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DP - 471

Nuclear Technology - Reactor Engineering and Technology

AEC Research and Development Report

AUTOMATIC DOSE COMPUTER FOR RADIATION FILM BADGES

by

J. E. Davis

Engineering Assistance Section

Works Technical Department

Savannah River Plant

April 1960

Issued by

E. I. du Pont de Nemours & Co.

Savannah River Laboratory

Aiken, South Carolina

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DP - 471
NUCLEAR TECHNOLOGY - REACTOR
ENGINEERING AND TECHNOLOGY
(M-3679, 25th Ed.)

AUTOMATIC DOSE COMPUTER FOR RADIATION FILM BADGES

by

John E. Davis

April 1960

Issued by
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Explosives Department - Atomic Energy Division
Technical Division - Savannah River Laboratory

Printed for
The United States Atomic Energy Commission
Contract AT(07-2)-1

Approved by
T. C. Evans, Superintendent
Engineering Assistance Section

[redacted]

ABSTRACT

A combination densitometer and analog computer is described which determines radiation exposure of photographic film used in personnel badges. The range of the instrument is 0 to 300 mr gamma and 0 to 300 mrad beta plus gamma. A novel phototube circuit is used to obtain logarithms directly.

CONTENTS

LIST OF FIGURES

AUTOMATIC DOSE COMPUTER FOR RADIATION FILM BADGES

INTRODUCTION

Badges that contain dental X-ray film packets are worn by personnel in areas where there is possible exposure to gamma or beta radiation. Darkening of the film is a measure of the integrated radiation exposure (exposure dose) received by personnel while the badges are worn. The film in the badges is replaced periodically; then, the exposure dose is estimated by measuring the optical density of the developed films. The conventional use of a densitometer and conversion tables to determine the exposure dose, together with manual tabulation and filing of the data, is time consuming; in addition, the several steps involved are subject to human error.

SUMMARY

To increase the speed of film reading and to eliminate sources of error, a computer was developed to measure the optical density of the film and to compute automatically the exposure dose, producing the information as direct meter indications and electrical analog signals suitable for input to automatic data-handling equipment.

The range of the computer is 0 to 300 mr for gamma and 0 to 300 mrad for beta plus gamma. A novel circuit that uses a vacuum photocell as a logarithmic element greatly simplified the computer circuit design.

DISCUSSION

FILM BADGE DESCRIPTION

Figure 1 shows the film badge that was in service during the development of the Automatic Dose Computer. The film is identified by numbers placed on it by pressure from an embossed number plate on the back of the film badge. Within the badge, the film package is shielded from all but gamma radiation except where an open window in the shielding allows beta radiation to expose one area of the film.

BASIC REQUIREMENTS OF A FILM BADGE DOSE COMPUTER

An Automatic Film Badge Dose Computer must be capable of measuring the darkening of the shielded and open window areas of films, and computing the radiation exposure. This computation must take into account the facts that a given number of mrad of beta exposure will not produce the same amount of darkening as an equal number of mr of gamma, and that a given amount of gamma radiation will not produce the same amount of darkening in the open window area as it does in the shielded area.

The relationships between dosimeter film optical transmission and the corresponding exposure dose are given below for the open window and shielded areas on the film badge.

$$T_1 = e^{-(A\beta + B\gamma + K)} \quad (1)$$

$$T_2 = e^{-(C\gamma + K)} \quad (2)$$

where:

T_1 = Optical transmission of the open window area

T_2 = Optical transmission of the shielded area

β, γ = Beta and gamma radiation dose, respectively

A, B, C = Film darkening constants, which are a function of the type and energy of radiation

K = Film fogging constant, which represents the transmissivity of an unexposed film

Equations (1) and (2) are derived from the transmission-density equation,

$$T = C^{-eD}$$

and the dose-density equation,

$$D = E \times \text{Dose}$$

where:

E = Constant

These relationships are reasonably accurate with a single set of constants for doses between 0 and 500 mr or mrad. Examples of beta-exposed and gamma-exposed film are shown in Figure 2.

The mathematical functions performed by the computer to solve the two transmission equations are shown in Figure 3. Electronic components of the computer include photocell logarithmic circuits, DC-to-AC converters, AC amplifiers, a transformer wired in series opposition, and AC-to-DC converters. Figure 4 is the schematic diagram of the computer, and Figure 5 is the diagram of the control and readout unit. The DC output voltage is a linear function of dose and can easily be converted to digital form for IBM data recording. Figure 6 shows the prototype, which used meters for readout.

EQUIPMENT DESCRIPTION

PHOTOCELL LOGARITHMIC CIRCUIT

Transmissions T_1 and T_2 are simultaneously measured by a pair of RCA type 934 vacuum photocells. These are mounted in the small trapezoidal box shown in the left foreground of Figure 6. The photocells are connected in a novel circuit arranged so that they operate in a self-generated retarding field (i.e., plate negative with respect to cathode). They provide an output current that is proportional to the logarithm of the incident light in the light range from 0.3 to 0.2 lumen. The output current for this light range is 0.01 to 0.04 microampere. Figure 7 gives the voltage output versus light intensity for the photodiode.

The voltage equivalents of the fogging constant "K" are removed by subtracting a reference voltage from the signal that appears across the amplifier input resistor. Control of the reference voltage permits the amplifier input to be adjusted to zero for an unexposed film reading without driving the photocells out of the logarithmic range of operation.

AMPLIFIER

The amplifiers used in the computer are modified circuits from millivoltmeters made by the Industrial Controls Company. They produce a 60-cycle output voltage with an rms value 100 times the DC input voltage. This circuit was used because of its simplicity and excellent stability.

SUBTRACTING TRANSFORMER

A portion of the amplified signal from the photocell that measures the shielded area of the film is applied to the subtracting transformer in series opposition to the signal from the open window photocell. This operation corrects for the unequal film darkening constants of beta and gamma radiation, represented by "A" and "B" in equations (1) and (2).

READOUT AND CONTROL

The readout and control unit is housed in a separate chassis. The AC signals that represent gamma dose and beta-plus-gamma dose are sent from the computer to the AC-to-DC conversion circuits in the control unit through the cathode followers V_A and V_B shown in Figure 5. The resulting DC voltages are filtered and read out as gamma dose on meter M_1 and beta-plus-gamma dose on meter M_2.

LIGHT SOURCE

The light source used with the prototype computer is a General Electric model 1323 incandescent lamp operated at 6 volts AC. Regulation of the supply voltage, which determines light source intensity and color, is required for stable operation of the photocell circuit.

CALIBRATION

The instrument is calibrated with films that have been exposed to known doses of beta and gamma radiation. The energy distribution of the radiation from the calibration source should correspond as closely as possible to the energies expected in the areas where dosimeter films are worn. Typical values of calibration film exposures are 50, 100, and 300 mr gamma and mrad beta. The instrument is adjusted to zero by inserting a blank film into the reading head and adjusting first R_1 and then R_2. The beta-plus-gamma channel is then calibrated for beta radiation by using a beta film and adjusting R_5. A gamma standard film is then inserted and R_4 is adjusted to give the correct reading on the gamma meter. R_3 is then adjusted to give the correct reading on the beta-plus-gamma meter.

The meter circuits are adjusted to have the same voltage calibration by setting potentiometers R_B to give identical readings on the two meters when 1.5 volts DC is applied to both filter capacitors through the connectors at J-2. Potentiometer R_B is located at the rear of the control unit chassis. Potentiometer R_7, located at jack J-2 on the computer chassis, is adjusted to permit operation of the factor control near the middle of its range. Although not found necessary during development work, it is possible that some selection of choppers may be required to prevent excessive phase differences between outputs. The error due to phase difference between the choppers is a function of the relative amplitudes of the voltages applied to the primary of the subtracting transformer, and affects the beta-plus-gamma reading.

OPERATION EXPERIENCE

This computer was in routine service for more than a year and performed satisfactorily. A similar computer that uses magnetic amplifiers has since been designed and substituted for this circuit.

J. E. Davis

J. E. Davis
Engineering Assistance Section

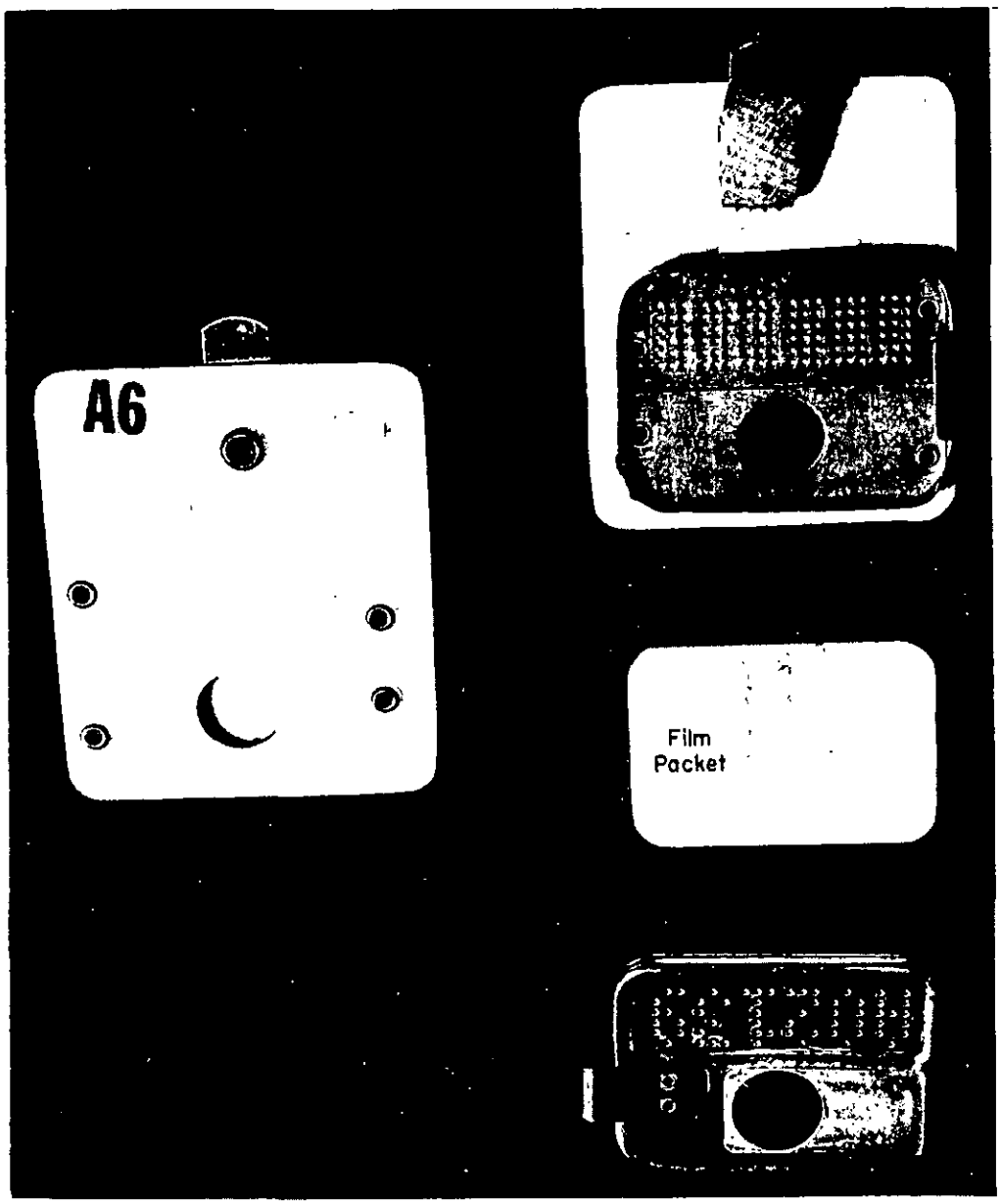
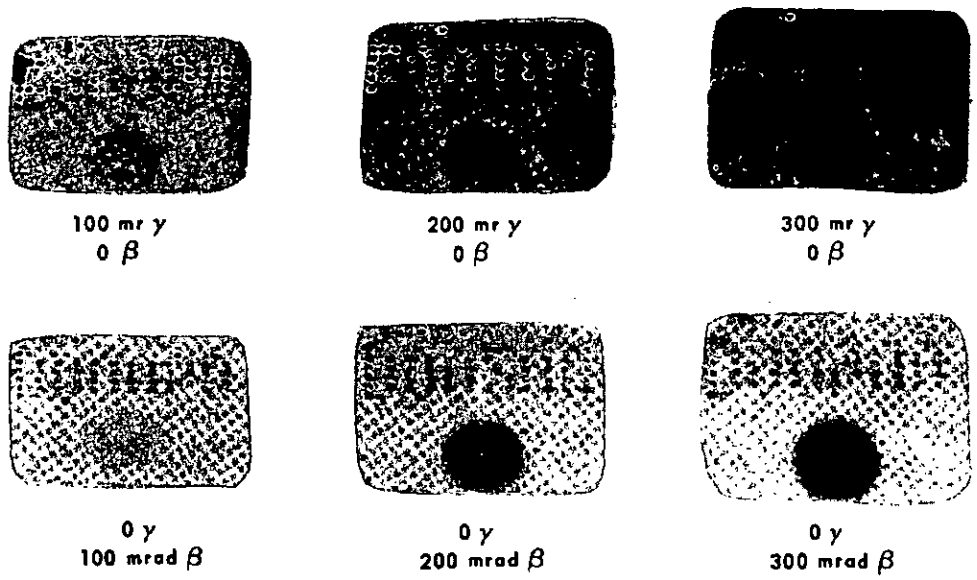


FIG. 1 FILM BADGE



Total dose is noted under each film.

FIG. 2 EXPOSED FILMS

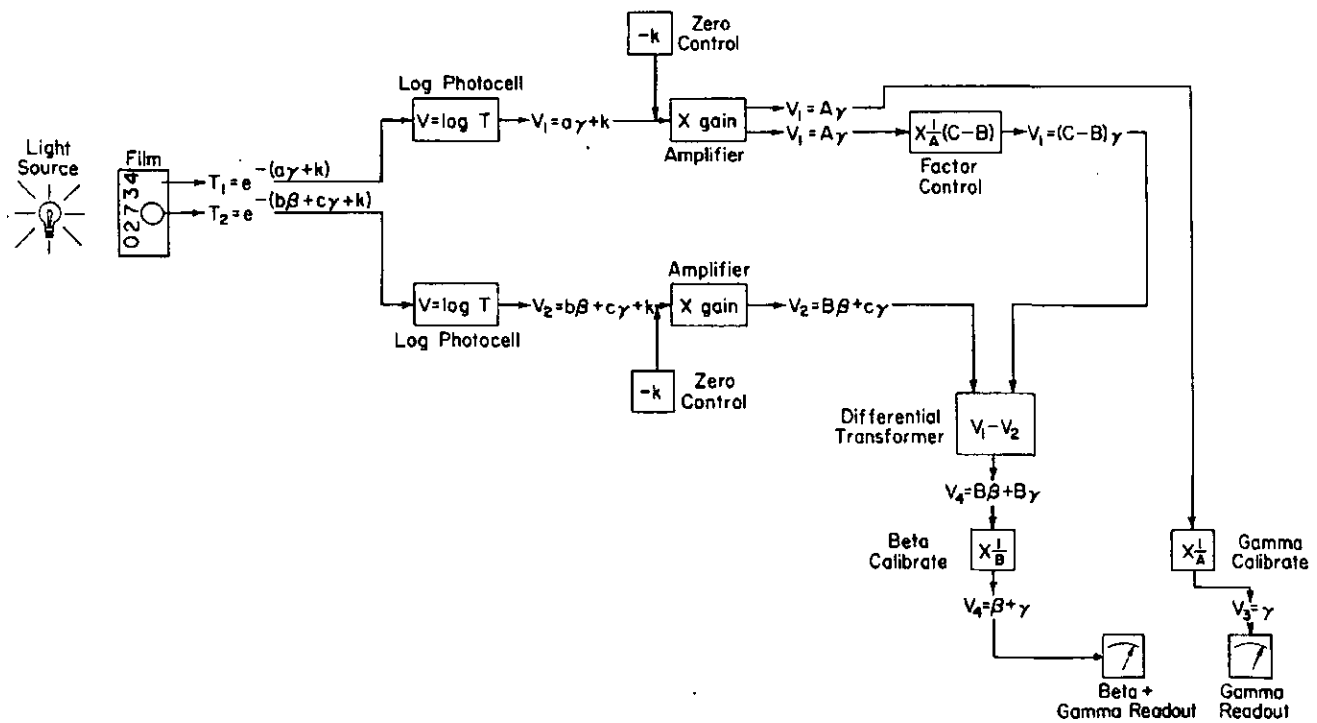
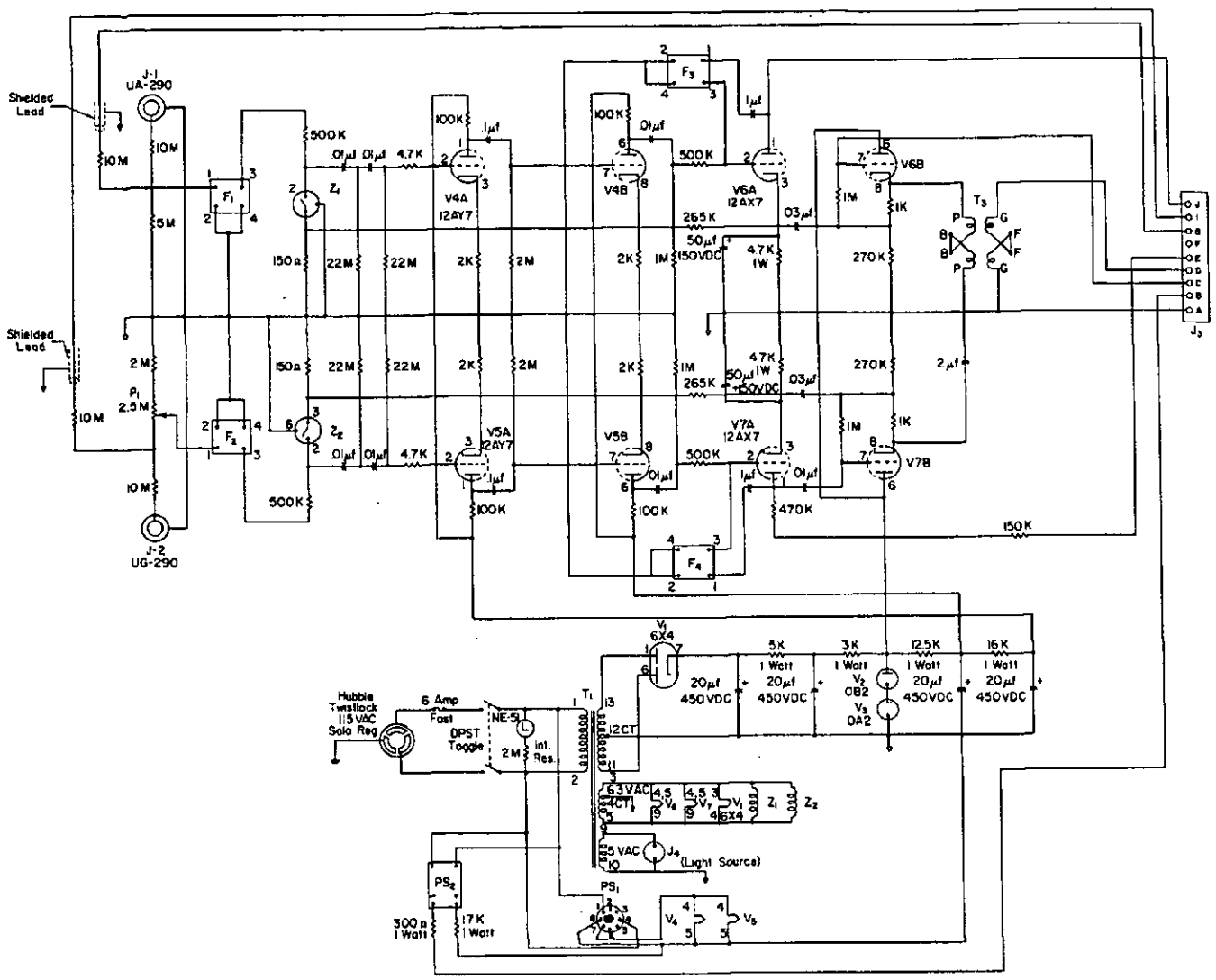


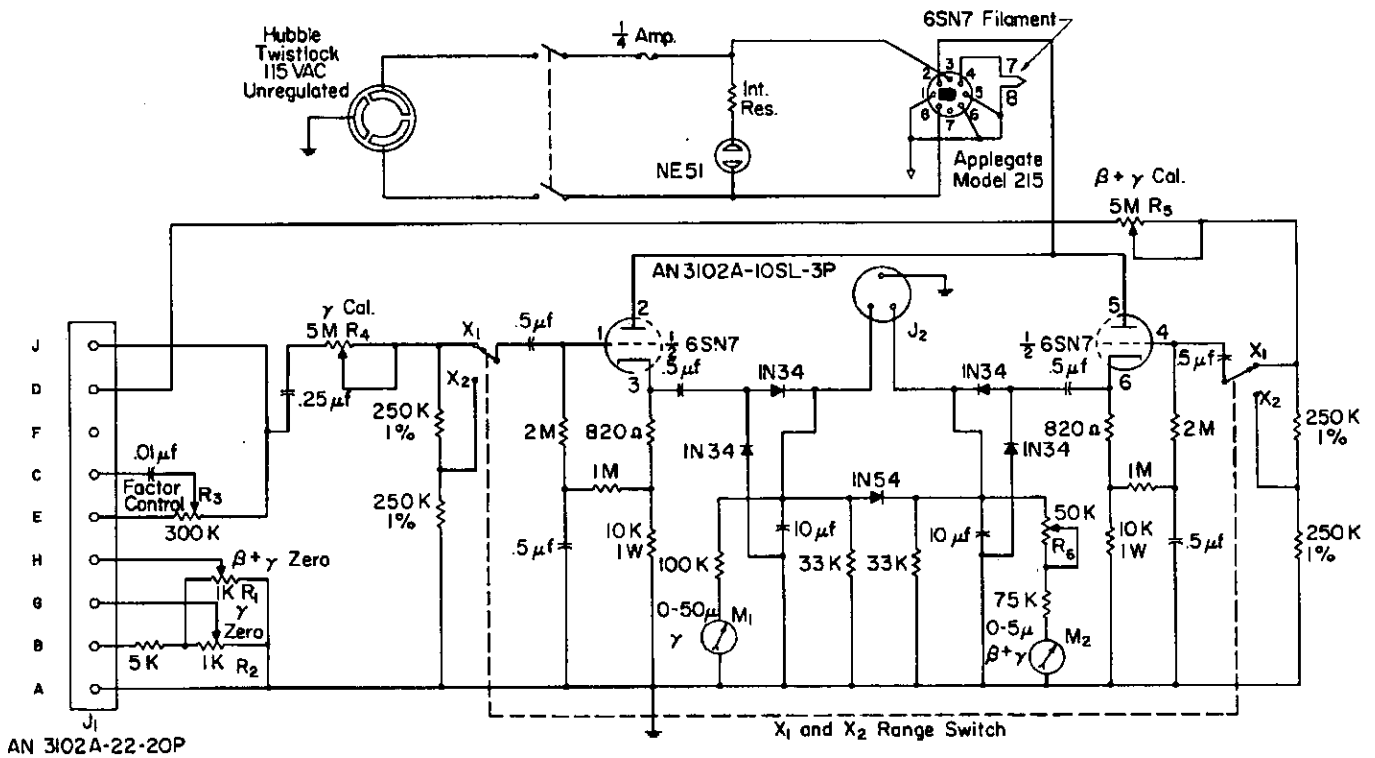
FIG. 3 BLOCK DIAGRAM OF FILM BADGE DOSE COMPUTER



General Notes

All resistors are ½ watt, 10% unless noted.
All capacitors are 400 volts unless noted.

FIG. 4 CIRCUIT DIAGRAM OF DOSE COMPUTER



Notes

All capacitors are 200 V DC
All resistors are ½ watt, 10% composition
unless otherwise shown.

FIG. 5 CIRCUIT DIAGRAM OF CONTROL AND READOUT UNIT

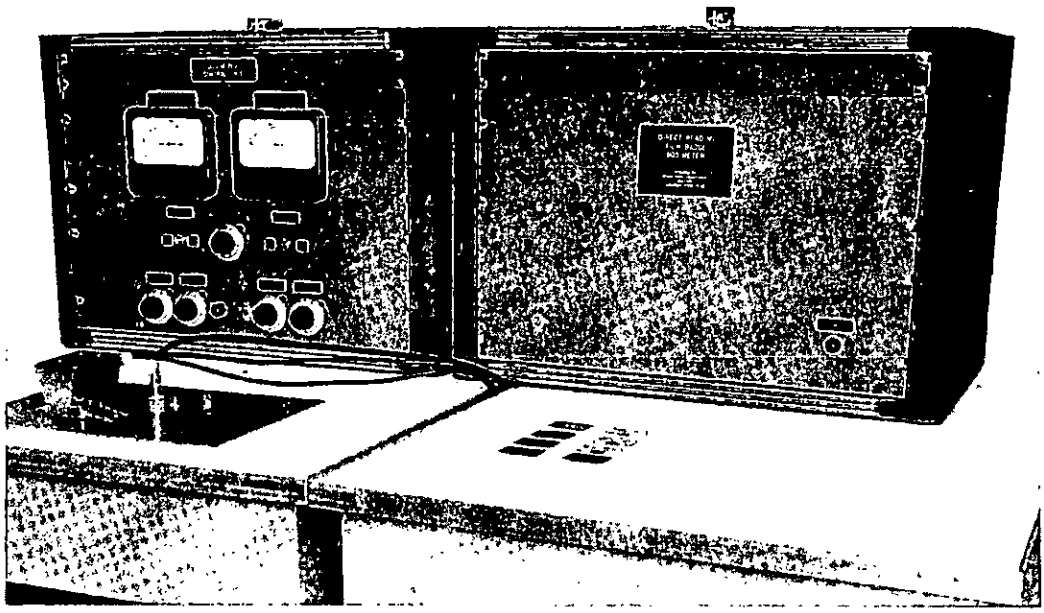


FIG. 6 PROTYPE FILM BADGE DOSIMETER

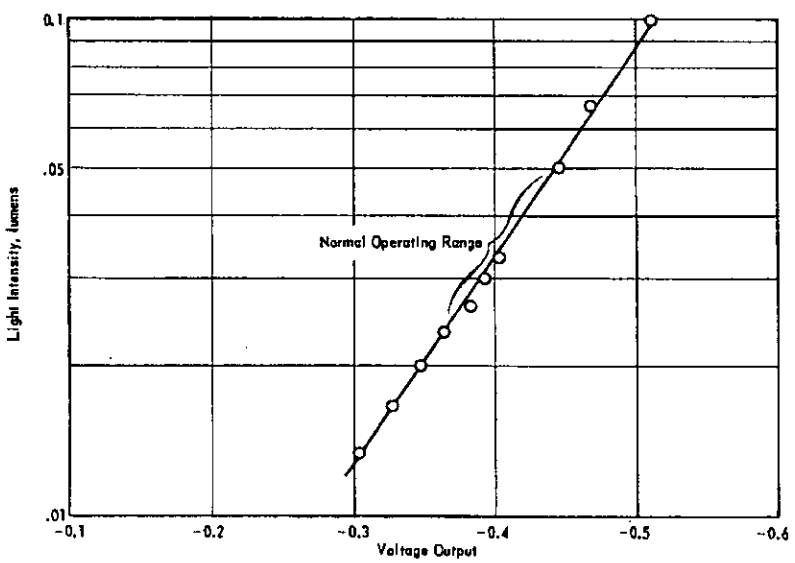


FIG. 7 OUTPUT VOLTAGE VERSUS LIGHT INTENSITY
RCA 934 Vacuum Phototube Operated in
the Retarded Field Region

Orig. Copy to W. B. Scott 10-10-62

J. W. Morris
W. B. Scott
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October 5, 1962

Mr. W. P. Overbeck, Director
Savannah River Laboratory
E. I. du Pont de Nemours & Company
Aiken, South Carolina

Attention: Dr. J. W. Morris, Director
Separations & Services Section

Dear Mr. Overbeck:

Please refer to my August 31, 1961, letter releasing a group of research and development reports with the administrative marking "Official Use Only". The following report, included in the above letter, has now received patent clearance:

DP-471 - "Automatic Dose Computer for Radiation Film Badges" - by J. E. Davis

The "Official Use Only" marking should be removed from all copies of the report.

Very truly yours,

G. H. Giboney, Acting Director
Safety & Technical Services Division

cc: R. L. Shannon, Chief
DTIE, Oak Ridge

10

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DP 471

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AIKEN, SOUTH CAROLINA
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T. C. Evans

April 27, 1960

Mr. P. J. Hagelston, Director (2)
Technical and Production Division
Savannah River Operations Office
U. S. Atomic Energy Commission
Post Office Box A
Aiken, South Carolina

Dear Mr. Hagelston:

PROPOSED PUBLICATION - DP-471

Attached for review as to classification and patent matter are five copies of the following report:

Automatic Dose Computer for Radiation Film Badges
by J. E. Davis

We propose to release the report for standard external distribution.

To facilitate the release of this report, it would be appreciated if you would telephone your comments to M. H. Wahl's office and send a confirming letter to me with a copy to M. H. Wahl. The report will be released when approval is received, but not until after 14 days from the date shown above.

If any clarification or technical information is needed to aid in your patent review, we suggest you get in touch with

T. C. Evans, Superintendent
Engineering Assistance Section
Savannah River Plant

If you decide to pursue a patent on any development covered in the accompanying material, I shall be happy to supply the additional information required such as appropriate references and the name of the person responsible for the development.

Very truly yours,

SWOR

Hood Worthington, Director
Technical Division

HW/sj
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EX-1184

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bcc: Hood Worthington - L. C. Evans
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J. W. Morris - S. W. O'Rear
W File (2)

HW H

June 10, 1960

Mr. T. B. Niland, Chief (2)
Classification Branch
Technical & Production Division
Savannah River Operations Office
U. S. Atomic Energy Commission
Aiken, South Carolina

Dear Mr. Niland:

CLASSIFICATION CONSIDERATIONS - DP-471

The above report, "Automatic Dose Computer for Radiation Film Badges" by J. E. Davis, which was transmitted to your office by letter of April 27, 1960 from Hood Worthington, has been reviewed for classification.

This report appears to be unclassified by topic 704.1 of the SRO Classification Guide.

Yours very truly,

S. A. McKnight
Technical Assistant
ATOMIC ENERGY DIVISION

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SAVANNAH RIVER OPERATIONS OFFICE
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TELEPHONE
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PARK 4-6311

TELEGRAM ADDRESS
AUGUSTA, GA.

IN REPLY REFER TO:

TI:TBN:mep

August 31, 1961

Mr. W. P. Overbeck, Director
Savannah River Laboratory
E. I. du Pont de Nemours and Company
Aiken, South Carolina

Attention: J. W. Morris, Director
Separations and Services Section

Dear Mr. Overbeck:

In reply to the March 24, 1961, letter from Dr. M. H. Wahl, the Manager, Savannah River, has authorized release of the following reports with the administrative marking "Official Use Only":

Report No.	Author	Title
DP-306	Aeroprojects	Ultrasonic Fusion Joining of Sintered Aluminum Powder Materials to Aluminum Alloys
DP-419	Aeroprojects	Ultrasonic Cleaning of Long Al-Clad Tubes
DP-447	E. R. Russell	Anion Exchange Recovery of Pu from Reduction
DP-448	C. S. Schlea	Off-Gas Control in Uranium Dissolution
DP-471	J. E. Davis	Automatic Dose Computer for Radiation Film Badges
DP-493	A. S. Ferrara	Swaging of Uranium Dioxide Tubes - I
DP-523	F. P. Caiati	Neutron Spark Counter
DP-537	D. W. Colvin	In-Line Monitor of Nitric Acid Concentration

The above reports should be distributed in accordance with the most appropriate category contained in M-3679, and should not be made available to the Civilian Application Program. DP-544 was released to Du Pont by my letter of June 16, 1961.

I regret the delay in answering Dr. Wahl's letter.

Very truly yours,

Paul J. Hagelston

Paul J. Hagelston, Director
Technical & Production Division

cc: Hood Worthington, Du Pont
Wilmington
S. W. O'Dear, TIS, SRL

cc: J E Beard

JOB RECORD SHEET
(TIME COUNT)

DP- 471 S C U
Title
Author Dawn
Division Plant

Date	TIS Supv.	TIS Edit	TIS Type	TIS Dwg	TIS Make-up	TIS Proof	Author Proof	TIS Corr.	Author Corr.	RC Appr.	TIS Print	Final Rev	TIS Bind
4/19										X			
4/20										X			
4/21	X JWH												
4/22											X		
4/25											X		
4/26											X		
4/27												X	X
4/28													X
4/29													X
5/2	LT	Dawn											
+ 14 d. 12													
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5/3	Ready -												
5/2	5000 in	new Rt. Mat Typed by Sec.											
5/2	Revised												
6/14	Stock -	Rt.	Letter										

INTERNAL ISSUE 5/2/60 (5/27/60) AEC PHONE RELEASE _____ EXTERNAL ISSUE _____
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OSR-24-A-140

JOB RECORD SHEET
(TIME COUNT)

DP- 471 S C U
Title Automatic Dose Computer for Radiation Film Badges
Author [redacted] J. E. Davis
Division

Date	TIS Supv.	TIS Edit	TIS Type	TIS Dwg	TIS Make-up	TIS Proof	Author Proof	TIS Corr.	Author Corr.	RC Appr.	TIS Print	Final Rev	TIS Bind
3/2/60	X												
3/3	X												
3/4		Wsay											
3/5		X JP											
3/7	X JWH	Y											
3/8				Ktg. in									
3/9			X	X									
3/10			X	X									
3/11			X	X									
3/14				X									
3/15				X									
3/16		X Ehai		X									
3/17				X									
3/18				X									
3/21				X									
[redacted]/22			X	X				X					
3/23				X (1)	X Vars. Type			X					
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3/25				X "	X "			X					
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3/29				X	X								
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3/31					X "								
4/1					X "								
4/4					X "			X					
4/5													
4/6													
4/7		X			X								
4/8										X			
4/11										X			
4/12										X			
4/13										X			
[redacted]/14										X			
4/18										X			

INTERNAL ISSUE _____ AEC PHONE RELEASE _____ EXTERNAL ISSUE _____

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OSR-24-A-140

OSR 3-4A

DUPONT

INTER-OFFICE MEMORANDUM

SAVANNAH RIVER PLANT

CC: J. S. Stutheit
TPO File

February 23, 1960

TO: TECHNICAL INFORMATION SERVICE, 773-A
S. W. O'REAR

FROM: TECHNICAL PROCEDURES OFFICE, 703-A
T. E. ABBOTT

TEA

DP REPORT BY J. E. DAVIS

The accompanying report is to be issued as a DP report. It has been approved by T. C. Evans and W. P. Overbeck.

The author of this report, J. E. Davis, is no longer at the Savannah River Plant. If any questions concerning the report arise, please call me or J. S. Stutheit.

TEA:mbm

Date 4/22/60

TO: Print Shop and Document Section

FROM: Editing Group

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OSR-24-A117

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E. I. DU PONT DE NEMOURS & COMPANY
INCORPORATED

AIKEN, SOUTH CAROLINA

(TEL. & TEL. ADDRESS, AUGUSTA, GA.)

EXPLOSIVES DEPARTMENT
SAVANNAH RIVER LABORATORY

CC: F. A. Robertson, SROO
S. A. McNeight, Wilm.
M. H. Smith, Wilm.
L. C. Evans - H. Worthington, Wilm.
W. F. Overbeck - J. W. Morris -
S. W. O'Rear - TIS File
T. C. Evans

July 28, 1961

Mr. P. J. Hagelston, Director (2)
Technical and Production Division
Savannah River Operations Office
U. S. Atomic Energy Commission
Post Office Box A
Aiken, South Carolina

Dear Mr. Hagelston:

PROPOSED PUBLICATION - DP-471

On April 27, 1960, the following report was sent to you for review as to classification and patent matter:

Automatic Dose Computer for Radiation Film Badges,
by John E. Davis

As a possible aid to you in your patent review, we are attaching a prepublication review by J. E. Beach.

Very truly yours,

Hood Worthington

Hood Worthington, Director
Technical Division

SWO'R:pa

TECHNICAL DIVISION
SAVANNAH RIVER LABORATORY

M E M O R A N D U M July 27, 1961

TO: C. W. J. WENDE

FROM: J. E. BEACH JEB

PREPUBLICATION REVIEW

Document: Report DP-471

Title: Automatic Dose Computer for Radiation Film Badges

Author: J. E. Davis

Contractual Origin: AT(07-2)-1

Present Classification: Unclassified

References: (1) Bancroft, L. C., Automatic Film-Badge Processing, AECL-302, June 1960

(2) Wilhelmsen et at, Automatic Film-Badge Reader; Nucleonics Vol 18, No. 4, pp 84-88, April 1960

I have noted no item in the report which, in my opinion, has sufficient novelty to justify calling it to the attention of the AEC.

The dose computer was described in reference (1). A similar device developed at Idaho Falls was described in reference (2).

JEB:pa

DP-471 2nd Issue

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