To: Dr. Donna Cragle **From:** Hap West

Date: June 7, 1993 **Copies To:** Distribution

Subject: BRIEF HISTORY OF THE Y-12 EXTERNAL MONITORING PROGRAM

The following is a brief history of the Y-12 external monitoring program. This history is based partly on my memory. I worked in the departments that ran or managed the Y-12 health physics program from 1950-1985 and was supervisor of the section responsible for the external monitoring from 1956-1982. The following steps were taken previously or in conjunction with the write up.

1. A study of the computerized records of film and pocket meter data from 1948-49 period.

[Note: Based on this study of these results, and the fact that there were no doses for many of weeks involved, these result were modified to more adequately reflect the actual dose as described in my memo of March 13, 1991 "Correction of the Y-12 Film Badge Results for the 1948-49 Period."]

2. A study of a small sample of the hard copy computer printout data from Y-12 records showing weekly and monthly doses for the years 1952 through 1960 period.

[Note: Based on this study certain changes were made to the 1950-1955 data that in conjunction with the program to assign doses to individuals for the ORFCOM and subsequent studies would be more accurate. These changes are described in my memo February 19, 1991 titled "Correction of Y-12 Film Badge Results in the 1950 through 1955 Period."]

3. A group of Quarterly "Automatic Film Reader Equations" written by the Y-12 Statistical Services Department to C. M. West during the 1975-1979 years were reviewed.

4. Computer data showing the dose distribution and percent monitored for Y-12 film and TLD meter badges for the 1948 through 1984 period were reviewed

In addition I read the following reports which documented certain aspects of the monitoring programs.

1. Y-1401 Y-12 Radiation Safety Manual by P.C. McRee, C.M. West and J.D. McLendon, 1965.

2. Y-DD-268 External Radiation Monitoring of Union Carbide Nuclear Division Personnel compiled by J.D. McLendon, 1980.

3. Dan Strom's[1] thesis as it relates to Y-12 external dose estimates.

The following is a brief summary of the history of the film/TLD badge program for this period (1948-1985).

1948-49 Period

Weekly film badge monitoring was begun on a small fraction of the Y-12 population in 1948-1949. To my knowledge no external monitoring was done in Y-12 prior to that time. For these two years pocket meters were also worn and read daily. Our computer files contains the film weekly badge results and weekly summations of pocket meter results when available. The film was worn in a stainless steel badge which had a completely open window and a cadmium front shield. It had a different shield in a different position in front than in the back so that it could be ascertained if it was exposed from the front or the rear. This is believed to be the same badge used by ORNL in 1949 and 1952 described by Thornton[2]. No documentation to support this belief is available. Neither do I have any recollection or documentation as to how the calibration was done in this period. Strom[1] states and the data confirms that the MDL for the film badge was 30 mrem. Strom says the pocket chambers were read to a level of 5 mrem or lower. A great number of the weekly film badge and pocket meter periods were recorded as NR (no results). When they were recorded an inordinate number was entered at 30 mrem. Thirty mrem was recorded when film meter indicated a dose of 30 or less. The weekly doses were revised using both the film and pocket meter doses as available. In addition a best estimate dose of 9 mrem week was used for any week for which there was monitoring but no results of either kind.

1950-1951 Period

As noted by Strom[1] and confirmed by our own records we have only one positive annual dose in 1950 and 1951. It is surmised from this fact that Y-12, during these years, recorded doses <MDL results as 0. [Note it was suggested by the dose assessment group that such doses and other doses less than the doses to be assigned to unmonitored individuals in the same type of department be assigned the dose of like unmonitored individuals for years prior to 1961. However, it is my understanding that is has been decided not to do this for the ORFCOM study. This ORFCOM decision will probably not make much difference since the monitored group is small compared to the unmonitored group. However, it will result in some unmonitored individuals with lesser exposure potential than monitored individuals being assigned a higher dose than monitored employees.]

1952-55 Period

This 1952-1955 program differed in at least two aspects from the 1951-1952 (1) instead of assigning a zero to the weekly badge result if it was less than the MDL the minimum detectable dose was assigned for each week when a badge result was available. It was noted from my perusal of the hard copy computer reports however, that in many cases monitoring results were missing. Sometimes these were indicated with a NOTAV (not available) however, there were more times when nothing was entered into the record. There were three different MDL entered as dose during this period as indicated in the table below.

Year or Period	MDL Dose Assigned
1952 (to 38 weeks or there abouts*)	50 mrem
1952 (from 39 weeks or there abouts*)	43 mrem
1953	50 mrem
1954 (before week 30 or there abouts*)	50 mrem
1954 (after week 30 or there abouts*)	30 mrem
1955	30 mrem

* The change in amount did not occur on all employees on the same week.

The results were available on a computer printout for review. A small fraction have been reviewed. It is also noted that the policy of inserting 30 mrem when the result were less than the MDL was continued through the first half of 1956.

During this period another practice was followed that further increased the difficulty of estimating dose from these data, in that an administrative decision was made as to which kind of radiation a person was liable to be exposed to and his/her dose was interpreted as beta or gamma depending on this administrative decision. The determined dose or the <MDL assigned dose was attributed to this type of exposure. There also seemed to be some change in thinking on this matter with years in that in 1952 essentially all cases spot checked had all gamma's or no gamma's or betas. In 1953, 4 of the 14 cases spot checked showed only beta dose. In 1954 and 1955, 13 of the 14 doses spot checked showed only beta dose. [Note: We tried to adjust for this as outlined in my memorandum of February 19, 1991 titled "Correction of Y-12 Film Badge Results for the 1950-1955 Period" in which certain changes were made in the data which in conjunction with the adjustment of the data for this period should have resulted in a somewhat better estimate of the penetrating dose.]

1956-1960 Period

The use of the stainless steel badge discussed earlier was continued. Calibration curves were developed from badges exposure to know amounts of radiation from a Cobalt-60 source for gamma exposure, against a Am-241 Be Source for neutron exposure and against a uranium slab for beta exposure. My recollection is that ORNL counted the tracks and made the dose estimate for the few people we had with neutron exposure potential.

In mid 1956 I took over as the supervisor over the film monitoring program. In addition, the plant laboratory took over film processing from the Health Physics Department. I remember and the data bear me out, that one of the first things we did was [redacted] the amount of dose assigned when the reading was less the detectable limit fr[redacted] mrem the (MDL at the time) [redacted] half the minimum detectable level or [redacted]. A spot check of the record and the annual data both indicate that practice entering 15 mrem as the minimum detectable level was begun in mid 1956 and at this amount was entered only as beta doses. On a spot check of 8 doses per year I found the minimum gamma doses to be 6, 13, 10 and 10 mrem for 1957-58-69-60 respectively. None of these doses were repeated frequently enough to make it appear to be an insert value for a MDL. The film was developed, read and interpreted during this period by the plant laboratory. Health Physicist administrated the program, prepared the calibration film and looked over the laboratory's shoulder. However Health Physics was preoccupied with internal exposure problem and not paying to much attention to external monitoring 1956-1960. This post 1955 approach did however result in a much lesser percent of zero's than was experienced in the 1952-1955 period as shown by the table below.

Percent Zero Table

Year	Number of Persons Monitored	% of Monitored With Zero Dose
1950	148	99
1951	184	100
1952	394	18
1953	366	58
1954	662	94
1955	622	76
1956	729	18
1957	795	13
1958	1002	10
1959	1265	5
1960	1295	8

1959

Another factor that led to the lesser percent of zero's was the fact that we quit monitoring weekly in 1957 and began changing meters monthly. This change was made because the quarterly limits that had been generally accepted in 1957 and had been made "official" by the National Committee on Radiation Protection Handbook 59 in 1959. We continued to use the stainless steel badge. The calibration set up and procedure described in some detail below was in use during this period.

1961-1979 Period

In 1961 a big change was made. Union Carbide upper management decided that all personnel would be film badged quarterly. Y-12 management and health physics decided to develop all film, interpret and record these doses. In 1961 Y-12 changed over to an ORNL developed Badge which also had components for use in estimating dose to an inadvertent criticality. This badge (as shown broken down from a report by Hurst & Richie[3] attachment 1) had four areas for use in routine dose interpretations. These were an open window, and areas with plastic, aluminum, and cadmium shields. Y-12 made a density measurements in all areas, but used only the open window and cadmium areas in their routine interpretation. This interpretation was done using equations developed from voltage reading from a semi-automatic film reader as described below. Also included is a description of the calibration procedure. [The description below is copied in its 'entirely' from a description of the Y-12 Radiation Safety Program.[4]]

External Radiation Monitoring

Radiation-sensitive film is used in all plant security dosimeter badges to measure the doses of beta, gamma, X-ray, or neutron radiation received by plant personnel. Films used for beta, gamma, or X-ray dosimetry are processed quarterly. Special emulsion films used for routine neutron dosimetry are changed semiannually but are processed only when possible neutron exposure is suspected. However, neutron films are changed and processed quarterly for those persons who work with neutron sources. Any individual film is processed immediately if there is reason to suspect that an accidental overexposure may have occurred.

The film badge presently in use at Y-12 has been approved by the AEC and serves both as a security pass and personnel routine and emergency monitoring dosimeter. An "exploded" view of the badge is shown in Figure 1. It consists of a plastic case with the photoidentification on the front and an insert that holds the film in position. Two types of films are used: DuPont, Type 544, for beta-gamma monitoring and Eastman NTA for neutron measuring. On the front side of the slide there is a strip of indium on which the employee's payroll number is indented. The indium serves as one of the emergency monitoring features of the meter. The badge is designed for energy determination of a radiation exposure and has four areas for this purpose: the open window, plastic, aluminum, and cadmium. In addition to the indium for emergency monitoring, there are two gold discs, bare and cadmium-shielded, and a sulfur pellet.

Badge Distribution – All badges are assembled and loaded with film by the Plant Security Department. Payroll numbers and the quarter identification code are X rayed

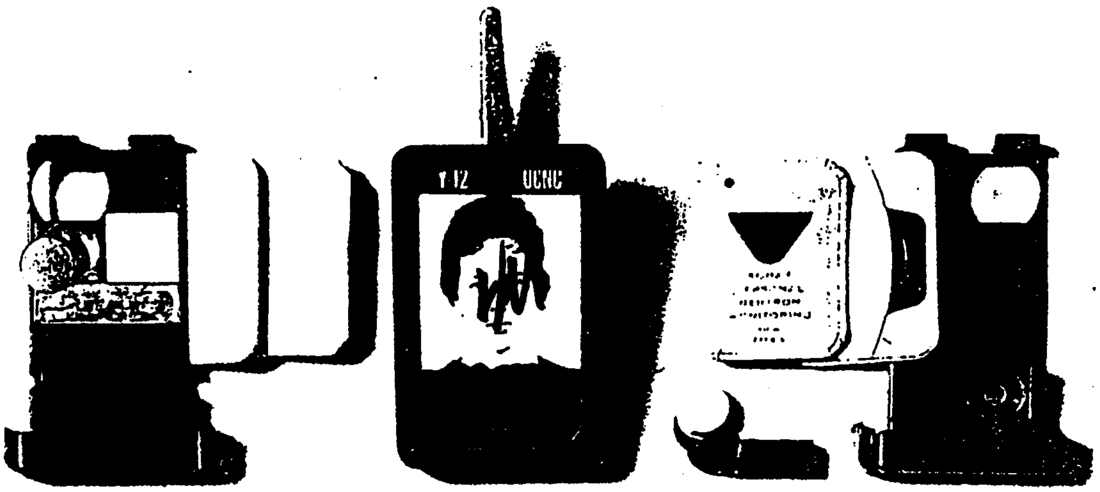

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Figure 1. SECURITY BADGE AND PERSONNEL MONITORING DOSIMETER.

onto the film badge before the badges are distributed. On the last day of the calendar quarter, during the evening shift, the badges are placed in numerical order by badge payroll number in badge exchange racks at stations located inside each plant entrance. The employee picks up his badge at the station of his choice which he has indicated previously in writing, and leaves the badge for the quarter just ended in the rack from which the new badge was selected. Two weeks are allowed to complete the exchange after which all badges are picked up by plant guards and taken to the Badge and Pass Laboratory where the film is removed from last quarter's badge and sent to the Bioanalysis Laboratory for processing. Persons failing to exchange badges at the portals within the period of two weeks must go to the Badge and Pass office to make their exchange.

Processing – Beta-gamma films are developed by standard film developing techniques using a DuPont developer and replenishing solution. After a three-minute developing time, the films are put through the fixer, rinse, and drying cycles before reading. Densities are read for the four areas: open window, plastic, aluminum, and cadmium, on a semiautomatic reader and recorder. Results are translated into volt units (1.800 volts) and punched automatically by the reader into IBM tabulation cards along with the employee's badge number which an analyst reads from the film and punches into the card. The cards are sent to Tabulating Services for dose calculations and recording. A penetrating dose and total skin dose are calculated from the film response values for the cadmium and open window areas by comparison of the volt units obtained with those determined from a set of precalibrated films. These volt units are also converted to optical density units for ease of comparison with other systems.

The Eastman NTA neutron films are developed by the same processing method as that used for the beta-gamma films but using a five-minute developing time. Films are read under a microscope by counting the number of tracks in 50 fields and the dose is computed by calibration against an approved neutron source of known strength.

Recording - A quarterly radiation dose is calculated from the information punched on IBM cards, and is compiled and recorded by machine on IBM sheets for each individual in numerical payroll number order by departments. Recorded on the sheet is the beta, gamma, and neutron doses in mrads with total skin dose and total penetrating dose in mrems. At the end of each calendar year a tabulation of all exposures that have been reported for each individual is made and filed by badge number. The annual exposure records, the quarterly IBM cards, and the developed films are retained as permanent personnel exposure records.

Reporting - A summary of all exposures is made for each division and is included in the Y-12 Plant Quarterly Report. In addition, a breakdown of the results is included in a personnel exposure report made annually to the AEC. Significant exposures are handled as outlined in Table 2.

Film Calibration - All routine films are read against sets of quarterly calibrated films. (See the section titled, CALIBRATION PROGRAMS, Page 74.)

Control Program - Three sets of calibrated film are processed each quarter for both beta and gamma. These films are picked at random from the same boxes from which the films loaded into the personnel badge were taken, and are exposed to known doses in the range of 30 - 5000 mrems. They are then processed through the laboratory in a random manner along with the film from the badges worn by plant personnel during the quarter. The film results at several levels are composited and the precision of the measurement spanned by these levels is calculated by the Statistical Services Department and reported quarterly in the Quality Control Report. If the precision shows an unusually high limit of error, attempts are made to locate and correct the influencing factor or factors.

In addition to the films just described, approximately 50 films are exposed to 960-mrem gamma and sent to the laboratory. These films are used by the laboratory to check on the consistency of the interpretation between and within processing batches.

CALIIBRATION

Films for Personnel Monitoring Meters

In order to interpret personnel radiation exposures by means of film dosimetry it is necessary that film be calibrated. This calibration is done by exposure to known doses of radiation and plotting and writing equations for film response as a function of the dose. Personnel film exposure can then be compared with the calibrated film, and dose measurements determined. Separate calibrations are made for beta and gamma exposures. Dose from a given source can be controlled by varying either time or distance. This control is currently accomplished by varying time.

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Figure 41. INSTRUMENT CALIBRATION FACILITY FOR LOW-GAMMA RADIATION.

Beta-Sensitive Films – Films are calibrated for beta dose by exposure to uranium beta radiation. The beta dose rate at the surface of the uranium slab is taken as 240 mrads per hour. Three sets of films, with twelve each, are exposed in plant-type badges. One badge from each set (three badges) is given one of 12 doses ranging from 0 to 5000 mrads. The badges are placed in an automatic timer-controlled holder (Figure 42) which positions them on the uranium slab and removes them at the end of the predetermined exposure time. The films are then unloaded from the badges and given to the Bioanalysis Laboratory for processing.

Gamma-Sensitive Films – Gamma rays from cobalt-60 are used to calibrate gamma films. The Co-60 source is calibrated quarterly using a Victoreen R-Meter. Dose rate is determined by placing the R-Meter chamber in juxtaposition with the badges and reading the dose over a measured period of time. Figure 43 shows the facility

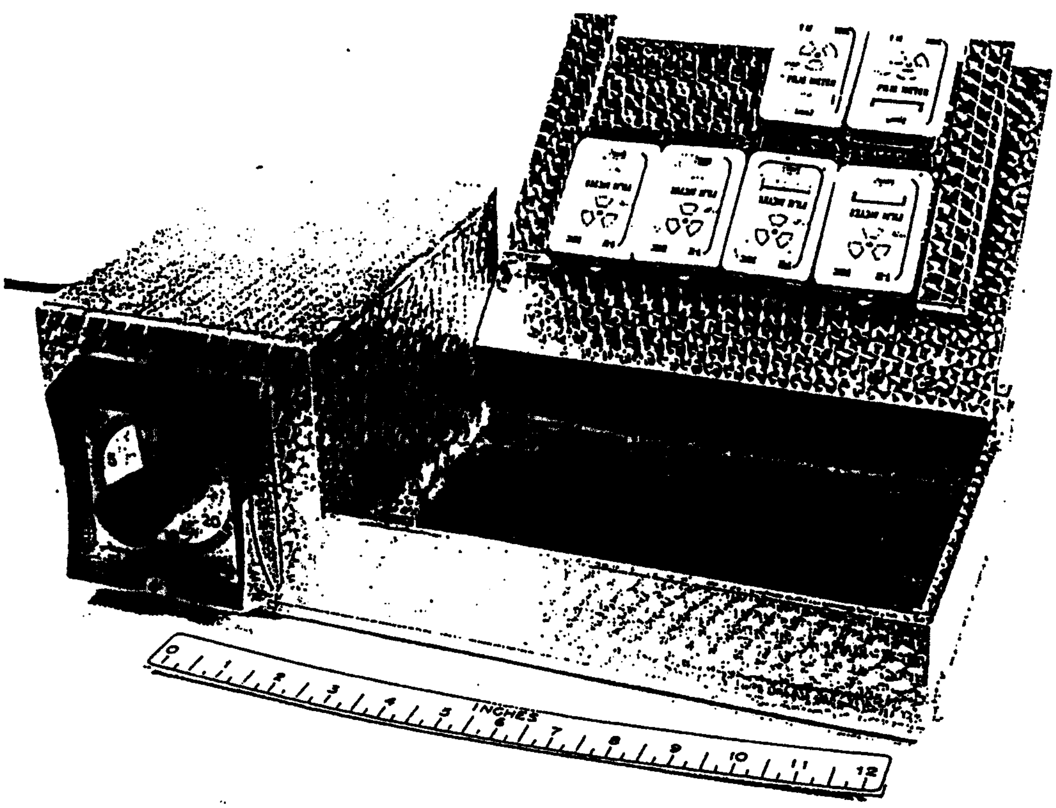

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Figure 42. FILM CALIBRATION INSTRUMENT FOR BETA RADIATION.

used for this purpose. Three sets of films, with 12 films in each set, are loaded into badges which are placed onto the lucite disc three at a time. Vacuum is used to raise the source into position in the center of the disc. The badges which are backed up by four inches of lucite are one foot from the source when it is in position. Dosage is varied with time which is controlled by an electric timing device. When the vacuum pump (shown in upper left corner of Figure 43) stops, the source drops by gravitational force back into the shield. Three badges at a time (one from each set) are given one of the following doses in mrads: 0, 30, 120, 240, 480, 720, 960, 1440, 1920, 2880, 3840, or 5000. The films are unloaded from the badges and sent to the Bioanalysis Laboratory for processing.

All calibration films are processed by standard processing procedures along with routine films. After the films have been read, the results are given to the Statistical Services Department who determines the dose-determination equations to be used by Tabulating Services in calculating personnel exposures from routine film badges.

Neutron-Sensitive Films - An americium-beryllium source is used as a primary neutron standard for neutron film calibration. Films are placed at measured distances from the source (suspended in air) and dose calculations made for these distances.

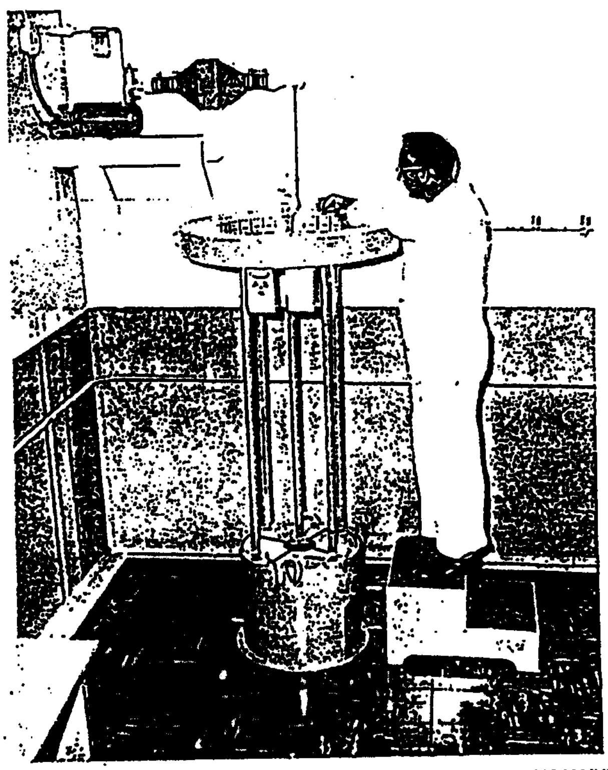

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Figure 43. GAMMA FILM BADGE CALIBRATION FACILITY.

This program ran much the same with minor modification for the rest of the time we monitored by film meters. There are several points of significance. (1) the formulas developed by the statistical services department allowed interpreting the film as it was read by the semi-automated densitometer or automated densitometer and the dose estimated to the nearest mrem down to zero. Although many of these readings were not statistically different from zero they were entered into the record as determined. Consequently [redacted] were only entered when the densitometer showed 100% transmission or more when compared to a blanks, for all quarters monitored during a year. (2) The film badge was subject to darkening from sources other than radiation. This was no different from earlier film but Y-12 did a study in which indicated that summer heat and absolute humidity resulted in a mottled darkening. When film were "hand" read on a densitometer the technician could minimize any overestimated from such mottling by picking the "lightest" spot in field to be read. However, with the automated reader such minimization was not possible since the film was inserted into the reader and read in the center of the four region. We didn't think this to be of any particle significance, at the time, since at the time most of our exposure were less than the level at which we were required to monitor for i.e. 500 mrem year for penetrating radiation. (3) Y-12 believed and our results showed that the areas where we had the highest percent of the radiation protection guide for external radiation was in our depleted uranium area particularly in the foundry area. The dose came from beta radiation from U-238 daughters. Consequently Y-12 expended any effort made toward reducing external dose toward reducing that exposure potential. However, most of the exposure control effort continued to be directed toward controlling internal exposure. (4) Y-12 had a film badge control program. Earlier in the period this program was conducted by processing controls with known exposure and submitting the data gathered to the statisticians to analyze. Subsequently this statistical evaluation was made on the variability shown by the six sets of film used in the calibration from which the formulas used for dose interpretation were developed. Y-12 health physics and laboratory followed the results of these studies in a general sort of way. The results were specially reported once/quarter. However, the format of reporting the limit of error for mrem valves between 0-1400 mrem or 0-1759 mrem assured that there was action only if there was great difference in the positive direction of this limit of error. In addition the limit of error was based on pure beta and gamma exposure instead of mixed exposure as could have been experienced in the field. In retrospect this control program seems [redacted] to be more of a statistical exercise then it was a control program.

1980-1985 Period

The next major change in the external monitoring program came early in 1980 when a switch was made from a film meter to a TLD meter. A report[5] was issued which gives a terse discretion of the meter badges used is reproduction in full below.

DESCRIPTION OF SECURITY BADGE AND HEALTH PHYSICS METER

E. D. Gupton[(b)]

The Nuclear Division badge meter consists of: (1) a security badge for identification and (2) a health physics meter for personnel radiation monitoring. The badge and the meter are held together with a plastic strap, which has a metal clip for attaching the badge meter to clothing. The employee badge meter, to be issued for use within the Nuclear Division of Union Carbide Corporation in early 1980, is shown in Figure 1.

SECURITY BADGE

New features incorporated into the badge meter include a color portrait photograph for more accurate identification and new employee-identification numbers assigned according to company service date. The color of the badge designates the level of personnel security clearance: blue for Q-cleared, yellow for L-cleared, red for uncleared, and white for uncleared noncitizens. The badge is worn prominently displayed above the waist with the photograph facing forward. Loss or damage to a badge is reported promptly to the installation security office.

HEALTH PHYSICS METER

The dosimeter, manufactured by Harshaw Chemical Company,[(c)] is an aluminum card in which two TLDs are mounted. The card has a bar-coded machine-readable serial number for identification. The TLDs are small (0.32 x 0.32 x 0.09-cm) chips of lithium fluoride (LiF).

The complete meter assembly is the TLD card and an aluminum filter (for beta-gamma radiation discrimination) sealed in a plastic envelope. A label for identifying the meter and the employee is sealed within the envelope so that it may be read through the plastic.

Ionizing radiation causes electrons within the thermoluminescent material—LiF in this case—to be raised to a higher energy level where they may be trapped. On subsequent heating, the trapped electrons are released and return to their base energy level with the emission of visible light. The sum of the stored electron energy and, thus, the amount of light emitted on heating is proportional to the radiation dose.

In LiF, the higher energy trap levels are quite stable with time; and relatively few of those electrons are released until the TLD is heated above the range of 250 to 300°C. Thus, LiF may be used for long periods of time without loss of dose information.

(b) A member of the ORNL Industrial Safety and Applied Health Physics Division.

(c) Harshaw Chemical Company, Cleveland, Ohio.

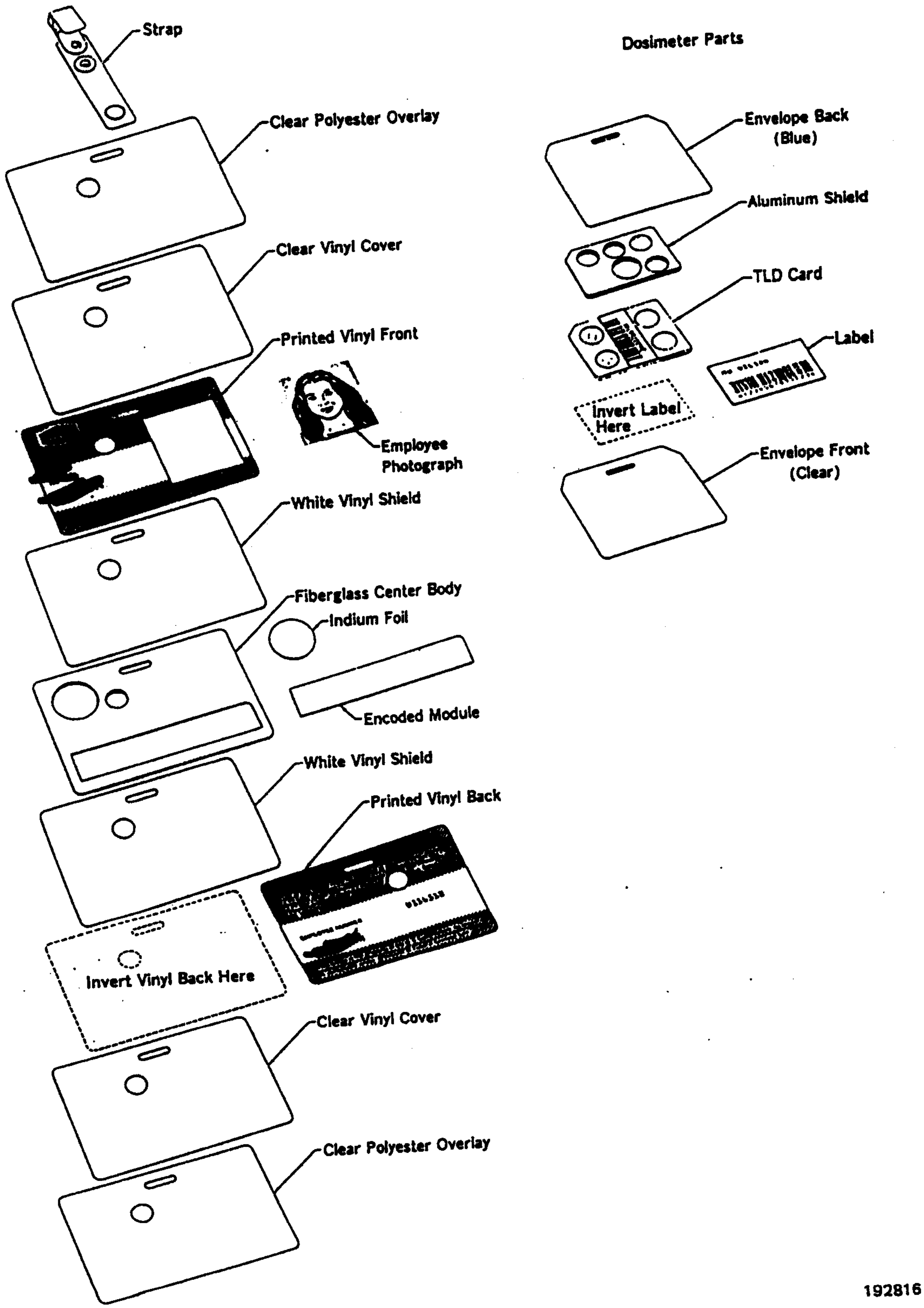

Figure 1. EMPLOYEE METER BADGE COMPONENTS.

Another advantage of LiF is that its energy response to radiation approximates that of human soft tissue. Multiple filters, as for film, are not required for correcting energy response.

The two TLDs are oriented with respect to the badge so that one is aligned with a hole in the badge, in order that beta and low energy X rays may be registered, while the other is filtered by the badge plus 0.0625 inch of aluminum so that only higher energy gamma and X rays are registered. This arrangement is for determining superficial (skin) and depth (whole body) doses as required by the Department of Energy (DOE) Manual Chapter 0524, *Standards for Radiation Protection*.

There were other changes of significance. Only those person thought to have exposure potential were monitored quarterly. For Y-12 this was about 250-500 people. The rest of the employees were audited annually. Y-12 processed the meters for all three Oak Ridge Facilities and Paducah. To help level the processing work load each facility's annual meter badges were changed at the end of a different quarter. Orginially Y-12 was scheduled to change at the end of September each year but we swapped with X-10 and after the first year and changed them at the end of June. These estimated doses from annual meters although they spanded two calendar years were assigned to a single year. Usually the year assigned was the year of their removal from use. Although these meters were considered by the health physics department to be a continuing audit of whether all the employees with exposure potential were monitored results of there TLD's were considered as the best estimate available for the year and have been used as the annual dose by CER.

There was another change of significance in the TLD data handling . A dose of 1 rem per week of each week between the time a TLD was read and annealed and the next time it was read an anneal was subtracted as background. In addition if the reading did not indicate more than 20 mrem the dose was set at zero. So annual meter might have to exceed an indicated dose of 80 mrem (ie 60 weeks between reading x 1 mrem week + 20 mrem) before any dose was recorded. Above this threshold the dose was recorded to the nearest 10 mrem. The change in this philosophy in Y-12 was largely due to the fact that top management wanted the four facilities TLD to processed and handle the data in the same manner and the X-10 member of the committee was adamant in his position that the approach out lined above to be used.

A control program was continued, a brief description of this program as contained in YDD-286 is quoted below.

QUALITY ASSURANCE

B. F. Rutherford[g]

As a check on the reliability of personnel exposure estimates from the TLDs in the badge meters, a control program will be administered at the Y-12 Plant. The control exposures, statistical analyses, and quality control reports involved in the program are outlined below.

CONTROLS

Each month, control TLD meters will be exposed to known levels of ionizing radiations by the Y-12 Health Physics group by using uranium-238 and cobalt-60 sources. The number and level of controls to be prepared each month are listed in Table 1. The exposed controls will be merged into the regular meter processing stream in such a way that anonymity will be ensured.

STATISTICAL ANALYSES

After processing along with regular TLDs at the Y-12 Plant Laboratory, results will be sent to the computer center, where control results will be separated from personnel data. These control data will be forwarded for evaluation in Y-12's routine measurement control program operated by the Certification Quality Control Group.[1] Early data from this

Table 1

EXPOSURE LEVELS AND FREQUENCIES FOR MEASUREMENT CONTROL THERMOLUMINESCENT DOSIMETER CARDS

Set	Meters Per Month	Exposure Level for Each TLD Card (mrem) Superficial	Depth	Resulting Exposure for Each of two LiF Chips (mrem) Superficial Plus Depth	Depth	Basis for Exposure Level
1	3	1000	500	1500	500	10% of Annual RPS(1)
2	3	200	300	500	300	10% of Quarterly RPS
3	3	70	100	170	100	10% of 1/3 of Quarterly RPS (monthly RPS)
4	3	0	0	0	0	Blank (contains only background)
5	3	0	500	500	500	No Beta Exposure
6	3	1000	0	1000	0	No Gamma Exposure

(1) Radiation Protection Standard (RPS).

(g) A member of the Y-12 Radiation Safety Department.

program will be used by this group to generate statistically established control limits at the 99-percent confidence level. Subsequent data sets will be compared with these statistical control limits. Monthly plots of each data set will be maintained.

The control data will be used quarterly to generate estimates of averages, precisions, and biases. A comparison of current-period averages and variations will be made with the corresponding control levels and limits.

QUALITY CONTROL REPORTS

Reporting of control data will be both special and routine. Out-of-control data will be reported on a special basis as soon as they are detected by statistical analyses of the data. Routine measurement quality reports, containing estimates of precisions and biases, as well as a summary of all statistically significant changes that have occurred, will be issued quarterly. These reports will be addressed to the Y-12 Plant Laboratory for necessary remedial action as indicated. Copies will be sent to Health Physics at each plant.

SPECIAL CHECKS

At their discretion, the groups responsible for personnel monitoring at the installations may submit meters with known exposures to the Y-12 Plant Laboratory and evaluate the results for their assurance of laboratory control under conditions of special interest to their facilities. The results of any such evaluations will be made known to the Y-12 Plant Laboratory and the other Health Physics groups.

These are the programs and procedures that were in use when I left Y-12 in 1985. They were continued through 1988. In 1989 a new TLD was put into use.

Attachment

CMW:ss

Distribution: Dr. E.L. Frome
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J. Watkins
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Files/ERF

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5. YDD-286 Compiled by J.D. McLendon - External Radiation Monitoring of Union Carbide Corporation Nuclear Division Personnel, 1980.

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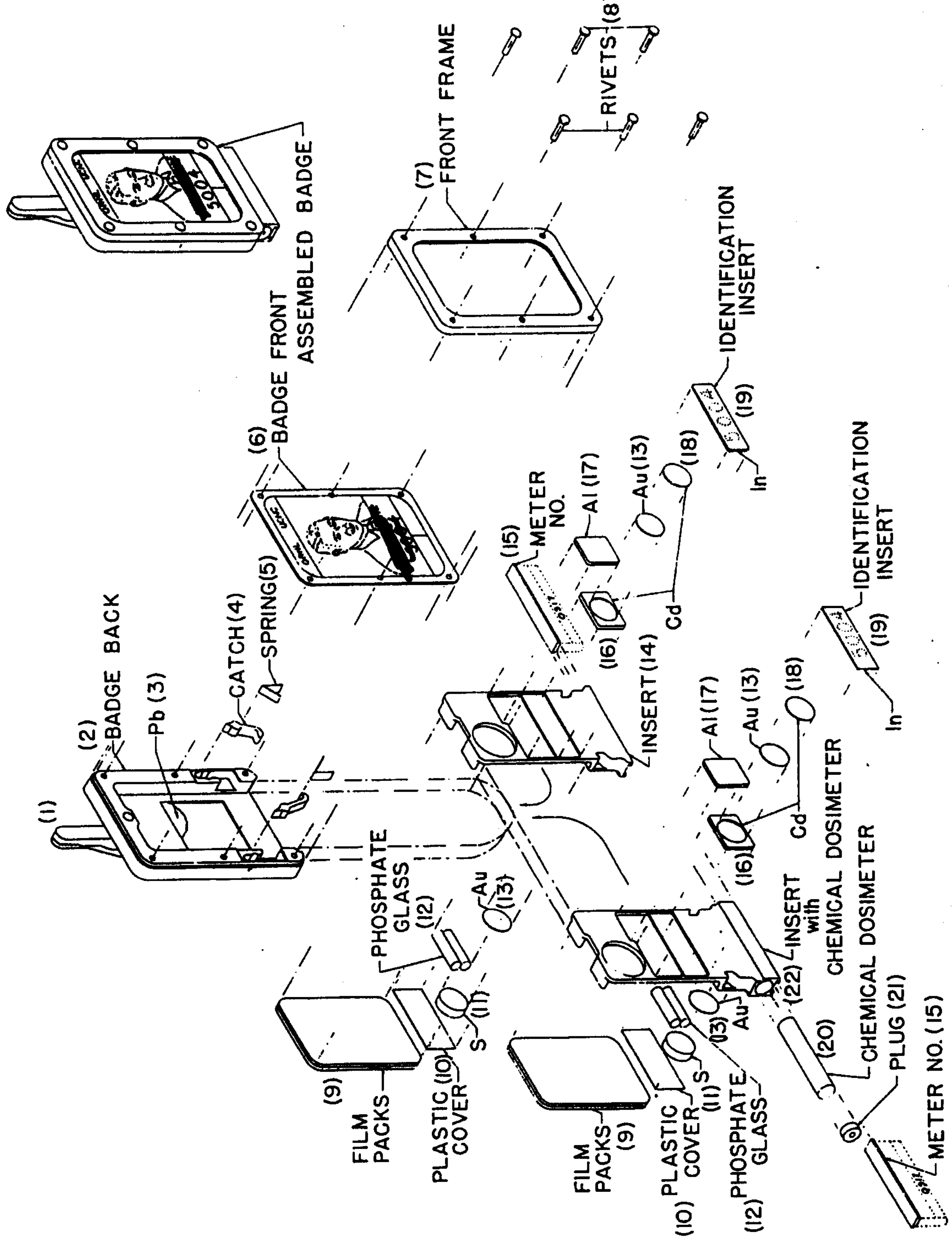

Figure 36 New Health Physics Multi-Purpose Badge Meter.