

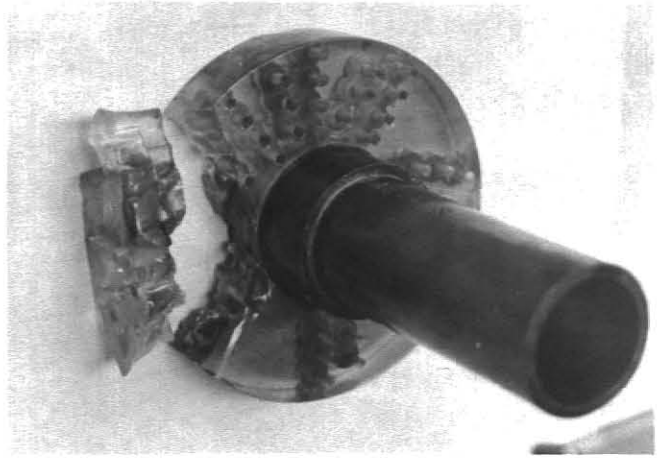


Figure 5. Radiation damaged source holder.

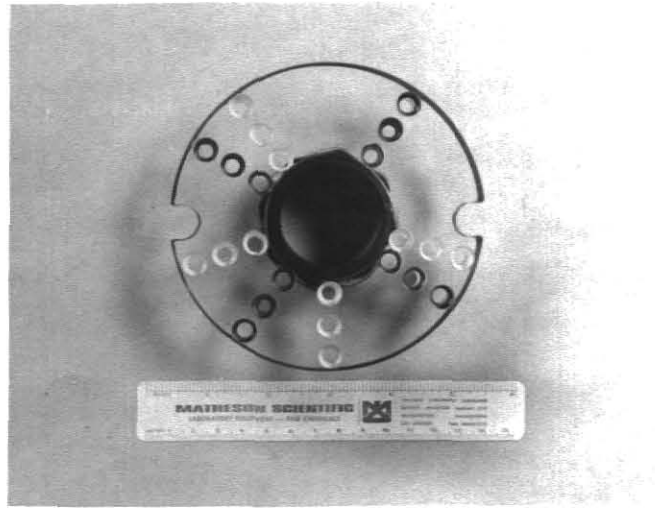


Figure 6. New plexiglass ^{252}Cf source holder with fewer source locations.

each possible source location to allow the water from the circulation system to flow upwards.

Experience with radiation damage to plexiglass indicated that such a source holder would last for nearly one year before replacement. In actuality, the holder lasted only 9 months before it broke. One of the sources had to be retrieved from the bottom of the 8-foot pipe. Damage to the holder is shown in Fig. 5. A new holder was constructed with similar material and the same dimensions as before. Fewer source locations were provided because of the lack of significant change in flux from configuration 1 to configuration 4, Fig. 6.

The center of the holder contained a threaded female connector for placement of the central thimble, Fig. 7. The connector and the lower 6 feet of the central thimble are made of 1 1/4 inch inside diameter acrytonitrile butadiene styrene (ABS) plastic pipe. The upper 8 feet of the central thimble is made of 1 1/4 inch inside diameter PVC. The ABS does not activate as readily as the PVC. Therefore it is more desirable to have nearer the sources.

2.4 ^{252}Cf Source Accessibility

Special features were added in order to traverse the thimble and sources to the raised position. The top of the thimble is guided and clamped into place by a three-pronged laboratory clamp. The fitting at the six-foot level is utilized to prevent movement of the central thimble past this clamp. Therefore, the sources cannot be raised higher than one foot below the floor level of the tank without significant effort.

An electrical traversing mechanism rests on top of the tank and aluminum cover as a second guide and clamp for the central thimble, Fig. 8. The cover and mechanism were used with the old subcritical assembly. The electrical

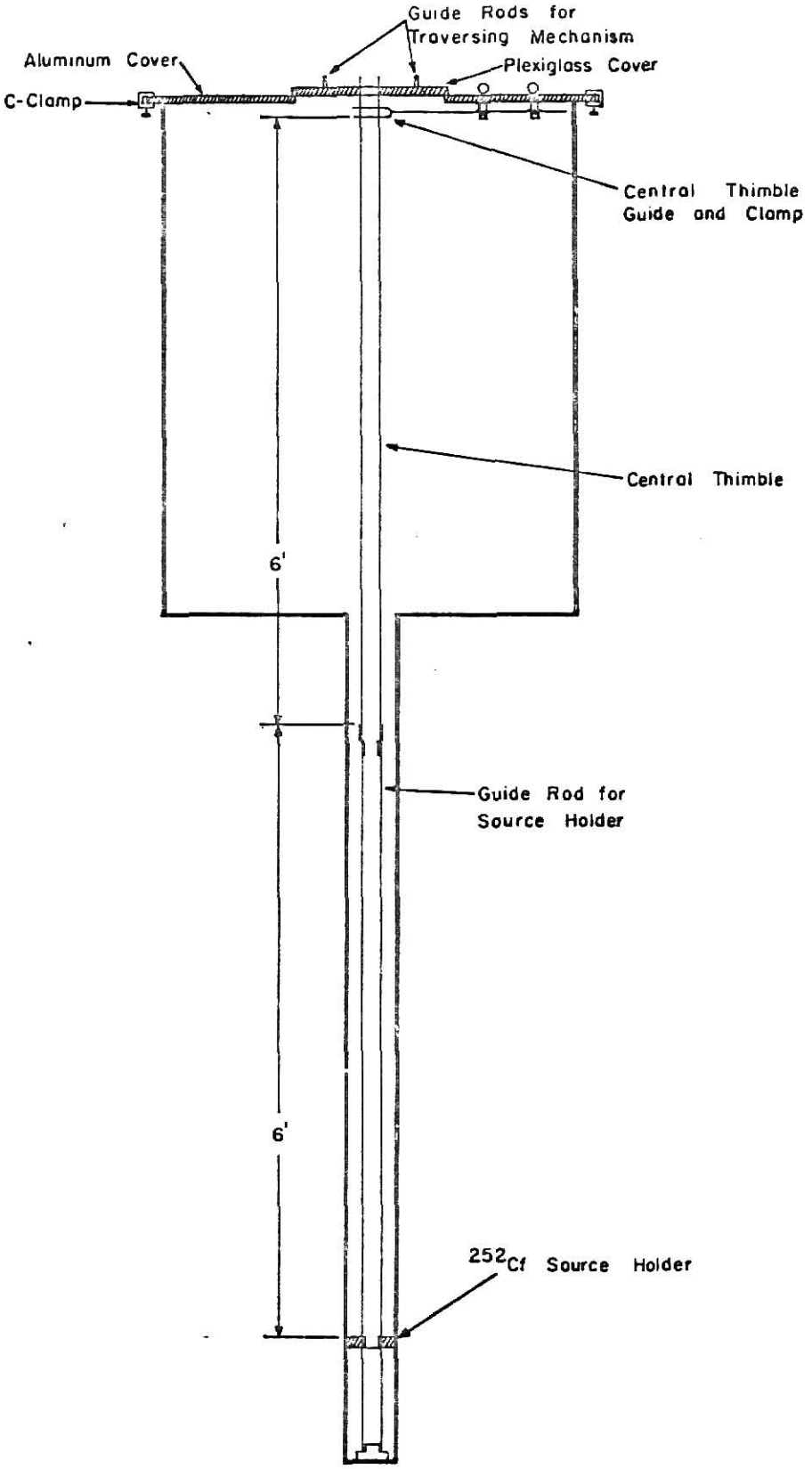


Figure 7. Cross section view of KSU ^{252}Cf Facility.

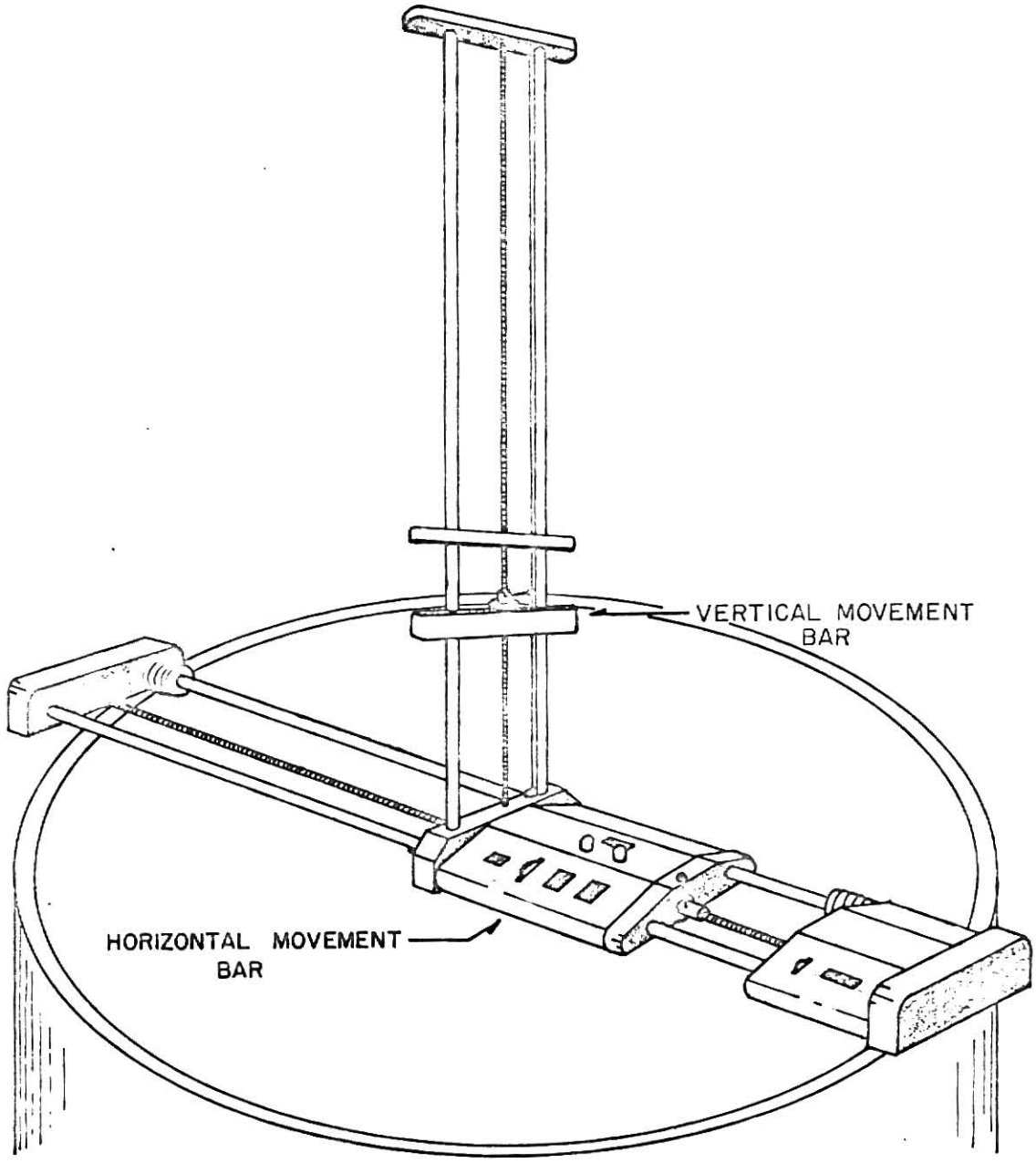


Figure 8. Electrical traversing mechanism.

motors in the traversing mechanism move the thimble too slowly for normal use so the mechanism is traversed manually. This mechanism only traverses 3 feet and must be reset. Lifting the sources to the raised position is a two-step process. This process lessens the chances of non-experienced personnel lifting the sources and creating a safety hazard.

It was deemed unnecessary to keep the ^{252}Cf Facility locked because the sources are located in the reactor bay area. This area is a controlled area and supervisory personel are present. The added traversing features also helped to negate the need for a lock.

Samples will be injected into the system using 1 1/8-inch plastic vials (the same vials presently used with the KSUTMIINR). A remote control device was constructed to aid in sample entry and removal, Fig. 9. The central thimble is removable for changes in sample sizes or for changes from dry to wet entry conditions.

A high intensity tensor lamp was reconstructed to provide lighting for movement of the sources during special operations, Fig. 10. The bulb and reflector are mounted on the end of a 6 foot long by 3/8 inch diameter stainless steel pipe, and are enclosed in a water-tight plexiglass shield. The assembly is amped to the traversing mechanism and the light is placed near the ^{252}Cf sources when in use.

A transparent plexiglass boat was constructed to visually aid the operating personnel, Fig. 11. The boat eliminates the water ripples which distort the operator's vision at the floor level of the tank. The boat fits around the central thimble and can be pushed to the side for source movement.

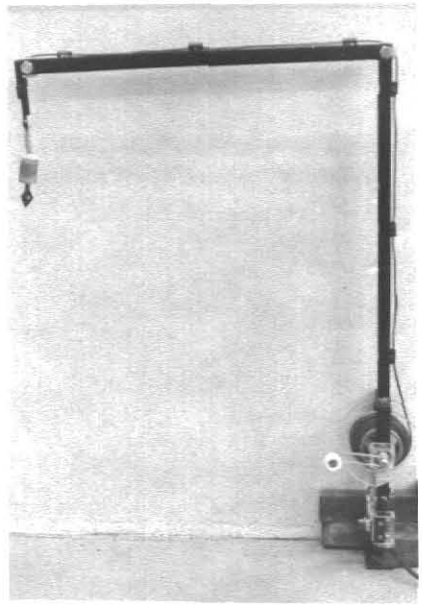


Figure 9. Sample entre remote control device.

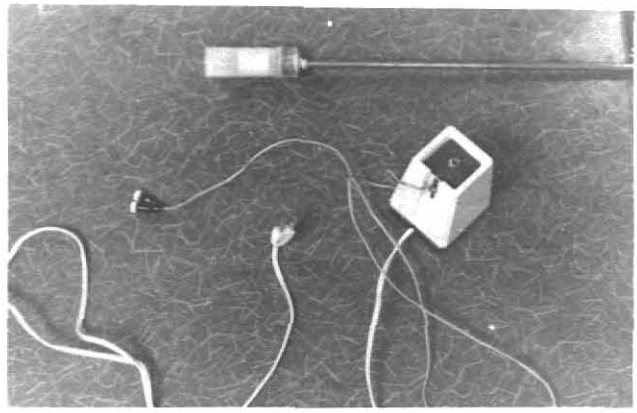


Figure 10. Underwater high intensity lamp.

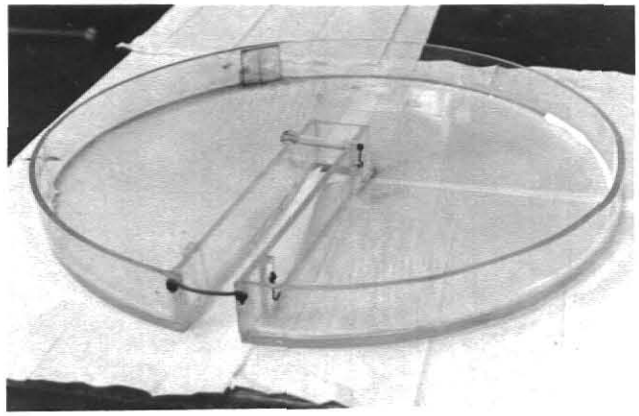


Figure 11. Transparent plexiglass boat.

3.0 LICENSING THE KSU ^{252}CF FACILITY FOR USE

3.1 License Application

Action was informally initiated for the licensing of 50 milligrams (mg) of ^{252}Cf for KSU in April, 1970. The Radiation Safety Officer (RSO) at KSU informed the State of Kansas Department of Health (KSDH) of the fact that the KSU DNE would engage AEC representatives in discussions concerning the possession of ^{252}Cf. It was suggested that the sources could be stored in an unusual water moderated subcritical assembly container. It was also indicated that the sources would probably be of the SR-Cf-100 series, described in the AEC publication (1). The SR-Cf-100 series sources are constructed in two parts: 1) The inner capsule, made of 90% platinum, 10% rhodium, and 2) The outer capsule made of 304L stainless steel. The capsules are pressure tested and indicate a burst strength of 52,000 psi at 25°C. Other tests are described in Appendix 2.3.

It was further stated that the sources would be used under the direction of "radiation safety conscious faculty members of the DNE" and would be available for campus wide research projects. It was emphasized that the letter was not an official license application, rather preliminary communications to keep the KSDH informed of actions at KSU.

As actual construction of the ^{252}Cf Facility was initiated in October, 1970, a formal application for Radiation Safety Committee (RSC) authorization was made, Appendix 2.1. Immediate supervisory personnel were named and the actual storage facility was described. The application was written to allow maximum flexibility for movement and use of the sources within the storage tank. The application was directed to the RSO at KSU.

The RSO formally applied to the KSDH for Amendment No. 22 to Kansas Radioactive Materials License 38-C011-01, on October 19, 1970, Appendix 2.2. The request was to receive, possess, use, and transfer approximately 50 mg (30 curies, nominal) of ^{252}Cf. The material is to be contained in 5 sources as described in (1). The license application proposed that leak tests of the sources would be difficult. Therefore, a request was made to test aliquots of water on a quarterly basis using a gamma-ray spectrometer, with continuous monitoring using G-M tube KSUTMIINR area monitors for gross contamination.

In November, 1970, the RSC approved the proposal to receive and use 50 mg of ^{252}Cf with the following conditions:

1. A liner should be placed in the pit on the outside of the stainless steel sleeve to maintain the integrity of water containment.

2. If the water is circulated in the system, it should be picked up by a pump at the bottom of the eight-foot pit to insure proper circulation.

3. The RSC should be kept apprised of changes and progress involved in the ^{252}Cf procurement.

Additional information was sent to the KSDH in December, 1970, as requested, Appendix 2.3. The information requested by the KSDH indicated an uncertainty with the initial request. Clarifying information was sent to indicate performance characteristics and prototype data for the zircoloy packeted source. A description was made of the device for raising, lowering, and securing the sources in the tank, plus procedures for controlling unauthorized personnel when the sources are raised. Anticipated dose rates (1) at the tank surfaces were indicated. A complete description of the water system for the ^{252}Cf Facility was presented. Sensitivities for detection of a ruptured source were given and emergency procedures were outlined. The tank dimensions

were restated and unloading procedures were discussed. Operating procedures were reiterated and leak tests versus activation products in water were reviewed. The KSDH again wrote in reference to Amendment 22 in January, 1971. They requested the following additional information:

1. A description of the mechanism for raising and lowering the sources. (This should include drawings and a bill of materials.)

2. A description of the tong mechanism to be used for source manipulation.

3. An indication of the magnitude of leakage that could be detected in both still and circulating water systems.

4. Any indication of the location of the proposed tank in relation to permanent or semipermanent work stations for reactor personnel or experimentors.

5. An estimate of the weight which the tank cover will be able to support. (Will the facility design be such that it will be required or convenient to use the cover as a support for equipment or personnel?)

The reply to these questions is contained in Appendix 2.4.

Amendment No. 22 was finally approved on January 20, 1971 (Appendix). It would have been advisable to invite the KSDH to visit the ^{252}Cf Facility while it was being constructed. Perhaps verbal communication and direct exchange of ideas would have speeded the approval of the amendment.

3.2 License Amendments

Telephone communications with the SRO office in February, 1971, indicated that one of the fabricated sources to be received at KSU was larger than the prescribed 10 mg. Application for Amendment No. 23 was made by the RSO to increase the source strength of the individual ^{252}Cf sources from 5.2 curies each, to 6.0 curies, Appendix 2.5. Approval for the amendment was granted in early March, 1971 (Appendix).

In late March, 1971, the RSC discussed the fact that there was no record of the Compliance Division of the AEC having been advised of our intent to interconnect ^{252}Cf and KSUTMIINR bulk shielding tank. The RSC was informed of the steps taken to guard against inadvertant faulty valving which might drain either the bulk shielding tank or the ^{252}Cf Facility. Section 2.2 provides a complete explanation of the circulation system.

The ^{252}Cf sources arrived April 15, 1971, and information sheets concerning each source were sent from the SRO office (Appendix). One source was identified as being constructed of a stainless steel outer capsule. This required that an additional license amendment be requested.

Amendment No. 25 was requested from the KSDH in May, 1971 (Appendix). The request permitted the possession and use of a ^{252}Cf source encapsulated in stainless steel. The request also asked permission that all operators of the ^{252}Cf Facility to be certified to be approved by a subcommittee of the RSC. Approval of Amendment No. 25 was granted on May 20, 1971 (Appendix).

3.3 KSU ^{252}Cf Facility Monitoring Procedures

Because of the large source strength of the ^{252}Cf sources at KSU, special monitoring arrangements were made. Normal neutron source monitoring procedures at KSU required a direct wipe test of each source. Such a wipe test of the ^{252}Cf sources would constitute undue danger to the monitoring personnel. The following is the procedure for the weekly ^{252}Cf Facility check:

1. Begin circulation of ^{252}Cf Facility water on each Monday morning.
2. Open all valves to the tank and close all valves to the bulk shielding tank.
3. Check the water level in the ^{252}Cf Facility for proper intake into the skimmer.

4. Circulate water for 24 hours.
5. Monitor the ion exchange column of the system with the Texas Nuclear Model 9149 NEMO detector.
6. Record the reading at the back of the log book.
7. Turn off the system and close all valves.

The following is the procedure for the quarterly ^{252}Cf Facility check:

1. Circulate the facility water for 24 hours as in the weekly check.
2. Remove a sample of at least 15 ml of water from the tank.
3. Analyze two 5 ml portions by gamma spectroscopy with the Packard Tri-Carb Model 3375 Liquid Scintillation Spectrometer (PT-CS). Compare the results to a 5 ml sample of top water.
4. Measure two 2 ml portions of original smaple into glass counting vials.
5. Add 20 ml of dioxine flour to each sample.
6. Prepare a similar tapwater sample.
7. Place all three samples in the PT-CS and allow to cool.
8. Count the samples and compare results.
9. Record the results in the back of the log book.
10. Place a copy of calculations in the brown envelope in the back of the log book.

The ^{252}Cf Facility can be used for Neutron Activation Analysis (NAA), as well as for other purposes. A log book has been established to record all uses of the ^{252}Cf sources. A combination of procedures similar to those for the KSUTMIINR and the KSU Gammacell 220 Facility are followed. For example the procedures for NAA are:

1. Estimate the source strength of the isotope to be produced.
2. Record the name of the facility operator.
3. Record the name of the project.
4. Indicate the source configuration.
5. Record the number of samples and the sample material. Place the samples in the plastic vial.
6. Record the time of insertion into the central thimble.
7. Record the time of removal from the central thimble.
8. Record the dose rate at the surface of the plastic vial.
9. If the dose rate is very large, indicate the dose rate at 1 meter.
10. Wipe the sample with filter paper and monitor the paper with the Nuclear Chicago Model 1619A detector.
11. Record the counts per minute from the wipe sample.
12. Record the total irradiation time.

For operations other than NAA, the procedures are:

1. Record the name of the facility operator.
2. Record the name of the project or nature of operation.
3. Indicate source configuration (or single source(s) involved).
4. Record the number of samples and the sample material.
5. Record the beginning time of the operation.
6. Record the ending time of the operation.
7. Record the dose rate of the sample and/or working area.
8. Record the total operation time.

4.0 TRANSPORTATION AND UNLOADING

4.1 Transportation Arrangements

Arrangements for transportation started months before the sources were fabricated. Several private companies, e.g., Monsanto, ATCOR, Inc., and Protective Packaging, Inc., were contacted in order to locate adequate shipping containers. All replied that a Type B shipping container suitable for these sources was unavailable, however, plans were being made for the fabrication of a shipping container to meet requests for shipping these large sources.

The unavailability of shipping containers from private industry turned our attention to the AEC and their casks. Arrangements were made for use of the AEC Americium-Curium U(D38) Shielded Shipping Carrier (AECACSSC) commonly called the "Cannonball." The Cannonball weighs 28,800 pounds and is attached to a complementary trailer.

After deciding on a shipping cask, carrier arrangements were necessary for the actual delivery. Tri-State Motor Transit Co. of Joplin, Missouri, was contacted for the job because of their known capabilities and the lack of local trucking firms that were qualified for such a move. Tri-State quoted rates:

Loaded Container - Savannah River, S. C. to Manhattan, Kansas
32,000 Pound Minimum - 310¢ per hundred

Empty Container - Manhattan, Kansas to Savannah River, S. C.
Return within 24 hours
24,000 Pound Minimum - 91¢ per hundred
Return exceeding 24 hours
24,000 Pound Minimum - 200¢ per hundred

Special arrangements were necessary because Tri-State was not licensed to deliver radioactive materials to Manhattan, Kansas. An Emergency Temporary Authority (ETA) was applied for with the Department of Transportation (DOT). ETA approval was granted and numbered R-341. The DOT shipping permit number

was 6323. This document is displayed in Appendix 5. Mileage was stated at 1068 miles with an average speed of travel of 35 mph. Estimated travel time from Aiken, South Carolina, to Manhattan, Kansas, was 30 hours.

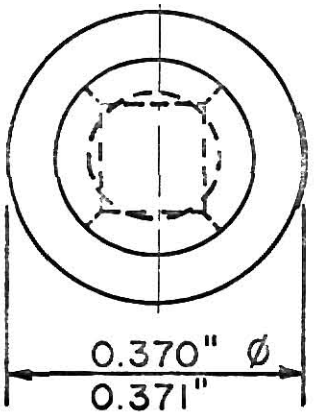
4.2 Unloading Arrangements

While arranging for transportation, equipment for unloading was constructed. J. P. Faraci (2) indicated that the sources would be shipped with an attached magnetic eyelet, Fig. 12. Eight to ten feet of string would be tied to the eyelet of each source.

A 1-inch in diameter bamboo pole, 9 feet long, Fig. 13, was adapted for carrying the sources from the Cannonball to the ^{252}Cf Facility. A lead cup was attached to one end by a three-pronged laboratory clamp and duct tape. Aluminum string guides were also taped to the pole. A PVC cap was taped to the opposite end of the pole for the comfort of the pole handler. String from the source was to be tied to additional string on the pole. Then the source would be drawn inside the lead cup. Finally, the string would be secured on the anchor.

Two additional devices were necessary for the cutting of the string once the sources were placed inside the tank. A holding device, Fig. 14, was constructed of 3/4 inch diameter aluminum pipe, 6 feet long. A flat steel tip was brazed to the end of the pipe. This device was to be used to hold the ^{252}Cf source firmly on the tank floor while the string was cut from the magnetic eyelet. The second device, the cutting tool, Fig. 14, was made from 3/4-inch diameter aluminum pipe, 6 feet long. A tile cutting blade was attached to the end by duct tape.

A magnetic pickup tool was constructed for normal handling of the sources, Fig. 15. A metal scriber with magnetic tip (Sears, Craftsman No. 4001) was purchased. The scriber case is made of aluminum. The scriber tip was removed



NOTE: Eyelet holder to be used with "shakeproof" type 1210-00 lock washer O.D. modified to 0.365". Strong, flat, nylon electrical lacing cord, 1/8 inch wide, or equal, should be used with eyelet. A fishermans clinch, a bowline, or equal knot should be used to attach line to eyelet.

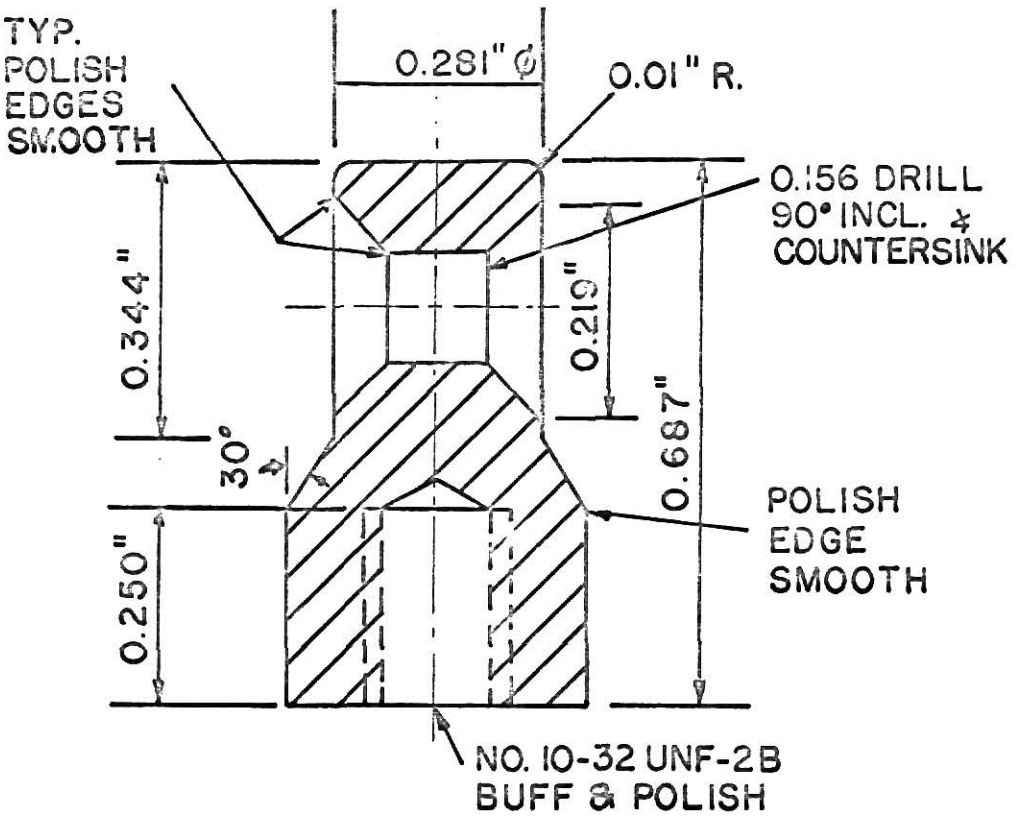


Figure 12. ^{252}Cf source magnetic eyelet.

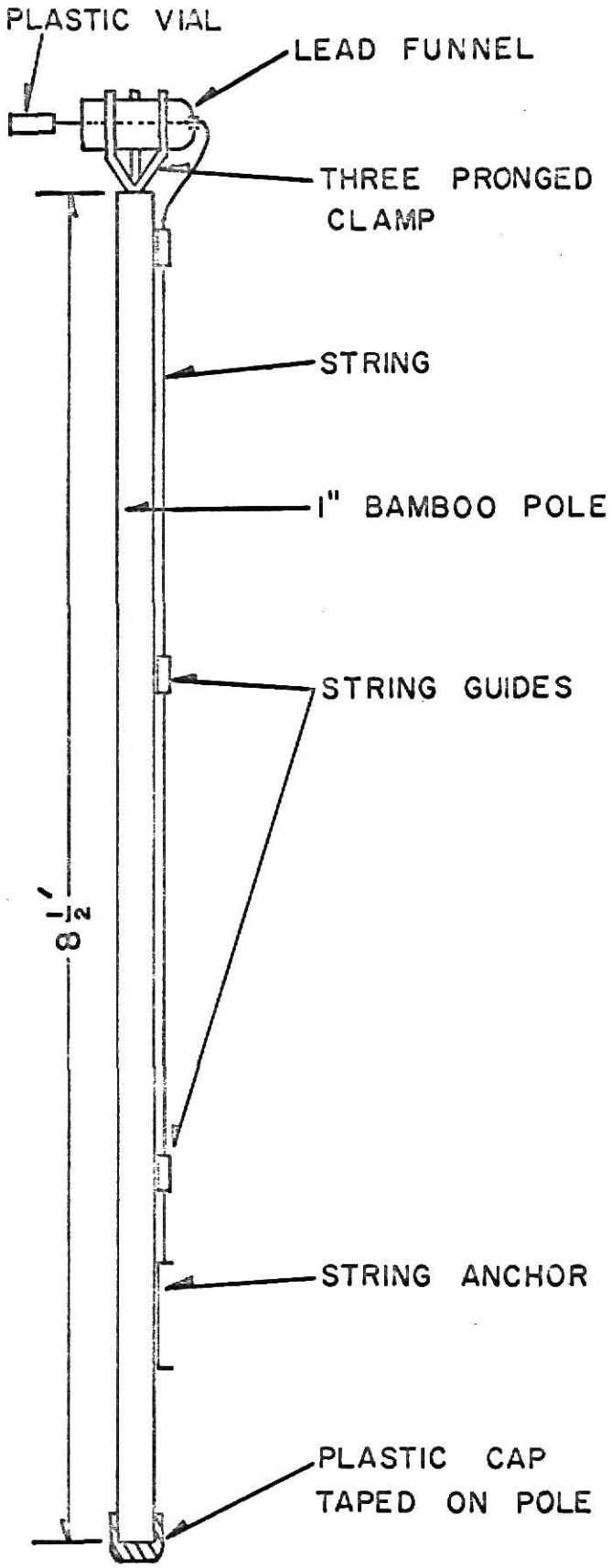


Figure 13. Bamboo ^{252}Cf source carrying pole.

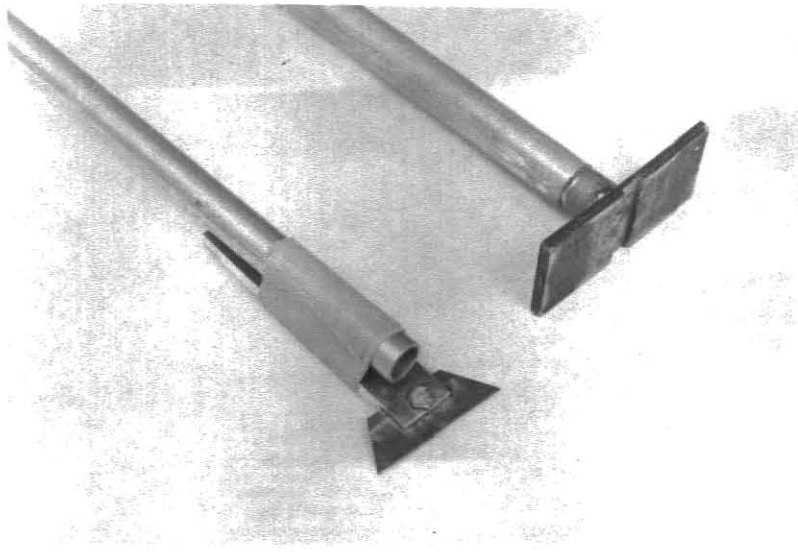


Figure 14. ^{252}Cf source unloading holding device (right) and cutting tool (left).

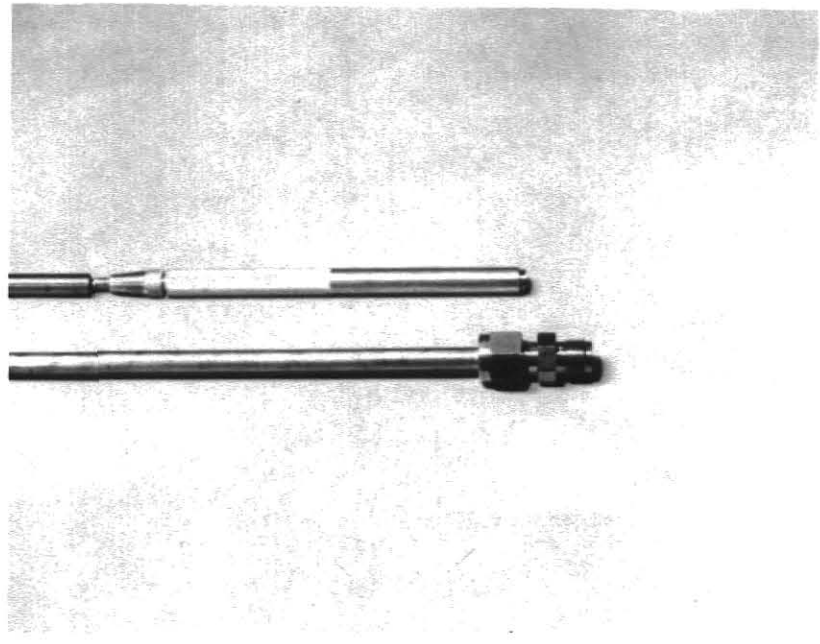


Figure 15. Magnetic pickup tool.

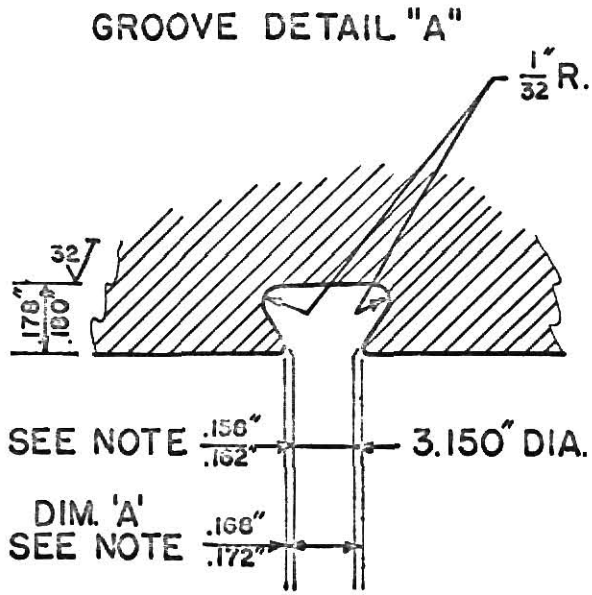
and the remaining case and magnet was brazed to four feet of 1/4-inch diameter stainless steel pipe. Three additional feet of the pipe were attached by a stainless steel swage lok fastener.

This tool was reconstructed nearly a year later, by replacing the 1/4-inch diameter stainless steel pipe with 7 feet of 3/8-inch diameter stainless steel pipe. A grooved handle was added for better gripping. The heavier pipe prevents the pickup tool from bending and better control of the magnetic tip is possible for source manipulation.

Arrangements for unloading were also being made by the SRO personnel. The Cannonball was being adapted for the shipment of four 10.0 mg ^{252}Cf sources. A set of working drawings of the AECACSSC assembly before alteration is shown in Appendix 6. Alterations were made on the inner plug of the shipping carrier, Figs. 16, 17, and 18.

4.3 ^{252}Cf Source Unloading

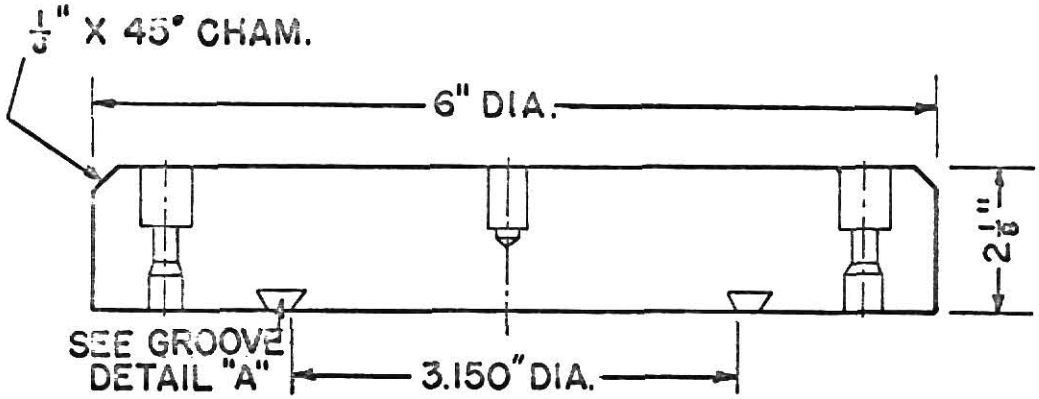
Three weeks prior to the actual unloading, procedures were outlined, Table 1, and trial runs were conducted. The procedures were outlined for maximum safety in case one of the sources was dropped enroute from the carrier to the tank. Sheet plastic was placed under the reactor bay stairway which led to the reactor bay floor so that a dropped source would slide to one location at the bottom of the stairs. A backup man carried the magnetic wand for use in retrieving a dropped source. The source was to be placed in the bulk shielding tank if dropped before reaching the reactor bay stairway. Arrangements were not made for the possibility of separation of the eyelet from the source. This should have been considered because recently others have received sources in this condition.



NOTE: First cut groove to sharp edge then round off edges to DIM 'A'

P(.323 DIA) Drill thru
3/4 DIA C'bore x 1 1/4 deep
3/8-16 UNC-2 tap 7/16 DIA
Drill 5/8 deep opposite
side typ 8 holes eq.
spaced on 4 3/4 DIA BC

P(.323 DIA) Drill
1 5/8 deep - 3/8-16 UNC
Tap 1 1/2 DP. 1 hole



NOTE: soc hd cap scr (captive)
1. 3/8-16 UNC x 1 3/8 lg to be used for 8 holes on 4 3/4 BC
2. "O" ring 3 1/8 ID x 3 1/2 OD x 3/16 NO 2-338 Mat'l: rubber-silicone

Figure 16. ^{252}Cf adaptation to AECACSSC inner plug 304L SST flange.

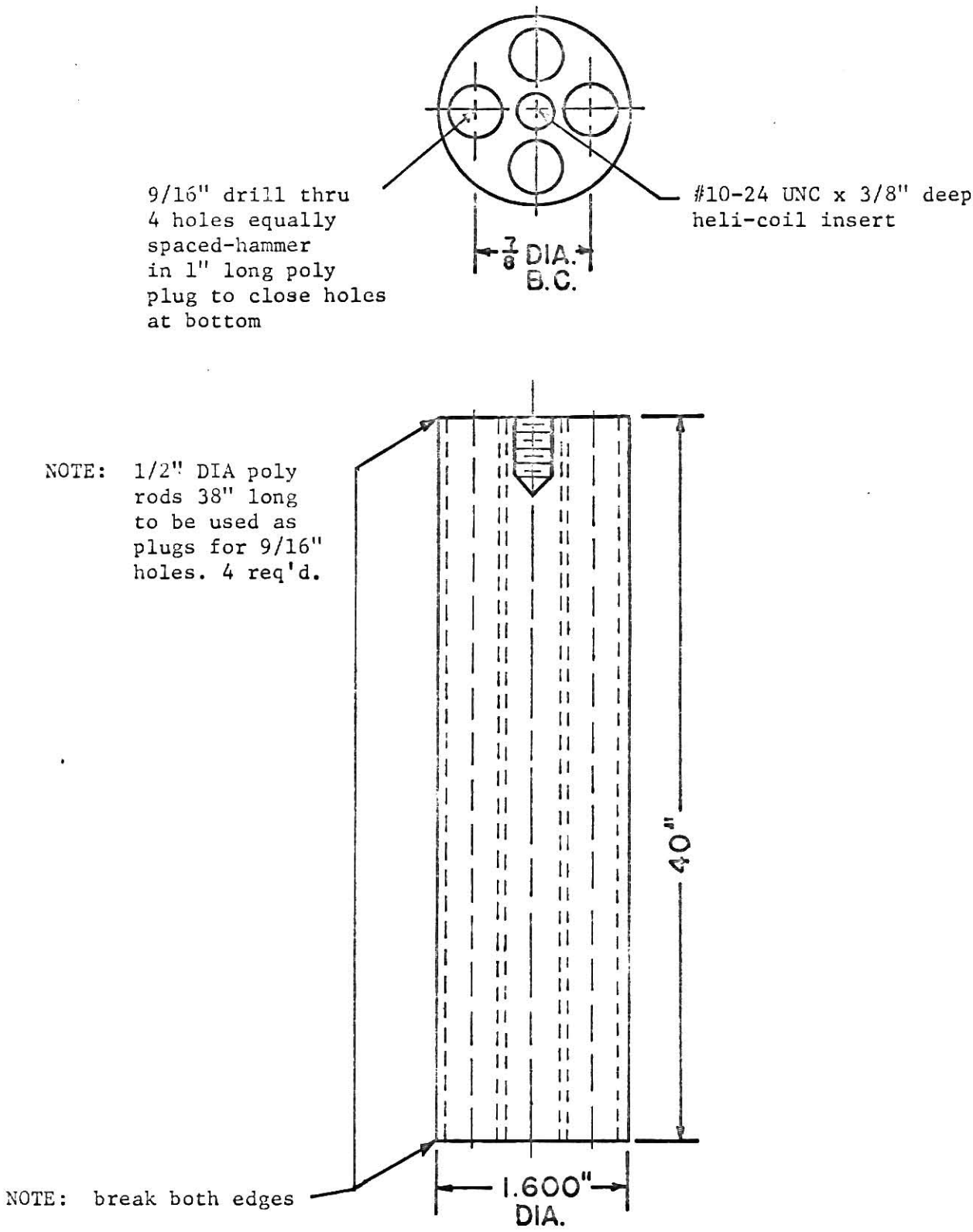


Figure 17. ^{252}Cf adaptation to AECACSSC polyethylene inner plug.

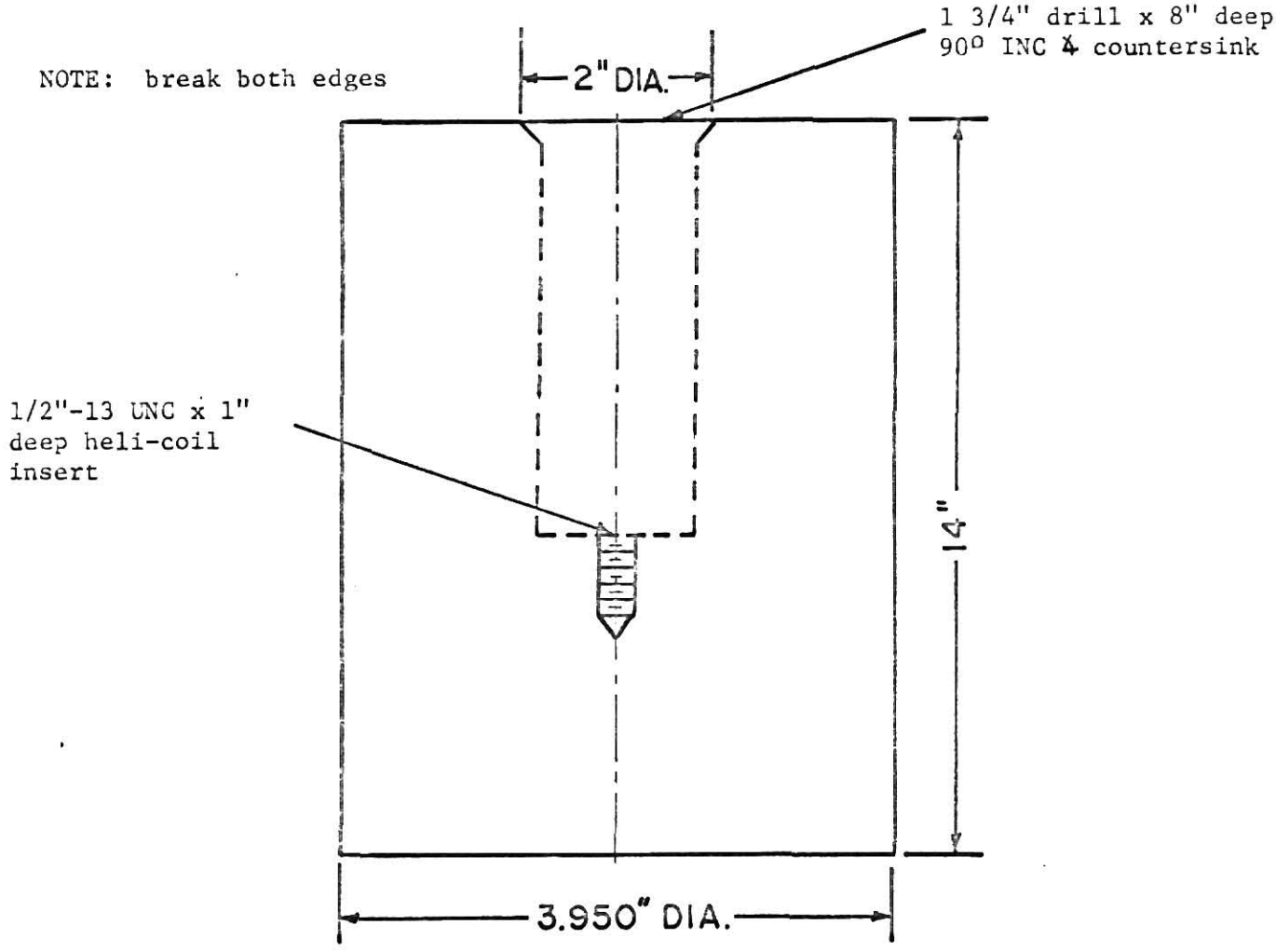


Figure 18. ^{252}Cf adaptation to AECACSSC polyethylene well plug.

TABLE 1

Unloading Procedures for Four 10 mg ^{252}Cf Sources from DOT SP No. 6323

1. Review shipping cask specifications and talk through the procedures.
2. Insure that the KSUTMIINR is shut down and open the outside doors.
3. Survey cask and begin wipe tests.
4. Remove 12 nuts from the 18" diameter cover plate and break seal wires.
5. Remove cover plate.
6. Loosen 8 captive bolts from the 6" diameter, 2" thick, plug flange located in the top well below the cover flange.
7. Remove the 6" diameter plug flange with captive bolts.
8. Determine which position contains the 8.45 mg source, tie strings together, and trim up knot.
9. Test the knot to assure a good tie, and remove the 3/8" diameter polyethylene shielding plug.
10. Take a wipe test of the shielding plug.
11. Clear all personnel from the top of the cask and to a distance of at least 15' from the pathway along which the source is to be carried.
12. Pull the string until the source is inside the lead cup, and wrap the string around the anchor.
13. Carry the source to the tank, unwrap the string and drop the source into the water.
14. Two assisting personnel follow the carrier, and move onto the platform at the signal, "source is down."
15. One assistant places the magnetic tool in position, while the other secures the source on the tank floor with the holding tool.
16. The first assistant moves to the far side of the tank and pulls the source string tight.
17. The source carrier cuts the string with the cutting tool.
18. The second assistant removes the holding device and the bamboo pole.
19. The source carrier places the source in the specified location with the magnetic tool.
20. Read out all EG&G TLD body dosimeters.
21. Prepare the bamboo pole for the next carry.
22. Reclaim dosimeters.
23. Replace the polyethylene plug.
24. Repeat steps 8-23 for the 10.48 mg source.
25. Repeat steps 8-23 for the 11.14 mg source.
26. Repeat steps 8-23 for the 10.79 mg source.
27. Replace the 6" plug flange.
28. Replace the 18" cover plate.
29. Remove all radioactive labels from the cask body and trailer.
30. Place two "EMPTY" labels, 180° apart, on the body of the cask.
31. Return carrier and cask, as soon as possible, to:

E. I. du Pont de Nemours & Co.
Savannah River Plant
Dunbarton, South Carolina
Attention: R. H. Hobert

The total trial-run time required for the unloading of one source was 90 seconds. This time was composed of two major parts: 1) lifting out of the cask to dropping into the tank (30 seconds), 2) dropping into the tank to placement into the holder (60 seconds). The dose for each part was estimated to be 53.2 mr. Total dose for the transfer of all four sources was estimated to be approximately 215 mr. This represented approximately one-sixth of the total allowed quarterly dose as specified by State of Kansas regulations.

The actual shipment left SRO at 10:40 a.m. EST, April 12, 1971. The truck drivers called at 1:43 p.m., on April 13, 1971, from Moran, Kansas, estimating their arrival time at 5:30 p.m. that afternoon. The carrier actually arrived at the KSUTMIINR at 6:20 p.m., Fig. 19.

The cask was surveyed by the RSO at KSU. Assisting in the survey was the Health Physicist from the KSDH. A Nuclear Chicago Model 2588 survey meter was used to detect the 15-20 mr/hr (gamma-ray dose rate), at the surface of the cask. A contribution of 10-15 mr/hr (neutron dose rate at the surface) was detected by a Texas Nuclear Model 9149 NEMO detector. The top of the cask was measured to have 1-2 mr/hr neutron dose rate at the surface.

Once the preliminary surveys were made, the unloading instructions from SRO were reviewed. The seal on the cask was broken and actual unloading procedures began. Additional surveys were made after the removal of the 18-inch diameter cover plate and the 6-inch diameter, 2-inch thick plug flange. The gamma contribution was 20-25 mr/hr (at the surface) on the top, with the cover plates removed, Fig. 21. Using a Cd covered G-M tube, the neutron contribution was 4-5 mr/hr at the surface. In addition to the surveys, smear tests were made on several areas of the cask. A PT-CS was used to analyze the tests. The results of the smear tests are summarized in Table 2.

Figure 19.

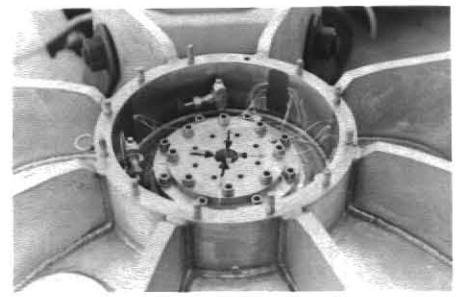


Figure 20.

Figure 21.

Figure 22.

Figure 23.

Figure 24.

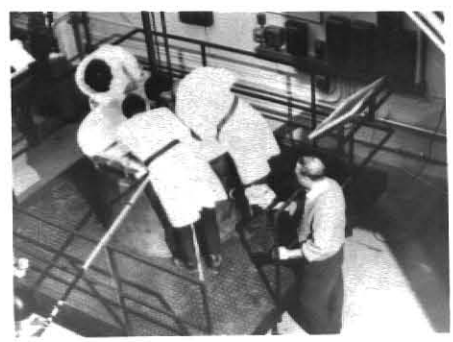


Figure 25.

Figure 19 (1st Row, Left). AECACSSC and Tri-State Motor Transit Carrier.

Figure 20 (1st Row, Right). Top view of AECACSSC with cover plates removed.

Figure 21 (2nd Row, Left). Wipe test of AECACSSC polyethylene shielding plug.

Figure 22 (2nd Row, Right). Lifting ^{252}Cf source from AECACSSC.

Figure 23 (3rd Row, Left). ^{252}Cf source carry.

Figure 24 (3rd Row, Right). ^{252}Cf source drop into tank.

Figure 25 (4th Row). Cutting of string and placement of ^{252}Cf source into holder.

TABLE 2

Summary of the ^{252}Cf Source Unloading Smear Test Results

Smear No.	Location	Net Counts*	Conversion Factor	Disintegrations per Minute (dpm)**	Curies $(10^{-3})^{\dagger}$
1.	cover plate bottom	9	0.47	18	0.08
2.	AECACSSC rib surface	185	0.42	440	0.20
3.	6" flange bottom	25	0.52	48	0.02
4.	6" flange bottom	136	0.50	272	0.12
5.	8.45 mg polyethylene plug end	92	0.52	184	0.08
6.	10.48 mg polyethylene plug end	115	0.51	230	0.10
7.	11.14 mg polyethylene plug end	120	0.52	240	0.11
8.	10.79 mg polyethylene plug end	406	0.50	812	0.37

*75 counts total background

$$**\text{dpm} = \frac{\text{Net Counts}}{\text{Conversion Factor}}$$

$$^{\dagger}\text{Curies} = \frac{\text{dpm}}{2.2 \times 10^{6}\ \text{dpm}/\mu\text{c}}$$

Actual unloading was conducted without any major problems and the estimates of total dose proved to be generally in excess of those actually measured. The three personnel directly involved with the source transfer were monitored with EG&G, TL-15, neutron sensitive body dosimeters. The dosimeters were attached to the unloading personnel before surveying the cask and removal of the plugs. They were read out after first transfer and after each of the other transfers. The results are summarized in Table 3.

The reason for the high first read-out is believed to be due to the exposure from the cask and the fact that the dosimeters were not zeroed immediately prior to the unloading task. Nearly one hour was spent in surveying and removing the plugs in preparation for the first carry. The total dose recorded for each of the personnel should probably be at least 50 mr less than shown, because of the inordinately high dose of the first readout.

The personnel also wore two neutron sensitive film badges. No significant dose was received according to the film badge results which are shown in Table 4.

The total time for unloading was much less than anticipated in the trial runs. Lifting out of the cask to dropping into the tank, took only 20 seconds on the average. Placement into the holder took about 45 seconds or more. Average moving time for each of the four sources was 65 seconds.

Only three minor problems were encountered. The placement of the second source took extra time because the eyelet adaptors were so long that the magnetic wand attached near the center of the source, caused the source to be at a 90° angle to the wand. The source had to be brushed against the 5 inch diameter pipe wall before insertion into the holder. The second problem was that the knot connecting the string from the source to the string of the bamboo pole did not pass through the string guides. The source was not on the bottom

TABLE 3

Summary of the EG&G, TL-15 Body Dosimeter Results

Name	^{252}Cf Source	Body Location	Dose (mr)	Total Dose (mr)
Roberts	8.45 mg	Neck	101.0	181.2
		Waist	120.0	293.5
	10.48 mg	Neck	29.8	
		Waist	56.5	
	11.14 mg	Neck	22.4	
		Waist	*	
	10.79 mg	Neck	28.0	
		Waist	117.0**	
Hoffman	8.45 mg	Chest	186.0	248.6
	10.48 mg	Chest	25.4	
	11.14 mg	Chest	18.1	
	10.79 mg	Chest	20.0	
Brown	8.45 mg	Face	109.0	154.0
		Waist	111.0	199.5
	10.48 mg	Face	16.0	
		Waist	16.0	
	11.14 mg	Face	14.5	
		Waist	*	
	10.79 mg	Face	14.5	
		Waist	72.5**	

*Dosimeter not read out.

**Total dose for 11.14 and 10.79 mg sources.

TABLE 4

Summary of the Film Badge Radiation Dosimetry Reports

Name	Exposure Period (whole body)	Dosimeter Type	Total Dose
Roberts	4/01/71 to 4/14/71	N*	M†
	4/01/71 to 6/30/71	J**	M
	4/15/71 to 4/31/71	N	M
	4/01/71 to 6/30/71	J	M
Hoffman	4/01/71 to 4/14/71	N*	M†
	4/01/71 to 6/30/71	J**	M
	4/15/71 to 4/31/71	N	M
	4/01/71 to 6/30/71	J	M
Brown	4/01/71 to 4/14/71	N*	M†
	4/01/71 to 6/30/71	J**	M
	4/15/71 to 4/31/71	N	M
	4/01/71 to 6/30/71	J	M

*Fast neutron - body film badge.

**Regular beta-gamma body film badge.

†Exposure below minimum quantity measureable.

of the tank when personnel approached the source to cut the string. No noticeable increase in dose was measured. To prevent this from happening, the guides on the pole should be made larger, and at least 15 feet of string should be attached to the source before loading.

The third problem was psychological rather than mechanical in nature. The low-level alarms which are used to monitor the reactor bay had not been adjusted to sound at a higher level. As the first source approached the double doorway, all the alarms sounded, which resulted in noticeable increase in the speed of the unloader. This caused a general increase in nervousness of all three unloaders. It may have caused difficulty in clear thinking if a serious accident had occurred.

The sources were unloaded and the carrier was started on the return trip within 2 1/2 hours after arrival. The largest quantity of ^{252}Cf in the Market Evaluation Program (40.86 mg) had been unloaded. Figures 19-25 illustrate the unloading procedure. Super-eight millimeter movies were also made and can be viewed via special arrangements with the Department of Nuclear Engineering, Kansas State University, Manhattan, Kansas 66506.

5.0 FLUX MEASUREMENTS

5.1 Cadmium Ratio and Thermal Neutron Flux Measurements by Indium Foils

The purpose of the work of this section was to determine the cadmium ratio and the thermal neutron flux provided by 40.86 mg of ^{252}Cf in a water moderator. The date of determination was June 1, 1971. Two source configurations were considered, Fig. 6.

Indium foils were positioned in the central thimble by means of polystyrene vials, Fig. 26. To minimize shadowing effects, the foils were positioned at least five inches apart along the vertical axis. Half of the foils were covered with cadmium on both sides. The remaining foils were covered on both sides with aluminum. The foils were irradiated a minimum of seven hours to saturate ^{116}In production. Delays of up to five hours were necessary because of the high activity of those foils closest to the californium sources. The four foils from positions 45.72 to 76.41 cm were counted after 3 minutes allowing only for decay of the 14 second isomer. All of the foils were counted with a 3 x 3 Na I(Tl) detector and a TMC Model 402 Multichannel Analyzer for a counting efficiency of 33%. The definitions and equations for the calculations are shown in (13).

The results of the cadmium ratio measurements are plotted and shown in Fig. 27. The thermal fluxes for both configurations are plotted and shown in Fig. 28. The peak thermal flux is $4.014 \pm 0.002 \times 10^7$ n/cm^2-sec.

5.2 Neutron Flux Measurements with Scandium Oxide

The purpose of the work of this section was to determine the neutron flux provided by 40.86 mg of ^{252}Cf in a water moderator. The date of determination was June 1, 1971. Two source configurations were considered, Fig. 6.

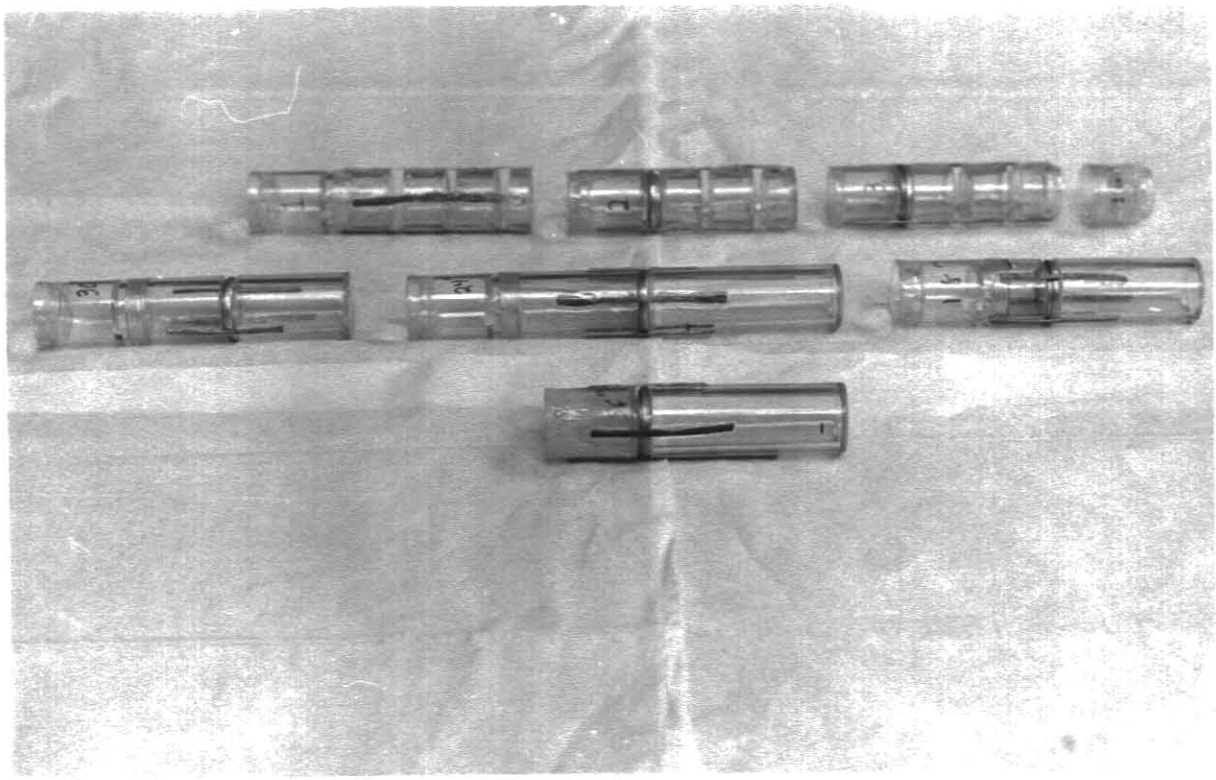


Figure 26. Polystyrene vials used for indium foil placement.

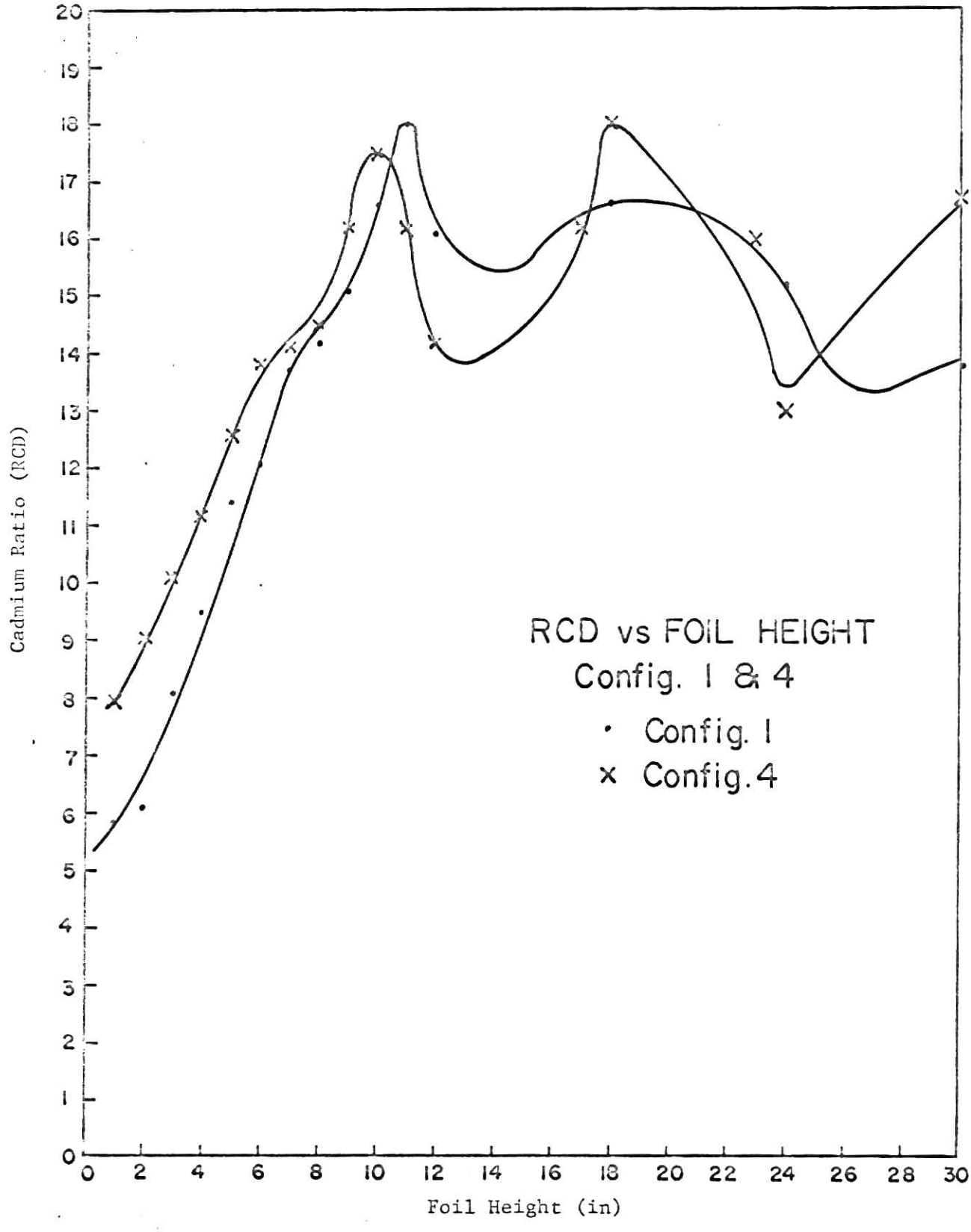


Figure 27. Cadmium ratio versus foil height for configurations 1 and 4.

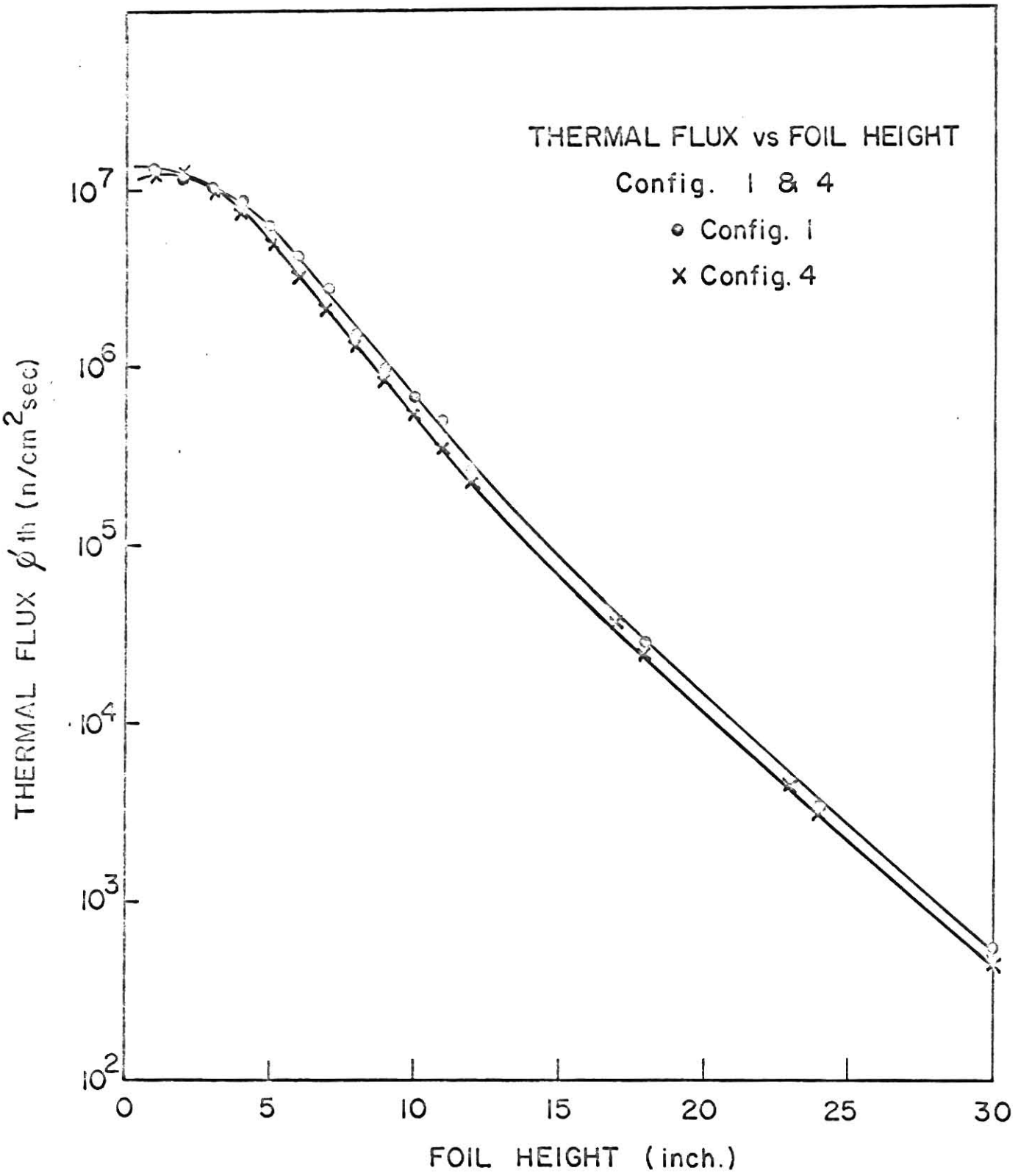


Figure 28. Thermal flux versus foil height for configurations 1 and 4.

Scandium oxide was weighed into polyethylene vials and positioned in the central thimble. The vials were irradiated and then counted using a 25 cc. Ge(Li) detector and a TMC 4096 Multichannel Analyzer. Table 5 is the summary of experimental data for configurations 1 and 4.

A computer program was used to calculate the areas under the three peaks. The definitions and equations for the program are shown in (19).

The values for both flux determinations are summarized in Table 5. The average calculated flux for configuration 1 is 4.76×10^8 n/cm^2-sec. The flux versus time is shown in Fig. 29. Also shown is the thermal flux as determined by the cadmium ratio technique. The difference between the two measurements is due to epithermal and fast neutrons. The flux measured by the cadmium ratio technique was determined by the thermal neutron contribution. The resonance peaks for scandium oxide were for both thermal, epithermal, and fast neutrons. Therefore, the neutron flux determined by the sum peak method is higher than the flux determined by the cadmium ratio technique.

TABLE 5

Summary of Experimental Data for Configurations 1 and 4

Sample No.	Weight (grams)	Irradiation Time (minutes)	Decay Time (minutes)	Counting Time (minutes)	Flux Values (10^8 n/cm^2-sec)
Configuration 1					
1001	.2081	148[a]	11,000	50	4.69
1006	.0675	107[b]	71,000	120	4.68
1007	.2081	148	80,000	120	4.86
1008	.0675	107	73,610	120	5.16
1009	.2081	148	83,003	120	4.42
Configuration 4					
1005	.0966	240[c]	46,000	120	4.05
1010	.0966	240	52,156	120	3.63

[a] May 25, 1971

[b] May 31, 1971

[c] June 17, 1971

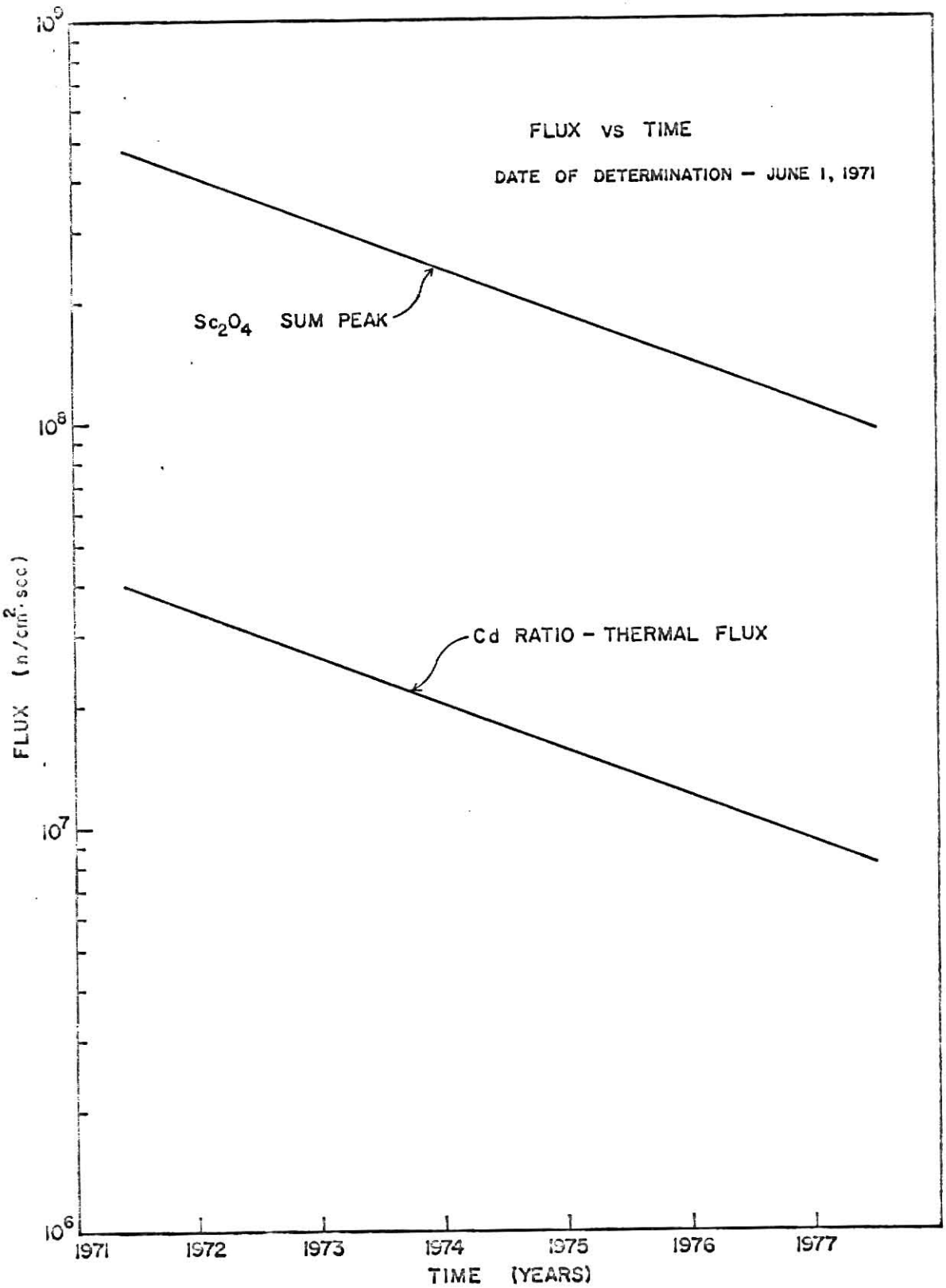


Figure 29. Plot of neutron flux versus time for scandium oxide and cadmium ratio.

TABLE 6

Reference Sample Material and Weights

A	El	Z	t 1/2 (minutes)	Degree of Sensitivity	Compound	Wt of Compound (grams)	Gamma-Ray Energy (keV)
11	Na	24	900.00	0.00059	$Na_2(SO_4)$	1.0853	2754.14
							1368.53
12	Mg	27	9.50	0.0059	MgO	0.4101	1014.40
							843.76
							170.82
13	Al	28	2.27	0.1013	Al_2O_3	0.7478	1778.89
17	Cl	38	37.20	0.0410	NH_4Cl	1.1922	2167.60
			0.014				1642.70
20	Ca	49	8.70	0.0396	CaO	0.6177	3084.49
22	Ti	51	5.76	0.00507	TiO	0.5027	929.29
							608.55
							321.41
25	Mn	56	154.00	0.0134	MnO_2	0.2498	2112.60
							1811.20
							846.60
29	Cu	64	765.00	0.0000204	Cu	0.7503	1345.76
							511.00
51	Sb	122	4.20	0.00531	SbO_3	0.2507	1256.83
			3945.00				1140.60
							692.76
							564.08
66	Dy	165	141.00	0.0364	Dy_2O_3	0.0104	715.40
			0.54				633.50
							361.70
							279.76
							94.70
72	Hf	180	330.00		Hf	0.1493	
72	Hf	181	6105.60	0.00967	Hf	0.1493	482.96
							345.95
							136.25
							133.05

6.0 SECURITY AUTHENTICATION BY USE OF NEUTRON ACTIVATION ANALYSIS

6.1 Purpose of Experimental Work

The purpose of the work of this section was to determine the feasibility of security authentication by use of NAA with ^{252}Cf. The feasibility hypothesis is as follows:

> Each security would be encoded by a combination of readily detectable elements. This combination would be properly recorded but known only to the proper authorities. When the securities are redeemed or transferred, verification of authenticity could be obtained by a very short irradiation using ^{252}Cf followed by a short scanning count to interpret the security's code.

6.2 Sample Preparation and Procedure

A set of reference sample materials were weighed and placed in polyethylene vials. A list of the materials and their weights is found in Table 6. The weight for each sample was estimated in terms of the cross-section, the isotopic abundance, and the source strength of the KSU ^{252}Cf Facility. Irradiation times were selected for a minimum amount of time in order to illustrate the usefulness of the technique. Authentication by this method requires that customer delay be held to a minimum.

The samples were irradiated for 5 minutes and counted for 2 minutes with a 25 cc lithium-drifted germanium (Ge(Li)) detector and accompanying Technical Measurements Corporation 4096 Multi-Channel Analyzer. The data were stored on magnetic tape and the computer program CONVERT (20) was used to transfer the data to punched cards. The computer program REFS (20) was used to normalize

the data. The normalized data were placed in graphical form by a Calcomp plotter program. The resulting plots are shown in Figs. 30-40.

6.3 Results

Best results were obtained from two elements: dysprosium and hafnium. No other element is present in paper samples (3). Both elements could be dissolved in ink and placed on the matrix during the printing process. The two elements have the favorable characteristics of a large neutron cross-section and a short half-life.

Five minute irradiation of 0.0104 gm of dysprosium and a 2 minute count netted approximately 80,000 counts in each of the two prominent gamma-ray peaks. A similar irradiation and count of 0.1493 gm of hafnium netted some 900 counts in two prominent gamma-ray peaks. Approximately 0.01 to 0.15 mgm of dysprosium will be needed for detection in a paper matrix. Detection of hafnium will require the concentration of approximately 0.1 to 1.5 mgm of material. The use of a NaI(Tl) crystal and refined data analysis should enhance the detection limits for both elements.

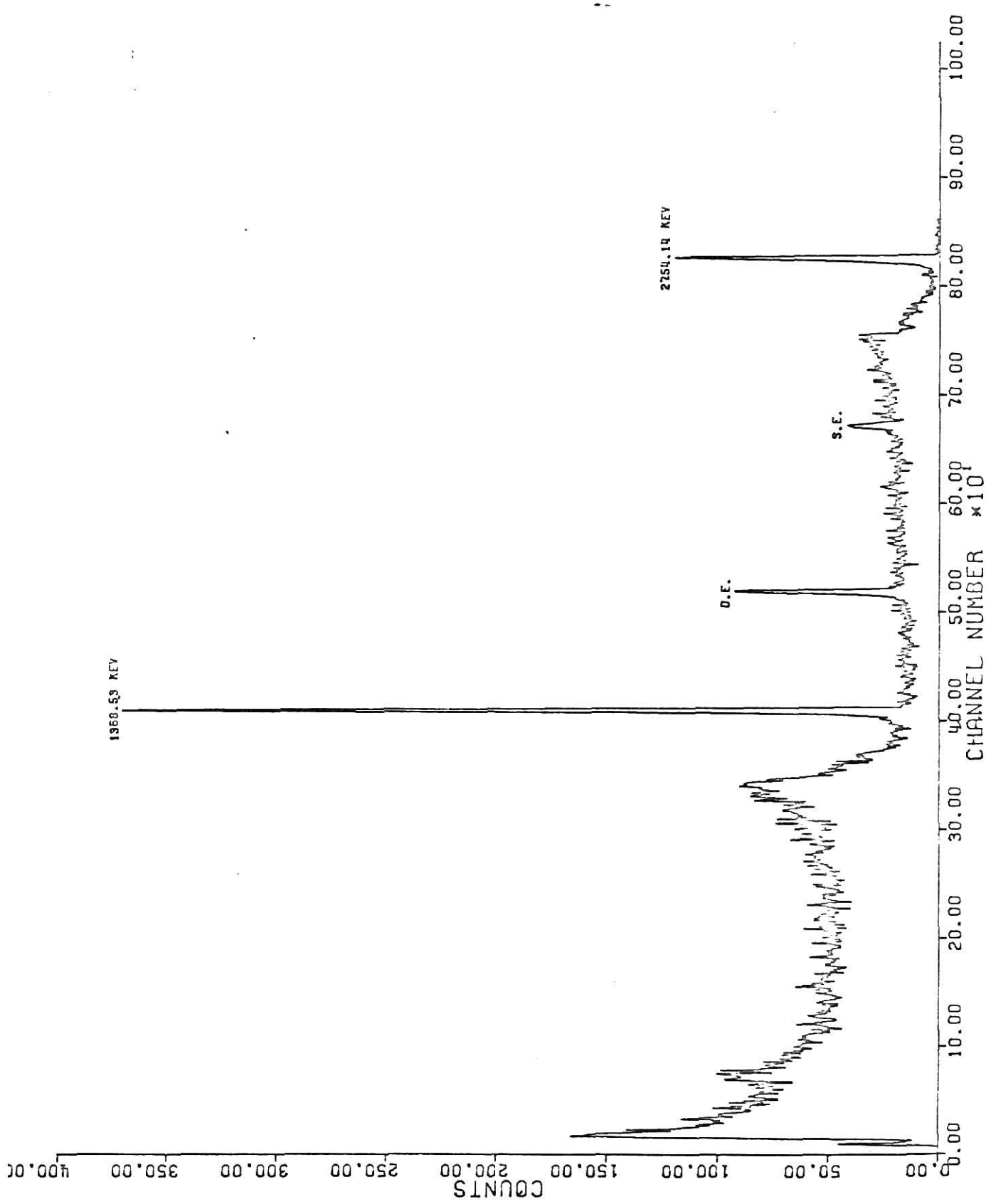


Figure 30. Normalized spectrum of ^{24}Na.

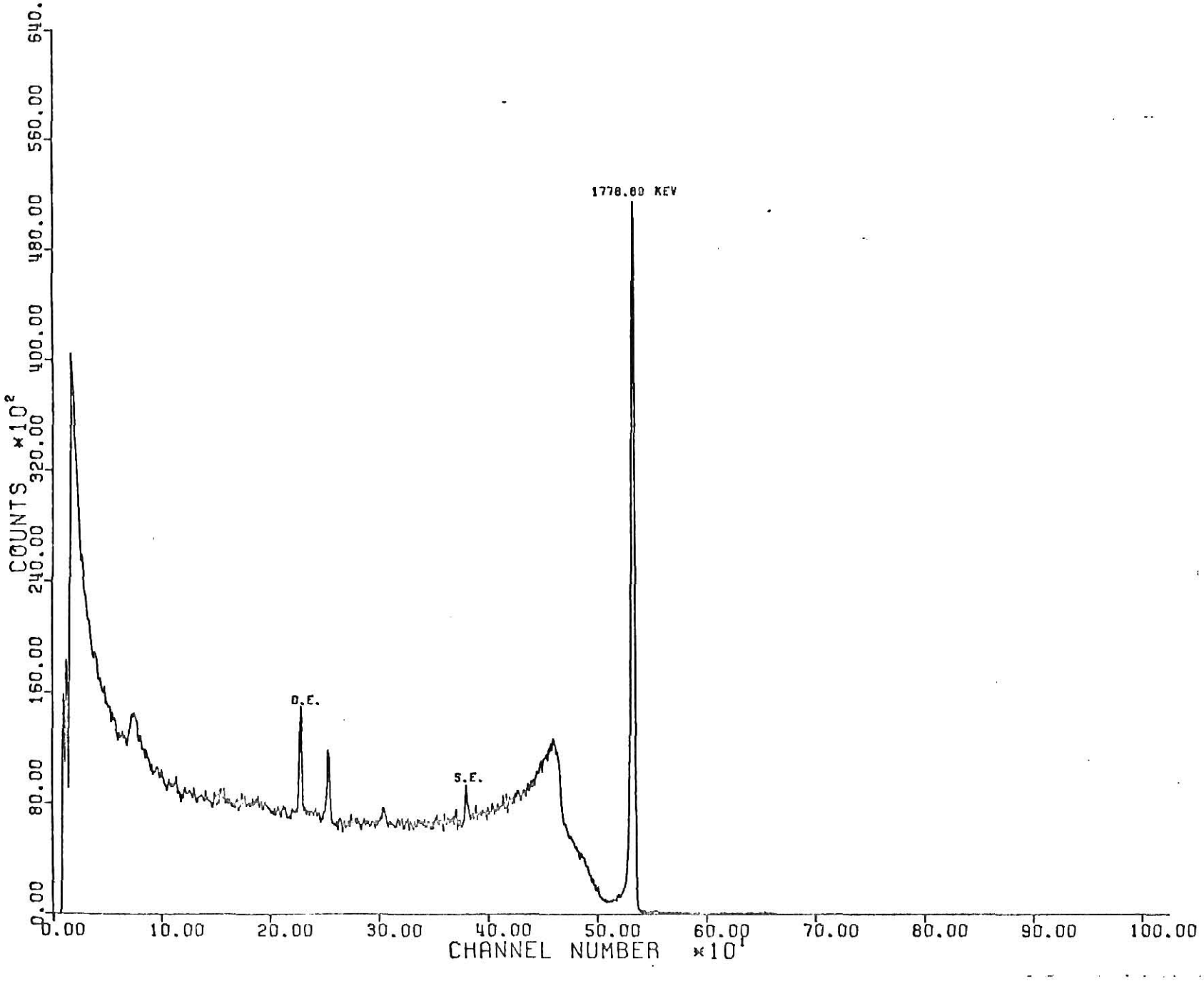


Figure 32. Normalized spectrum of ^{28}Al.

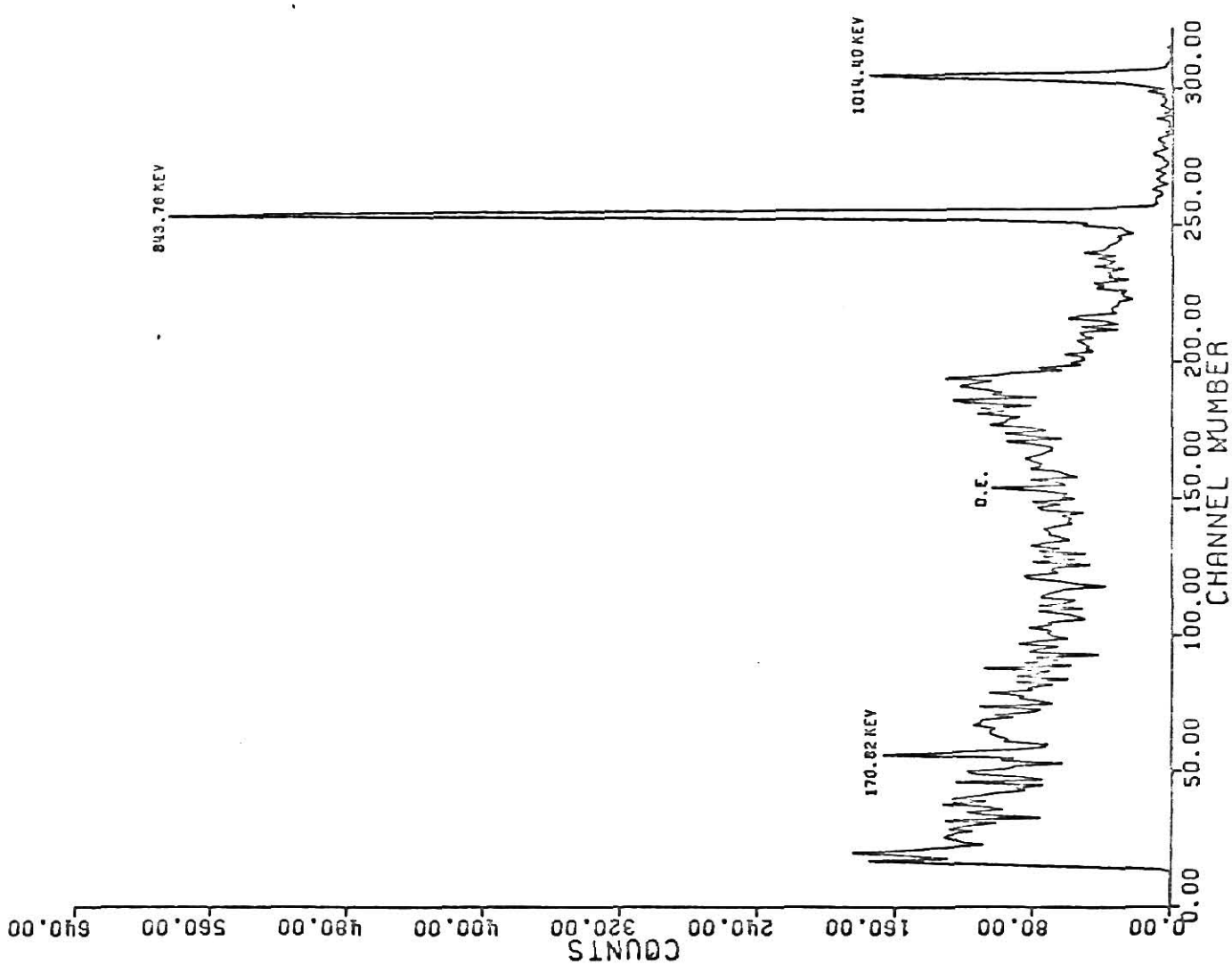


Figure 31. Normalized spectrum of ^{27}Mg.

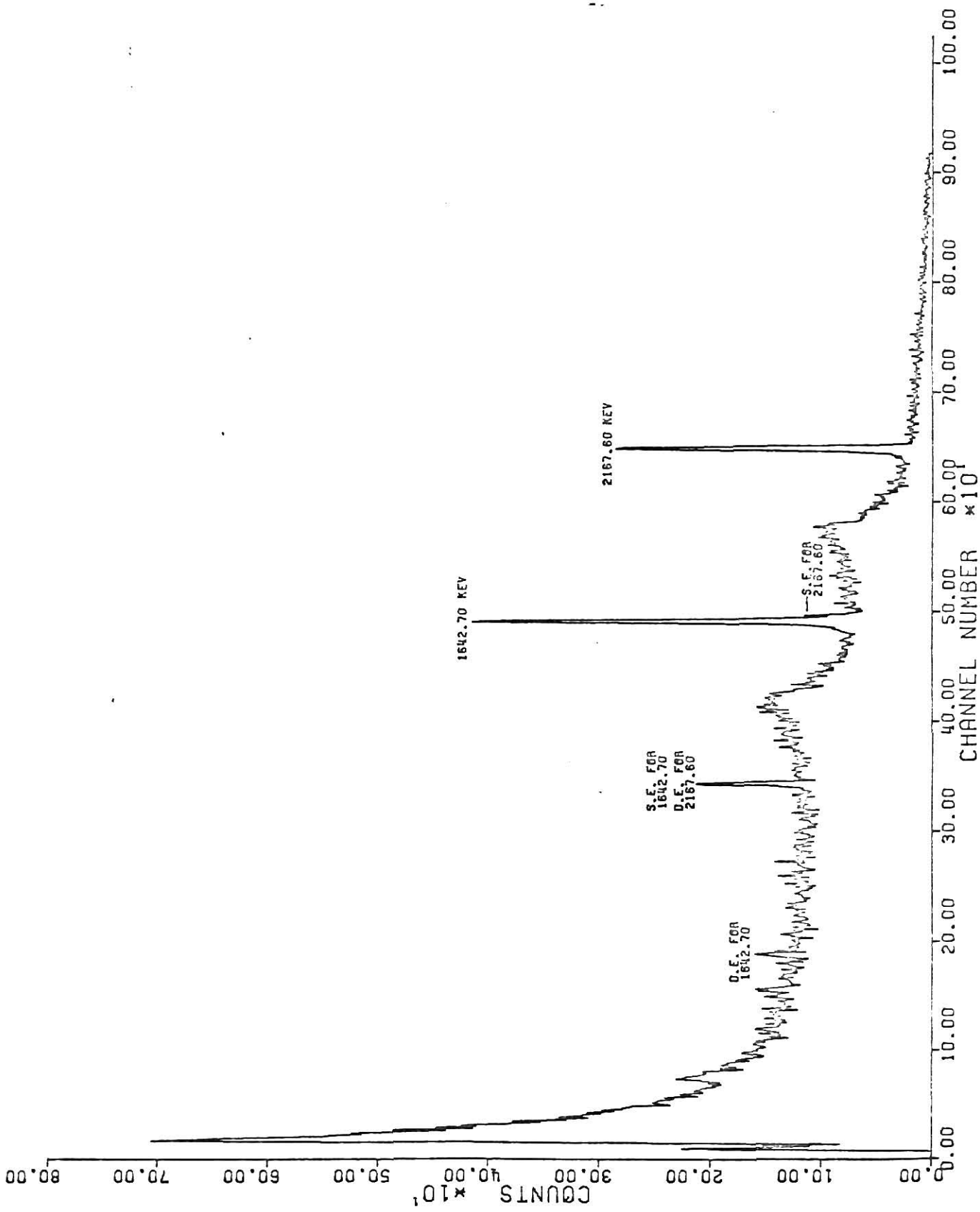


Figure 33. Normalized spectrum of ^{38}Cl.

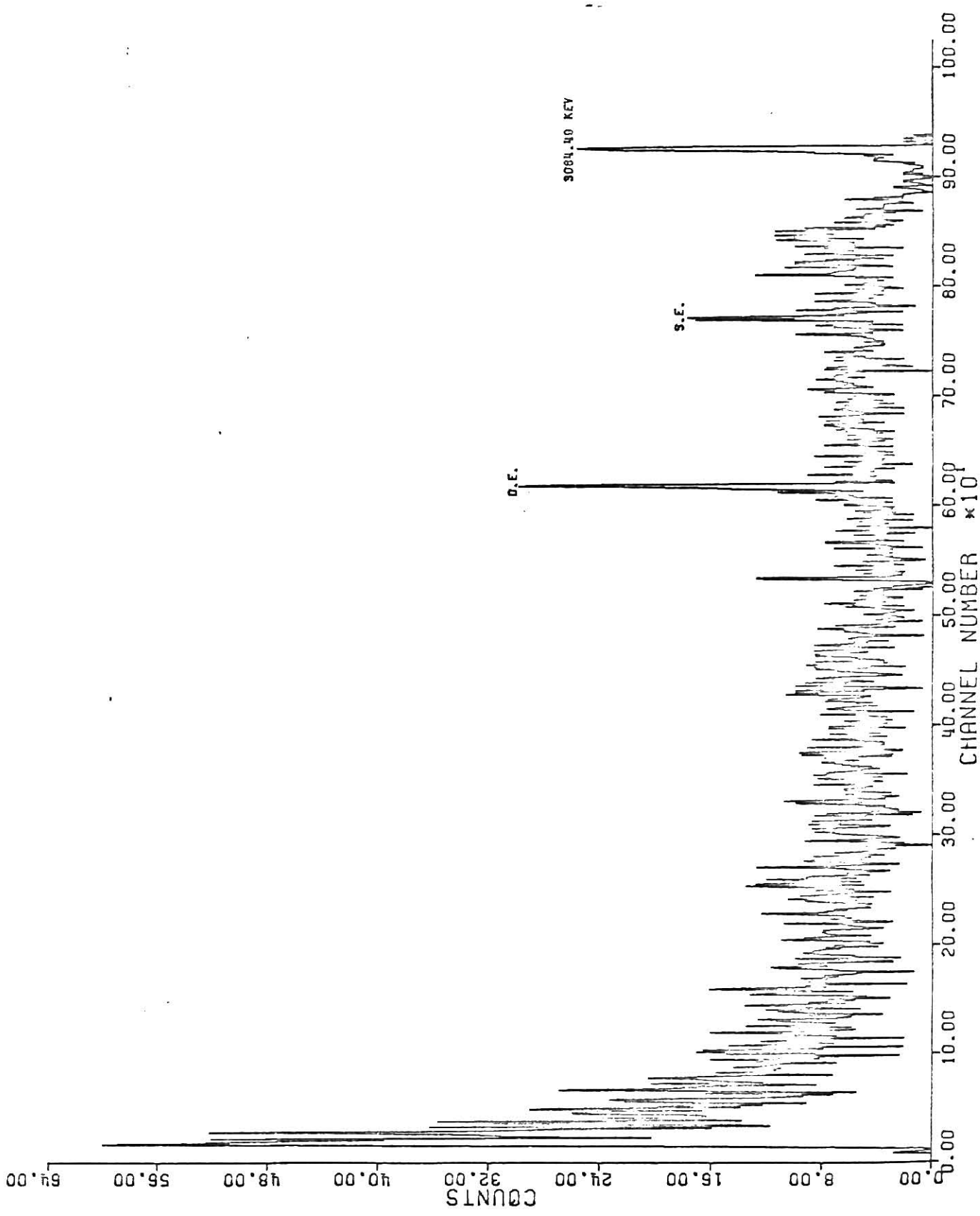


Figure 34. Normalized spectrum of ^{49}Ca.

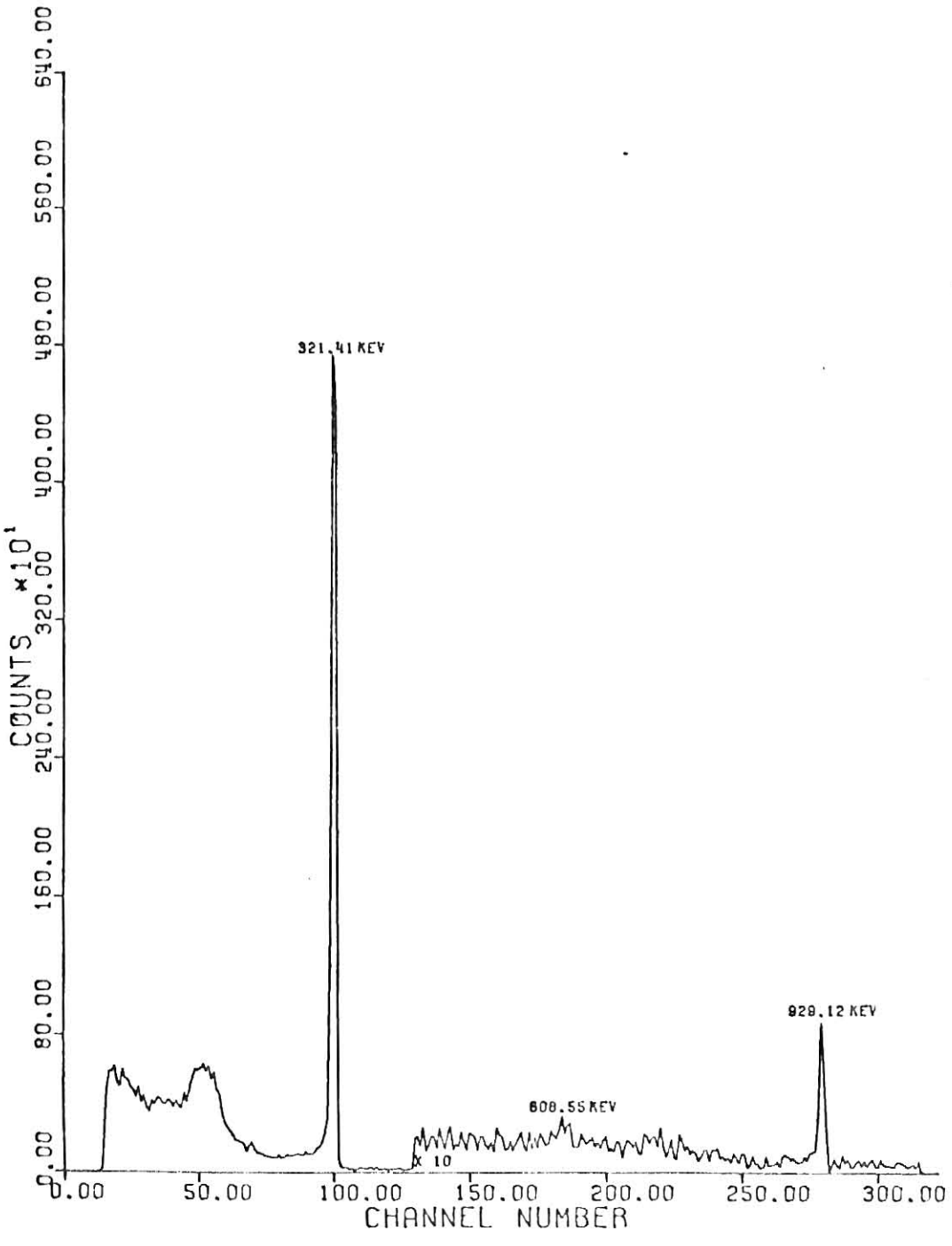


Figure 35. Normalized spectrum of ^{51}Ti.

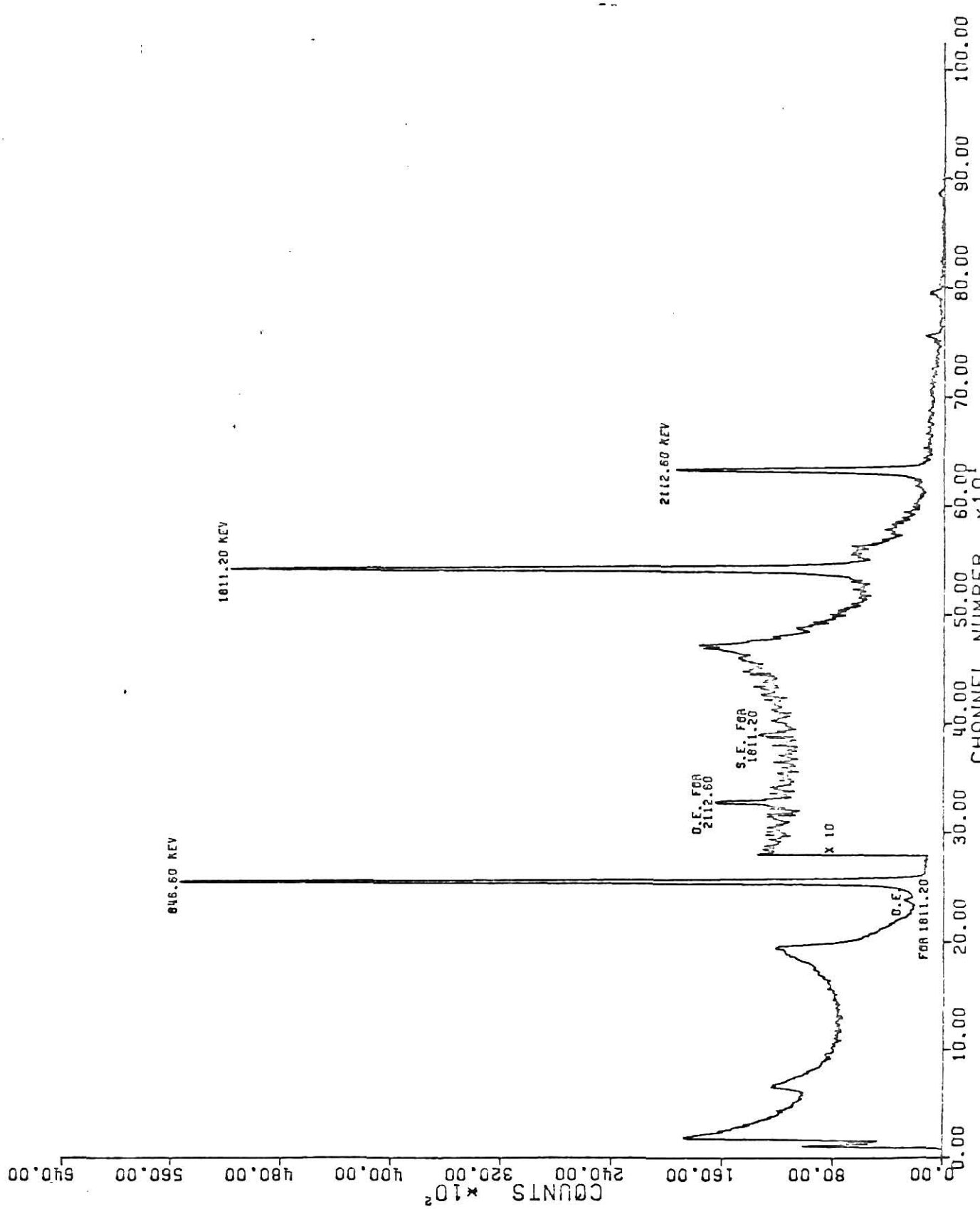


Figure 36. Normalized spectrum of ^{56}Mn.

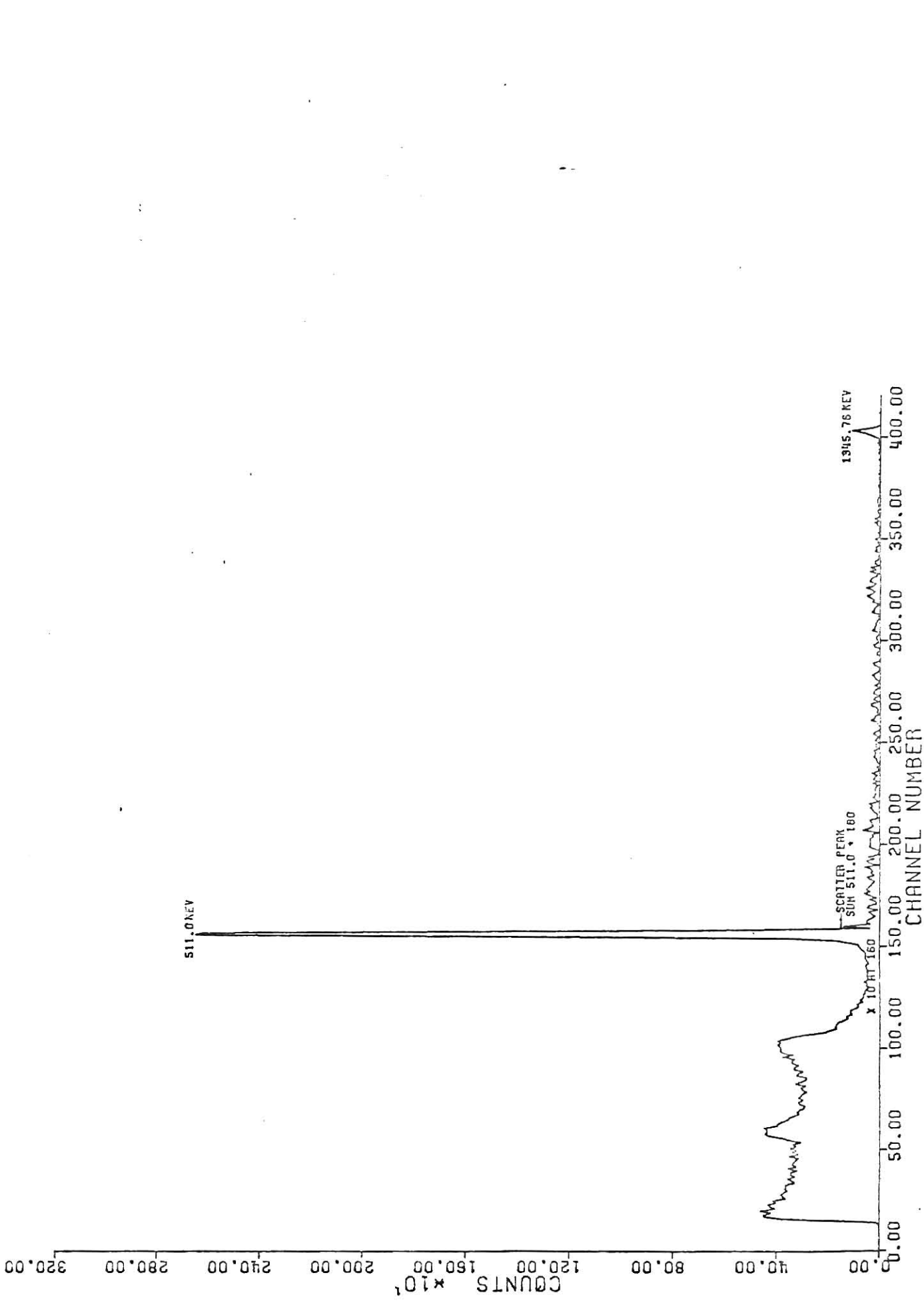


Figure 37. Normalized spectrum of ^{64}Cu.

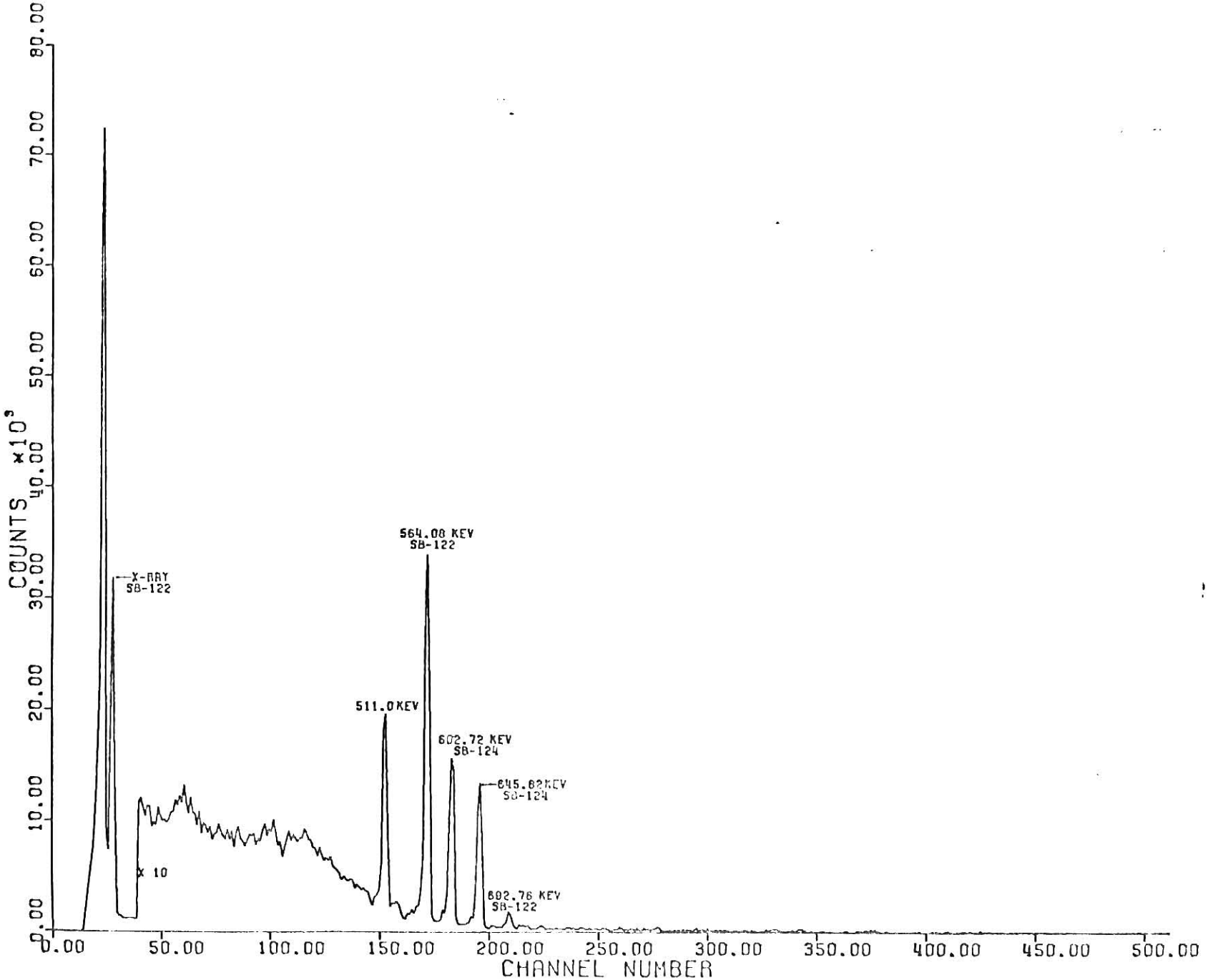


Figure 38. Normalized spectrum of ^{122}Sb.

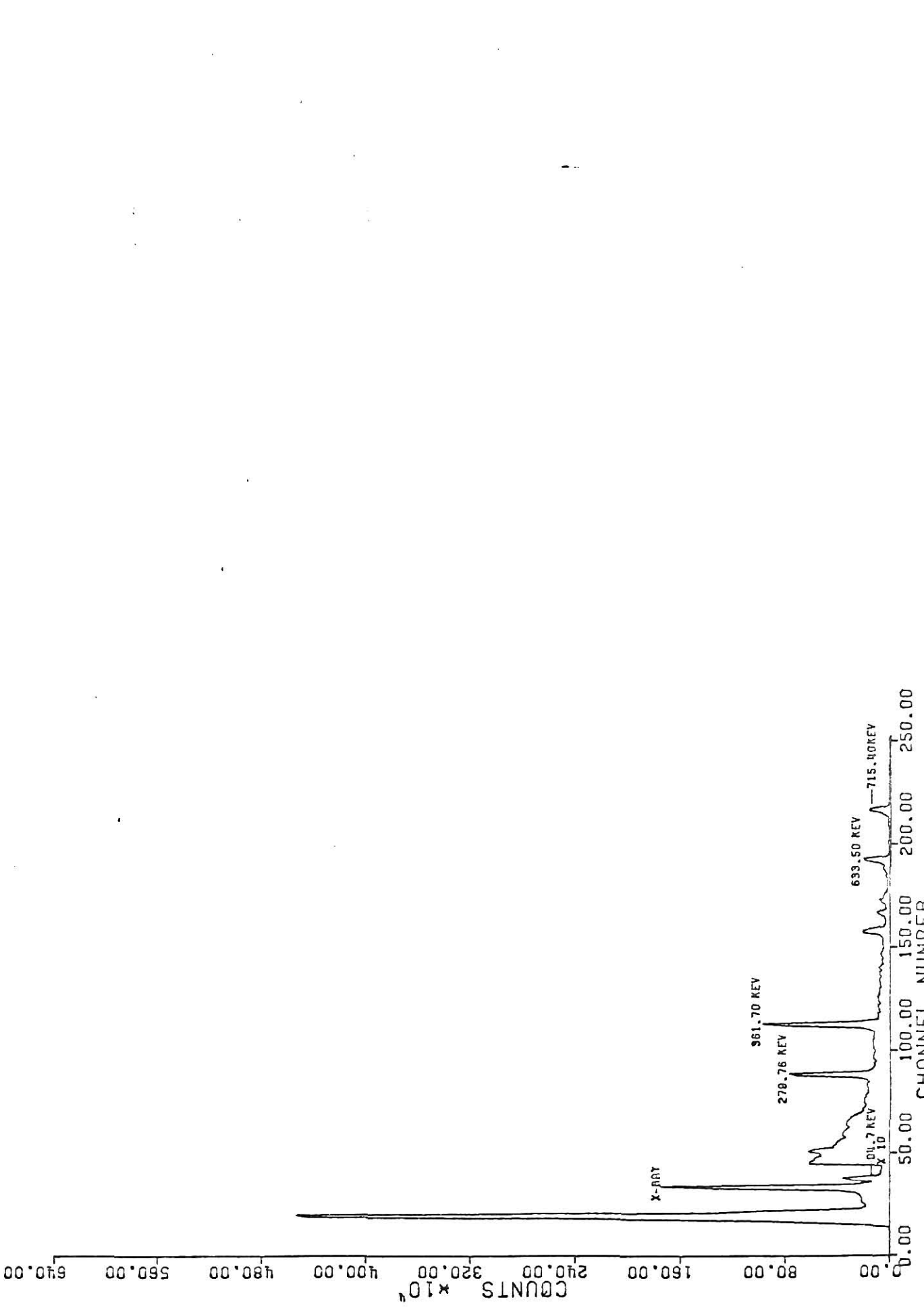


Figure 39. Normalized spectrum of ^{165}Dy.

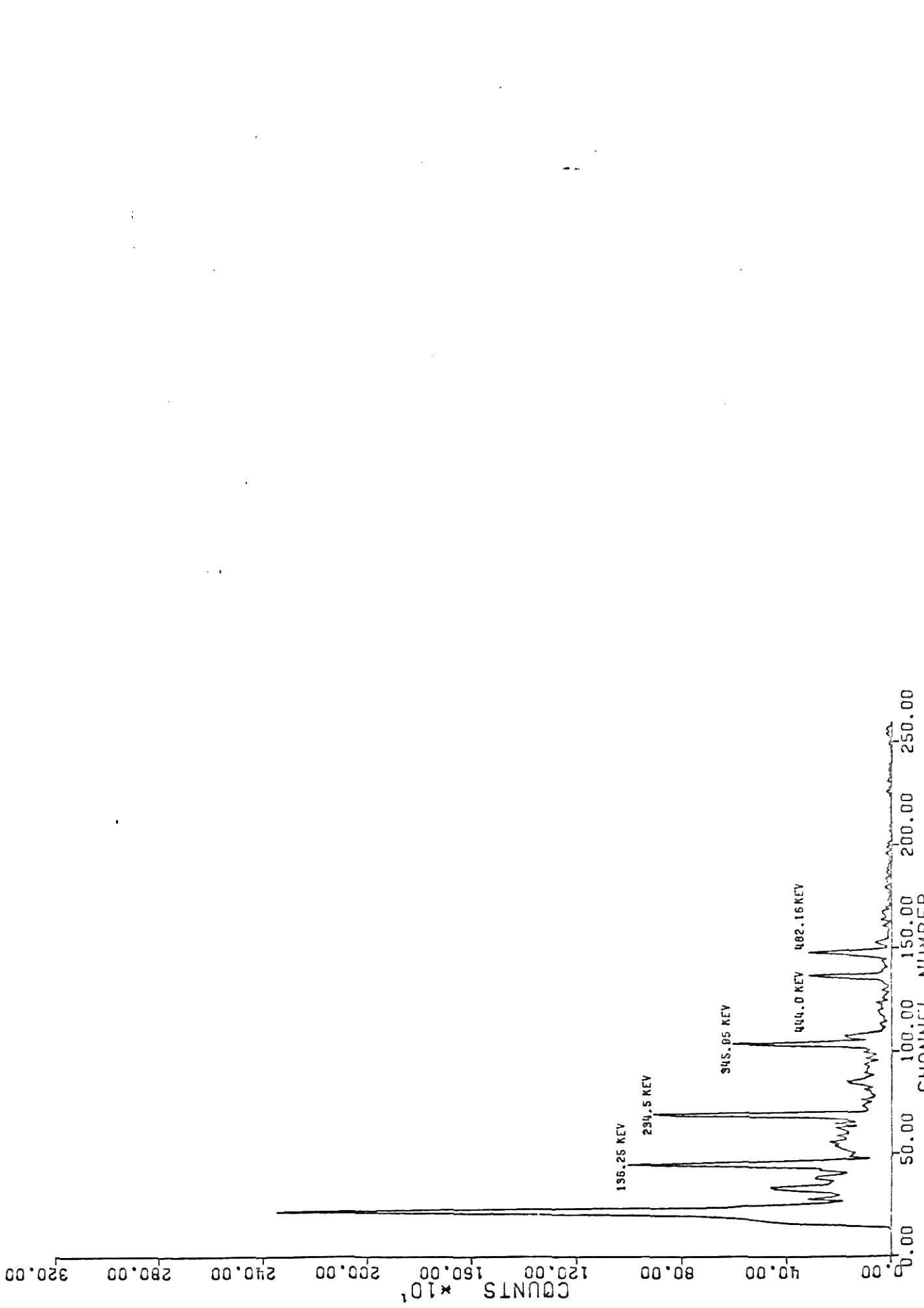


Figure 40. Normalized spectrum of ^{180}Hf.

7.0 PROTEIN DETERMINATION OF WHEAT BY CAPTURE GAMMA-RAY ANALYSIS

7.1 Introduction

The purpose of the work of this section was to develop a method of protein determination by capture gamma-ray analysis. The importance of this study is to aid in the development of an *in situ* protein analysis system for use by grain elevator operators. The specific task was to accurately determine the amount of nitrogen and sulfur present in a wheat sample. This study is based on the determinations of nitrogen and sulfur ratios and their relationship to protein quality (4).

The Kjeldahl method is the best method for determining protein quantity in wheat (5). This technique requires more than 2 hours for a single sample and costs \$1.50 to \$2.00 per sample. Two to five grams of sample are needed for the analysis and check. The Kjeldahl method is a destructive test, i.e., all of the sample is destroyed. The nitrogen determined is expressed as protein by multiplying by a conversion factor of 5.7 (1 gm gluten protein/1 gm nitrogen). The precision of the analysis for protein ranges from .1 to .2 per cent, e.g., $12.0 \pm .1$ for an optimal analysis arrangement.

The percentage of protein is usually normalized to a sample moisture of 14% for multiple sample comparison. The moisture of wheat at harvest time is generally close to 14% and decreases with storage time. The nitrogen and sulfur are generally present in the sample in a weight percent of approximately 2% and .2%, respectively (6).

Neutron capture gamma-rays are usually emitted when a neutron is absorbed by the nucleus. These capture gamma-rays, which are emitted within about 10^{-14} sec, vary from a few keV to about 11 MeV in energy (7). This method is

considered rapid because the irradiation and counting are simultaneous. Bulk samples can be analyzed because the neutrons and emitted photons are penetrating radiations.

The nitrogen 5.267 MeV gamma-rays are emitted in about 25% of the capture events (7). The sulfur 5.420 MeV gamma-rays are emitted in about 42% of the capture events (7). Both of these energies are in the mid range of the capture gamma-ray spectrum, but of the elements of significant weight per cent in wheat (6), only potassium (5.38 MeV, 7.30%) has a prominent capture gamma-ray within 100 keV.

The high resolution of the Ge(Li) detector could certainly resolve the wheat spectrum for analysis. The average spectrum peak spread is 10 keV. Analysis with a NaI(Tl) detector decreases the resolution capabilities. Nominally the peak spread is 100 keV. A faster analysis can be obtained by using the NaI(Tl) detector because of greater counting efficiency (≈2.5%). A 25 cc Ge(Li) detector is approximately a factor of 0.03 less efficient (≈0.075%).

In this particular study, the accompanying counting equipment will be a multichannel analyzer with associated pulse shaping electronics and analysis computing equipment. Ultimately, single channel analyzers would be effective for collecting data for the desired energy peaks.

Two capture gamma-ray techniques are discussed by D. Duffey (8). The first technique, known as the internal geometry technique (INGT), places the sample near the source, and the detector facing the sample and source, Fig. 41. The INGT results in more gamma-rays from the sample, but with a loss in the solid angle viewed by the detector. A water or paraffin moderator is placed between the sample and source, and the detector. This technique can be used in the determination of sulfur in a coal stream analysis (9). The second technique,

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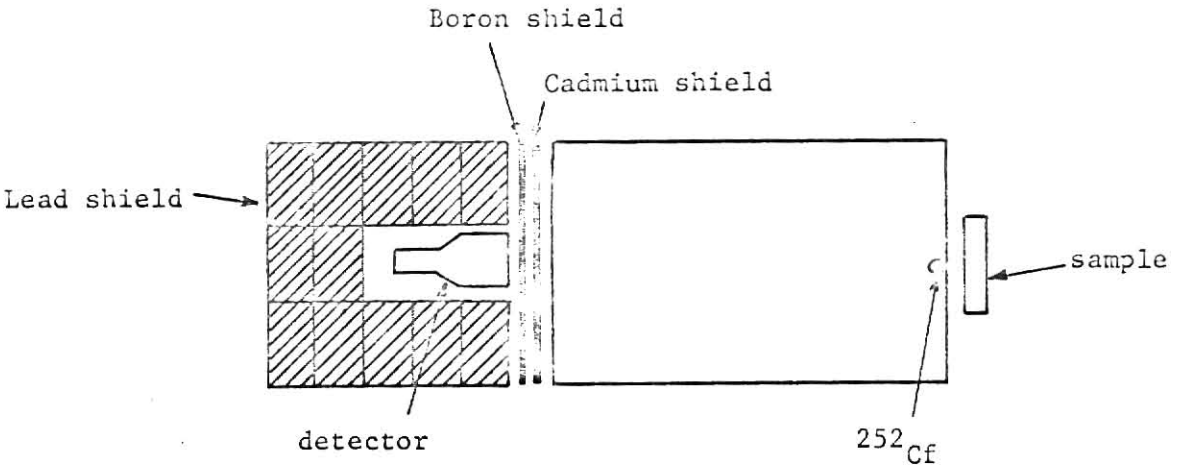


Figure 41. Internal geometry configuration.

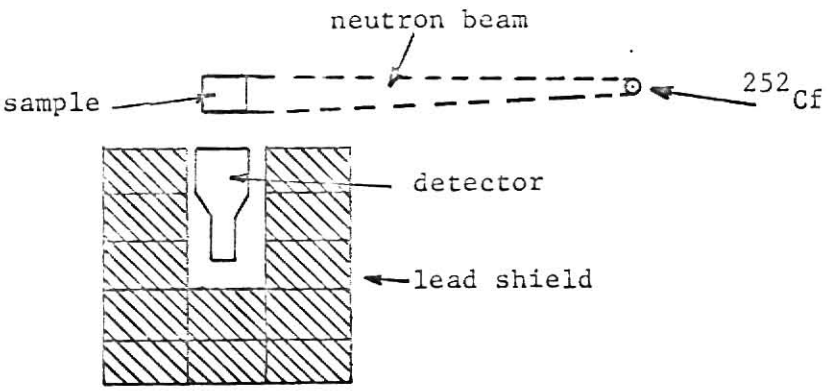


Figure 42. External geometry configuration.

known as the external geometry technique (EXGT), places the sample in a flux some distance from the neutron source, and the detector perpendicular to the neutron beam, Fig. 42. This technique is used in the determination of elemental capture gamma-ray spectrum (7). The EXGT allows more flexibility in changing the experimental arrangement, but with fewer gamma-rays emitted from the sample. The INGT requires a neutron emission rate of $\sim 10^8$ n/sec and the EXGT utilized a neutron emission rate of $\sim 10^{12}$ n/sec.

7.2 Experimental Work with the KSU ^{252}Cf Facility

First attempts for protein determination in the KSU ^{252}Cf Facility were made with the INGT. Approximately .05 pounds of wheat were placed at varying distances from a ^{252}Cf source. The source was placed at the floor level in a plexiglass holder. The sample was contained in a polystyrene sample vial. The 30 cc Ge(Li) detector was placed in a hole in the reactor bay floor so that the crystal was 1 meter from the source. Approximately 24 inches of water was between the source and the detector. All results from this setup were inconclusive because the 2.2 MeV hydrogen peak was the only visible capture gamma-ray peak. The live time on the detector was approximately 10%. This low live time indicates that the detector was essentially inoperable due to the very high background of source and hydrogen capture gamma-rays. Additional shielding for the detector was added both inside and outside the tank but the results were the same, with the live time increased to approximately 25%. After many alterations of the basic INGT setup, the technique was abandoned for the EXGT.

The EXGT first utilized the Ge(Li) detector in the same location but turned perpendicular to the neutron beam. Later the NaI(Tl) detector was utilized to increase the distance from the neutron source. Live times were increased to approximately 50% with the detector 6 feet from the sources and

with large amounts of paraffin and lead shielding. The many variations of the EXGT included attempts to construct a tangential beam port with graphite to improve the neutron to gamma-ray ratio. All results were inconclusive with only the hydrogen peak present.

The lack of measureable progress with the KSU ^{252}Cf sources prompted the development of a capture gamma-ray system with the KSUTMIINR. The NaI(Tl) detector was placed in the EXGT configuration outside the thermal beam port of the KSUTMIINR. A 3 1/2 pound sample of aluminum was placed in the neutron beam and power levels were varied to determine the optimal neutron flux. A power level of 20 KW for 40 minutes produced detectable aluminum capture gamma-ray peaks of 7.724 MeV. A 4 pound sample of wheat was placed in the neutron beam for 40 minutes and the 10.82 MeV peak was detected. The limited success of the reactor experimental work indicated that nitrogen determination in wheat is possible but the ^{252}Cf sources are not the correct size for such analysis. The sources are too large for the INGT and too small for the EXGT. An improved detection system is also deemed necessary for satisfactory nitrogen and sulfur determination with the KSUTMIINR.

The lack of a smaller source and improved detection equipment necessitated the remainder of this work to be performed at the United States Bureau of Mines (BOM) at Morgantown, West Virginia.

7.3 Experimental Work with the Bureau of Mines

Arrangements were made with the BOM to conduct protein measurement studies of wheat with the 45 μgm, stainless steel encapsulated, ^{252}Cf source. This source was on loan to the BOM under the Market Evaluation Program from SRO. The experimental arrangements were for the measurement of the content of sulfur in coal.

The Kansas Wheat Improvement Association, Manhattan, Kansas, shipped three, approximately 500-pound lots of wheat to the BOM in early April, 1972. The test information concerning the three samples is found in Table 7. Protein analysis by the Kjeldahl method were obtained from samples taken before and after the capture gamma-ray analysis at the BOM. The Kjeldahl tests were obtained from two locations and the results, corrected for moisture, are shown in Table 8. Because of the consistency of the results from the Kansas State Grain Inspection Department (KSGID), Topeka, Kansas, these figures were used in comparision to the capture gamma-ray determinations.

A schematic of the BOM experimental arrangement is shown in Fig. 43. A summary of the electronic components is found in Table 9. The pulse shaping electronics were used to allow the multichannel analyzer to receive meaningful data from a detector counting at the rate of greater than 300,000 counts/sec. In so doing the resolution of the NaI(Tl) detector was poorer than normal and the data between 2.5 MeV and 3.5 MeV was of questionable integrity. However, this system has had a long development period and significant results from coal analysis have been obtained. Therefore, it was found that all of the coal work could be relied upon for preliminary work with wheat. In fact, the wheat spectra collected were very similar to coal spectra, except the wheat spectra did not have the prominent sulfur 5.420 MeV peak.

The detector is a 6" x 7" NaI(Tl) detector, and is surrounded by a shield, Fig. 44. The shield is a 50/50 fiberglass composite of polyester and boron carbide. The detector was wrapped with a 1/8" sheet of lead. An outside cover was made 1/8" to 1/4" larger than the lead sheet. The bottom of the cover was poured 1/8" to 1/4" full of the fiberglass material. The lead sheet was placed inside the cover and the sides were poured. After the material had set-up, the

TABLE 7

Test Information for the Three 500 Pound Wheat Samples

Protein Level	Variety	Total Weight Tested (lb)	Test Weight (lb/bu)	gm/1000 kernels
High	Satanta	519.5	63.5	31.03
Med	1/3 Satanta 1/3 Scout 1/3 Parker	518.5	61.5	31.20
Low	Scout	488.5	62.5	31.06

TABLE 8

Kjeldahl Protein Analysis for the Three 500 Pound Wheat Samples

Protein Level	% Protein KSU		% Protein KSGID	
	Before	After	Before	After*
			12.80	12.76
			12.76	12.80
			12.71	12.76
High	12.98	12.41	12.76	12.77
			12.04	12.04
			12.09	11.94
			12.04	11.99
Med	12.27	11.90	12.06	11.97
			10.79	10.74
			10.79	10.77
			10.88	10.70
Low	11.01	10.68	10.82	10.74

*Assumed a similar moisture basis (14%) since KSGID after samples were run at the same time as the KSGID before samples.

TABLE 9

Components of the BOM Capture Gamma-Ray Electronic System

A-1:	Keithley Model 109 Pulse Amplifier (20 db gain)
A-2:	Keithley Model 111 Pulse Amplifier (0 db gain)
A-3:	Keithley Model 109 Pulse Amplifiers (2 units, 40 db gain)
A-4 thru A-7:	EG&G Model AN201/N, Quad Amplifier, 2 Modules
B-1 thru B-6:	MERC Constructed
D-1 thru D-4:	EG&G Model TR204/N Dual Discriminators 2 Modules, C-1 and C-2 are in the same module and modified.
L-1:	EG&G Model 102B/N Dual Twofold Coincidence Gate
L-2:	EG&G Model OR102/N Dual OR/NOR Gate
M-1:	EG&G Model 102/N, Linear Gate and Stretcher, Modified.
M-2:	Nuclear Chicago, Model 27002, Double Delay Line Amplifier.
M-3:	Nuclear Chicago, Model 40-913, High Voltage Power Supply Modified by adding an additional filter capacitor to the output.
M-4:	Hewlett Packard Model 5586A Spectrum Stabilizer
M-5:	Hewlett Packard Model 540113 Multichannel Analyzer

NOTE: All cables are 500 Ω impedance.

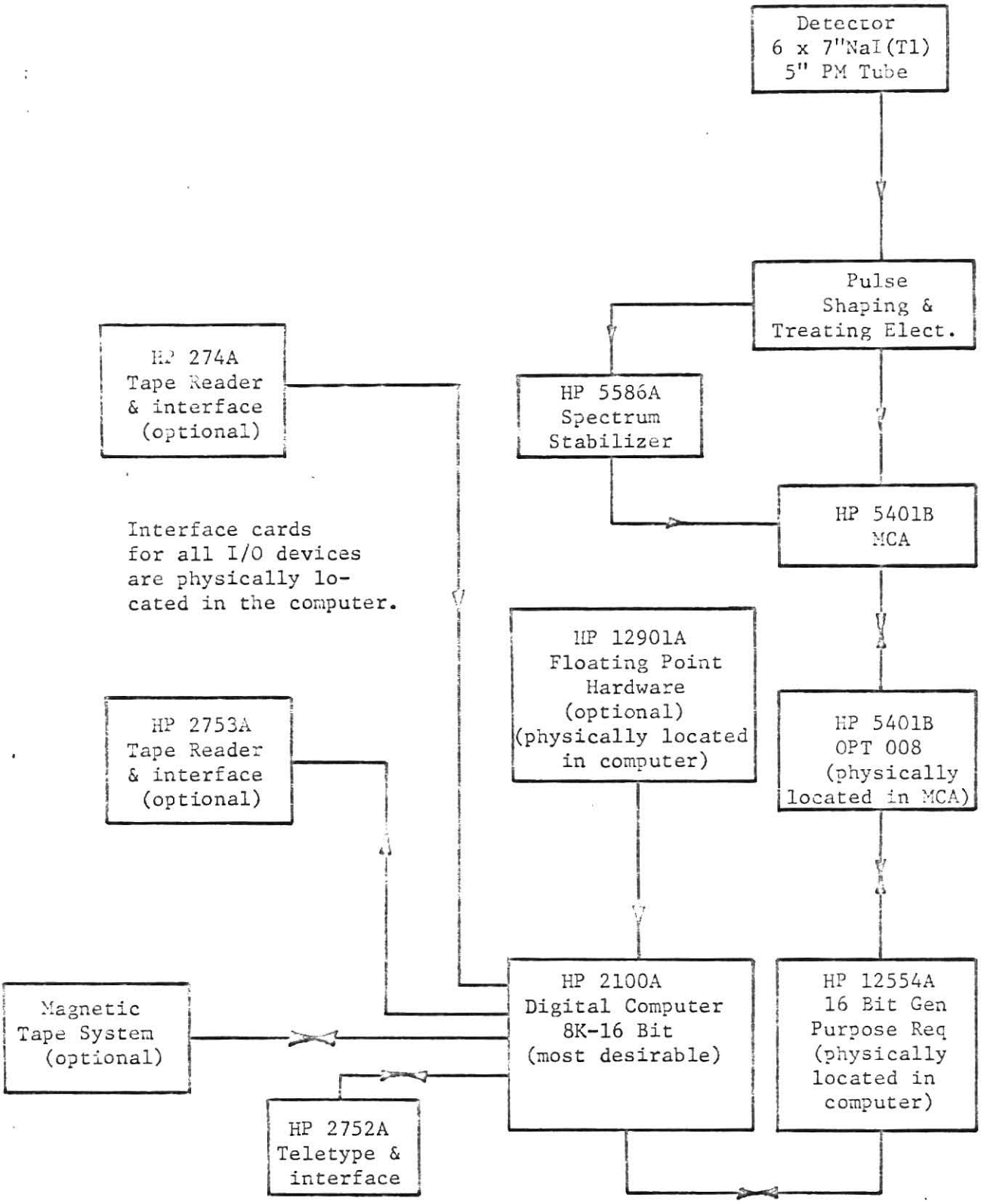


Figure 43. System block diagram for BOM electronic equipment.

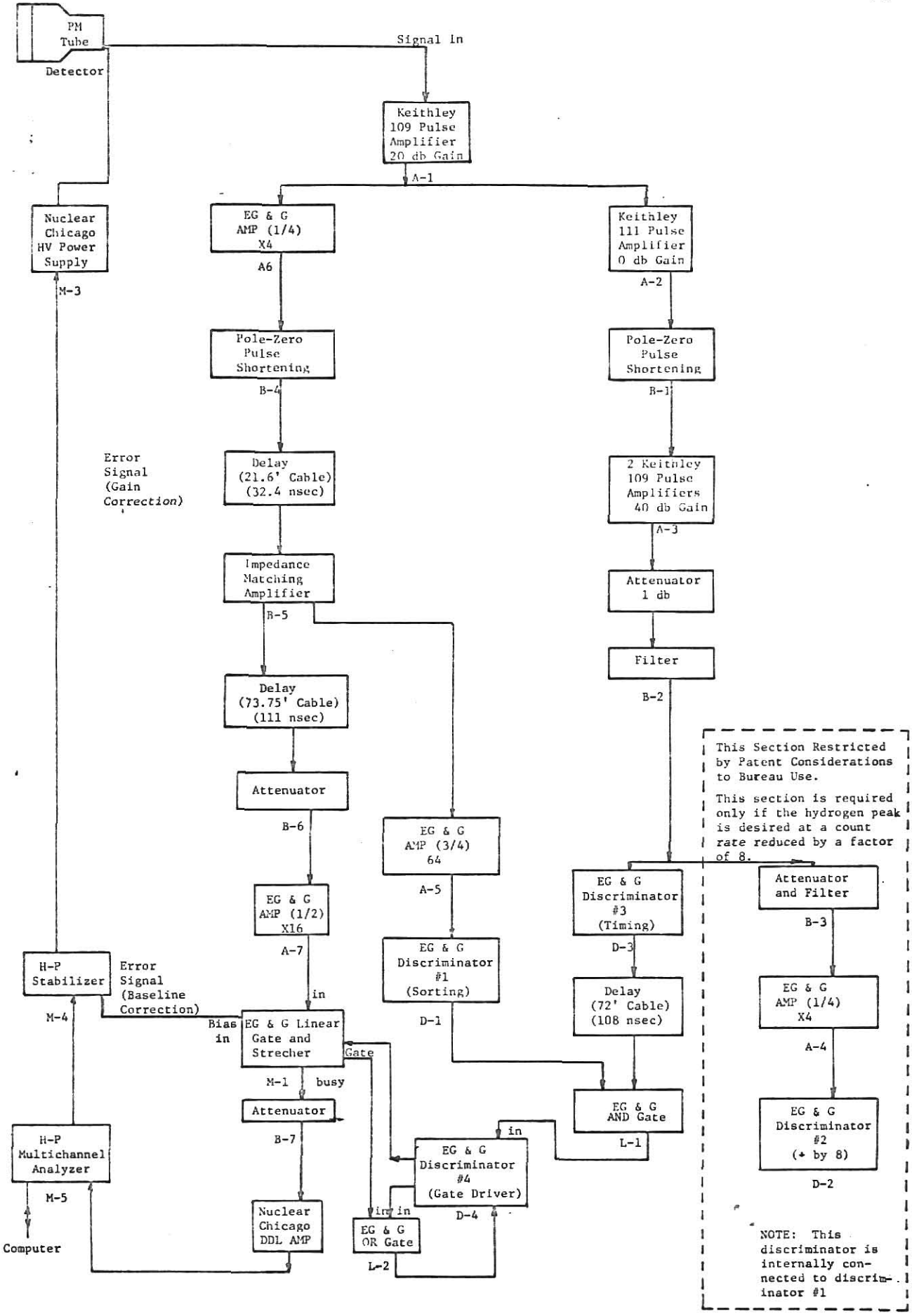


Figure 43 continued. System block diagram for BOM electronic equipment.

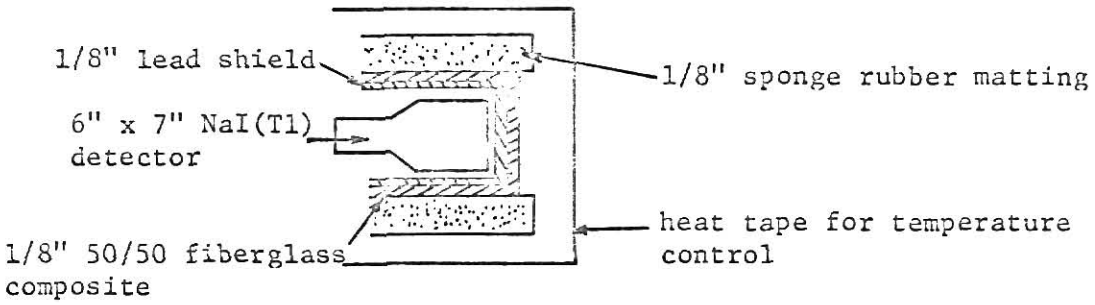


Figure 44. BOM NaI(Tl) detector and shield.

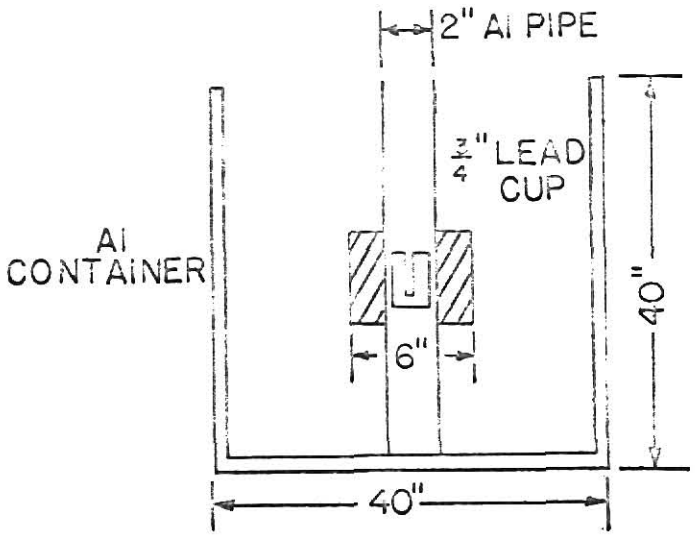


Figure 45. BOM aluminum container.

outside cover was removed. The detector was then shock-proofed in 1/8" thick sponge rubber matting. The entire detector assembly was wrapped with heat tape and temperature controlled to 90°F.

The wheat was contained in an aluminum container, 40" in diameter and ~40" high, Fig. 45. The ^{252}Cf source was centered inside the container, surrounded by 3/4" of lead.

7.4 Results

The low protein spectrum, run #2, is shown in Fig. 46. The region of interest for the eight data runs was from channel 240 to channel 340. The region of interest for each of the runs are shown in Figs. 47-54. Channels 240-295 include the 5.276 MeV nitrogen and the 5.429 MeV sulfur peaks, and channels 295-335 include the 6.32 MeV nitrogen peak. The spectrum show increased counts with increased protein.

A linear regression method was used to analyze the region of interest data. A computer program, ADOLPH, was designed to compare the eight regions of interest to the three Kjeldahl protein averages. The region of interest is redefined at each pass. ADOLPH was written to reduce the region of interest from both the high and low ends, or to reduce the region of interest from either the high or low end. The peaks are summed together and normalized to the hydrogen peaks, e.g.

$$\text{counts} = \frac{\sum_{i=1}^{3} \left(\frac{8.6 \times 10^6}{\text{H counts}}\right)(i,\text{peak 3, count} + i,\text{peak 4, count})}{3}$$

Table 10 shows the results of the analysis of the protein levels with varying regions of interest.

Comparison of the capture gamma-ray nitrogen per cent to the Kjeldahl nitrogen per cent is shown in Table 10. The normalized nitrogen percentages

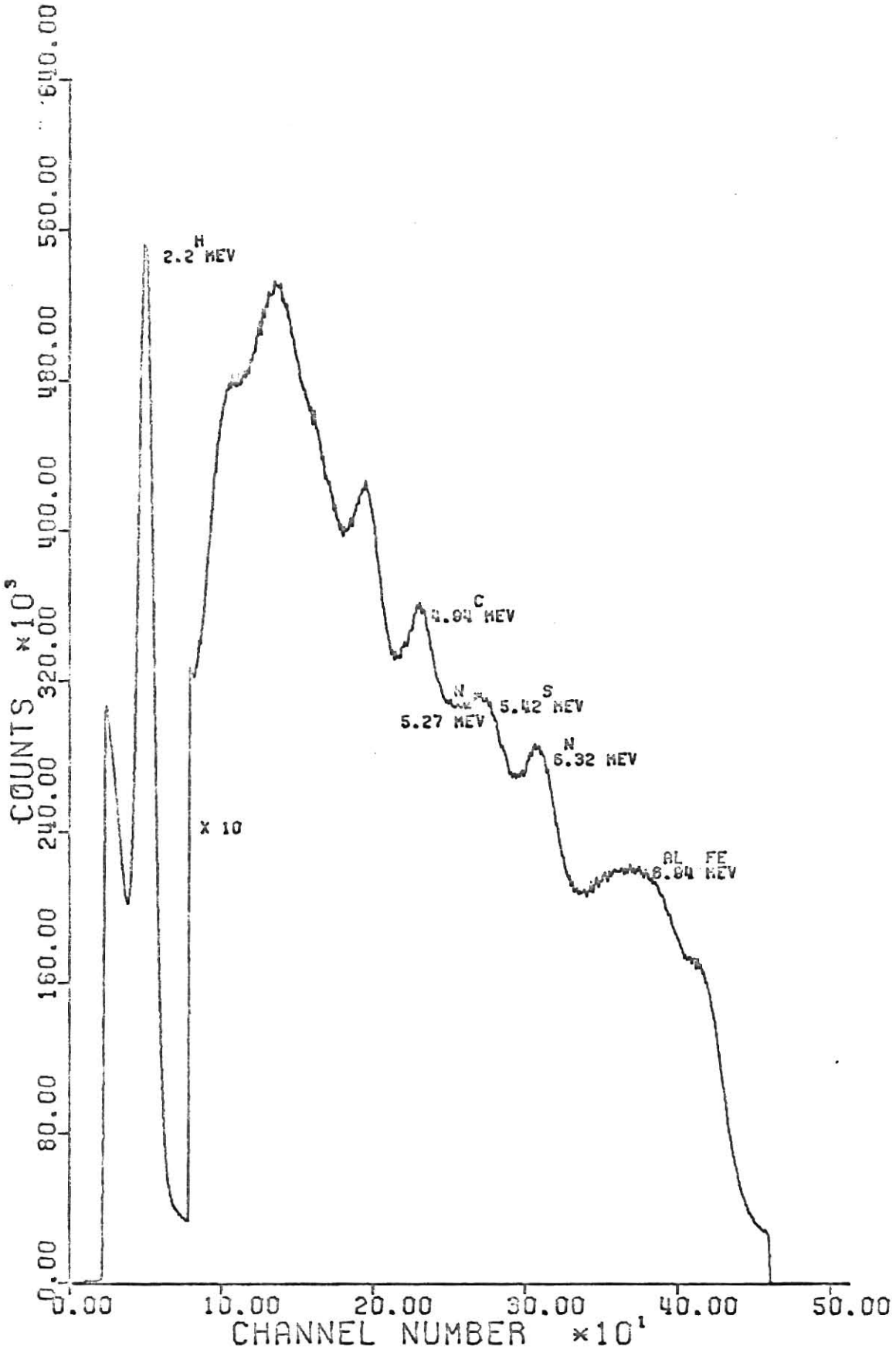


Figure 46. Low protein spectrum run No. 2.

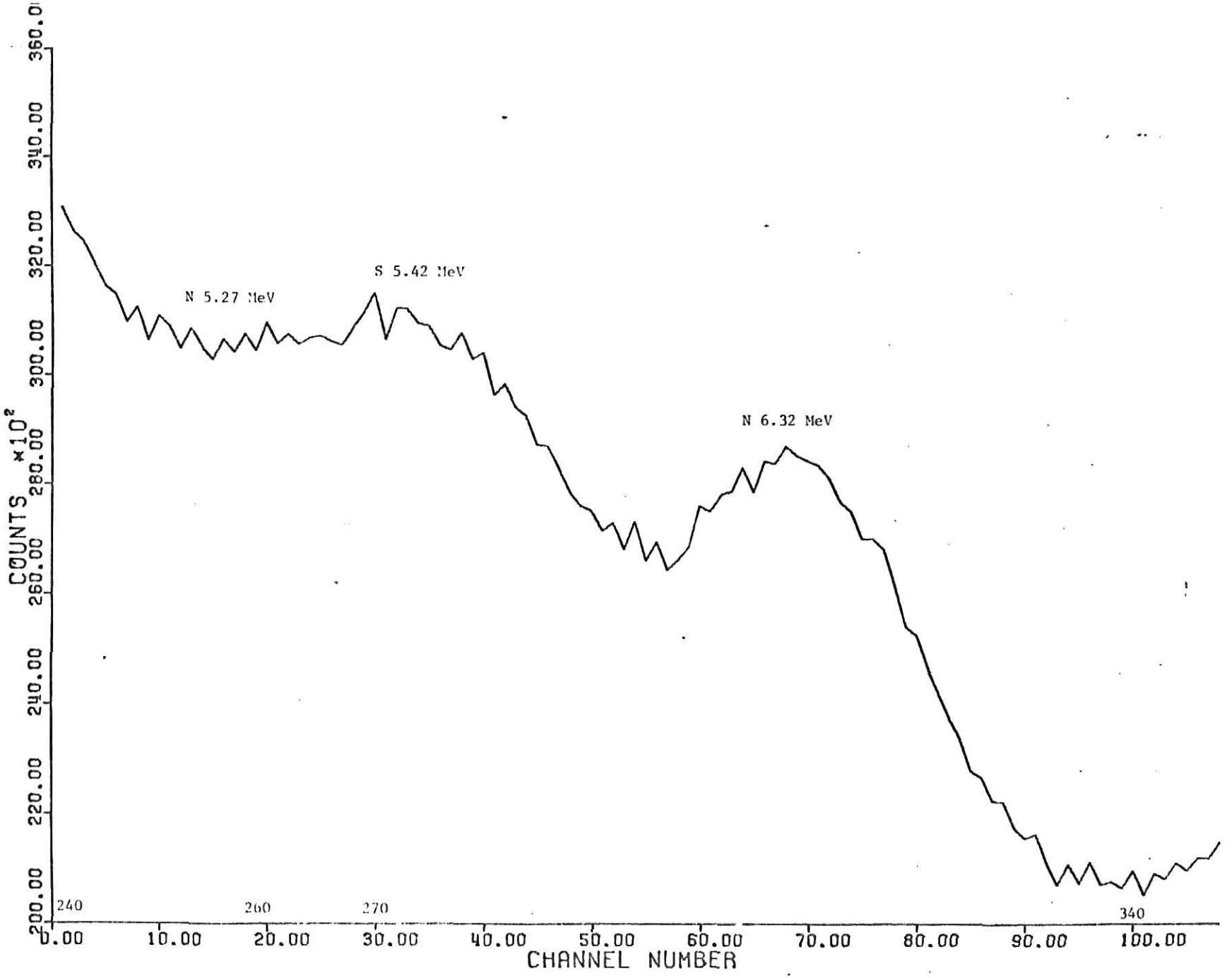


Figure 47. Low protein region of interest No. 1.

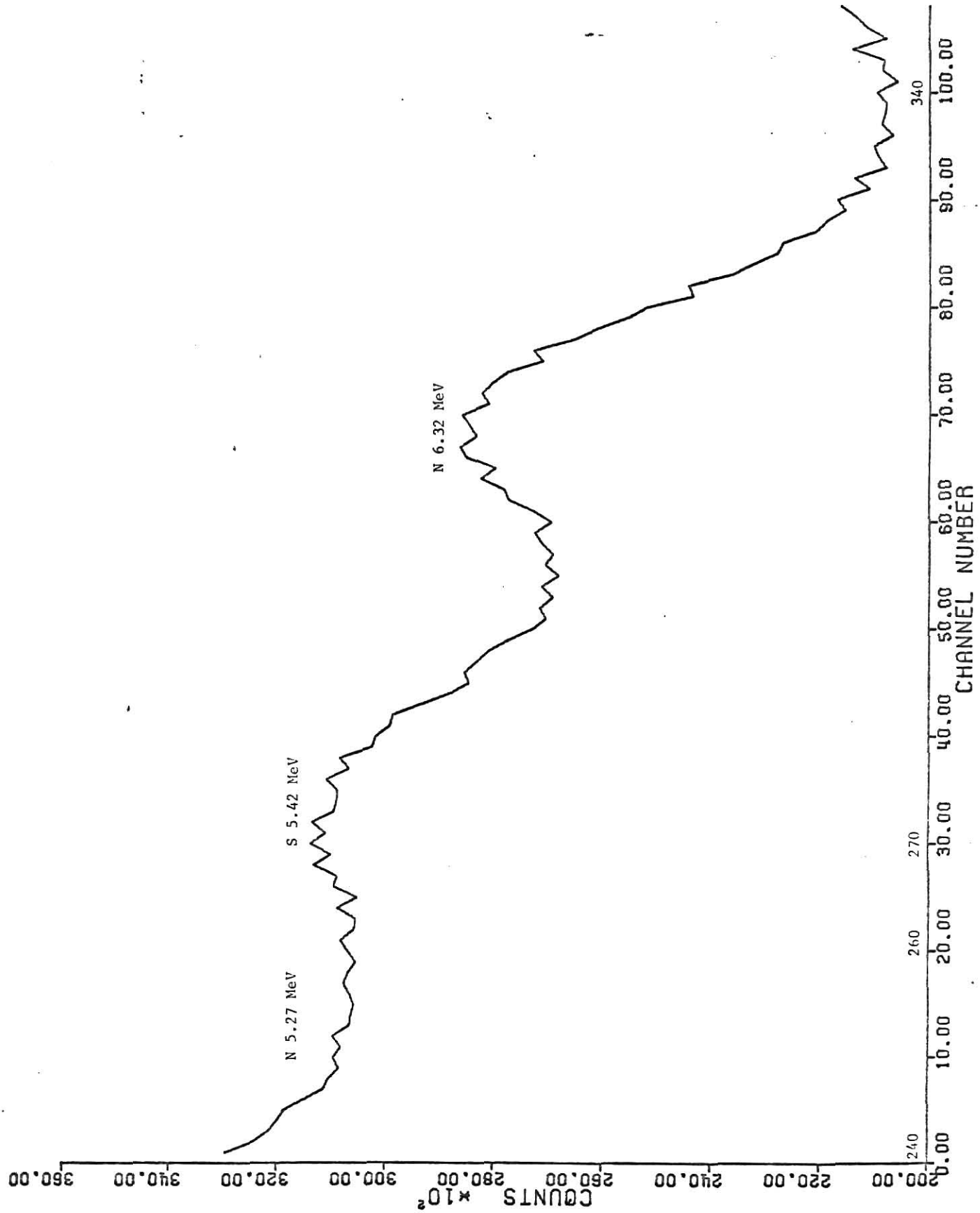


Figure 48. Low protein region of interest No. 2.

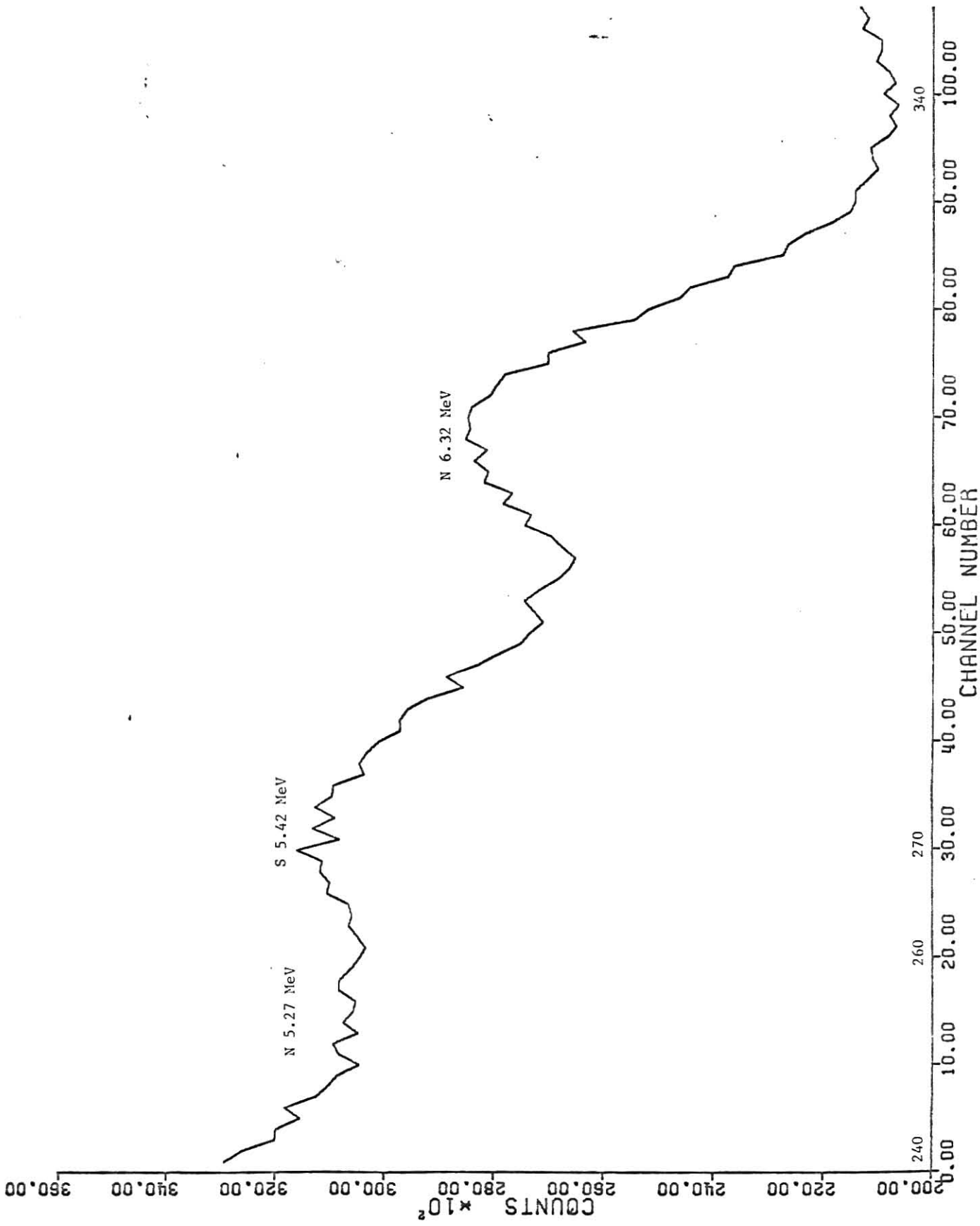


Figure 49. Low protein region of interest No. 3.

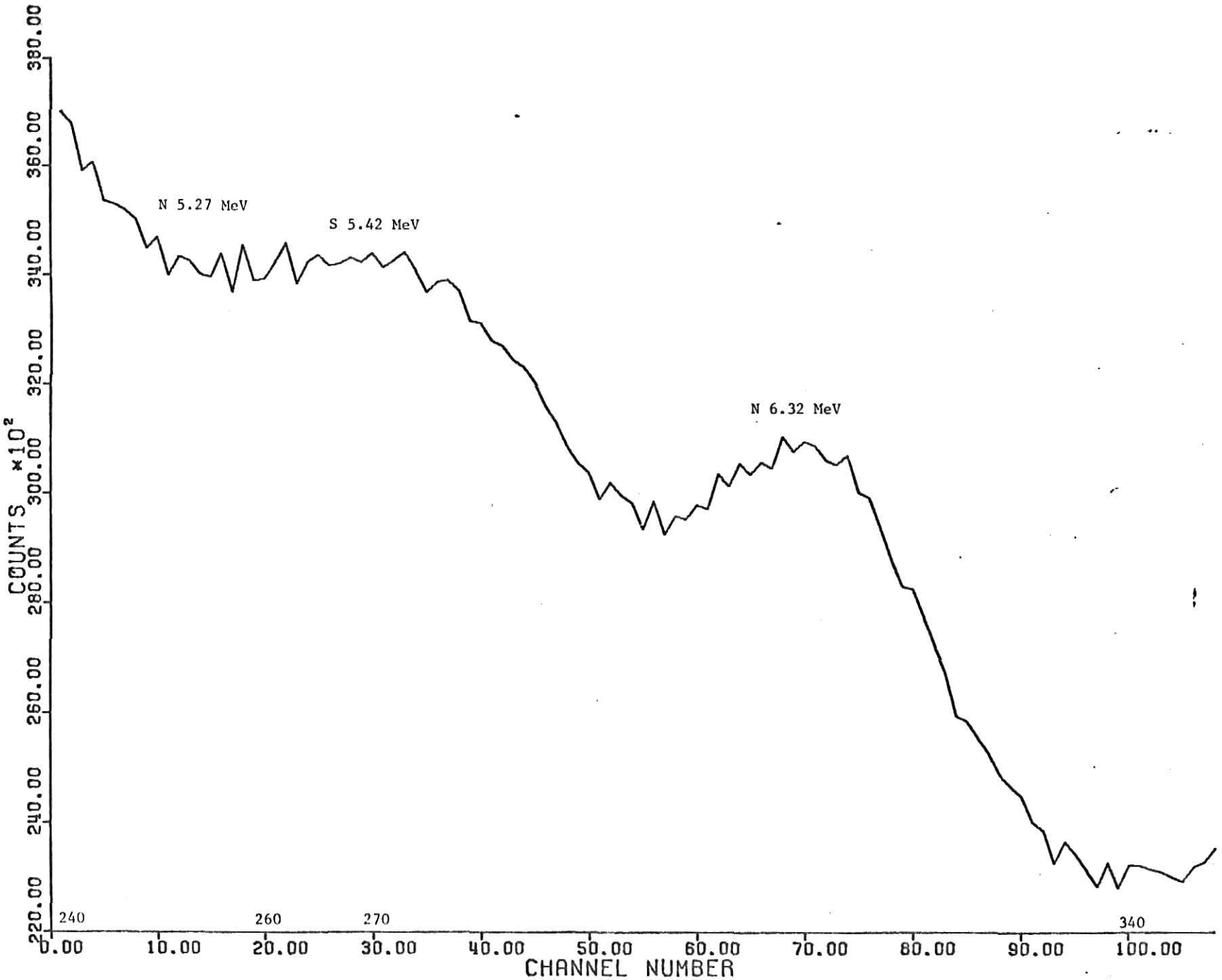


Figure 50. Medium protein region of interest No. 1.

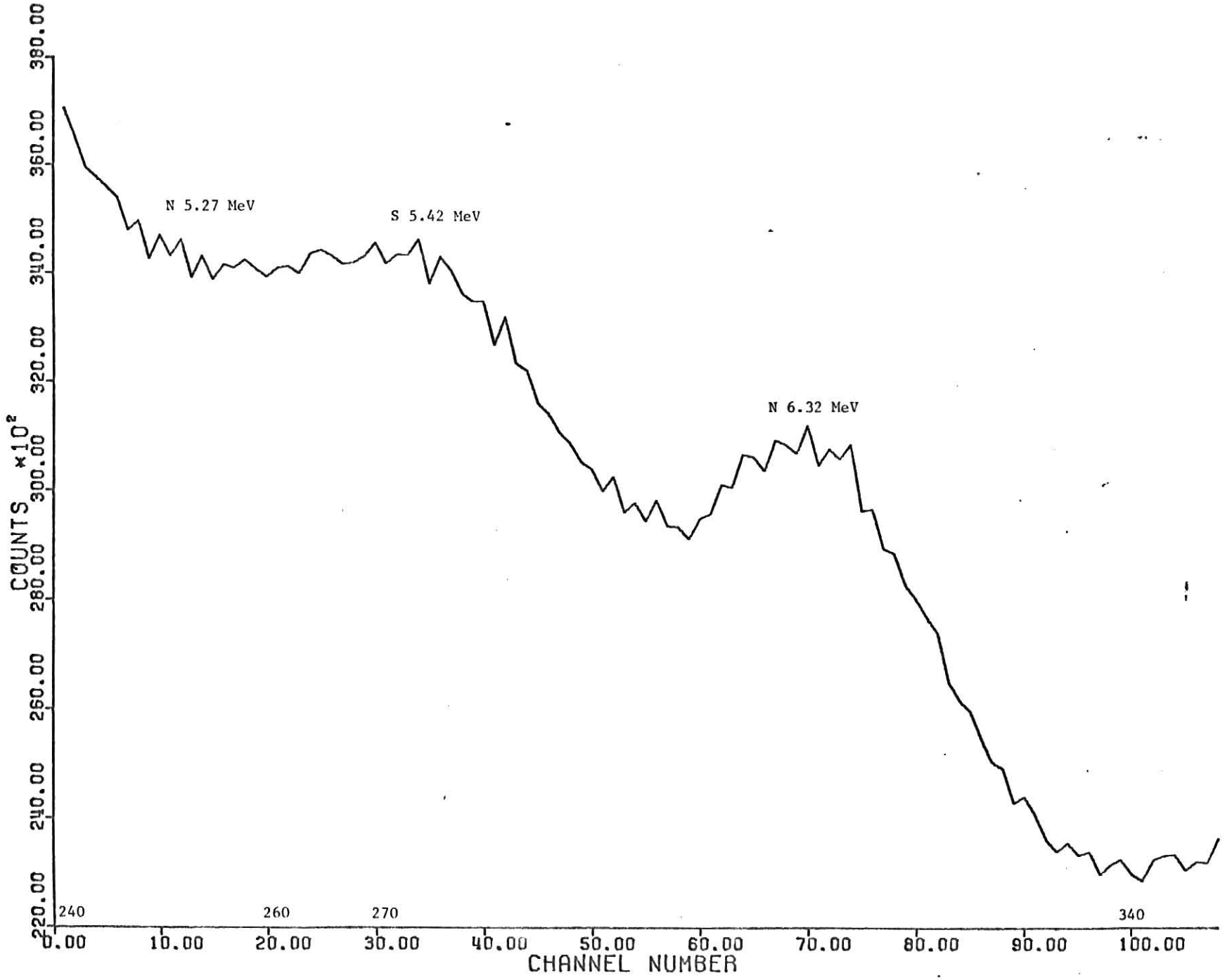


Figure 51. Medium protein region of interest No. 2.

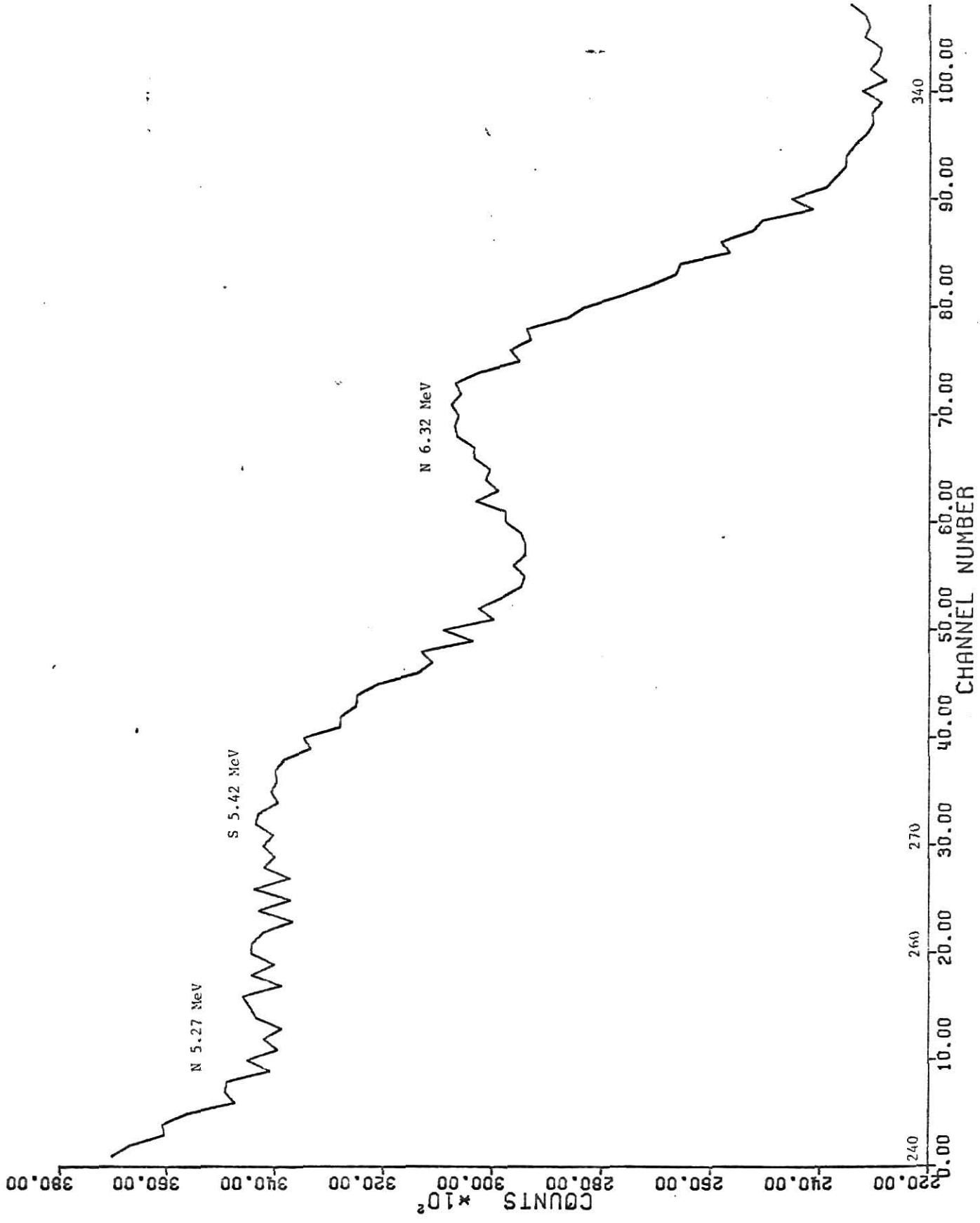


Figure 52. Medium protein region of interest No. 3.

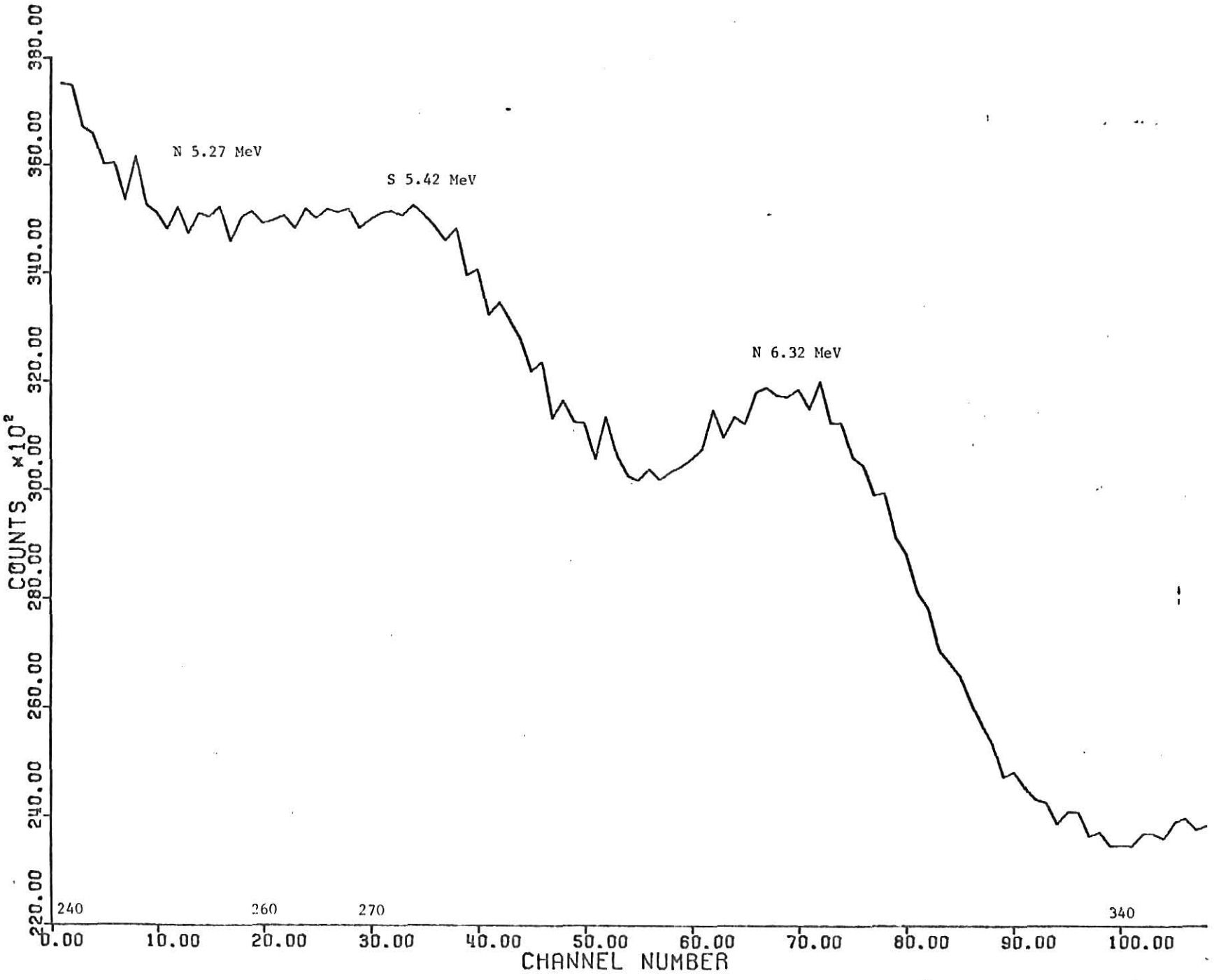


Figure 53. High protein region of interest No. 1.

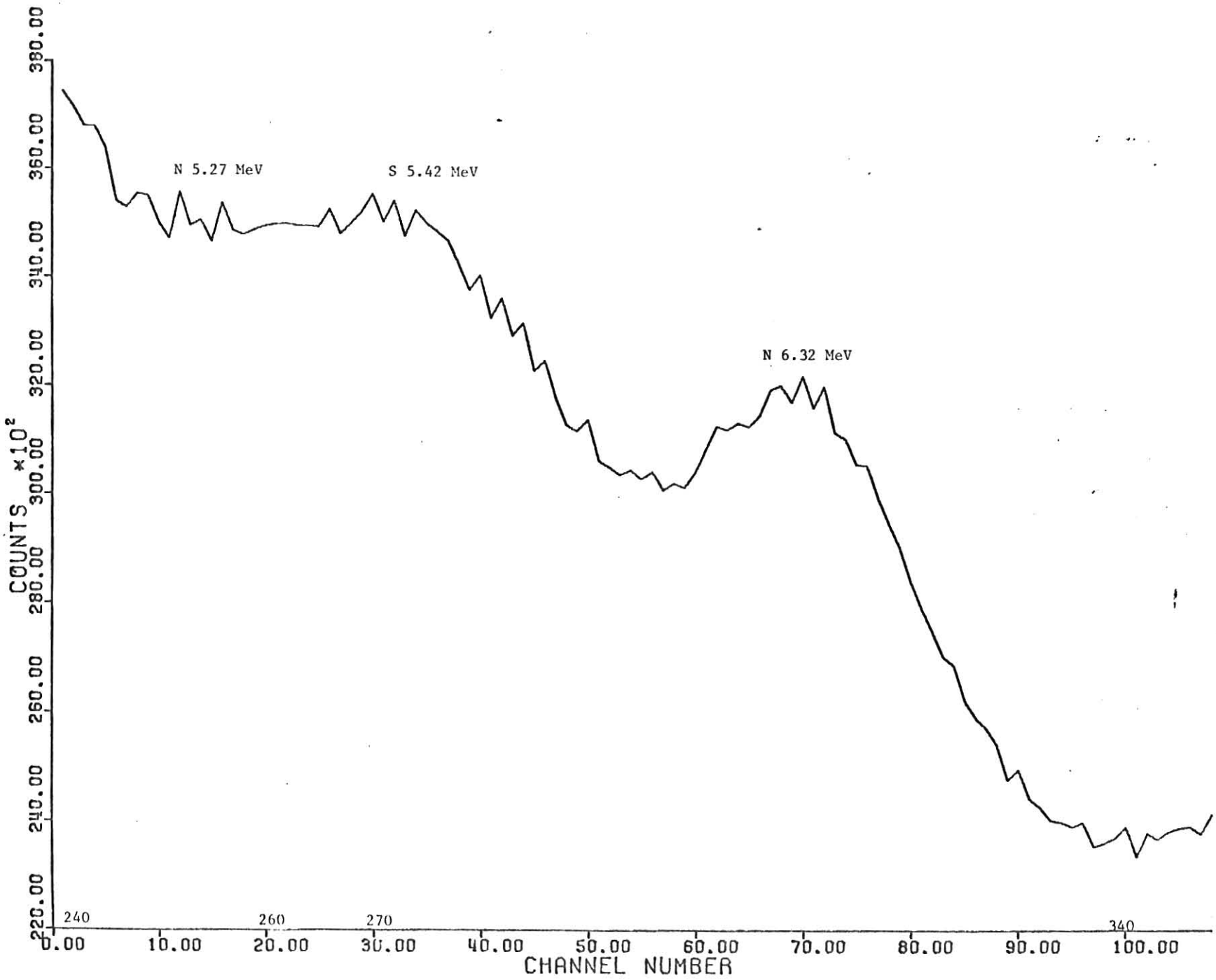


Figure 54. High protein region of interest No. 2.

TABLE 10

Results of Capture Gamma-Ray Analysis for Protein Determination

Region of Interest (Low Channel)	(High Channel)	Input Nitrogen %	Normalized Nitrogen %	Difference %
240	340		2.3572	+0.1192
246	259	High--2.2380	2.3055	+0.0675
272	344		2.3850	+0.1470
240	340		1.9962	-0.1198
246	259	Med--2.1160	2.0481	-0.0679
272	344		1.9684	-0.1476
240	340		1.9452	+0.0472
246	259	Low--1.8980	1.9245	+0.0265
272	344		1.9563	+0.0583

indicate a positive trend to the analysis by the capture gamma-ray method. This trend is strong enough to suggest detailed study and analysis of present data. More samples should be analyzed for conclusive results.

8.0 RADIATION-INDUCED CONDUCTIVITY IN POLYETHYLENE

8.1 Introduction

The purpose of the work in this section was to determine the effects of neutron and gamma radiation on the electrical conductivity of polyethylene. The importance of this study is to aid in the design of electronic systems and components that are subjected to nuclear radiation.

Much published work has appeared concerning the effects of gamma and x-ray radiation on the electrical conductivity of polyethylene (10-16).

Fowler (10) found that as the temperature of the sample of polyethylene increased from 20°C to 80°C, the static (dark) conductivity increased from 10^{-20} to 10^{-16} $(\Omega\text{-cm})^{-1}$. After irradiation of the polyethylene sample in a vacuum using 220 to 250 KeV x-rays and exposure rates from 0.06 to 63.6 R/min it was found that the steady state electrical conductivity was proportional to the 0.81 ± 0.03 power of the exposure rate. In addition the post irradiation recovery is hyperbolic in time if measured from the time of termination of the irradiation.

Wintle (11) found the post irradiation recovery to be neither hyperbolic nor exponential. With an exposure rate of 0.014 R/min of gamma radiation at 25°C, it was found that several minutes were required for the conductivity to decrease to one half of the initial value.

Adamec (12) reported, after irradiating polyethylene at room temperature with 15-38 KeV x-rays at exposure rates of 0.004 to 400 R/sec, that, upon applying an electric field, the conductivity decreased with time while the relaxation time decreased with an increased exposure rate.

Wicklein, et al. (13), studied the effects on mylar (poly [ethylene-terephalate]) using 0.2 μsec pulses of x-rays and 0.011 sec pulses of a TRIGA

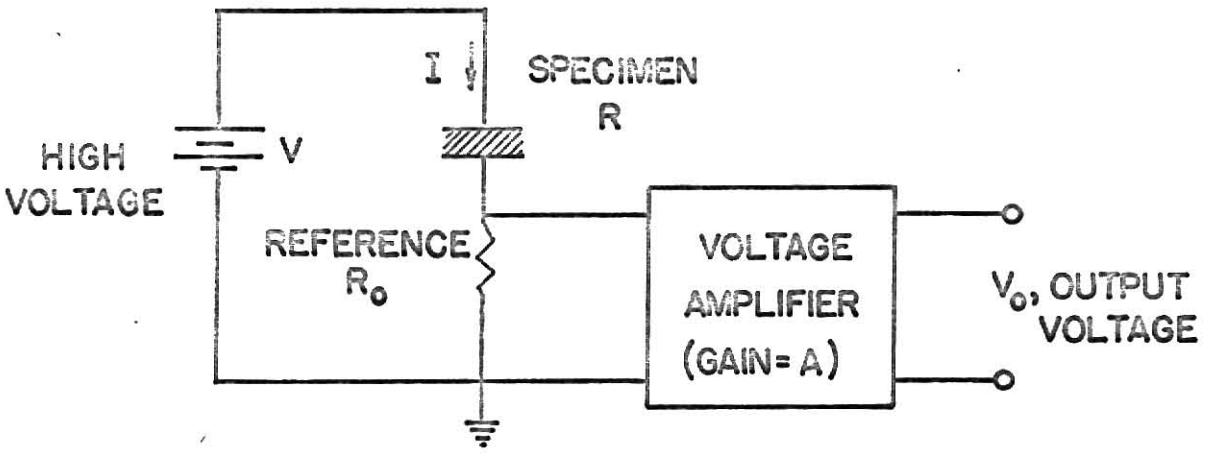
reactor. They found that the post irradiation conductivity to be exponentially decreasing. Compton, et. al. (14), using 4.5 μsec pulses of 30 MeV electrons, found the steady state conductivity to be proportional to the 0.8 power of the dose rate, and the post irradiation conductivity to be proportional to a lower power. The time dependence of the post irradiation conductivity was of the hyperbolic form observed by Fowler (10). Fellers (15), using gamma ray dose rates of 123 Rad (H_2O)/min to 11,808 Rad (H_2O)/min, found that the post irradiation recovery was exponential in nature.

In this study a polyethylene sample was irradiated by 4 ^{252}Cf sources whose total mass is 34.9 mg. The date of measurement was December, 1971. Results were observed for distances of 5.2 and 37.7 cm from source.

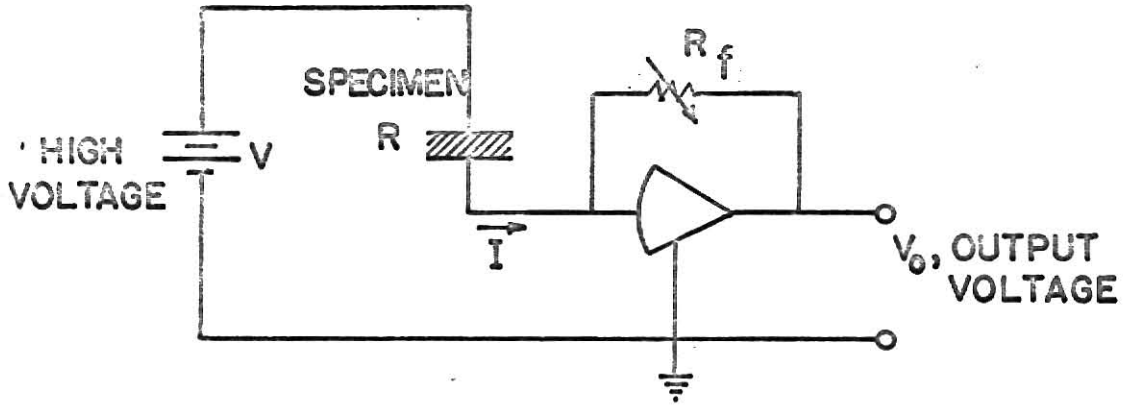
8.2 Methods and Materials

Measurement of the current flowing through a dielectric specimen as a function of time, applied voltage, radiation time and distance from ^{252}Cf sources is required. Two methods have been used; Fellers (15) measured the current by amplification of the voltage drop across a reference resistance, and Faw and Robinson (16) measured the current using an electrometer operational amplifier. The second technique, employed in this work, used a stable, very high gain, very high input impedance electrometer operational amplifier, along with precision feedback resistors from 10^9 to 10^{13} ohms. The amplifier was fed simultaneously to a strip chart recorder and a digital volt meter. Both techniques are illustrated in Fig. 55.

The second technique was chosen for this work, because in the voltage method used by Fellers (15), the reference resistance must be large enough to give a measurable voltage drop yet not so large as to be comparable to the input impedance at the voltage amplifier or to affect the applied voltage to



a. Voltage Method: $I = V_o/AR_o$



b. Current Method: $I = -V_o/R_f$

Figure 55. Two techniques for current flow measurements.

the specimen. There are high impedance problems as well as noise and amplifier drift problems.

The sample holder and the electronic equipment used were identical to those used by Faw and Robinson, except that aluminum electrodes were used to avoid the neutron activation problems associated with copper. A list of the electronic equipment used is found in Table 11 and the sample holder is illustrated in Fig. 56.

Because of the underwater working conditions, a watertight cylindrical sample holder casing was designed. It was constructed of 3/8 inch thick plexiglass. This watertight enclosure is illustrated in Fig. 57. Attached to the top of the watertight enclosure was 15 feet of 1-1/2 inch diameter ABS pipe through which the electrical connections were passed. Attached to the bottom of the enclosure was a threaded section of plexiglass to allow connection of different lengths of ABS pipe for the different irradiation positions.

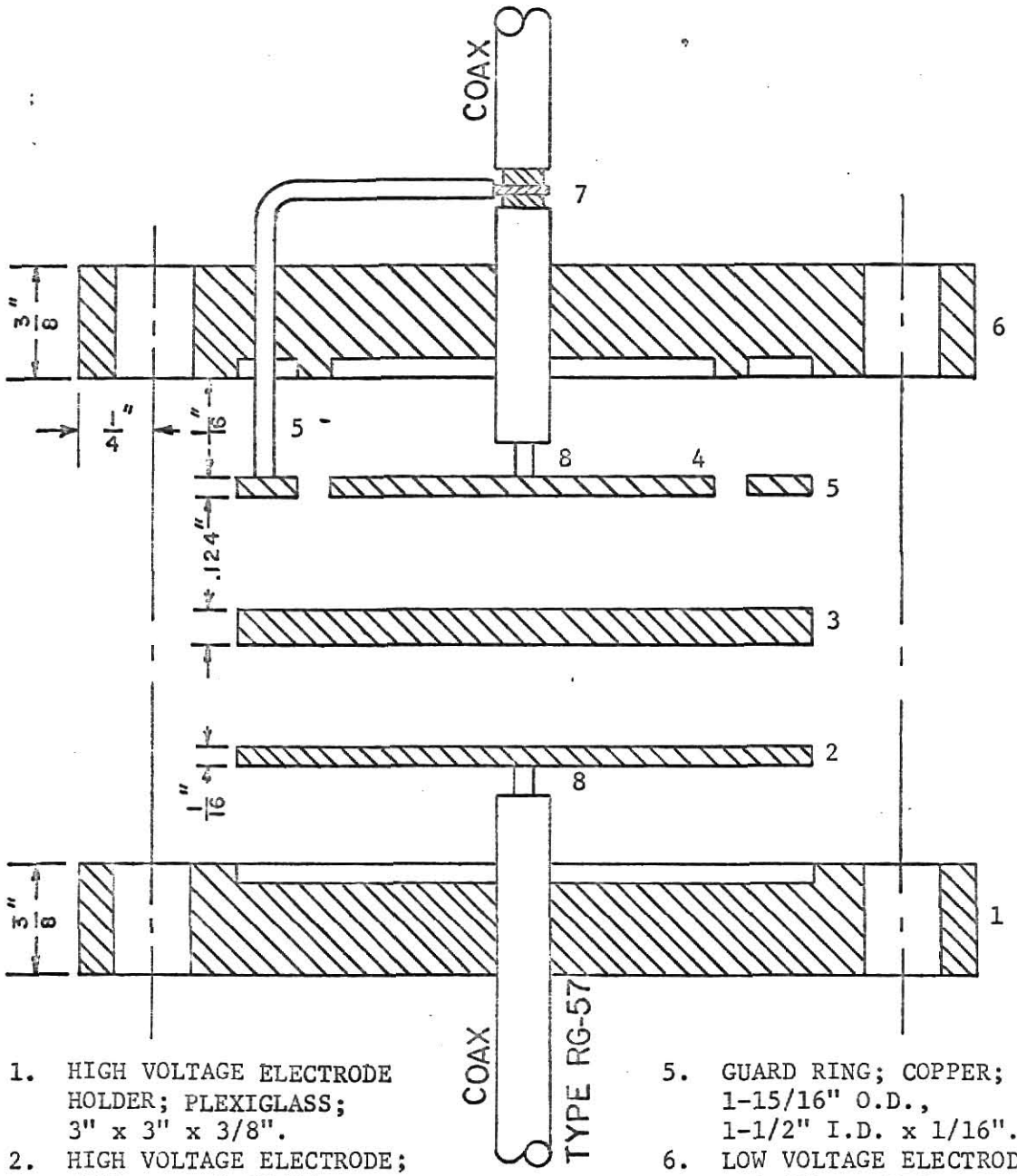
Specimen preparation is described in detail by Fellers (15). Specimens were cut from sheet polyethylene stock, cleaned, dried and conditioned at constant temperatures and humidity for 40 hours. The specimen was then painted with silver conducting paint, placed between the aluminum electrodes in the sample holder, and potted in paraffin. The specimen dimensions were 2 inches in diameter by 0.060 inches thick.

A common industrial technique was used for the electrical conductivity measurements. A fixed increment of voltage ΔV was applied to the specimen. At a time interval Δt later the current was determined and an additional increment of voltage applied, followed by current measurement Δt later, and

TABLE 11

Equipment Used for the Study of the Radiation-Induced Conductivity in Polyethylene

High Voltage Power Supply:	John Fluke Model 415B
Shielded Switch:	Keithley Model 3011
Feedback Resistors:	Keithley Precision Resistors - 10^9, 10^{11}, 10^{12} and 10^{13} ohm
Electrometer:	Keithley Model 300 (Alternate) Keithley Model 301
Electrometer DC Power Supply:	Keithley Model 3012 (Alternate) Lambda Model IDD422FM
Digital Voltmeter:	Eldorade Model 1820
Strip Chart Recorder:	Varian Model G-1000
Picoampere Source:	Keithley Model 261
Gamma Ray Source:	AECL Gammacell 220



1. HIGH VOLTAGE ELECTRODE HOLDER; PLEXIGLASS; 3" x 3" x 3/8".
2. HIGH VOLTAGE ELECTRODE; ALUMINUM; 1-15/16 DIA x 1/16" THICK.
3. TEST SPECIMEN; POLYETHYLENE; 1-15/16" DIA x 0.124" THICK.
4. LOW VOLTAGE ELECTRODE; ALUMINUM; 1.3" DIA x 1/16" THICK.
5. GUARD RING; COPPER; 1-15/16" O.D., 1-1/2" I.D. x 1/16".
6. LOW VOLTAGE ELECTRODE AND GUARD RING HOLDER; PLEXIGLASS; 3" x 3" x 1/16" THICK.
7. GUARD RING WIRE ATTACHES TO SHIELD BRAID OF COAX CABLE.
8. CENTER WIRE OF COAX CABLE ATTACHES TO ELECTRODES.

Figure 56. Two techniques for current flow measurements.

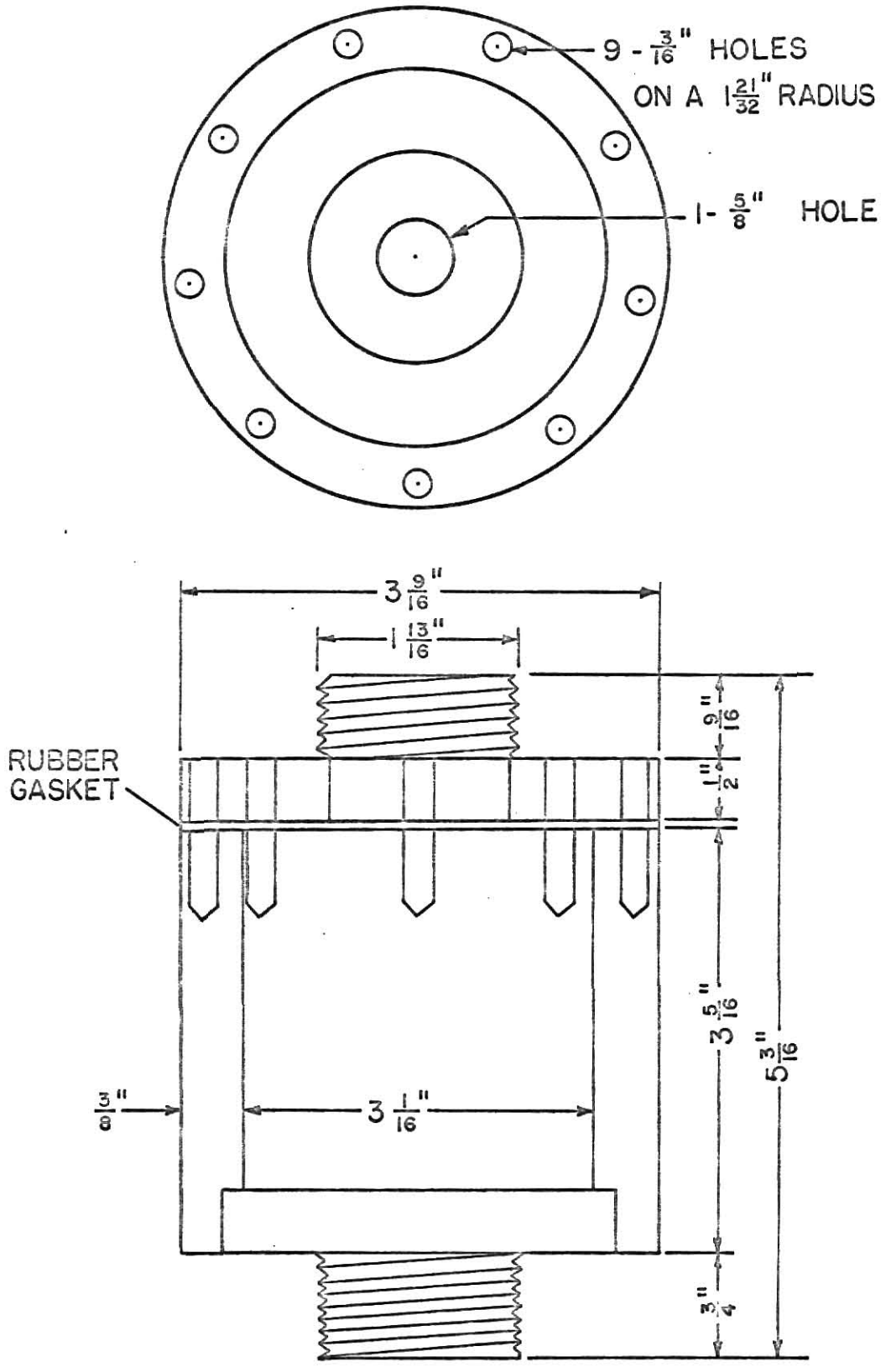


Figure 57. Water-tight container for the polyethylene sample holder.

so on. Since the dielectric charging current depends on changes in voltage, after a few steps, the increment in voltage divided by the increment in current is just the resistance of the specimen.

8.3 Experimental Data and Results

Measurements of the conductivity, starting at -500 V, were performed at positions of 5.2 and 37.7 cm from the ^{252}Cf sources. The applied voltage was changed by 100 V increments at three minute intervals. Current measurements were made just preceding the voltage changes. Results for the I-V chacteristics are presented in Figs. 58 and 59. The electrical conductivity was calculated using the equation, where L is the specimen thickness and A is the effective area of the specimen. With L = 0.315 cm, A = 8.81 cm^2, and ΔV = 1000 V, the electrical conductivity (σ) at the 5.2 cm position was found to be 4.39×10^{-14} $(ohm\ cm)^{-1}$, with $\Delta I = 12.3 \times 10^{-10}$ Amps. At the 37.7 cm position, $\sigma = 1.57 \times 10^{-15}$ $(ohm\ cm)^{-1}$, using $\Delta I = 4.4 \times 10^{-11}$ Amps. Total irradiation time of the sample was approximately 30 min. in each position.

Determination of the static (dark) conductivity was carried out by Faw and Robinson (16). This voltage was changed by 100 V increments at five minute intervals. They found the static electrical conductivity to be 7.84×10^{-18} $(ohm\ cm)^{-1}$.

No attempt was made to determine the nature of the post irradiation recovery of the polyethylene irradiated by ^{252}Cf. Attempts to obtain data at distances greater than 37.7 cm for a more complete study were unsuccessful because of the small magnitudes of the current to be measured, and the extreme sensitivity of the cables to stray electrical fields.

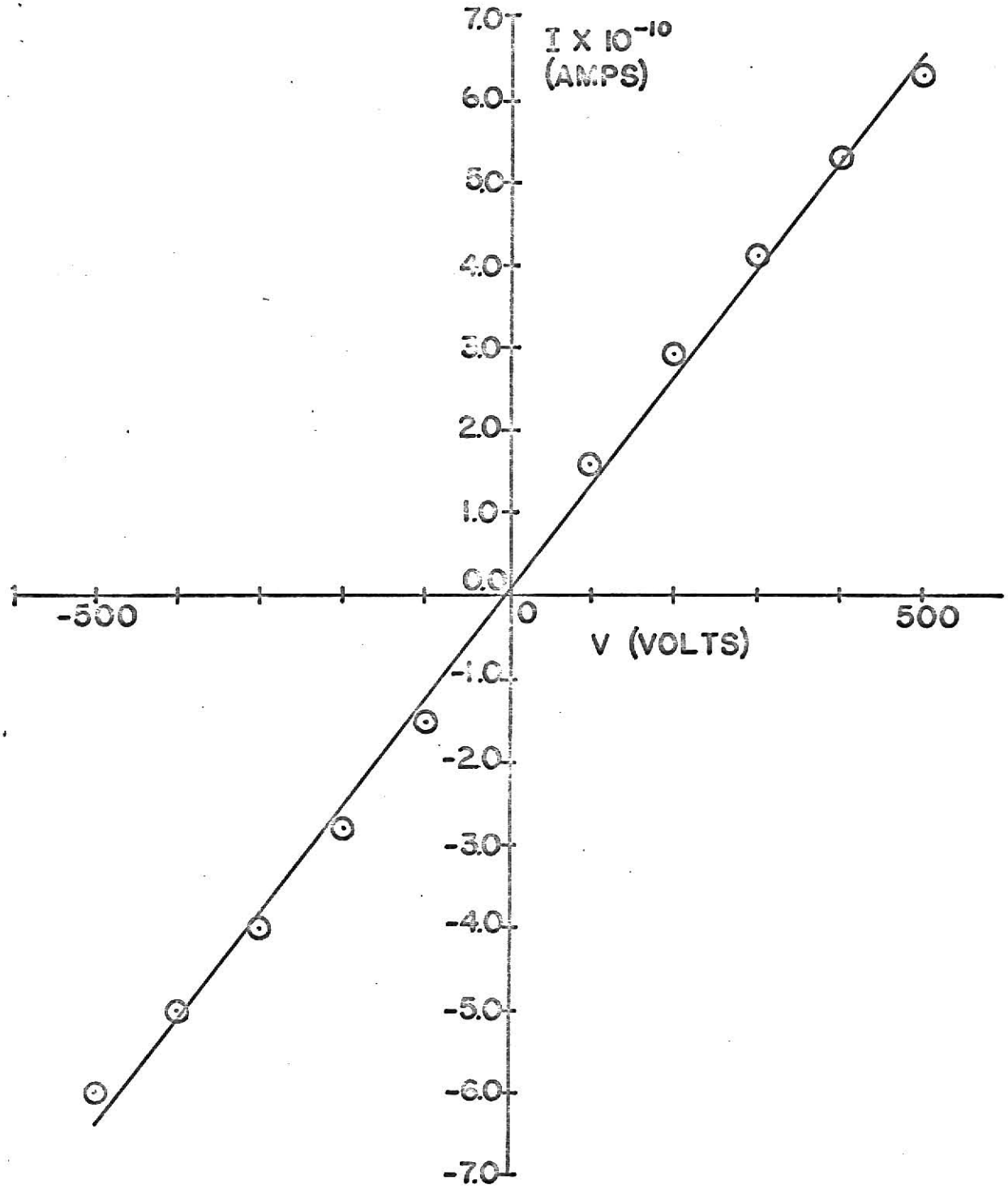


Figure 58. I-V characteristics for irradiation at 3 min intervals for 5.2 cm.

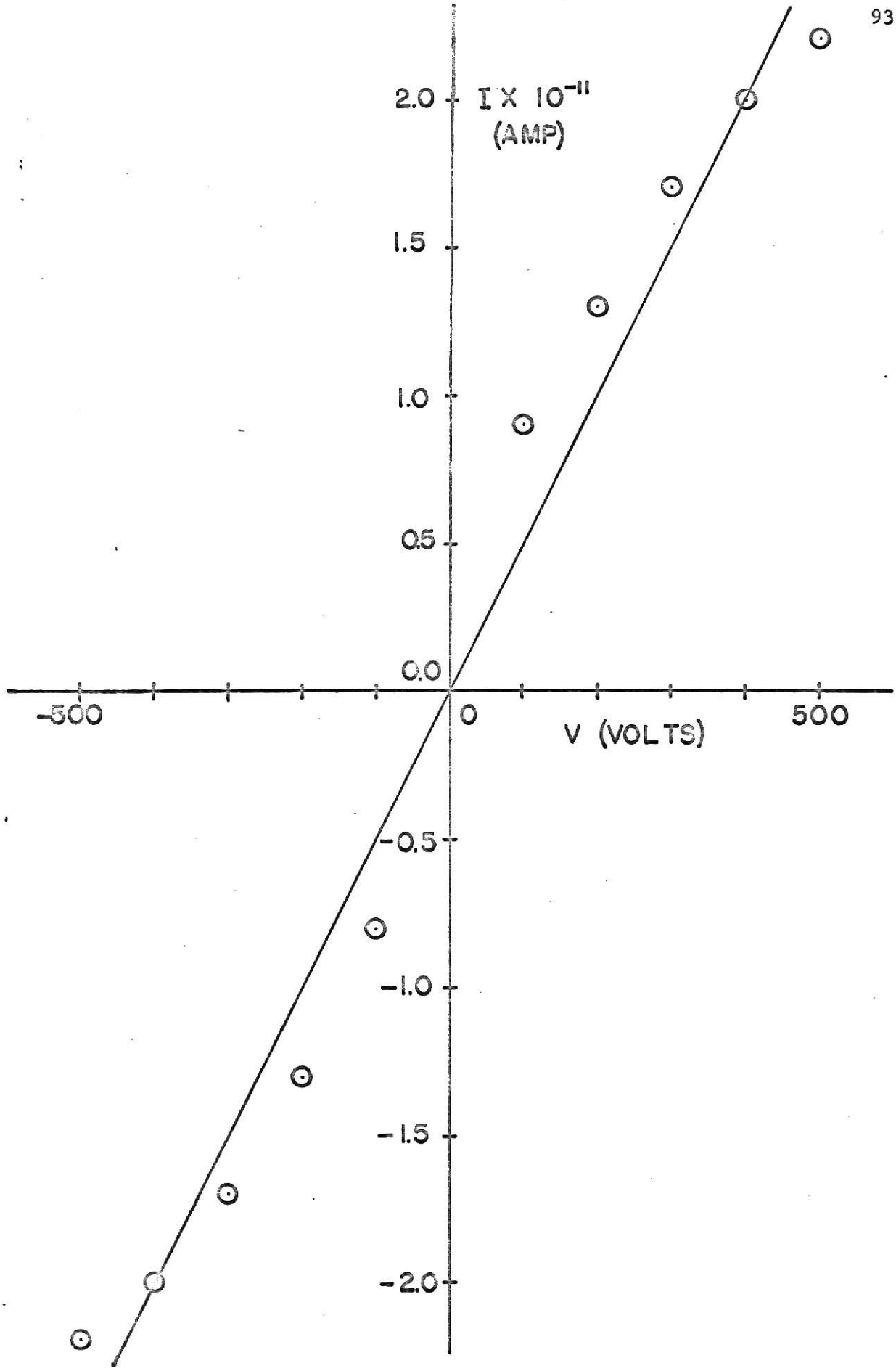


Figure 59. I-V characteristics for irradiation at 3 min intervals for 37.7 cm.

In conclusion the electrical conductivity of the polyethylene specimen increased with closer proximity to the ^{252}Cf sources, i.e. greater dose rates. The nature of this relationship was not determined because only two points were measured. A comparison of these results with Feller's results is not possible because the dose and dose rate at the distances considered are not known.

9.0 CONCLUSIONS

9.1 Introduction

The safe and inexpensive construction of a multimilligram ^{252}Cf facility is certainly possible. Imagination and craftsmanship are the two major requirements for a successful endeavor. Approximately $1,000.00 was spent for materials and labor in the construction phase.

No major expenditures were required for the licensing of the facility. The monitoring equipment was already in existence for use with the KSUTMIINR and no new systems were required. There was minimal expense in terms of secretarial time and in equipment repair, e.g., license application and correspondence, and repair of the electronic equipment.

The transportation and unloading of the sources was the major expense. The transportation costs were $1,088.00. The labor and materials for the unloading cost approximately $1,700.00.

The operation of the facility required the expense of a 0.5 graduate assistant and part time undergraduate help. Approximately $6,000.00 were spent for personnel during the 1 1/2 years of operation. The estimate included the limited amounts of materials and shop time required for operation, and the secretarial time required for quarterly reports.

The protein determination studies required the expenditure of approximately $450.00. This includes the expenses of travel, wheat procurement and shipment, and other materials.

The total expenditures for the KSU ^{252}Cf Facility from September, 1970, to June, 1972, are approximately $11,000.00.

9.2 Primary Contract Obligations

The most important conclusions to be drawn are the status of contractural obligations with the AEC. The following is a contract performance summary in terms of the primary contract obligations:

9.2.(a)(1)	Description	Determine neutron source strength, and therefore amount of ^{252}Cf, required to do commercially useful protein analysis of cereal grain.
	Status	It has been established that 50 micrograms of ^{252}Cf will provide sufficient neutron flux to do commercially useful protein analysis of wheat involving approximately 500 pounds of wheat and 2-10 minute counting time.
9.2.(a)(2)	Description	Determine detection and instrumentation, including data processing equipment if appropriate, required for commercially useful protein analysis of cereal grains.
	Status	The following equipment is indicated for protein analysis of cereal grain: Ge(Li) cryogenic detector, 1024 multichannel analyzer, associated pulse shaping electronics, and data analysis computing equipment, Figs. 43-45.
9.2.(a)(3)	Description	Prepare a projection or estimate of analysis costs as compared to present industry standards for protein analysis.
	Status	Capital costs for an NAA facility for protein analysis are estimates at \$20,000-50,000 including \$500 (@\$10/µgm) for ^{252}Cf. For process control there is no equivalent wet chemical technique which will give on-line information. The payout for capital equipment is estimated to be one to five years depending on the process control application.
9.2.(a)(4)	Description	Prepare a summary or guide relating to licensing and safety requirements a typical commercial user would face.
	Status	All necessary data and information for this guide are on hand. The guide can be completed from information found in Sections 3.0 and 4.0.

9.2.(a)(5)	Description	Prepare detailed instruction on how to use the suggested "package" of apparatus, source and instrumentation, to measure protein quality. Instructions will be reduced to language understandable to an alert and interested high school graduate.
	Status	Necessary experience and information to complete this requirement are on hand. An instruction guide for a typical NAA/californium facility can be completed from information found in Section 7.0.
9.2.(b)(1)	Description	Development of adequate techniques for nuclear-radiation dosimetry and spectrography usable in high intensity radiation experiments as well as in the mixed fast-neutron and gamma-radiation environments.
	Status	This study is well advanced and is expected to be successfully completed (17, 18, 19, 20, 21).
9.2.(b)(2)	Description	Studies of microscopic phenomena and macroscopic effects induced by irradiation of solid and amorphous insulator materials.
	Status	This phase of the contract is active at the present time. The work will be reported in (17, 19, 20, 22, 23, 24).
9.2.(b)(3)	Description	Studies of radiation-induced lattice-defect characteristics and bulk-material properties of semiconductors.
	Status	Substantial progress has been made in this phase (22, 23, 24).
9.2.(c)(1)	Description	Determine neutron source strength, and therefore the amount of ^{252}Cf required to do on-line or random sample analysis of food for mercury content, sensitive to 0.5 ppm.
9.2.(c)(2)	Description	Identify compatible instrumentation for mercury analysis.
9.2.(c)(3)	Description	Identify economic projections in terms of incremental costs per unit weight of food represented by the analytical technique.

Status — It is advised that the FDA uses atomic absorption for mercury analysis of food and as a consequence the food processing industry is reluctant or unwilling to turn from an analytical technique which the FDA will accept to one which the FDA may not accept. Mercury analysis by NAA in food chains has little market potential, but a report can be prepared for results consistent with terms of the contract.

9.3 Secondary Contract Obligations

The contract specified that KSU was to determine, as time permits, the feasibility of utilizing ^{252}Cf in the following applications:

9.3.(a) Description — Security Authentication by NAA

Status — Studies indicate that the neutron flux available from 40 mg of ^{252}Cf is inadequate to achieve swift and unambiguous security authentication with the securities currently in use. However, the securities can be "doped" with large activation cross-section nuclides. The possibilities for future studies are indicated in Section 10.1.

9.3.(b) Description — Educational Uses

Status — The ^{252}Cf has been used in connection with the following theses either completed or in progress:

STUDENT NAME	DEGREE	MAJOR PROFESSOR
Alexander	Ph.D.	Donnert and Merklin
Iyengar	Ph.D.	Faw
Kaiseruddin	Ph.D.	Donnert and Merklin
Mehta	Ph.D.	Donnert and Merklin
Sun	Ph.D.	Faw
Kan	M.S.	Donnert and Merklin
Khanna	M.S.	Donnert and Merklin
Prigel	M.S.	Meyer
Ryman	M.S.	Faw

NE 695 NUCLEAR TECHNOLOGY LABORATORY

Fermi age, diffusion length and neutron flux profile measurements, neutron shielding experiments.

9.3.(c) Description — Feed-Lot Run-Off Analysis

Status — Locating interest in this objective has been unsuccessful. This effort would, perforce, be an interdisciplinary effort. We tried but failed to stimulate interest either in the feed lot industry or among colleagues on this campus who might be expected to have scholarly interest in this area. Lack of interest rather than the lack of possibilities seems to prevail.

9.4 Additional Contract Obligations

9.4.(a) Description — Collaborate with interested industrial companies to establish the potential market for ^{252}Cf in these applications.

Status — A listing of organizations which have been contacted to stimulate interest in cooperative use of ^{252}Cf follows:

H. J. Heintz
International Business Machines
Kerr-McGee Oil
McNally-Pittsburg
Kansas Bureau of Investigation
KSU Department of Grain Science and Industries
KSU Department of Agricultural Engineering
Bendix Corporation
Martin Marietta Corporation
University of Kansas, Radiation Biophysics
University of the West Indies

9.4.(b) Description — Provide at the conclusion of the investigation an evaluation of the technical feasibility of and an estimate of the potential market for ^{252}Cf in the application being studied.

Status — Based on information collected to date, the evaluation can be summarized as follows:

a) Assuming FDA will approve neutron irradiation of wheat going into the human food chain, ^{252}Cf may find a significant market in the area of protein determination. The potential impact on human nutrition is not easily overstated.

9.4.(b) cont'd

b) Assuming a major overhaul in the securities printing procedure, ^{252}Cf may find a limited market in the area of security authentication. There are several large security exchange locations which might utilize such a system.

c) Assuming an expansion of studies for process control at KSU, ^{252}Cf may find a significant market in the field of agriculture and related areas. The market might include: all phases of cereal grains and subsequent handling, feed-lot feeding control, and wood and paper products industry.

10.0 SUGGESTIONS FOR FURTHER STUDY

10.1 Security Authentication by Use of NAA

Several items should be considered in the future study of security authentication. These include: industrial interest, a study of elemental solubility and concentration in ink, security printing procedures, and refined irradiation and detection equipment.

The factor of industrial interest is important but not absolutely necessary for future investigation. The proposed security authentication method is certainly feasible, but security exchange personnel may want to see a more specific study completed before financing advanced research. Certainly no major development should be undertaken unless the security exchange personnel are extremely favorable to such an authentication method.

A more complete study of the proposed method would pertain to the solubility of dysprosium and hafnium in ink. Chemical methods for concentration of the elements in the ink should be studied thoroughly. The concentrations and therefore the detection levels should be analyzed. Other elements might be included in the encoding procedure and analysis. The amounts of ^{252}Cf needed for irradiation should be considered in parallel to the elemental concentrations in the ink. Estimates should be made comparing the costs for the ^{252}Cf to the costs for concentration of the elements in the ink.

Advanced research should include a study in security printing procedures. The elemental code could be determined during the printing process. The possibility of dividing the security into a number of regions for various elemental ratio concentrations should be examined.

Counting and detection equipment should be developed in conjunction with the printing procedures. Limited counting area NaI(Tl) detectors could be

arranged to count the defined regions of the security. A hard-wired analyzer system would accompany such an array of detectors. The development of a binary or similar ratio code seems logical, with a readout system that would show the analyzed code.

10.2 Protein Determination of Wheat by Capture Gamma-Ray Analysis

The potential for the ^{252}Cf program at KSU is largely contained in the possibility of process control applications. This potential was recognized from the efforts directed to the protein determination in wheat samples. An array of ^{252}Cf source strengths, e.g., 10 μgm, 50 μgm, 100 μgm, and perhaps 200 μgm-500 μgm, would be necessary to develop a viable program in process control applications.

The process control work should be a coordinated effort between applications in the grain industry, coal industry, wood and paper products industry, and ores processing industry. The DNE could seek to form a consortium of the Kansas Agricultural Experiment Station, the Federal Grain Marketing Research Laboratory at Manhattan, the Department of Grain Science and Industry, the Department of Animal Sciences, the Department of Horticulture and Forestry (at KSU and Oklahoma State University), the BOM, the McNally-Pittsburg Manufacturing Company of Pittsburg, Kansas, and the Kerr-McGee Corporation of Oklahoma City, Oklahoma. Possibly other groups and companies might join at a later time. This consortium should be goal-oriented to solve two to three very specific problems. It should be administered by the DNE with the advice and support of the other groups involved. From the various university groups should come student and faculty support for the work of the project as

well as ideas and proposals for development of financial support. The companies and federal laboratories should provide financial and personnel support as well as the immediate goal-oriented problems.

The problem of wheat protein determination should be developed in three major areas: electronics, in situ facility, and harvest parameters. The necessary electronic equipment should be obtained for use with a ^{252}Cf source of at least 200 μgm. This would probably include equipment similar to the BOM as outlined in Section 7.0.

The optimal detector temperature should be considered. Large scale usage of the method would indicate the possibility of centralizing analysis equipment with remote counting stations at the local elevator site. The work should be conducted where the in situ difficulties could be determined and remedied. The system should be developed to give additional information now gathered at the local elevator, e.g. moisture and inert materials (dockage). Other cereal grain analyses should be developed for maximum financial benefit to the elevator operator.

The entire system should be operable by a competent high school graduate. Analysis times should be no longer than 10 minutes, with the accuracy of the analysis to be determined by the needs of the industrial companies. The entire system could be placed permanently at the elevator site or be developed for easy transport to follow the harvest season areas.

Extended use in the food industry would require the study of amounts of residual radioactivity and related problems. The Food and Drug Administration should be approached and questioned about the use of the proposed protein analysis facility.

10.3 Radiation Effects Studies

The radiation effects studies should be continued because of the positive results obtained from studies discussed in Section 8.0. The studies should be directed by the DNE faculty interested in this work. The development of adequate techniques for nuclear-radiation dosimetry and spectrography usable in high intensity radiation experiments as well as in the mixed fast-neutron and gamma-radiation environments is possible.

The studies of microstructure phenomena and macroscopic effects induced by irradiation of solid and amorphous insulator materials should be completed. This will require the study of Al_2O_3 and SiO_2 insulators. Post-irradiation recovery should also be considered.

Progress is possible with the studies of radiation-induced lattice-defect characteristics and bulk-material properties of semiconductors.

10.4 Miscellaneous Projects

The educational uses of the KSU ^{252}Cf Facility can be expanded. Several class laboratories contain the possibility for undergraduate and graduate study. The use of the sources for mercury and other toxic material determinations in the food chain is possible. The sources could be utilized in conjunction with feed-lot run-off analysis if the proper interest is generated. Other interdepartmental areas include: biology, veterinary medicine, and agriculture.

11.0 ACKNOWLEDGEMENTS

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The direction and support of the Radiation Safety Officer, John Lambert, is recognized as essential for the licensing of the facility. An invaluable part of the entire operation of the facility is credited to the shop mechanic, Mr. G. W. Abshire, and his inate ability to make something from nothing, at no cost. Gratitude is expressed to Mr. S. Hoffman and Mr. K. L. Brown for their contributions in construction and unloading and to Mr. Brown for his assistance during the initial experimental work. The continued aid of the KSUTMIINR personnel, Mr. L. Raney, Mr. M. J. McEwan, and Mr. N. Graves, is acknowledged. The experimental work of Mr. J. A. Bailey, Mr. J. R. Villarreal, and Mr. A. L. Caraway was essential to the progress in the fulfillment of the contract.

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Industry and Mr. G. Bothwell of the Kansas State Grain Inspection Department, Topeka, Kansas, are to be thanked for the Kjeldahl analysis of the wheat.

Finally, the author's appreciation of the continued support and advice of his wife, Karen, and of his parents and brother can never be adequately stated.

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20. S. K. MEHTA, "Study of Thermoluminescence Color Centers in TLD-100," Kansas State University Master's Thesis, unfinished.

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13.0 APPENDIX

13.1 USAEC ^{252}Cf Market Evaluation Program Contract

U. S. ATOMIC ENERGY COMMISSION
Savannah River Operations Office

CONTRACT NO. AT(38-1)-612
KANSAS STATE UNIVERSITY

THIS CONTRACT, entered into this _____ day of _____, 1970, by and between the UNITED STATES OF AMERICA (hereinafter called the "Government") as represented by the UNITED STATES ATOMIC ENERGY COMMISION (hereinafter called the "Commission"), and KANSAS STATE UNIVERSITY (hereinafter called the Contractor"), an educational institution incorporated under the laws of the State of Kansas.

WITNESSETH THAT:

WHEREAS, the Commission has, or in the near future expects to have a limited supply of the radioisotope californium-252 (^{252}Cf) which it, in order to encourage scientific and industrial progress, is willing to make available for use in research programs of various types; and

WHEREAS, the Contractor has requested the Commission to furnish it with neutron sources containing ^{252}Cf for use in studies to evaluate the application of ^{252}Cf for protein analysis of cereal grains, nuclear radiation effects research, and analysis of toxic material in foods; and

WHEREAS, the information from the studies to be undertaken by the Contractor with the use of the sources containing ^{252}Cf is of interest to the Commission and has the potential of facilitating scientific and industrial progress with the use of said material; and

WHEREAS, the Contractor is desirous of and agreeable to participating with the Commission in the development of a program, as are other investigators, to assure coverage of the field of application of ^{252}Cf as completely as possible; and

WHEREAS, the intent of the parties to this contract is that during the term of this contract, one or more third parties may use the sources and/or participate in the investigation under arrangements mutually acceptable to all parties; and

WHEREAS, this contract is authorized by law including the Atomic Energy Act of 1954, as amended;

NOW, THEREFORE, the parties do mutually agree as follows:

ARTICLE I - DEFINITIONS

As used in the Contract:

a. The term "Commission" means the United States Atomic Energy Commission or any duly authorized representative thereof, including the Contracting Officer except for the purpose of deciding an appeal under the Article entitled "Disputes."

b. The term "Contracting Officer" means the person executing this Contract on behalf of the Commission and includes his successors or any duly authorized representative of such person.

c. The term "person acting on behalf of the Commission" means employees and contractors of the Commission, and employees of such contractors, who implement or participate in the implementing of this Contract pursuant to their employment or their contracts with the Commission.

d. The term "private parties" means U. S. citizens, U. S. corporations, and any foreign government with whom the Government has an agreement of cooperation for the production or utilization of special nuclear material or atomic energy.

ARTICLE II - SCOPE OF WORK

a. The Contractor shall conduct in its own facilities at Manhattan, Kansas, a research and development program to evaluate the application of ^{252}Cf for protein analysis of cereal grains by neutron activation, for a cohesive study of electronic materials and components in nuclear-radiation environments, and quantitative analysis of mercury and selected additional toxic material in commercially processed foods for humans, as set forth in the Contractor's proposal dated June 26, 1970. The work to be performed will specifically include:

1. Primary Objectives

(a) Protein Analysis of Cereal Grains by Neutron Activation Analysis

(1) Determine neutron source strength, and therefore amount of californium-252, required to do commercially useful protein analysis of cereal grains.

(2) Determine detection and instrumentation, including data processing equipment if appropriate, required for commercially useful protein analysis of cereal grains.

(3) Prepare a projection or estimate of analysis costs as compared to present industry standards for protein analysis.

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(4) Prepare a summary or guide relating to licensing and safety requirements a typical commercial user would face.

(5) Prepare detailed instructions on how to use the suggested "package" of apparatus, source and instrumentation, to measure protein quality. Instructions will be reduced to language understandable to an alert and interested high school graduate.

(b) Cohesive Study of Electronic Materials and Components in Nuclear-Radiation Environments

(1) Development of adequate techniques for nuclear-radiation dosimetry and spectrography usable in high intensity radiation experiments as well as in the mixed fast-neutron and gamma-radiation environments.

(2) Studies of microstructure phenomena and macroscopic effects induced by irradiation of solid and amorphous insulator materials.

(3) Studies of radiation-induced lattice-defect characteristics and bulk-material properties of semiconductors.

(c) Quantitative Analysis of Mercury and Selected Additional Toxic Material in Commercially Processed Foods for Humans

(1) Determine neutron source strength, and therefore amount of californium-252, required to do on-line or random sample analysis of food for mercury content, sensitive to 0.5 ppm.

(2) Identify compatible instrumentation for mercury analysis.

(3) Identify economic projections in terms of incremental costs per unit weight of food represented by the analytical technique.

2. Secondary Objectives

Determine, as time permits, the feasibility of utilizing ^{252}Cf in the following applications.

(a) Security Authentication by Neutron Activation Analysis

(b) Educational Uses

(c) Feed-lot Run-off Analysis

3. Collaborate with interested industrial companies to establish the potential market for ^{252}Cf in these applications.

4. Provide at the conclusion of the investigation an evaluation of the technical feasibility of and an estimate of the potential market for ^{252}Cf in the applications being studied.

b. The research and development program shall be under the overall direction of Dr. Curtis G. Chezem, Professor and Head of Nuclear Engineering assisted by such assistant investigators and supporting services as the Contractor may deem necessary and appropriate. The Contracting Officer shall be notified promptly in writing of the replacement or reassignment of the principle investigator.

ARTICLE III - LOAN OF PROPERTY

a. The Commission agrees to furnish to the Contractor five (5) sources each containing approximately 10 milligrams of ^{252}Cf subject to (1) the availability of such sources, and (2) the Contractor's possession of appropriate licenses to receive, possess, and transport such sources. The Commission will use its best efforts to furnish the sources. Such sources shall be encapsulated in forms to be mutually agreed upon by the parties.

b. Changes in the type, active length or ^{252}Cf content of the sources may be made by written agreement of the parties without formal amendment to the Contract.

c. The neutron activity of each source measured as of a specific date, together with the Commission's calculations of the ^{252}Cf contained therein as of such date, also will be furnished to the Contractor at the time of each shipment from the Commission's Savannah River Plant. If requested, the Commission will make available to the Contractor details of the procedures or methods used in such measurements and calculations. The Commission will use its best efforts to supply such sources to the Contractor in accordance with a schedule to be mutually agreed upon by the parties.

ARTICLE IV - TERM

The term of this Contract shall be for one year from the date of execution hereof; provided that such term may be extended by mutual agreement of the parties in writing.

ARTICLE V - INSPECTION AND REPORTS

a. The Commission shall have the right to inspect, in such manner and at all reasonable times as it deems appropriate, all activities of the Contractor arising in the course of its performance of work set forth in Article II - SCOPE OF WORK.

b. The Contractor shall make and furnish to the Commission six (6) copies of the following reports:

1. The Contractor shall submit to the Commission on a monthly basis during the course of the work under this Contract, progress reports on the research and development investigations conducted in accordance with Article II - SCOPE OF WORK. The format and information to be included in these monthly reports shall be established by mutual agreement between the Contractor and the Commission;

2. The Contractor shall submit to the Commission on a quarterly basis (or more frequently if it so desires) status reports containing detailed technical data regarding the progress of the research and development investigation conducted in accordance with Article II - SCOPE OF WORK. The format and information to be included in this report shall be established by mutual agreement between the Contractor and the Commission;

3. Not later than ninety (90) days after conclusion of the work specified in Article II - SCOPE OF WORK, the Contractor shall submit a final report summarizing all technical data generated with respect to such items of work, including appropriate charts and figures, and the Contractor's evaluation of the investigations; and

4. Such other reports as the Commission may reasonably require from time to time.

ARTICLE VI - PATENTS

a. Foreground

1. Whenever any invention or discovery is made or conceived by the Contractor or its employees in the course of or under this Contract, the Contractor shall promptly furnish the Commission with complete information thereon; and the Commission shall have the sole power to determine whether or not and where a patent application shall be filed, and to determine the disposition of the title to and the rights under any application or patent that may result; provided, however, that the Contractor, in any event, shall retain at least a non-exclusive, irrevocable, royalty-free license under

said invention, discovery, patent application, or patent. The title and additional rights shall in each instance be determined by the Commission as it deems equitable and appropriate after consultation with the Contractor. Subject to the license retained by the Contractor, as provided in this paragraph, the judgment of the Commission on these matters shall be accepted as final; and the Contractor, for itself and for its employees, agrees that the inventor or inventors will execute all documents and do all things necessary or proper to carry out the judgment of the Commission.

2. No claim for pecuniary award or compensation under the provisions of the Atomic Energy Act of 1954, as amended, or under Title 35, U. S. Code, Section 183, shall be asserted by the Contractor, or its employees with respect to any invention or discovery made or conceived in the course of or under this this Contract.

3. Except as otherwise authorized in writing by the Commission, the Contractor will obtain patent agreements to effectuate the purposes of paragraphs a. and b. of this article from all persons who perform any part of the work under this Contract, except such clerical and manual labor personnel as will not have access to technical data.

4. With respect to any U. S. Patent Application filed by the Contractor on any Contract invention or discovery made or conceived in the course of the Contract, the Contractor will incorporate in the first paragraph of the U. S. Patent Application the following statement:

> The invention described herein was made in the course of or under, a Contract (if desired, may substitute Contract with identifying number) with the U. S. Atomic Energy Commission.

b. Background

In addition to the rights of the parties under the foregoing paragraphs in and to inventions or discoveries made or conceived in the course of or under the Contract, the Contractor agrees to grant, at the request of the Commission, to the Government and to responsible private parties at reasonable terms, nonexclusive licenses to make and use and to have made and used any inventions or discoveries actually reduced to practice before the effective date of this Contract owned or controlled by the Contractor and to any inventions or discoveries actually reduced to practice or acquired during the Contract period but not subject

to the foregoing Foreground invention rights provisions, which shall be or are utilized, tested, incorporated or embodied in the work under this Contract. The Commission shall make such request only when such inventions or discoveries are considered by the Commission to be necessary for the use of the technology developed under this Contract. In the event that the Contractor and prospective licensees cannot agree upon a reasonable royalty, the Contractor agrees that the royalties may be fixed pursuant to the procedure set forth in Section 157(c) of the Atomic Energy Act of 1954, as amended.

ARTICLE VII - TECHNICAL DATA

a. Foreground

In addition to the rights of the parties set forth above in Article V - INSPECTION AND REPORTS, all drawings, sketches, designs, design data, specifications, notebooks, technical and scientific data, and all photographs, negatives, reports, findings, recommendations, data and memoranda of every description relating to work or any part thereof under this Contract shall be subject to inspection by the Commission at reasonable times and a copy of the foregoing shall be furnished by the Contractor at the request of the Commission without any claim on the part of the Contractor for additional compensation. Any document report or data furnished or made available to the Commission under this paragraph may be used by the Government for any purpose whatsoever, including dissemination to the public, without charge for use; provided, however, that at the Contractor's request, the Commission shall delete any material in such document, report or data to be disseminated to the public which is not directly related to the Contract work and not necessary to an understanding thereof.

b. Background

In addition to the rights of the parties set forth above in paragraph a. of this Article VII, the Contractor agrees to and does hereby grant to the Government an irrevocable license and right to use any secret process, technical information, or know-how of the Contractor, made, developed, or acquired prior to or on the effective date of expiration or completion of this Contract, which shall be or is utilized, tested, or embodied in the work under this Contract, or which shall be or is specifically incorporated in any scientific or technical report rendered under this Contract; provided, however, that to the extent that any such background "secret processes, technical information or know-how" when furnished or delivered is specifically identified by the Contractor at the time of delivery to the Commission, the same shall not be used by the Government except in the performance of other

contracts or subcontracts with or for the benefit of the Government, unless such material and information is generally available to the public or has been made available to the Government from other sources or previously made available by the Contractor without limitation as to use. Nothing in this clause shall be deemed to grant a license under any patent rights of the Contractor except to the extent that licenses under such patent rights may be granted under Article VI - PATENTS, of this Contract.

ARTICLE VIII - NOTICES

a. Any notices required by this Contract of the Contractor shall be submitted in writing to the Commission addressed to:

Mr. Nathaniel Stetson, Manager
Savannah River Operations Office
U. S. Atomic Energy Commission
P. O. Box A
Aiken, South Carolina 29801

b. Any notices required by this Contract of the Commission shall be submitted in writing to the Contractor addressed to:

Mr. Ralph H. Perry, Comptroller
Comptroller's Office, Anderson Hall
Kansas State University
Manhattan, Kansas 66502

ARTICLE IX - ADDITIONAL CONTRACT PROVISIONS

Appendix A attached hereto and made a part hereof, sets forth additional general contract provisions of this Contract.

IN WITNESS WHEREOF, the parties hereto have executed this Contract as of the day and year first above written.

UNITED STATES OF AMERICA
BY: U. S. ATOMIC ENERGY COMMISSION

BY: _____

TITLE: _____

KANSAS STATE UNIVERSITY

BY: _____
Daniel D. Beatty

TITLE: Business Manager

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APPENDIX A

General Conditions

ARTICLE A-I	-	CHARGES
ARTICLE A-II	-	TERMINATION
ARTICLE A-III	-	USE OF LOANED PROPERTY
ARTICLE A-IV	-	GOVERNMENT PROPERTY
ARTICLE A-V	-	WRITTEN MATERIAL
ARTICLE A-VI	-	PUBLICATION OF RESULTS
ARTICLE A-VII	-	INDEMNITY
ARTICLE A-VIII	-	CONTAINERS
ARTICLE A-IX	-	DISPUTES
ARTICLE A-X	-	ASSIGNMENT
ARTICLE A-XI	-	PERMITS
ARTICLE A-XII	-	COMPLIANCE
ARTICLE A-XIII	-	COVENANT AGAINST CONTINGENT FEES
ARTICLE A-XIV	-	OFFICIALS NOT TO BENEFIT

APPENDIX A

General Conditions

ARTICLE A-I - CHARGES

a. The ^{252}Cf source(s) supplied to the Contractor by the Commission pursuant to Article III shall be furnished to the Contractor, F.O.B. Savannah River Plant. There will be no charge made to the Contractor for use of the ^{252}Cf source(s) or for loss of ^{252}Cf through normal radioactive decay while the source(s) is in the possession of the Contractor.

b. All costs incurred with respect to source fabrication and encapsulation, handling and packaging prior to shipment of the source(s) by the Commission to the Contractor shall be borne by the Commission.

c. The Contractor shall assume sole responsibility for and pay all charges connected with the shipment of the source(s) from the Savannah River Plant to the Contractor and all costs incurred in connection with the handling, packaging and transportation of the source(s) in connection with its return from the Contractor to the Commission, F.O.B. Savannah River Plant.

ARTICLE A-II - TERMINATION

a. The Commission may terminate this Contract at any time without cost to or liability of any kind incurred by the Government by written notice to the Contractor in the event (1) the right of the Contractor to possess the source(s) subject to this Contract expires or is suspended or terminated by any authority having power to take such action, or (2) the Commission finds that any source(s) furnished by it to the Contractor has been diverted by the Contractor, without approval of the Contracting Officer, from exclusive use in the program described in Article II, or (3) bankruptcy or insolvency proceedings are commenced by or against the Contractor, or if receivers are appointed to take possession of the business or property of the Contractor, or (4) the Contractor shall fail to perform its obligation hereunder and shall fail to take corrective action within 30 days of the date of written notice by the Commission of such failure to perform unless such failure arises out of causes beyond the control and without the fault or negligence of the Contractor.

b. Upon the expiration or termination of this Contract, the Contractor shall return to the Commission, F.O.B. Savannah River Plant, within 30 days, any property of the Government made available to the Contractor pursuant to this Contract. In the event return is not effected within

this period, the Commission shall have the right (1) to enter upon the Contractor's premises to recover or take possession of such property and (2) to charge to the Contractor the Commission's full costs of such recovery or repossession, as determined in accordance with established Commission pricing policy in effect at the time of such recovery or repossession.

ARTICLE A-III - USE OF LOANED PROPERTY

The Contractor, except as otherwise authorized in writing by the Commission and under arrangements mutually acceptable to all parties concerned, shall use the source(s) supplied to it by the Commission pursuant to Article III of this Contract solely in the performance of the work specified in Article II - SCOPE OF WORK. The Contractor shall retain each such source in the physical form in which it is supplied by the Commission. The Contractor further specifically agrees that no monetary charge of any type will be made to others for use by the Contractor of the ^{252}Cf source(s) supplied to it by the Commission pursuant to this Contract.

ARTICLE A-IV - GOVERNMENT PROPERTY

a. Title to the ^{252}Cf source(s) furnished to the Contractor pursuant to this Contract shall remain in the Government except as provided in paragraph h. below. Title to such property shall not be affected by incorporation or attachment thereof to any property not owned by the Government; nor shall any such property, or any part thereof, be or become a fixture or lose its identity as personalty by reason of affixation to any realty.

b. The Contractor shall be responsible for and shall reimburse the Commission for any loss, damage, or destruction of any source furnished the Contractor pursuant to this Contract, whether or not such loss, damage or destruction is due to the fault or neglect of the Contractor, damages resulting from normal uses excepted, or any other cause occurring from the time of delivery to the Contractor and until such source(s) has been returned to the Commission as provided herein.

c. The Commission shall determine prior to shipment the amount of ^{252}Cf contained in each source to be furnished under this Contract and the Commission's costs of fabricating and encapsulating such source(s). Such quantity and cost determinations shall be furnished promptly to the Contractor and shall be final and binding upon all parties to this Contract.

d. The Contractor shall notify the Commission promptly of any loss, damage or destruction of such source(s). In notifying the Commission, the Contractor shall utilize its best efforts to accurately fix the time of such loss, damage or destruction on the basis of a specific occurrence.

e. The Commission shall determine as of the time fixed for such loss, damage or destruction, the amount of ^{252}Cf contained in each source. Such determination shall be furnished promptly to the Contractor and shall be final and binding on all parties to this Contract.

f. In the event of loss or destruction of any source the Contractor shall reimburse the Commission for the Commission's full fabrication and encapsulation costs in addition to the rate of $25 per microgram (or at such lower rate as may have then been established and published by the Commission) of ^{252}Cf contained in the source at the time fixed for such loss.

g. In the event of damage of any source, the Contractor shall reimburse the Commission's full costs in restoring the source(s) to full serviceability as of the time fixed for such damage taking into consideration the amount of ^{252}Cf contained in the source(s) as of the time so fixed.

h. Title to source(s) which has been lost or destroyed shall pass from the Government to the Contractor upon payment to the Commission of the amount due.

ARTICLE A-V - WRITTEN MATERIAL

a. The Contractor hereby grants to the Government a royalty-free, non-exclusive, irrevocable license to reproduce, translate, publish, use and dispose of, and to authorize others to do so, all copyrightable material produced or composed or delivered to the Government or its designees under this Contract, including work not first produced or composed by the Contractor in the course of performance under this Contract but incorporated in the material produced or composed or delivered under this Contract (but only to the extent that the Contractor now has, or prior to final settlement of the Contract may have, the right to grant such license to such previously produced or composed work without becoming liable to pay compensation to others solely because of such grant).

b. The Contractor agrees that, except as the Commission may otherwise specifically authorize in writing, the Contractor will not include in any report or other material delivered under this Contract, or any published material relating to the work under this Contract, any copyrighted material owned by others which such owners have not consented to have so included.

c. The Commission will not publish in advance of the Contractor's publication without prior consultation with the Contractor.

ARTICLE A-VI - PUBLICATION OF RESULTS

a. The Contractor shall submit for publication in appropriate trade and other professional journals the significant results of the work performed by it pursuant to this Contract. Published results shall indicate the manner in which research was supported by the Commission. Seven (7) copies of each article submitted by the Contractor for publication shall be promptly sent to the Commission. The Contractor shall also inform the Commission when the article is published and furnish seven (7) copies of the article as finally published.

b. In order that public disclosure of such information will not adversely affect the patent interest of the Commission, patent approval for release and publication shall be secured from the Commission prior to any such release or publication.

ARTICLE A-VII - INDEMNITY

a. Neither the Government, the Commission, nor persons acting on their behalf will be responsible for any injury to or death of persons or other living things or damage to or destruction of property or for any other loss, damage or injury of any kind whatsoever resulting from the performance of services or furnishing of materials hereunder.

b. Neither the Government, the Commission, nor persons acting on their behalf makes any warranty expressed or implied (1) with respect to the accuracy, completeness or usefulness of any information furnished hereunder, (2) that the use of any such information may not infringe privately-owned rights, (3) that the services, materials, or information furnished hereunder will not result in injury or damage when used for any purpose, and (4) that the services, materials, or information furnished hereunder will accomplish the intended results or are safe for any purpose including the intended purpose.

c. Neither the Government, the Commission, nor persons acting on their behalf will be responsible, irrespective of causes, for failure to perform the services or furnish the materials or information hereunder at any particular time or in any specific manner therefor where appropriate.

d. The Contractor agrees to indemnify and save harmless the Government, the Commission, and persons acting on their behalf from (1) all liability, including costs and expenses incurred, resulting from the Contractor's use or disclosure of any information in whatever form, furnished hereunder, and (2) all liability to any persons including the Contractor for injury to or death of persons or other living things or injury to or destruction of property arising out of performance by the Government, the Commission, or persons acting on their behalf and not directly resulting from the fault

or negligence of the Government, the Commission, or persons acting on their behalf, or arising out of the use of the services performed, materials supplied, or information given hereunder by any persons including the Contractor. The foregoing provisions shall have no application to public liability for nuclear incident as defined and provided for in the Atomic Energy Act of 1954, as amended.

e. The Contractor agrees to indemnify the Government, the Commission, and persons acting on their behalf against liability of any kind (including costs and expenses incurred) for the use of any invention or discovery and for the infringement of any Letters Patent (not including liability, arising pursuant to Section 183, Title 35 (1952) U. S. Code, prior to the issuance of Letters Patent) occurring in the performance by the Contractor of the work set forth in Article II - SCOPE OF WORK.

ARTICLE A-VIII - CONTAINERS

a. All shipments of source(s) from the Commission to the Contractor, and from the Contractor to the Commission, will be made in Contractor-furnished containers: Provided, however, That in the event the Commission determines that the required containers are not reasonably available from commercial sources, the Commission may furnish Government-owned containers if such are available. Any Government-owned containers to be used for shipment of source(s) will be made available to the Contractor, F.O.B. Contractor vehicle or commercial conveyance at the Savannah River Plant unless otherwise agreed. Contractor-furnished containers shall be delivered to the Savannah River Plant within a reasonable time specified by the Commission prior to the scheduled delivery of source(s) to be shipped to the Contractor in such containers. Contractor-furnished containers will be used by the Commission only for the shipment of source(s) from the Commission to the Contractor and for temporary storage of materials shipped therein.

b. All containers, whether Government-owned or Contractor-furnished, must meet Commission regulations, specifications, and practices as to safety, design criteria, cleanliness and freedom from contamination in effect at the time furnished, utilized or returned, of which the Commission shall be the sole judge. The Commission will promptly return to the Contractor non-Government-owned containers but will not be responsible for any loss of or damage to such containers except as may result from its fault or negligence. Such return shipments by the Commission will be made F.O.B. Contractor vehicle or commercial conveyance at the Savannah River Plant.

c. Title to Government-owned containers shall remain in the Government. The Contractor shall pay such rental charge for such containers as shall be established by the Commission for general application to users of such Government-owned property. The Contractor will promptly return Government-owned containers to the Commission, F.O.B. Contractor vehicle or commercial conveyance at the Savannah River Plant. The

Contractor shall not be responsible for any loss of or damage to Government-owned containers except as may result from the fault or negligence of the Contractor, its agents or employees. Government-owned containers will be used only for shipment of material to and from the Commission and for temporary storage of materials shipped therein.

d. Whenever containers are shipped to the Commission or Government-owned containers are returned to the Commission, and the Commission elects to decontaminate the containers, railroad cars, trucks, or other shipping vehicles or the Commission's unloading area, because the containers or method of shipment fail to meet the health and safety standards prescribed by the Commission or other competent authority having jurisdiction over such material, the Contractor shall reimburse the Commission for the full cost of such decontamination as determined by the Commission in accordance with established Commission pricing policy.

ARTICLE A-IX - DISPUTES

a. Except as otherwise provided in this Contract, any dispute concerning a question of fact arising under this Contract which is not disposed of by agreement shall be decided by the Contracting Officer, who shall reduce his decision to writing and mail or otherwise furnish a copy thereof to the Contractor. The decision of the Contracting Officer shall be final and conclusive unless within 30 days from the date of receipt of such copy, the Contractor mails or otherwise furnishes to the Contracting Officer a written appeal addressed to the Commission. The decision of the Commission or its duly authorized representative for the determination of such appeals shall be final and conclusive unless determined by a court of competent jurisdiction to have been fraudulent, or capricious, or arbitrary, or so grossly erroneous as necessarily to imply bad faith, or not supported by substantial evidence. In connection with any appeal proceeding under this article, the Contractor shall be afforded an opportunity to be heard and to offer evidence in support of its appeal. Pending final decision of a dispute hereunder, the Contractor shall proceed diligently with the performance of the Contract and in accordance with the Contracting Officer's decision.

b. This "Disputes" article does not preclude consideration of law questions in connection with decisions provided for in paragraph a. above: Provided, that nothing in this Contract shall be construed as making final the decision of any administrative official, representative, or board on a question of law.

ARTICLE A-X - ASSIGNMENT

Neither this Contract nor any interest therein nor claim thereunder shall be assigned or transferred by the Contractor, except as expressly authorized in writing by the Commission. The Contractor shall not subcontract any research work under this Contract, except as expressly authorized in writing by the Commission.

ARTICLE A-XI - PERMITS

The Contractor shall procure all necessary permits or licenses and abide by all applicable laws, regulations, and ordinances of the United States and of the State, territory, and political subdivision in which the work under this Contract is performed.

ARTICLE A-XII - COMPLIANCE

The Contractor shall be required to comply with Commission regulations implementing Title VI of the Civil Rights Act of 1964.

ARTICLE A-XIII - COVENANT AGAINST CONTINGENT FEES

The Contractor warrants that no person or selling agency has been employed or retained to solicit or secure this Contract upon an agreement or understanding for a commission, percentage, brokerage, or contingent fee, excepting bona fide employees or bona fide established commercial or selling agencies maintained by the Contractor for the purpose of securing business. For breach or violation of this warranty the Government shall have the right to annul this Contract without liability or in its discretion to deduct from the Contract price or consideration, or otherwise recover, the full amount of such commission, percentage, brokerage, or contingent fee.

ARTICLE A-XIV - OFFICIALS NOT TO BENEFIT

No member of or delegate to Congress, or resident commissioner, shall be admitted to any share or part of this Contract, or to any benefit that may arise therefrom; but this provision shall not be construed to extend to this Contract if made with a corporation for its general benefit.

13.2 Licensing

13.2.1 Formal License Application--October, 1970

THE FOLLOWING DOCUMENT HAS PRINTING THAT EXTENDS INTO THE BINDING.

THIS IS AS RECEIVED FROM CUSTOMER.

Form RSC-1
5-67

APPLICATION FOR RADIATION SAFETY COMMITTEE AUTHORIZATION
KANSAS STATE UNIVERSITY

Submit two copies: Radiation Safety Office, Ward Hall

All requisitions for the purchase or procurement of radioisotopes must be directed to and approved by the Radiation Safety Office.

Each approved application is valid only for the user, radioisotope, millicurie amounts, application, location and until December 15 of each even numbered year.

1. Name, department, University address and extension of applicant performing immediate supervision of laboratory operations and radioisotopes.
   a) R. W. Clack, Nuclear Engineering, Ward Hall, Ext. 6918
   b) N. D. Eckhoff
   c) T. C. Roberts

2. Past experience and training of above named individual in the use of radioisotopes.
   a) Fifteen years, Reactor Supervisor, Diplomate Health Physics Society
   b) Six years, Graduate Student, currently Asst. Prof., KSU Dept. of Nuclear Engg.
   c) Graduate Student, KSU Nuclear Engineering, 2 years' experience

3. Name, department, University address & extension, and radioisotope experience of individuals using radioisotope under applicant's supervision (if student, state such).
   John Schauf* Norman Graves* (*-student) Nuclear Engineering, all with at least one year experience in use of radioisotope
   Patrick Ervin* Frank Pratt*
   Michael McEwan* John Leighty*

4.a RADIOACTIVE MATERIAL(S). (List chemical symbol and mass number of each.)	b. CHEMICAL AND/OR PHYSICAL FORM OF MATERIAL(S). (List Mfg. & model no. if sealed source)	c. POSSESSION LIMIT. (Maximum number of millicuries of each radionuclide that you will possess at any one time.
Californium-252 Cf^{252}	$Cf_2(C_2O_4)_3$, sealed source see attached drawings Appendix B of enclosure SR-Cf-100-Z	30,000 (nominal) (± 10%) estimated rate of use ___ mc/w

5.a Monitoring instruments available in the immediate area.
   Texas Nuclear Nemo (neutron sensitive)
   Eberline remote area monitoring system (1-1000 mr/hr)
   Multiple air monitors
   Hi and lo range beta/gamma survey meters (0-1000 rad/hr)

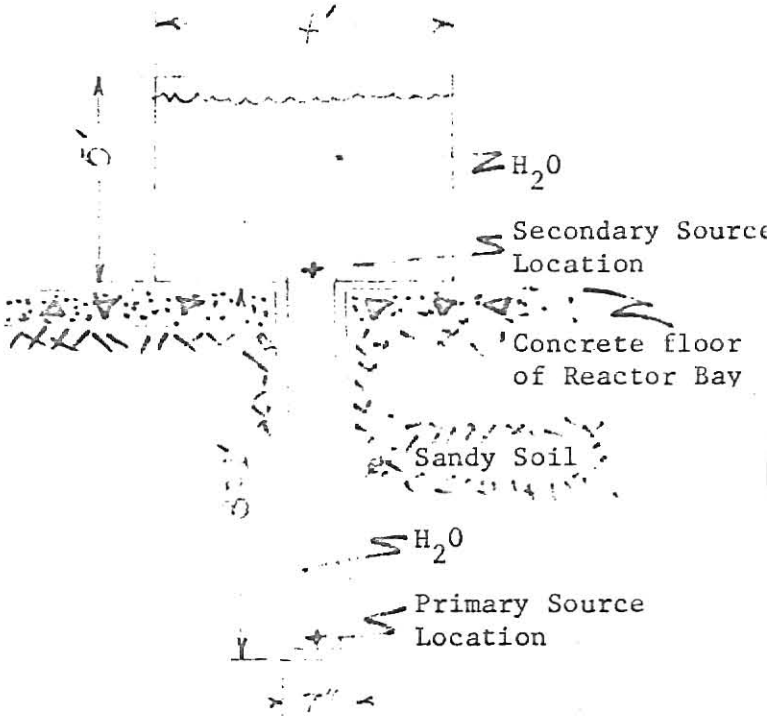
b Are your instruments capable of monitoring your radioisotope?

Yes XX No ____

6. PROPOSED USE: (Give sufficient detail concerning the problem and the methods of use of the radioactive material to provide a basis for a general evaluation of the health hazards and possible building contamination, including rooms involved for usage and storage.) The sealed californium sources, on loan from the Production Division of the U.S.A.E.C., willbe used for neutron activation analysis and radiation damage studies. The sources will normally be used and stored in the bottom of a 4 x 5 foot stainless steel pipe. The pipe will be attached to the bottom of a 4 x 5 foot stainless steel tank (see diagram). Installation will be in the reactor bay, WD 110, and will be continuously instrumented for beta/gamma dose rate.

Sources may, for experimental convenience, be raised to floor level for limited periods where special attention will be given to 10CFR20 limitations. Additional shielding may be required around the bottom of the tank if the sources are raised for any length of time.

Calculations indicate that a single 10 milligram californium-252 source could be brought to the raised position (i.e. centered at the bottom of the 4 x 5 ft. tank) would produce a whole body dose to a person standing on the tank platform of approximately 100 mrem/hr or 100 mrem/calendar week at the boundary of the restricted area, a lead annulus, or other appropriate geometry, will be placed on the floor of the tank to reduce the unrestricted dose rate to appropriate limits.



NOTE: APPLICANT'S SIGNATURE IMPLIES THAT HE HAS READ AND UNDERSTANDS THE KSU RADIATION SAFETY MANUAL.

7. Proposed method of disposal: (drain, burial, commercial firm or other.) Specify.

Radiation Safety Office will be the recepient of all radioisotopes ordered in order to open package and check for contamination.

8. Signature of Applicant Robert Clark Date 10/15/70
   Thelma Estabrook 10/15/70

9. Signature of Approval by the Radiation Safety Committee _____ Date _____

10. Expiration of this Authorization:

13.2.2 Application for Amendment No. 22

Kansas State University

Manhattan, Kansas 66502

Office of Radiation Safety
Ward Hall

October 19, 1970

Kansas State Department of Health
State Office Building
Topeka, Kansas

ATTENTION: Radiological Health Section

Gentlemen:

This is an application for Amendment No. 22 to Kansas Radioactive Materials License 38-C011-01, to permit us to receive, possess, use and transfer approximately fifty (50) milligrams (30 curies, nominal) of Californium-252. This radioactive material will be in five sources of ten (10) milligrams each. The construction of the sources is described in Appendix B of the enclosed booklet entitled, "Description of ^{252}Cf Sources," dated 8 September 1969. The sources are encapsulated under the SR-Cf-100 series with one exception which is that the outer or secondary capsule will be zircaloy in lieu of stainless steel. This change converts the model number from the previous one to SR-Cf-100-z.

The Californium sources will be housed normally in the bottom of a five inch diameter by eight foot long water-filled stainless steel pipe. The pipe will be attached to the bottom of a four-by-five foot stainless steel water-filled tank. Installation will be in the reactor bay floor (a hole bored 8' ± 1' deep) and will be continuously monitored by permanently installed beta-gamma detectors.

For experimental convenience, one or several sources may be raised to the floor level but still encased in the stainless steel tank. Additional shielding and monitoring may be required and will be added as necessary to maintain working levels of external radiation. The sources in the raised position will be infrequent; however, some work may require some of them to be raised at various times.

The sources will be used primarily for neutron activation analysis, radiation damage studies and educational experiments. During neutron activation analysis, the sample will be lowered into the neutron flux region via an access tube. After the sample is activated a specified amount of time, it will be removed and analyzed. Radiation levels of the activated samples will be monitored upon removal.

Leak tests of the sources will be difficult due to their location in a watery pit and also due to their relatively high curiage. It is proposed that since the sources are in water and that the water touching the surface of the sources is in common with the rest of the water, we be permitted to test aliquots of the water for radioactivity on a quarterly basis. In this way, we should be able to pick up contamination very rapidly. If gross contamination occurs, the area monitors

should detect it to inform us of the inconsistency.

If more information is required, please contact me.

Very truly yours,

John P. Lambert, Director
Environmental Health and Safety

JPL:dg

Appendix B was enclosed

also
See April 30, 1970 Ltr.

13.2.3 Additional Information--December, 1970

Kansas State University

Manhattan, Kansas 66502

Office of Radiation Safety
Ward Hall

December 3, 1970

Kansas State Department of Health
Radiological Health Section
State Office Building
Topeka, Kansas

ATTENTION: G. W. Allen
Public Health Physicist

Gentlemen:

Enclosed is additional information concerning the Californium-252 source which we hope to obtain in the near future. Not all of the requested information is available at this time, e. g., the method of transfer of the sources is not yet known because the cask for transporting the sources here has not been completely designed or built yet. Nevertheless, I will try to supply you with as much information concerning the sources as is possible. I will give you the infomation in the same order that you requested it.

1. Performance characteristics and prototype test data for zircaloy packeted source.
   ans. See enclosed sheet titled, Appendix B, (Addendum 1).

2. Description of device for raising, lowering and securing the source in the tank plus procedures for controlling unauthorized personnel when sources are raised.
   ans. The five sources will be positioned in a ½-inch thick, 5-inch diameter circular plexiglas device in which holes have been drilled to hold the sources. The plexiglas plate will be steadied by two metal rods that are semi-permanently positioned. When a source is raised, the plexiglas plate will be raised to a level one foot below the lower surface of the tank or floor level. A stop will be installed so that a traversing mechanism cannot raise the sources any higher than one foot below the floor level. Therefore, the plexiglas plate must be raised manually from this point. This will help to prevent unauthorized individuals from getting the Cf-252 sources out of the tank. The sources will then be raised by a long magnetic tipped tong and placed in the bottom of the water tank at desired locations. The design for the tong mechanism has not been finalized yet but will probably be similar to those used at Savannah River.

   The procedures that will be followed to insure that unauthorized personnel are excluded from the radiation area when a source is raised are similar to those that apply to reactor bay entrances. Only authorized personnel are issued [illegible]

usually number approximately 10-15 individuals) plus when a Cf-252 source is in the raised position, one of the advisers will be present at all times.

3. Anticipated dose rates at the tank surfaces. (See attached drawings.)
ans. Sources in the down position - minimal or not detectable above background. Sources raised to one foot below floor level - approximately 17-20 mrem/hr at four foot level of tank. Minimal at two foot level because a metal platform supported by "I" beams will be positioned at that height. If the dose rate is too high under the platform, some attenuator will probably be added.

Sources in raised position - 100-500 mrem/hr at three or four feet level of tank. (Ref: Estimation of Cf-252 Shield Requirements, H.E. Hootman, AEC Dp1232, Savannah River, April 1970).

4. Water system of tank
ans. Originally the water system will not be circulated. Initially, distilled and/or demineralized water will be used. If this proves unsatisfactory, a circulation system containing an ion exchange column is available and will be attached.

5. Minimum leak test
ans. If the source containment is ruptured so that fission products and Cf-252 leak from one of the sources it should be readily detectable. The lower sensitivity for the multi parameter gamma spectrometer is approximately 1×10^{-4} microcurie for I-131 or 20 times more sensitive then necessary to detect .005 microcurie. Radioactivity as low as one picocurie per milliliter is detectable in the "Tri-Carb" liquid scintillator. It is my opinion that we will have no problems detecting a leaking source if a rupture should occur.

6. Emergency procedures.
ans. If the shielding (water) is lost, the sources will still be in the bottom of the eight foot pit so that no direct hazard should be present. If containment is lost, wipe tests of the samples upon removal from the irradiation area or sampling the water should give an early indication. If another type emergency occurs giving a high radiation level on the area monitors, the persons are required to leave the reactor bay and contact the Radiation Safety Officer and/or the Director of the Nuclear Reactor Facility.

7. Tank dimensions
ans. The circular tank is five feet in height and four feet in diameter, and will be protected with an aluminum cover or plastic (polyethylene type) sheet.

8. Loading and unloading
ans. This is still to be determined because the transportation cask has not been constructed yet by the AEC. It is assumed that a transfer cask compatible with the transportation cask will be constructed. This will permit the two units to join together here, allow one 10-milligram source to drop into the transfer cask and then move that to the storage pit. The magnetic tongs will then be used to position the source into the plexiglas holder. This information must be confirmed so I would like to defer from answering this precisely until later.

9. Operating procedures
ans. Initially only four persons (N.D. Eckhoff, R.W. Clack, T.C. Roberts and J. Lambert) will be authorized to use the system and, therefore, one or several of the aforementioned men will know what is being introduced in the sample. The mechanism for sample positioning is the same as that used in the reactor - same type of vials and pulley or winch system. After a sample is removed, radiation levels and smears are checked. If a high radiation level exists, the sample will be placed in storage until the radiation dose rate is low enough to permit handling.

10. Leak tests vs. activation products in water
ans. There are several ways that one can detect a leaking Cf-252 source. These are;
    1) Gamma spectral analysis.
    2) If a source leaks, I-131 will be released and detected by the I-131 detector. Experience has shown that the I-131 detector is very sensitive.
    3) Cf-252 is an energetic alpha emitter and if alpha radiation is detected, one will readily be aware of a possible leaking source.

I hope that most of your questions have been answered satisfactorily. As more information is received on the transfer casks and the handling tongs, I will forward it to you.

Your expedient handling of this amendment request will be appreciated.

Sincerely,

John P. Lambert, Director
Environmental Health and Safety

JPL:dg

APPENDIX B
(ADDENDUM I)

INDUSTRIAL SOURCES, SR-Cf-100 SERIES (0 TO 10 MG OR 0 TO 50 CI)

A. Identification

Description: Zircaloy-2, Grade 32, is an acceptable alternative material to type 304L stainless steel for the outer capsules described in Appendix B (drawing SK-184-PM).

These capsules are the same design as the stainless steel capsules and have been tested and evaluated in the same manner. These tests include heating each completed Pt-Rh inner capsule for one-half hour at 1000°C in air before the final leak test. Testing, fabrication and handling procedures for Zircaloy-2 outer capsules that differ from those for the stainless capsules are described in this addendum.

E. Prototype Tests

1. Burst Test of Circumferential Weld

Hydrostatic burst test of the circumferential closure weld in the Zircaloy-2 outer capsule showed the average burst to be 41,000 psi internal pressure at 25°C. At 700°F the calculated burst strength is 13,000 psi internal pressure based on the decrease in tensile strength* at 700°F compared to 25°C.

F. Quality Control Procedures

4. Welding Control

Zircaloy-2 capsules are automatically TIG fusion welded in a controlled helium atmosphere.

*Table 2 - NUCLEONICS DATASHEET NO. 30

The pelletized platinum foil that contains the $^{252}Cf_2O_3$ is sealed by tungsten-inert-gas welding in the type 304L stainless steel primary capsule, shown in Figure II-2.

The primary capsule is then decontaminated, leak tested, and sealed by inert gas welding in a type 304L stainless steel secondary capsule, shown in Figure II-3.

The completed assembly is decontaminated, leak tested, and calibrated before shipment to the user.

E. Prototype Tests

The integrity of the source construction and seal weld was demonstrated by successfully subjecting the secondary capsule to internal and external pressure tests far in excess of pressures expected under the most adverse service conditions. Pressure created in the inner capsule from alpha decay and fission gas buildup of a 100 μg ^{252}Cf source are calculated to be 4.8 atm (70.7 psia) at 30°C and infinite decay, and 17 atm (250 psia) at 800°C and infinite decay.

1. Burst Test of Circumferential Weld

Hydrostatic burst test on a circumferential closure weld in the outer capsule (Figure II-4) revealed that the average burst strength of the circumferential weld is 47,500 psi at 25°C. At 800°C the burst strength would be 2500 psi internal pressure based on the decrease in tensile strength* from 25°C to 800°C.

2. External Loading Tests

The two worst conditions to which the source is likely to be subjected are a) crushing by a heavy object such as the shipping cask, and b) collapse under hydrostatic pressure, such as the capsule would experience in deep well or deep sea environment.

a) Crush Test - A shipping cask for a 200 μg (104 mCi) source may weigh about 2000 pounds. Assuming a safety factor of 5, the source was placed between stainless steel anvils loaded with a total of 10,000 pounds, removed and pressurized with helium at 30 psi for 30 minutes, then tested for leaks with a helium leak detector. No leaks were detected. Photographs of the source after test are shown in Figure II-5.

b) Hydrostatic Compression Test - The hydrostatic pressure under 10 miles of sea water is about 25,000 psi. The capsule was subjected to 25,000 psi helium pressure without measurable deformation, and then tested for leaks with a helium leak tester whose lower detection limit is 2.8×10^{-8} cm^3/second. No leaks were detected.

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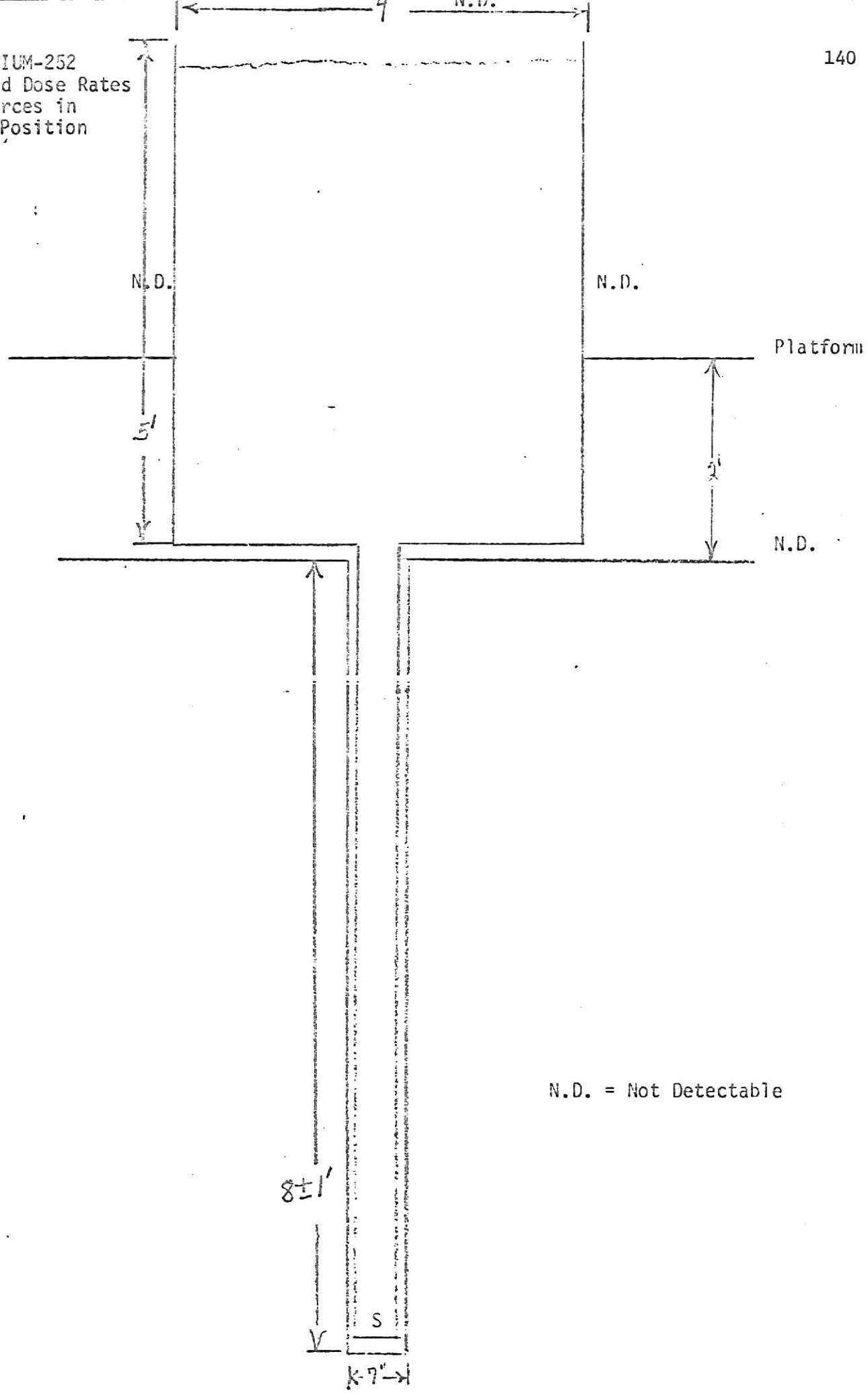
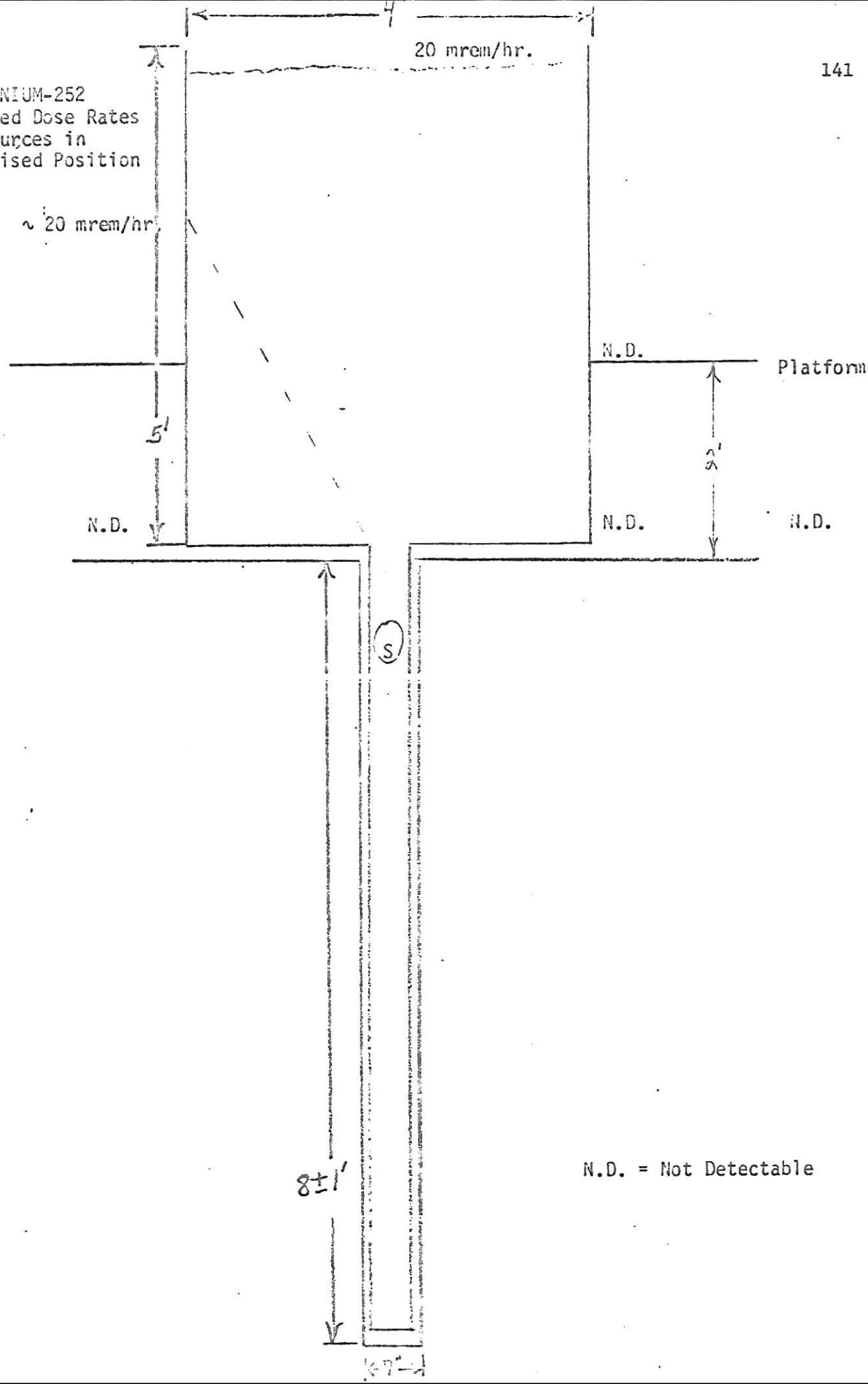
*Maximum allowable stress values in tension for austenitic stainless steels, Section VIII ASME, Boiler Code.

CALIFORNIUM-252
Estimated Dose Rates
With Sources in
Lowered Position



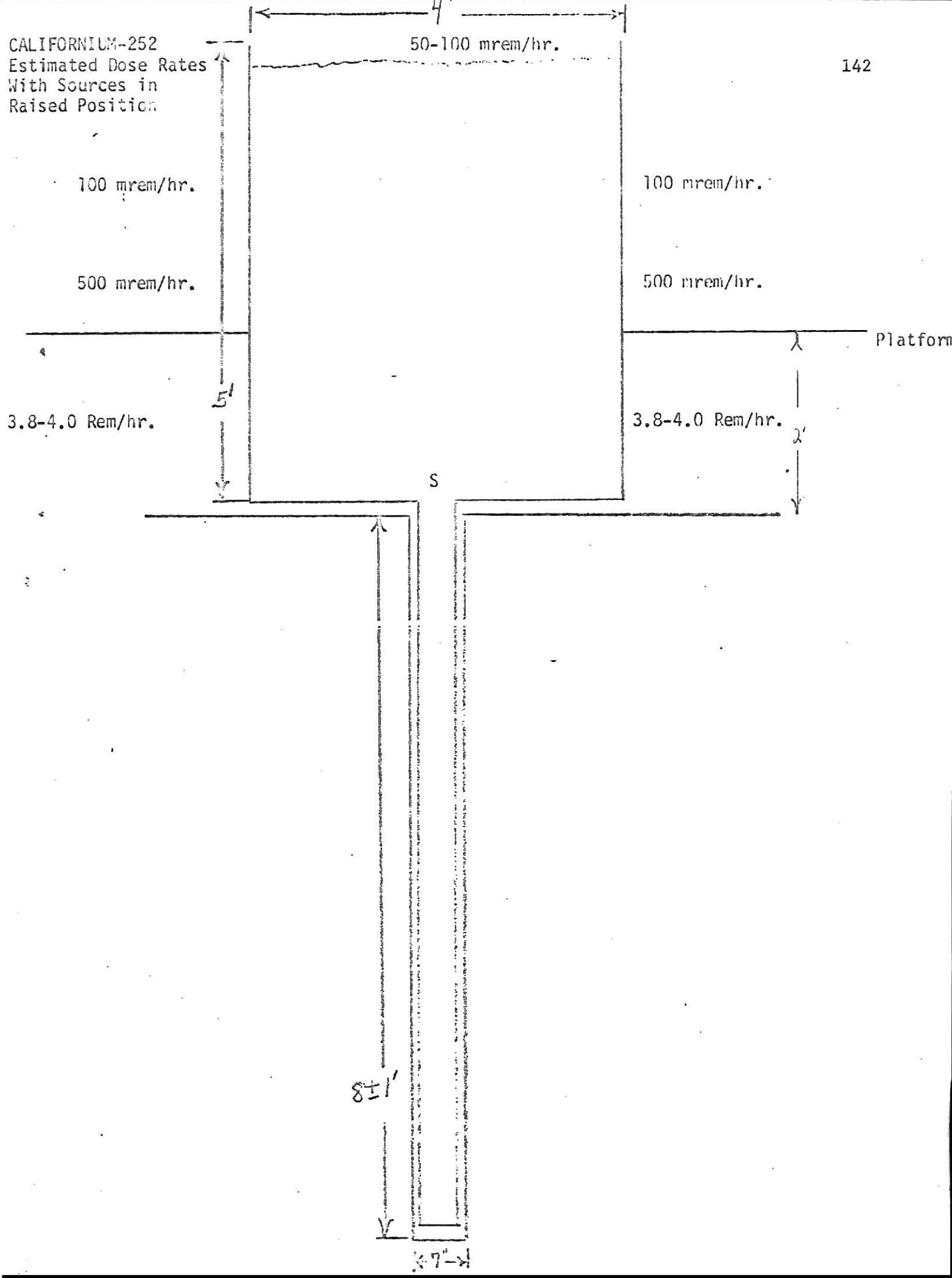
N.D. = Not Detectable

CALIFORNIUM-252
Estimated Dose Rates
With Sources in
Semi-Raised Position



N.D. = Not Detectable

CALIFORNIUM-252
Estimated Dose Rates
With Sources in
Raised Position



13.2.4 Additional Information--January, 1971

THE KANSAS STATE DEPARTMENT OF HEALTH

TOPEKA
KANSAS

E. D. LYMAN, M. D., M. P. H.
Director of Health

January 5, 1971

John P. Lambert
Kansas State University
Office of Radiation Safety
Ward Hall
Manhattan, Kansas

Dear Mr. Lambert:

This is in reference to your application, dated October 19, 1970, and letter dated December 3, 1970, pertaining to an amendment to Kansas Radioactive Materials license number 38-C011-01 to authorize possession and use of 30 Curies of Californium 252. The following additional information is requested:

1. A description of the mechanism for raising and lowering the sources. (This should include drawings and a bill of materials.)

2. A description of the tong mechanism to be used for source manipulation.

3. An indication of the magnitude of leakage that could be detected in both still and circulating water systems.

4. Any indication of the location of the proposed tank in relation to permanent or semipermanent work stations for reactor personnel or experimentors.

5. An estimate of the weight which the tank cover will be able to support. (Will the facility design be such that it will be required or convenient to use the cover as a support for equipment or personnel?)

Review of the application will be continued upon receipt of the information requested above.

If we can be of further assistance, please do not hesitate to contact this office.

Sincerely,

DIVISION OF ENVIRONMENTAL HEALTH

Gerald W. Allen
Public Health Physicist
Radiation Control Section

FORM A-1 GWA:al

Kansas State University

Manhattan, Kansas 66502

Office of Radiation Safety
Ward Hall

January 19, 1971

Kansas State Department of Health
Radiological Health Section
State Office Building
Topeka, Kansas

ATTENTION: G. W. Allen
Public Health Physicist

Gentlemen:

Additional information concerning our request for fifty (50) milligrams of Californium-252 is now available and it is hoped that the information provided is in sufficient detail for complete review of our application. The answers are in the same order as your questions asked in your letter dated 5 January 1971.

Question 1: A description of the mechanism for raising and lowering the sources.

Answer: Figure 1 represents a side view of the storage tank, (Dimensions and dose rates at various locations were submitted in letter of December 3, 1970). The central thimble is used for sample entry to the sources. It is made of acrytonitrile butadiene styrene (1½" plastic pipe) on the bottom six feet. The top six feet are made of polyvinyl chloride. The source holder (1" polyethylene plate) is attached to the central thimble by male-female connectors. The top of the thimble is guided and clamped into place by a 3-pronged laboratory clamp. The fittings at the six foot level are utilized to prevent movement of the central thimble past this clamp.

The thimble will be clamped to the traversing mechanism (See Fig. 2) on the vertical movement bar. This bar will be set to traverse three feet in total distance. The clamps will have to be reset before further traversing takes place. The mechanism shuts off automatically if this three foot limit is exceeded. Two traverses will raise the sources to the six foot level.

Question 2: A description of the tong mechanism to be used for source manipulation.

Answer: The source manipulation tool is a seven (7) foot long stainless steel pipe with a magnet attached to the end of it. This tool has been used with a dummy source in and out of water and no problems have been encountered with it. (See Fig. 3, MAG PICKUP TOOL).

Question 3: An indication of the magnitude of leakage that could be detected in both still and circulating water systems.

Answer: The volume of the tank is approximately 440 gallons (1.7×10^6CC), which, when diluting .005 microcurie of activity, provides an overall concentration of 3×10^{-9} µc/ml or only 6.6×10^{-3} dpm/ml, a limit that is not easily detected. Therefore, it is proposed that we be permitted to monitor the water on a quarterly basis and observe the increase in activity, if indeed there is any, plus monitor the ion exchange column with a gammascope on a quarterly basis and check the same column with a neutron monitor (NEMO) on a weekly basis. With these results available, it should be quite easy to detect any leak in a very short time. Also, past reactor experience has indicated that the earliest detection of an unknown release of fission products is usually picked up by an I-131 monitor, which we have located in the reactor bay.

This is actually a request to exempt us from Section 23-35-215 (A) and (B) LEAK TESTS, of Part 4 of the Kansas Radiation Protection Regulations because of the uniqueness of the situation. That is, the sources are in water and the water will go through an ion exchange column when circulated and it will be circulated at least one day prior to checking the ion exchange column with the gammascope. It is felt that the checks and the additional monitoring will more than compensate for the lack of leak testing plus it will provide as much information as necessary as well as being considerably safer than exposing personnel every six (6) months to large dose rates of external radiation.

Question 4: Any indication of the location of the proposed tank in relation to permanent or semipermanent work stations for reactor personnel or experimentors.

Answer: See Fig. 4. This plan taken from page 38 of the Hazards Summary Report for the TRICA II Reactor with the location of Cf-252 tank and platform added.

Distances	
Top of stairs to tank	28 feet (line of sight)
Bottom of stairs to tank	10 feet
Exit door to tank	25 feet (line of sight)

Access to the Reactor Bay is controlled on persons who are not positioned permanently or semipermanently in there. They may be in there doing their own business but not if the dose rates are too high. As mentioned before, the investigator will be around the bay and limiting access thereto when the radiation dose rates are excessive. The dose rate in the control room will not exceed 2 mrem/hr at anytime for a period longer than ten minutes.

Question 5: An estimate of the weight which the tank cover will be able to support.

Answer: See Fig. 5. The aluminum tank cover will support at least 170 lbs. It will be held in place by C-Clamps. The cover could be used to support equipment, but support of personnel will be discouraged. The plexiglass covers are removed by lifting them out by the handles. With the availability of the platform, a bridge across the top of the tank is unnecessary. An average sized individual can stand on the platform and reach to most areas of the tank, if necessary.

Additional Information: The sources when received will be packed in a plastic vial, 2" x ½" diameter, to which a string is attached. The string will be exposed even though the source will be shielded in the shipping cask. The string will be tied to anotner string which is part of the unloading device, a nine foot pole (See Fig. 6). After the strings are tied together, the operator will move back, pull the Cf-252 capsule into the lead shield and carry the source to the storage pit. The entire operation, according to our rehearsals, should be less than five (5) minutes. The calculated dose to the operator with the source in the open air would be approximately 200 millirem. With the source in the lead funnel, the dose will be considerably less than this.

After the source is in the water, the capsule will be opened by pulling the string and the magnetic tool will be used to position the source. Expected dose for this operation is less than one (1) millirem because of the water shielding.

Your prompt attention to this matter will be greatly appreciated.

Very truly yours,

John P. Lambert, Director
Environmental Health and Safety

JPL:dg

Figure 1. See Fig. 7, Section 2.3.

Figure 2. See Fig. 8, Section 2.4.

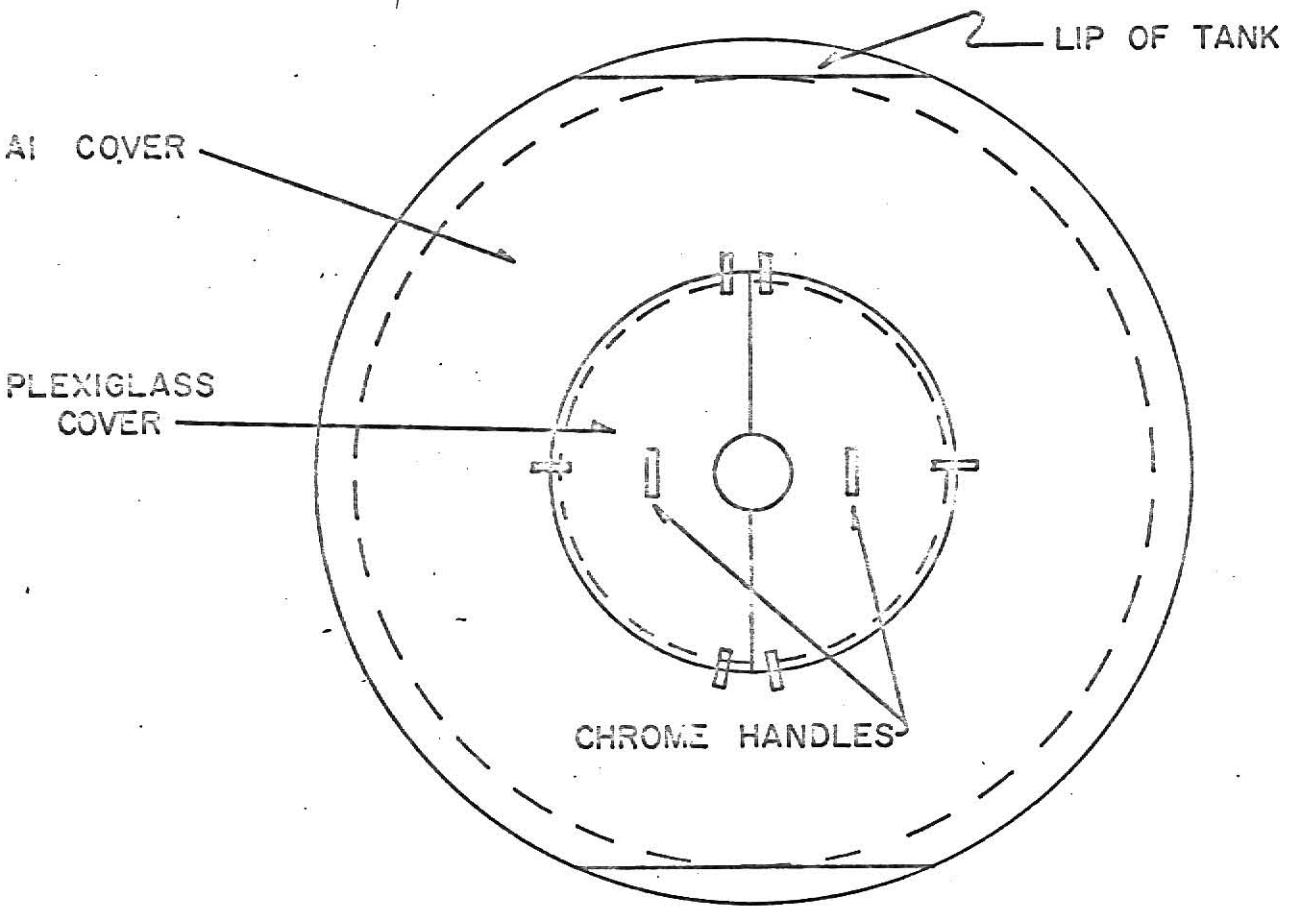
Figure 3. See Fig. 15, Section 4.2.

Figure 4. See Fig. 2, Section 2.1.

Figure 5. See next page.

Figure 6. See Fig. 13, Section 4.2.

FIG 5



TANK COVER

13.2.5 Application for Amendment No. 23

Kansas State University

Manhattan, Kansas 66502

Office of Radiation Safety
Ward Hall

February 25, 1971

Kansas State Department of Health
Radiological Health Section
State Office Building
Topeka, Kansas

ATTENTION: G. W. Allen
Public Health Physicist

Gentlemen:

Due to recent circumstances beyond our control, we are requesting Amendment Number 23 to Kansas Radioactive Materials License No. 38-0011-01 under which Kansas State University presently operates. This amendment is to permit us to increase the source strength of the individual Californium sources from 5.2 curies each to six (6) curies (±20%) each. The source number that we ordered (SR-CF-100) was described as having a maximum weight of 10 milligrams. However, the other day we received information that the first manufactured source contains 11.1 milligrams of Californium-252. Therefore, in order for us not to exceed our license, it is requested that our license be amended to permit us to receive, use and possess 50 milligrams (±10) with each of five (5) sources not to exceed six (6) milligrams (±20%) each.

Sincerely,

John P. Lambert, Director
Environmental Health and Safety

P.S. Please supply me with some RH-3 forms if you have them available.

JPL:Dg

13.2.6 Application for Amendment No. 25

May 5, 1971

Mr. John Lambert
Radiation Safety Officer

Dear Mr. Lambert:

This note is to initiate an amendment for license number 38-C011-01.

It is concerned directly with amendment 22, 7., BBB., Sealed Sources (AEC Savannah River Operations Model No. SR-CF-100-Z). The californium arrived in four sources and the information sheets for the sources are enclosed. You will notice that source SR-Cf-161 has the stainless steel outer capsule and not the Zircaloy-2. The fabricators at Savannah River mistakenly encapsulated the source in the stainless steel. They called and Prof. Clack indicated that we would take the source anyway.

Please find enclosed the test information sheets for the stainless steel capsule.

Sincerely,

Tom Roberts
Project Coordinator

TR/vmh

cc: R. W. Clack

Kansas State University

Manhattan, Kansas 66502

Office of Radiation Safety
Ward Hall

May 12, 1971

Kansas State Department of Health
Radiological Health Section
State Office Building
Topeka, Kansas 66612

Gentlemen:

Amendment No. 25 to Kansas Radioactive Materials License No. 30-C011-01 is hereby requested to permit us to use, possess and transfer Californium-252 sources encapsulated in stainless steel as well as the previously requested zircaloy metal. The manufacturer of our ten (10) milligram Californium sources inadvertently used stainless steel in the production of one of our sources in lieu of the requested zircaloy. Instead of delaying our acquisition of the sources, we accepted the stainless steel enclosed capsule so that our work could proceed as planned. The specifications for the encapsulation are listed under the Model No. SR-Cf-100 Series in the information sheets sent to you on 19 October 1970, entitled, "Description of ^{252}Cf Sources," dated 8 September 1969.

At this same time, I would like to get permission to allow operators of the Californium facility be certified or approved by a subcommittee of the Radiation Safety Committee. The records of these approvals would be maintained with the minutes of the Radiation Safety Committee meetings. I am sure that you can see the reasoning for this request in that as more experience is gained, more work should be performed on the facility requiring more individuals to do the work. Once again, let me remind you that the operators of the facility must be key holders to the nuclear reactor bay because the Californium is contained therein or, a key holder must be present to permit access to the facility. With this type of a control on the sources, I cannot foresee any situations that would be detrimental to the health or safety of other persons.

I would like to take this opportunity to register a new X-ray machine with your Department. The unit has the following specifications:

Manufacturer	Profexray
Model	T 1050
KVP	150
MA	1000
Serial No. (control panel)	C510-0171-002
Overhead tube	C9796 (Star Sapphire Tube)

It has an image intensifier that is usually used at the settings of 100 KVP and 3 ma.

This unit is a permanently installed, diagnostic X-ray used in the Veterinary Hospital at KSU.

Sincerely,

John P. Lambert, Director
Environmental Health & Safety

JPL:mlb

13.3 KSU ^{252}Cf Facility License

THE KANSAS STATE DEPARTMENT OF HEALTH

February 8, 1971

E. D. LYMAN, M. D., M. P. H.
Director of Health

Mr. John Lambert
Kansas State University of
Agriculture and Applied Science
Manhattan, Kansas 66502

Dear Mr. Lambert:

Enclosed is amendment number 22 , for Radioactive Materials License number 38-C011-01.

If we can be of further assistance, please do not hesitate to contact this office.

Sincerely,

ENVIRONMENTAL HEALTH DIVISION

Gerald W. Allen
Public Health Physicist
Radiation Control Section

GWA:hb
Encl.

ILLEGIBLE DOCUMENT(S)

THE FOLLOWING DOCUMENT(S) ARE OF POOR LEGIBILITY DUE TO CUTS, TEARS AND/OR MISSING PIECES

STATE OF KANSAS

RADIOACTIVE MATERIALS LICENSE

158

.ementary Sheet:

License Number 38-C011-01

Amendment No. 22

Kansas State University of
Agriculture and Applied Science
Manhattan, Kansas 66502

License number 38-C011-01 is hereby amended as follows:

To add:

6. Radioactive materials (element and mass number)	7. Chemical and/or physical form	8. Maximum quantity licensee may possess at any one time
BBB. Californium-252	BBB. Sealed sources (AEC Savannah River Operations Model No. SR-CF-100-Z)	BBB. 30.0 curies total, no single source to exceed 5.2 curie

CONDITIONS

BBB To be used in custom designed irradiation equipment as a source of neutrons for activation analysis, radiation damage studies and research.

Condition 13. (j) the letter dated October 19, 1970 signed by John P. Lambert, with attachments.

(k) the letter dated December 3, 1970 signed by John P. Lambert, with attachments.

(l) the letter dated January 19, 1971 signed by John P. Lambert, with attachments.

To add:

Condition 27: The leak test requirements of the Kansas Radiation Protection Regulations 28-35-216 (A) and condition 15 of this license will be considered to have been satisfied for the sealed sources described in subitem BBB providing the licensee conducts the special tests described in the letter dated January 19, 1971 and signed by John P. Lambert.

FOR THE STATE DEPARTMENT OF HEALTH

JAN 3 1971

Date

By

Robert C. Will, Chief
Radiation Control Section

33-2079 12-69-4M

STATE OF KANSAS

RADIOACTIVE MATERIALS LICENSE

159

Supplementary Sheet

License Number 38-C011-01
Amendment No. 23

Kansas State University of
Agriculture and Applied Science
Manhattan, Kansas 66502

License number 38-C011-01 is hereby amended as follows:

To read:

---

8. Maximum quantity licensee may possess at any one time

BBB. 30.0 curies total, no single source to exceed 6.0 curies

---

To add:

Condition 13. (m) the letter dated February 25, 1971, signed by John P. Lambert.

FOR THE STATE DEPARTMENT OF HEALTH

Date Mar. 3 1971

By

Robert C. Hill, Chief
Radiation Control Section

33-2079 12-63-4M

STATE OF KANSAS

160

RADIOACTIVE MATERIALS LICENSE

Supplementary Sheet:

License Number 38-C011-01

Amendment No. 25

Kansas State University of
Agriculture and Applied Science
Manhattan, Kansas 66502

License number 38-C011-01 is hereby amended as follows:

TO READ:

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7. Chemical and/or physical form

BBB. Sealed sources (AEC Savannah River Operations. Model No. SR-Cf-100Z or SR-Cf-100)

Condition 12. Radioactive material may be used only by, or under the supervision of, individuals designated by the Radiation Safety Committee or a subcommittee thereof, appointed and authorized by the Committee to act in its behalf on matters pertaining to the use of the sealed sources of Californium 252 described in item 7. BBB.

FOR THE STATE DEPARTMENT OF HEALTH

MAY 20 1971

Date

By

Robert C. Will, Chief
Radiation Control Section

13.4 ^{252}Cf Source Information Sheets

STRAIGHT BILL OF LADING — SHORT FORM

ORIGINAL — NOT NEGOTIABLE

SHIPPER'S No. 2228
162

Tri State Motor Lines
NAME OF CARRIER

CARRIER'S NO.

RECEIVED, subject to the classifications and tariffs in effect on the date of the issue of this Bill of Lading,

at Dunbarton, S.C. Apr. 12, 19 71 From Kansas State University

the property described below, in apparent good order, except as noted (contents and condition of contents of packages unknown), marked, consigned, and destined, as indicated below, which said carrier (the word carrier being understood throughout this contract as meaning any person or corporation in possession of the property under the contract) agrees to carry to its usual place of delivery at said destination, if on its route, otherwise to deliver to another carrier on the route to said destination. It is mutually agreed, as to each carrier of all or any of said property over all or any portion of said route to destination, and as to each party at any time interested in all or any of said property, that every service to be performed hereunder shall be subject to all the terms and conditions of the Uniform Domestic Straight Bill of Lading set forth (1) in Official, Southern, Western and Illinois Freight Classifications in effect on the date hereof, if this is a rail or rail-water shipment, or (2) in the applicable motor carrier classification or tariff if this is a motor carrier shipment.

Shipper hereby certifies that he is familiar with all the terms and conditions of the said Bill of Lading, including those on the back thereof, set forth in the classification or tariff which governs the transportation of this shipment, and the said terms and conditions are hereby agreed to by the shipper and accepted for himself and his assigns.

CONSIGNED TO:

Kansas City University
Dept. of Nuclear Engineering
Ward Hall
Manhattan, Kansas 66502
Attn: R.W. Clack/T.L. Roberts

MAIL OR STREET ADDRESS OF CONSIGNEE — FOR PURPOSES OF NOTIFICATION ONLY

ROUTE

Tri State Motor Lines

Trailer No. T-82932

DELIVERING CARRIER

CAR OR VEHICLE INITIALS | NUMBER

NUMBER PACKAGES	KIND OF PACKAGE, DESCRIPTION OF ARTICLES, SPECIAL MARKS, & EXCEPTIONS	WEIGHT * (Subject to Correction)	CLASS OR RATE	CHECK COLUMN
1	Cask Radioactive Material.	28,800 #		
	Radioactive Shipment:			
	Transport Group No. I			
	Radionuclides: Californium-252 as Oxide			
	21.248 Curies Total			
	Radioactive Yellow III Labels Required			
	Fissile Class: Not Applicable			
	Transport Index: 5 Units Radiation			
	Special Permit No. DOT SP 6323			
	"Radioactive" Placards Required, Black on Yellow			
	EXCLUSIVE USE VECHICLE SHIPMENT REQUESTED.			

Subject to Section 7 of Conditions, if this agreement is to be delivered to the consignee without recourse on the consignor, the consignor shall sign the following statement:

The carrier shall not make delivery of this shipment without payment of freight and all other lawful charges.

Per Ted V Taylor
SIGNATURE OF CONSIGNOR

If charges are to be prepaid, write or stamp here, "To Be Prepaid."

Collect

Received $ _____ to apply in prepayment of the charges on the property described hereon.

AGENT OR CASHIER

Per _____
(The signature here acknowledges only the amount prepaid.)

CHARGES ADVANCED:

$ _____

M.O. ORDER NO. SRS 6621 AGENCY ORDER NO. _____

The fiber boxes used for this shipment conform to the specifications set forth in the box maker's certificate thereon, and all requirements of Rule 41 of the Consolidated Freight Classification.

The fiber barrels, drums, pails, or tubs used for this shipment conform to the specifications set forth in _____ maker's certificate thereon, and all other requirements of Rule 41 of the Consolidated Freight Classification.

The paper bags used for this shipment conform to specifications for paper bags, Rule 40, Section 10 (c) of Consolidated Freight Classification.

The fibreboard covered veneer drums used for this shipment conform to the specifications set forth in drum maker's certificate thereon, and all other requirements of Rule 40 of the Consolidated Freight Classification.

Shipper's imprint in lieu of stamp; not a part of Bill of Lading approved by the Interstate Commerce Commission.

* If the shipment moves between two ports by a carrier by water, the law requires that the Bill of Lading shall state whether it is "carrier's or shipper's weight." NOTE—Where the rate is dependent on value, shippers are required to state specifically in writing the agreed or declared value of the property. The agreed or declared value of the property is hereby specifically stated by the shipper to be not exceeding .40 cents per pound.
PER

The carrier shall not make delivery of this shipment without payment of freight and all other lawful charges.

Per _____
SIGNATURE OF CONSIGNOR

If charges are to be prepaid, write or stamp here, "To Be Prepaid."

Collect

Received $ _____ to apply in prepayment of the charges on the property described hereon.

AGENT OR CASHIER

Per _____
(The signature here acknowledges only the amount prepaid.)

CHARGES ADVANCED:

$ _____

This is to certify that the above named articles are properly classified, described, packaged, marked and labeled, and are in proper condition for transportation, according to the applicable regulations of the Department of Transportation.

Manhattan, Kansas 66502

PER Ted V Taylor

Permanent post-office address of shipper

Tri State Motor Lines AGENT

PER George L. Wiley

UNITED STATES
ATOMIC ENERGY COMMISSION
SAVANNAH RIVER OPERATIONS OFFICE
P. O. BOX A
AIKEN, SOUTH CAROLINA 29801
(TEL. & TEL. NORTH AUGUSTA S. C.)

APR 15 1971

Dr. Curtis G. Chezem
Professor and Head
Department of Nuclear Engineering
Kansas State University
Manhattan, Kansas 66502

Dear Dr. Chezem:

Enclosed are the ^{252}Cf Neutron Source Information Sheets for the four sources that were shipped on Monday, April 12, 1971.

Sincerely yours,

N. Stetson
Manager

Enclosures:
As stated

cc: R. E. Perry, Comptroller
KSU, w/o encl

INFORMATION SHEET
"SPECIAL FORM" - ^{252}Cf NEUTRON SOURCE

Source Identification Number SR - Cf - 1512 Date: April 7, 1971

Shipped To: Kansas State University at Manhattan, Kansas
Attention: R. W. Clack/T. C. Roberts

Specification: Outer Capsule Reference Drawing SRL: SK-184-PM
Primary Capsule Reference Drawing SRL: SK-183-PM

DECONTAMINATION AND CLOSURE TESTS

Method

Capsule surfaces are decontaminated after closure in an ultrasonic bath until the flush solution contains less than 200 d/m per milliliter total alpha activity. The capsule is further decontaminated, if necessary, until all exterior surfaces are free of contamination as determined by a wipe test. Each assembly is immersed in a helium atmosphere with a pressure of at least 300 pounds per square inch for a period of 30 minutes, then transferred to a helium leak detector. The leak detector has a minimum sensitivity of 1.0×10^{-8} standard cubic centimeters of helium per second.

Tests

The finished capsule was found free of detectable leaks and contamination on February 22, 1971.

CALIFORNIUM CONTENT

Assay

The neutron emission rate of the finished assembly is determined by comparing its strength to that of a ^{252}Cf source calibrated at the National Bureau of Standards. The comparison is made by inserting the capsule assembly in an array of fission tube counters and measuring the subsequent induced electric current by a sensitive ammeter. The ^{252}Cf content given below is the effective or net californium content calculated from the neutron emission rate and is given in equivalent weight units assuming 2.311×10^{6} neutrons per second per microgram of ^{252}Cf. Corrections are made, when necessary, for the ^{254}Cf contribution to the total neutron emission rate. The ^{252}Cf present is assumed to decay with an effective half-life of 2.646 years; the ^{254}Cf, if present, is assumed to decay with a 60.5 day half-life.

Contents

The total neutron emission rate of this source was found to be 2.876×10^{10} neutrons per second with a standard error of ± 3.0% on February 22, 1971. The ^{254}Cf contribution to the total was calculated to be 0.307×10^{9} per second on the same date. The effective ^{252}Cf content was calculated to be 11.163 mg equivalent with a standard error of ± 3.0%.

The radiation intensity at three meters from a source in air at standard atmospheric conditions and without contributions from scattering media is no greater than 400 mrem/hr neutrons plus 30 mR/hr γ for each milligram of ^{252}Cf in the capsule.

R. H. Scott, Chief
Planning and Development Branch
SROO, USAEC
Aiken, South Carolina 29801

S. Mirshak, Director
Nuclear Engg and Materials Section
Savannah River Laboratory
E. I. du Pont de Nemours and Co.

INFORMATION SHEET
"SPECIAL FORM" - ^{252}Cf NEUTRON SOURCE

Source Identification Number SR - CF - 152Z Date: April 7, 1971

Shipped To: Kansas State University at Manhattan, Kansas
Attention: R. W. Clack/T. C. Roberts

Specification: Outer Capsule Reference Drawing SRL: SK-184-PM
Primary Capsule Reference Drawing SRL: SK-183-PM

DECONTAMINATION AND CLOSURE TESTS

Method

Capsule surfaces are decontaminated after closure in an ultrasonic bath until the flush solution contains less than 200 d/m per milliliter total alpha activity. The capsule is further decontaminated, if necessary, until all exterior surfaces are free of contamination as determined by a wipe test. Each assembly is immersed in a helium atmosphere with a pressure of at least 300 pounds per square inch for a period of 30 minutes, then transferred to a helium leak detector. The leak detector has a minimum sensitivity of 1.0×10^{-8} standard cubic centimeters of helium per second.

Tests

The finished capsule was found free of detectable leaks and contamination on March 3, 1971.

CALIFORNIUM CONTENT

Assay

The neutron emission rate of the finished assembly is determined by comparing its strength to that of a ^{252}Cf source calibrated at the National Bureau of Standards. The comparison is made by inserting the capsule assembly in an array of fission tube counters and measuring the subsequent induced electric current by a sensitive ammeter. The ^{252}Cf content given below is the effective or net californium content calculated from the neutron emission rate and is given in equivalent weight units assuming 2.311×10^6 neutrons per second per microgram of ^{252}Cf. Corrections are made, when necessary, for the ^{254}Cf contribution to the total neutron emission rate. The ^{252}Cf present is assumed to decay with an effective half-life of 2.646 years; the ^{254}Cf, if present, is assumed to decay with a 60.5 day half-life.

Contents

The total neutron emission rate of this source was found to be 2.165×10^{10} neutrons per second with a standard error of ± 3.0% on March 3, 1971. The ^{254}Cf contribution to the total was calculated to be 0.212×10^{10} per second on the same date. The effective ^{252}Cf content was calculated to be 8.449 mg equivalent with a standard error of ± 3.0%.

The radiation intensity at three meters from a source in air at standard atmospheric conditions and without contributions from scattering media is no greater than 400 mrem/hr neutrons plus 30 mR/hr γ for each milligram of ^{252}Cf in the capsule.

R. H. Scott

R. H. Scott, Chief
Planning and Development Branch
SROO, USAEC
Aiken, South Carolina 29801

S. Mirshak

S. Mirshak, Director
Nuclear Engg and Materials Section
Savannah River Laboratory
E. I. du Pont de Nemours and Co.

INFORMATION SHEET
"SPECIAL FORM" - ^{252}Cf NEUTRON SOURCE

Source Identification Number SR - Cf - 161 Date: April 7, 1971

Shipped To: Kansas State University at Manhattan, Kansas
Attention: R. W. Clack/T. L. Roberts

Specification: Outer Capsule Reference Drawing SRL: SK-164-PM
Primary Capsule Reference Drawing SRL: SK-163-PM

DECONTAMINATION AND CLOSURE TESTS

Method

Capsule surfaces are decontaminated after closure in an ultrasonic bath until the flush solution contains less than 200 d/m per milliliter total alpha activity. The capsule is further decontaminated, if necessary, until all exterior surfaces are free of contamination as determined by a wipe test. Each assembly is immersed in a helium atmosphere with a pressure of at least 300 pounds per square inch for a period of 30 minutes, then transferred to a helium leak detector. The leak detector has a minimum sensitivity of 1.0×10^{-8} standard cubic centimeters of helium per second.

Tests

The finished capsule was found free of detectable leaks and contamination on March 16, 1971.

CALIFORNIUM CONTENT

Assay

The neutron emission rate of the finished assembly is determined by comparing its strength to that of a ^{252}Cf source calibrated at the National Bureau of Standards. The comparison is made by inserting the capsule assembly in an array of fission tube counters and measuring the subsequent induced electric current by a sensitive ammeter. The ^{252}Cf content given below is the effective or net californium content calculated from the neutron emission rate and is given in equivalent weight units assuming 2.311×10^6 neutrons per second per microgram of ^{252}Cf. Corrections are made, when necessary, for the ^{254}Cf contribution to the total neutron emission rate. The ^{252}Cf present is assumed to decay with an effective half-life of 2.646 years; the ^{254}Cf, if present, is assumed to decay with a 60.5 day half-life.

Contents

The total neutron emission rate of this source was found to be 2.851×10^{10} neutrons per second with a standard error of 3.0% on March 16, 1971. The ^{254}Cf contribution to the total was calculated to be 0.369×10^{10} per second on the same date. The effective ^{252}Cf content was calculated to be 10.791 mg equivalent with a standard error of 3.0%.

The radiation intensity at three meters from a source in air at standard atmospheric conditions and without contributions from scattering media is no greater than 400 mrem/hr neutrons plus 30 mR/hr γ for each milligram of ^{252}Cf in the capsule.

R. H. Scott, Chief
Planning and Development Branch
SROO, USAEC
Aiken, South Carolina 29801

S. Mirshak, Director
Nuclear Engg and Materials Section
Savannah River Laboratory
E. I. du Pont de Nemours and Co.

INFORMATION SHEET
"SPECIAL FORM" - ^{252}Cf NEUTRON SOURCE

Source Identification Number SR - Cf - 1632 Date: April 7, 1971

Shipped To: Kansas State University at Manhattan, Kansas
Attention: A. W. Clack/T. C. Roberts

Specification: Outer Capsule Reference Drawing SRL: SK-184-1M
Primary Capsule Reference Drawing SRL: SK-182-PM

DECONTAMINATION AND CLOSURE TESTS

Method

Capsule surfaces are decontaminated after closure in an ultrasonic bath until the flush solution contains less than 200 d/m per milliliter total alpha activity. The capsule is further decontaminated, if necessary, until all exterior surfaces are free of contamination as determined by a wipe test. Each assembly is immersed in a helium atmosphere with a pressure of at least 300 pounds per square inch for a period of 30 minutes, then transferred to a helium leak detector. The leak detector has a minimum sensitivity of 1.0×10^{-8} standard cubic centimeters of helium per second.

Tests

The finished capsule was found free of detectable leaks and contamination on March 29, 1971.

CALIFORNIUM CONTENT

Assay

The neutron emission rate of the finished assembly is determined by comparing its strength to that of a ^{252}Cf source calibrated at the National Bureau of Standards. The comparison is made by inserting the capsule assembly in an array of fission tube counters and measuring the subsequent induced electric current by a sensitive ammeter. The ^{252}Cf content given below is the effective or net californium content calculated from the neutron emission rate and is given in equivalent weight units assuming 2.311×10^6 neutrons per second per microgram of ^{252}Cf. Corrections are made, when necessary, for the ^{254}Cf contribution to the total neutron emission rate. The ^{252}Cf present is assumed to decay with an effective half-life of 2.646 years; the ^{254}Cf, if present, is assumed to decay with a 60.5 day half-life.

Contents

The total neutron emission rate of this source was found to be 2.737×10^{10} neutrons per second with a standard error of ± 3.0% on March 29, 1971. The ^{254}Cf contribution to the total was calculated to be 0.314×10^{10} per second on the same date. The effective ^{252}Cf content was calculated to be 10.478 mg equivalent with a standard error of ± 3.0%.

The radiation intensity at three meters from a source in air at standard atmospheric conditions and without contributions from scattering media is no greater than 410 mrem/hr neutrons plus 30 mR/hr γ for each milligram of ^{252}Cf in the capsule.

J. H. Scott, Chief
Planning and Development Branch
SROO, USAEC
Aiken, South Carolina 29801

S. Mirshak, Director
Nuclear Engg and Materials Section
Savannah River Laboratory
E. I. du Pont de Nemours and Co.

13.5 KSU Application for ETA

March 22, 1971

Mr. John V. Barry
District Supervisor
Interstate Commerce Commission
1100 Federal Office Building
911 Walnut
Kansas City MO 64106

Dear Mr. Barry:

The University, on behalf of this department, has contracted with the U. S. Atomic Energy Commission (Production Division) for the use of several californium-252 radiation sources. These sources are the largest of their type ever fabricated and will total 50 milligrams. It is our understanding that the sources will be ready for shipment about April 1 of this year. Under terms of the contract, shipping arrangements are the responsibility of the University. The sources will be shipped in a Government-owned cask and integrally mounted highway trailer having a gross weight of approximately 20,000 pounds. One of our tasks is to identify a qualified trucking company to move the cask trailer from the Savannah River plant (near Dunberton, South Carolina) to the Manhattan campus of the University and return the cask/trailer to Savannah River.

Based on our inquiry, we conclude that Tri-State Motor Transit of Joplin, Missouri has measurably greater experience and qualification in movement of a source of this nature than any other carrier we have been able to identify.

It is our understanding that Tri-State is <u>not</u> now certificated to ship to Manhattan, Kansas although they do hold authorization to operate between Dunbarton (Savannah River) and points west of Manhattan. Because of the limited half-life of the sources and their intensely radioactive character, our interests and those of the general welfare will be materially served if we can obtain single-line service and single-carrier responsibility from a firm experienced in the handling of high-strength radioactive sources.

Accordingly, this is to request on behalf of Tri-State, one-time authority to transport the loaded cask/trailer to Manhattan and, following unloading of the sources, return the cask/trailer to the Savannah River AEC plant.

Mr. John V. Berry
Page 2
March 22, 1971

At least we are able to forecast at this time, a 15-day authority commencing April 1, 1971 should provide ample time for shipment, unloading and return of the cask/trailer.

Sincerely,

Robert W. Clack, Director
Kansas State University
TRIGA Nuclear Reactor Facility

STATE OF KANSAS)
) ss:
COUNTY OF RILEY)

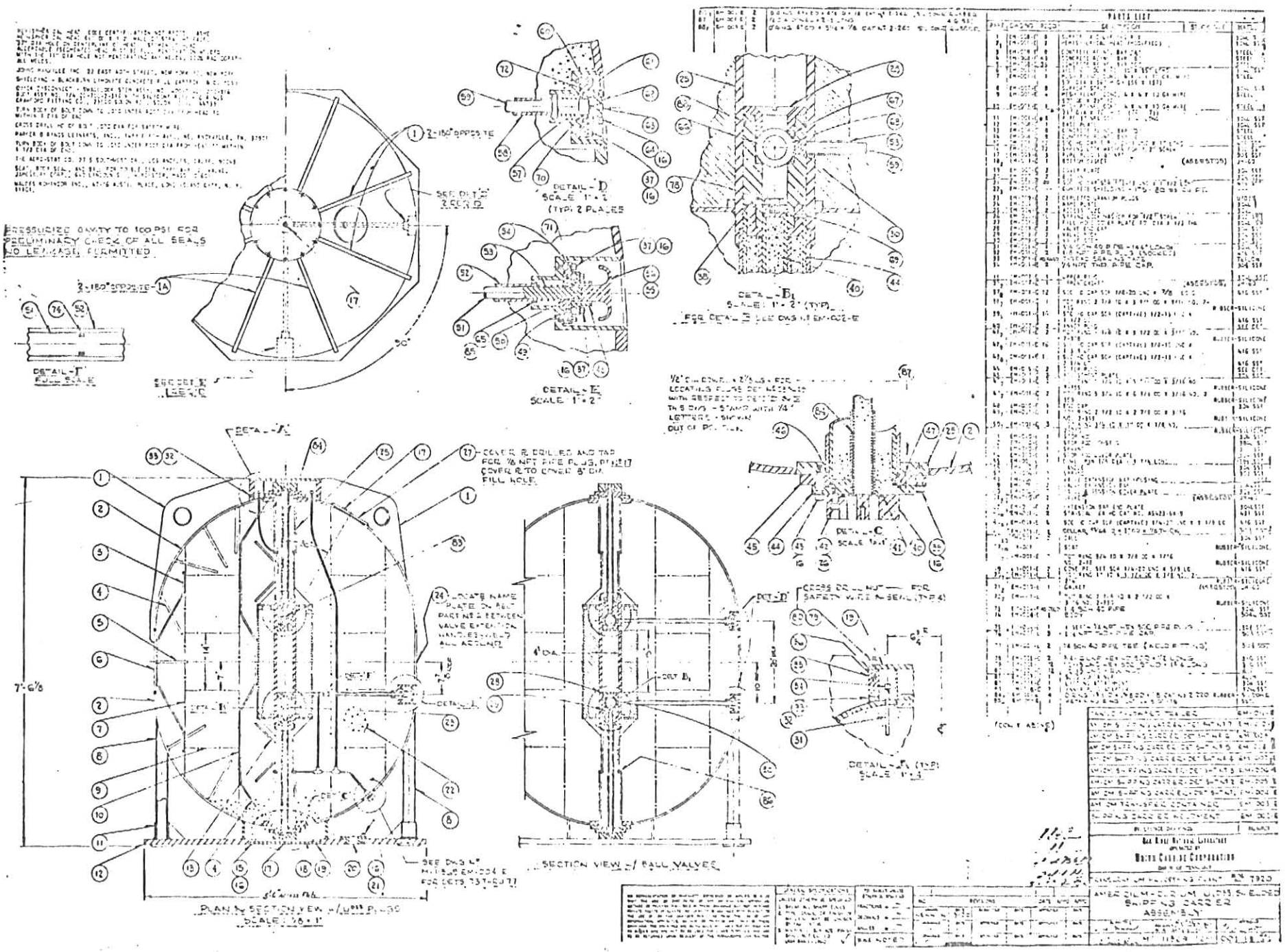
Subscribed and sworn to before a Notary Public in and for the State of Kansas.

Notary Public

My Commission Expires:

RWC/jea

13.6 Working Drawings for the AECACSSC


PRESSURIZE CAVITY TO 100 PSI FOR PRELIMINARY CHECK OF ALL SEALS NO LEAKAGE PERMITTED
DETAIL - T
FULL SCALE
DETAIL - D
SCALE 1" = 2"
(TYP. 2 PLACES
DETAIL - E
SCALE 1" = 2"
DETAIL - B1
SCALE 1" = 2" (TYP.)
DETAIL - C
SCALE 1" = 2"
DETAIL - F (TYP.)
SCALE 1" = 2"
PLAN & SECTION VIEW OF BALL VALVE
SCALE 1/2" = 1"
SECTION VIEW OF BALL VALVES
PARTS LIST
AMERICAN CHAIN & CABLE COMPANY
BALL VALVE ASSEMBLY

AN EVALUATION
OF THE KSU MULTI-MILLIGRAM ^{252}CF FACILITY

by

THOMAS CARROL ROBERTS

B.S., Kansas State University, 1970

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Nuclear Engineering

KANSAS STATE UNIVERSITY

Manhattan, Kansas

1972

ABSTRACT

In participation with the Atomic Energy Commission's ^{252}Cf Market Evaluation Program, a multi-milligram facility was constructed and licensed at Kansas State University. Transportation was arranged for the four sources, and the unloading of the sources was accomplished by Department of Nuclear Engineering personnel. Flux measurements of the facility were conducted by two methods: Cd ratio (In), and sum peak (Sc). Neutron activation analysis reference samples (Na, Mg, Al, Cl, Ca, Ti, Mn, Cu, Sb, Hf, Dy) were prepared and normalized for use in studies concerning possible security authentication. Capture gamma-ray analysis systems were constructed and tested for possible protein determination in wheat samples. This work was completed with a 45 μgm ^{252}Cf source at the United States Bureau of Mines, Morgantown, West Virginia, after many unsuccessful attempts with a 1 mgm ^{252}Cf source at Kansas State University. Results indicated that the 45 μgm ^{252}Cf source makes possible on-line process control of protein in wheat. Preliminary studies were started in the area of radiation-induced conductivity in polyethylene. A summary of the status of the market evaluation work is included. Suggestions for continuation and expansion of the use of the facility are also included.