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Evaluation of Docket Files for Terminated Special Nuclear Material Licenses

C. F. Holoway
P. M. Lantz
H. W. Dickson

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HEALTH AND SAFETY RESEARCH DIVISION
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C. F. Holoway
P. M. Lantz
H. W. Dickson

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Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37830
operated by
UNION CARBIDE CORPORATION
for the
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TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

HIGHLIGHTS

Terminated special nuclear material licenses from docket files of the Nuclear Regulatory Commission (NRC) have been evaluated with respect to the potential for residual radiological health problems. Some 668 special nuclear material docket files sent from the Federal Repository for NRC to Oak Ridge National Laboratory were evaluated. The files were inventoried, and a methodology was developed for evaluation of these files. The methodology included development of a combined analysis/computer input form. Pertinent data were abstracted from each file, placed on this form, and entered into a private-access computer file. At the same time, analysts using screening criteria made a preliminary categorization of the files. All files categorized initially as potential radiological health problems were reviewed in depth to arrive at a final categorization. Criteria for judgment included quantities of special nuclear material (^{235}U, ^{239}Pu, etc.) going to and leaving the site in question during the operational lifetime of the site, disposition of radioactive material not leaving the site, types of operations carried on at the site during the licensed period, radiotoxicity of the radioactive material involved, and the physicochemical forms of products and wastes involved. In the final analysis, 54 dockets were identified as having potential for residual radiological health problems.

1. INTRODUCTION

1.1 Purpose of the Project

In 1976, the General Accounting Office (GAO) requested the Nuclear Regulatory Commission (NRC) to provide assurance that no radiological health or safety problems exist at sites previously operated under licenses issued by the NRC or its predecessor, the Atomic Energy Commission (AEC). A random sampling of the files by GAO had indicated that documentation was lacking or inadequate, in some cases, to demonstrate that terminated licenses had been accompanied by adequate decontamination and/or radiological evaluation to verify that the sites could be returned to the public domain for unrestricted use. In recent years, decommissioning guidelines have become more restrictive, rendering previously cleared sites questionable.[1] By request of NRC, a team was assembled in the Dosimetry Applications Research (DOSAR) Group, Oak Ridge National Laboratory (ORNL) to evaluate docket files containing terminated licenses and other documents, representing sites where radioactive materials had been involved.

The purpose of the present study is to effect a screening and categorization of those special nuclear material (SNM) docket files which have been terminated. Special nuclear material is defined in Part 70 of the *Code of Federal Regulations* (CFR)[2] as plutonium, ^{233}U, uranium enriched in the isotope ^{233}U, or in ^{235}U, and any other material deemed to be special nuclear material, but excluding "source material" (see 10 CFR 40).[3] Evaluation of Part 70 docket files has been done to determine which, if any, of the sites represented by those files may be a potential radiological health hazard.

1.2 Scope of Project

A total of 668 terminated special nuclear material docket files were evaluated and placed in one of three categories:

1. No - meaning the docket contained information to indicate or suggest that one or more sites represented by that docket could be a radiological health problem.

2. OK – meaning evidence available in the folder provided reasonable assurance that the site(s) represented by he docket could be considered for unrestricted use, so far as that folder was concerned.

3. Uncertain (Un) – meaning that documentation did not include enough information, was too ambiguous, or otherwise lacked sufficient information for the ORNL analysts to make a No or OK decision.

The docket information available was limited to those folders shipped in 39 boxes of Part 70 docket folders to ORNL from the Federal Repository at Washington, for licenses expiring between 1956 and 1977. Excluded from this report are Part 30 (by-product materials), Part 40 (source materials), and Part 50 (production and utilization facilities) dockets. Where Part 30, 40, or 50 information was found in Part 70 folders, it was sometimes included on the computer input form (see Sect. 2.3.2) to the extent that such information: (1) gave clues as to the magnitude and variety of radioactive material handling at the site; or, (2) might be needed to supplement the Part 40 file created earlier.[4]

In addition to the primary task of evaluating dockets for sites that may be of potential radiological health concern, a secondary purpose was to create a computer file of extracted data upon which categorization was based. For the more routine dockets, computer records may eventually replace the original docket folders. Computer printouts from this Part 70 file can give no more significant data than was present in the original folder; however, they include the evaluation and categorization provided by the ORNL docket evaluation team. Final site assessments are to be made by the NRC, based in part upon the ORNL analysis effort and the computerized condensations, and in part on information that was not available to the ORNL team during the project period.

2. METHODOLOGY DEVELOPMENT

2.1 Inventory

An inventory list of Part 70 dockets was supplied by NRC, consisting of (1) licensee name; (2) city; (3) state; and (4) one or more license numbers with corresponding license issue date(s), numerically ordered by docket number. An independent ORNL inventory was made of the 140 boxes received on three pallets at ORNL on December 15, 1977. These boxes, containing Parts 40, 50, and 70 docket folders, were inventoried box by box, folder by folder, using a simple inventory form. The boxes from the Federal Repository had been divided before ORNL receipt into four numbered series of boxes: 6, 17, 25, and 95, by criteria not known to the ORNL group. A box number field was set up for computer use and became the principal manual retrieval mechanism for locating a docket folder, since folders were kept filed in their original boxes. Box 79/95, for example, represented the 79th box of the 95 series and contained 55 Part 70 dockets numbered between 651 and 773. Since 6, 17, 25, and 95 add up to 143 and 140 boxes were received, 3 remain unaccounted for.

Upon completion of the docket file evaluation, the computer file became the best inventory, predicated upon errorless handling of folders, computer input forms, and corrected printout sheets (see Sect. 2.6).

2.2 Screening Criteria

To complete the Part 70 docket analysis, reasonable, effective and efficient criteria were required for categorizing sites in terms of docket folder contents representing those sites. Conservative screening criteria enabled individual analysts to reduce the 668 dockets to 155, which could then be analyzed by group-analysis (see Sect. 4.4). Initial screening by individual analysts was followed by a final categorization of dockets in group sessions.

A simplified work sheet was used by each analyst to tabulate the kilograms of each radionuclide authorized by all of the licenses in the docket folder, as total amounts of elements and/or as equivalent amounts of fully enriched nuclide. Each of these quantities was then modified by various factors that took into account the relative radiotoxicity of the nuclide involved, the type of process or operation that was being done, and the degree of containment and control that was exercised. The result was a "total screening factor" (see Sect. 4).

As developed, the total screening factor (TSF) led to the following categorizations:

TSF	Category
<100	OK
100-1000	Un
>1000	No

The initial characterizations and data were then computerized, the questionable (No and Un) dockets printed, and the printouts analyzed (a) by each analyst for a second categorization, and (b) by the analysts as a group for the third and final categorization. In the group sessions of 3 to 4 analysts, additional criteria were invoked. All available information and experience was brought to bear on (1) contents of the docket folder with any accompanying notebooks, etc.; (2) the site(s) which the docket represents; and (3) the licensee(s) associated with that site. Frequently, the group decision was unanimous, but when split, the more conservative category, namely, No, instead of Un, or Un instead of OK, was chosen as the group category. Minority dissents were recorded, but not stored in the computer. Uncertainties and disagreements usually arose as a result of insufficient data, thus, permitting alternate scenarios as to likely pathways, conditions, quantities, and the potential for ultimate contact with humans.

Individual analysis of necessity was docket-oriented. In group-analysis, an attempt was made to be site-oriented. It is expected that use of the computer file will facilitate site-orientation. In this connection, three criteria are worth singling out.

(1) A given piece of real estate (site) could have had multiple and/or successive occupancy by two or more organizations (licensees) handling radioactive materials.

(2) It was assumed that the maximum amounts of radioactive material authorized by all licenses found in a given docket were possessed, unless there was documentation to suggest otherwise.

(3) It was assumed that the maximum amounts authorized and present on the site never left, unless documentation to the contrary was in the folder.

This third criterion often gave the most trouble since folders rarely carried a formal cutoff date other than license expiration dates, or agreement state transfers, and frequently contained no site decommissioning or final survey documentation. Licenses transferred to agreement states are out of NRC jurisdiction; however, this did not affect categorization on the basis of available docket material.

Large quantities of special nuclear material exported to other countries would not be pertinent to the present project unless some of it were to return in some form, such as spent fuel rods. Import licenses were OK'd in general, on the grounds that other licenses in other dockets would be available.

2.3 Analysis and Control Forms

Six forms were used to maintain control over the various operations, starting with receiving the docket folders; maintaining accessibility to and keeping track of the folders in use; extracting essential data from the folders and auxiliary materials; categorizing the dockets; and keeping track of input forms to and printouts from the computer group and of edited printouts to and from the same, as well as recording the results of group-analysis. These forms were inventory, analysis/input, data processing control, supplementary control, group-analysis, and computer monitoring/retrieval work sheets.

2.3.1 Inventory form

This form (Fig. 1) documented the condition of the box being inventoried, the box identification numbers assigned before arriving at ORNL, the type dockets in the box, number of folders in the box, and a complete tabulation of all folder docket numbers. Space for comments was also provided. This manual inventory of the 39 Part 70 boxes served (1) to document those docket folders actually received, (2) to locate and retrieve specific folders as needed, and (3) to maintain association of specific folders with their original box numbers until available on the computer.

2.3.2 Analysis/input form

The analysis work sheet (Fig. 2) was printed on the reverse side of the computer input form (Fig. 3) to avoid unneeded paper handling. The computer fields used for Part 70 dockets are defined in Sect. 3.1.

2.3.3 Data processing control form

The data processing control (DPC) form (Fig. 4) accompanied every batch leaving the DOSAR Group en route to the computer group and the input facilities. Each batch corresponded to one box of docket folders. Each box contained from 1 to 55 dockets which were represented by one to nine folders. At one extreme, batch number 126 consisted of a single sheet representing box number 19 of the 25 series. At the other extreme, batch 102 for box 79/95 contained 55 input sheets representing docket numbers 70-651 to 70-773. Part 70 batches began with 101; earlier numbers were assigned to Part 40 batches.[4]

This form gave individual box (batch) control for both the computer group and the analysis team. It showed the sheets per batch to minimize chance of one or more sheets becoming separated, and made division by batches a convenient way of dividing work among several

Inventory Form Page_____

Box No_________ Repository Job No_______ Part 30_ 40_ 70_ Chkd by_________

Box Condition____

Sealed? Y N No. of Folders_________

FOLDER NO.	COMPANY	COMMENT

NOTES:____

TX 5008
(5-80)

Fig. 1. Sample inventory form used to inventory dockets received by ORNL.

DOCKET ANALYSIS WORKSHEET SIDE   Doc No 70-________   Eox______ Analyst____________

(SITE DOC):   Batch_____ Date______________

01 ___"Sealed" Source as defined.

02 ___"Dispersible" Material as defined.

"SOURCE MATERIAL" means material containing U and/or Th in any physicochemical form (with or without daughters) in excess of 0.05% U(Th) by wt. (10CFR40.4(h))

"Sealed" Source as defined by 10CFR70(4)(q): "...means any special nuclear material that is encased in a capsule designed to prevent leakage or escape of same."

"Dispersible: On an open surface, air velocity greater than 0, particle size less than 1,000 microns; or smearable (transferable).

"SNM" = U235,U233,Pu,etc but not SM. (10CFR70.4(m).

		Nuclide	Kilos	Enrich	Pure Eq Kilos 1	Hazard Factor * 2	Operation Factor 3	Containmnt Factor 4	Screening Factor 1x2x3x4
	03	U-Nat				1.5 E+0			
	04	U-Pro				8.4 E-2			
	05	U-238				4.1 E-2			
SNM	06	U-235				3.3 E-1			
SNM	07	U-235-En				6.5 E-1			
	08	U-234				9.5 E-2			
	09	U-233				1.5 E+3			
	10	U-232				1.4 E+7			
	11					9.8 E+10			
	12	Pu-242				3.8 E+4			
	13	Fu-241				2.0 E+7			
	14	Pu-240				2.3 E+6			
SNM	15	Pu-239				6.2 E+5			
	16	Pu-238				1.5 E+8			
	17								
	18	Th-Nat				6.7 E-1			
	19	Th-Pro				1.3 E-1			
	20	Th-232				1.7 E-1			
	21	Th-228				2.5 E+9			
	22					4.1 E+4			
	23	Ra-226				2.1 E+5			
	24	Am-241							
						Total Screening Factor (TSF):			

25 _____Operation Factor: Storage (Dry_; Wet_) : 0.01
26 _____Operation Factor: Wet,Simple : 0.1
27 _____Operation Factor: Normal,Chemical : 1
28 _____Operation Factor: Wet,Complex : 10
29 _____Operation Factor: Dry, Simple : 10
30 _____Operation Factor: Dry,Dusty : 100
31 _____Operation Factor: Continuous Gas Release: 100
32 _____Operation Factor: ____________________:
33 _____Decontamination:____________________
34 _____Containment:____________________
35 _____Total Curies at 50 years:__________
36 _____Total Curies at 100 years:__________
37 _____Total Curies at 1000 yrs:__________
38 _____TSF <100=OK 39 ___TSF 100-1000=Un 40 ___>1000=No

CONVERSION UNITS	
1 lb	= 454 grams
1 kg	= 2.2 lbs
1 metric ton	= 1,000 kg
1 metric ton	= 2,200 lbs
gms/1000	= kg
uCi/1000	= mCi
mCi/1000	= Ci

*Categorizing Factor: See reverse.

Pu239-U235-Th231-Pa231-Ac227-Th227
Pu238-U234-Th230-Ra226-
Pu237-U233-Th229-Ra225-

TX 5009
(5-80)

Fig. 2. Sample worksheet used to evaluate the potential health hazard associated with a given docket.

(DOC NO) 0 0 7 0 - 0 0 | | | | | - | ·ͱ'ͻX) / | (FOLDERS) | (ANALYSTS)

(ORGANIZ) (REGION)

(ADRES A) (CITY A) (ZIP A) (STATE A)

(ADRES B) (C·· (ZIP B) (STATE B)

(ADRES C) ·) (ZIP C) (STATE C)

(SITE A) (SITE B) (SITE C)

(LIC A) 0 | | | - 0 0 | | | | | - | | (EXPIR A) (EFF A)

(ISOTOP A)	(ENRICH A)	(QUANTY A)	(UNIT A,	(PURE EQA)	(LIC YRSA)	(CHEM A)	(PHYS A)

(OPERTN A) FEF_ Fab_ Mfg_ Pro_ Test_ R&D_ Anl_ Reac_ Crit_ Subcr_ Sto_ Dist_
Exp_ Imp_ Ind_ Ed__ Hos__ Pow_ _ Other(Specify)______

(COMENT A) ______

(CROSRF A) 0 | | | - 0 0 | | | | | - |

(LIC B) 0 | | | - 0 0 | | | | | - | | (EXPIR B) (EFF B)

(ISOTOP B)	(ENRICH B)	(QUANTY B)	(UNIT B)	(PURE EQB)	(LIC YRSB)	(CHEM B)	(PHYS B)

(OPERTN B) FEF_ Fab_ Mfg_ Pro_ Test_ R&D_ ·nl_ Reac_ Crit_ Subcr_ Sto_ Dist_
Exp_ Imp_ Ind_ Ed__ Hos_ _ _ Other(Specify(:______

(COMENT B) ______

(CROSRF B) 0 | | | - 0 0 | | | | | - |

(WASTE TY) U235_ Pu239_ TransU_ Scrap_ Sludge_ Solid_ Liq_ Other(Specify):______

(DISPOSAL) On-Site Disposal Method ______
Off-Site Disposal To ______

(TRM SRVY) ______

(FACTORS) 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20
21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40

(NEEDED) ______

(CATEGORY) 1OK__ 1No__ 1UN__ 2OK__ 2No__ 2Un__ 3__ 1 = After 1965
2 = Before 1966

(UPDATE) G; ______ (COMENT 1) ______

(TSF)______ yr mo da * If properly supervised, contained, cleaned up, surveyed.

$$\text{Hazard Factor} = \frac{\text{(S.A. of Nuclide in uCi/ug) (6.06 E-6)}}{(\text{MPC})_a \text{ of Nuclide in uCi/ml as available in ICRP2(1959)}}$$

For discussion of Hazard Factor, see Section 4.1 of text.

Fig. 3. Computer input form used for transferring pertinent data from dockets to a computer file.

Page_____

PRODUCTION COVER SHEET

DATABASE NAME: DOSAR
GROUP: DOCKET
DEPT CHARGE: 3490

USER: DOSAR/NRC
BLDG NO: 7710
CSD CHARGE: 16942
EXT NO: 5851, 5854, 5855 or 5858

DEADLINE DATE: ____________________

COMMENTS: ____________________

ORIGINAL INPUT FORMS						
BATCH NO	BATCH TYPE	BOX NO	SHEETS IN BATCH	ANALYST	DATE OVER	DATE BACK

PRINTOUT EDITING				
TYPE EDITING	EDITED BY	DATE OVER	DATE BACK	

COMMENTS: ____________________

TX 5010
(5-80)

Fig. 4. Data processing control form used for batch control of computer input forms.

inputters. Only the input side of each analysis input form in the batch served as input to the computer, the other side serving as a work sheet for the analysts. During group-analysis, a second work sheet was provided via the individual computer printout sheets on questionable dockets. Comments, corrections, additions, and deletions from the individual analysts' work sheets were combined onto one master printout sheet after the group-analysis for computer update. Batches with their control forms are on file.

2.3.4 Supplementary control form

The supplementary control form (Fig. 5) was a master cumulative control sheet for the individual batches leaving and returning to the DOSAR Group. Dates of batch returns were kept in a separate logbook. This form, independent of a logbook maintained by one of the analysts, was a running total of work status.

2.3.5 Group analysis form

The group-analysis form (Fig. 6) was used to keep a record of (1) initial categorization by one analyst, (2) final categorizations by each of the analysts after group discussion, (3) a final single category assignment by majority vote, (4) the probable site(s) in question for the given docket, (5) licensee(s) associated with that site, and (5) a brief reason for changing the category (unless OK'd by the group vote).

2.3.6 Computer monitoring/retrieval form

Frequent searching of the file as it developed required a log to keep track of the monitoring and retrieval aspects. Computer input progress was followed by a remote terminal available to the DOSAR Group. Printouts for group-analysis statistics for monthly progress reports, searches requested by NRC, etc., were obtained from this terminal. The computer monitoring/retrieval form (Fig. 7) was the instrument used.

Part 70 Page________

BATCH NO	DATE OVER	DATE BACK	BOX NO	SHEETS BY BATCH	SHEETS BY INVENTORY	TYPE INPUT		COMMENT

TX 5011
(5-80)

Fig. 5. Supplementary control form which served as the master cumulative record of computerization.

Group Analysis Form

Page____

No.	Doc. No.	Cat.	PML	JSE	CFH	HWD	Group	Site	Comments	Organization(s)

TX 5012
(5-80)

Fig. 6. A group-analysis form used to record the final categorization action for dockets.

70 Page__

ORLOOK NO:______ Video___ Teletype___ File Name__________ Date:______________

Update:_________ Total Records:_______ Crossref:__________ Page____ of _______

PROBLEM:____ Time Start:_______
End:_______

____ Hardcopy On? Y N

Strategy:_______________________________________ Part: 40__ 70__

____ CATEGORY 2No________

Comment:____ 1No________

____ 2Un________

1Un________

2OK________

1OK________

Other_____

Total_____

No.	Subset No.		K E Y W O R D S			No.	Citations		Print	Time Rel
01						01				
02						02				
03						03				
04						04				
05						05				
06						06				
07						07				
08						08				
09						09				
10						10				
11						11				
12						12				
13						13				
14						14				
15						15				
16						16				
17						17				
18						18				
19						19				
20						20				
21						21				
22						22				
23						23				
24						24				
25						25				
26						26				
27						27				
28						28				
29						29				
30						30				

Total times and costs for this accounting period: Printout Recd:____________

Connect Time:________min. Cost:______dollars Account No.:____________

CPU Time:____________sec. Cost:______dollars For:____________________

Remarks:____

Followup:____

TX 5013
(5-80)

Fig. 7. Computer monitoring/retrieval form used to log access to computer file information.

2.4 Computerization

The computerization process is illustrated in Fig. 8. Data were manually extracted from the docket files and placed on a computer input form (Fig. 3). The input form contained 58 computer fields, which are defined in Table 1. The fields were selected based on the type of information that the NRC considered essential for a permanent record. The NRC desired to keep data for each license separate with its license number, so the input form and mode of retrieval at computer terminals were made slightly more complicated. For example, when searching for quantities of isotopes per docket number having two licenses, it is necessary to ask for two sets of quantities instead of one, or if three sites are involved per docket, but only two licenses tabulated, then a 1:1 correspondence cannot exist between site and license. In going from docket file contents to input form, an average reduction factor of perhaps 100 was effected in numbers of sheets of paper involved. In restricting extractable data to the computer fields selected, some information was unavoidably lost; however, every reasonable effort was made to preserve all essential information. Liberal use of comment fields gave an opportunity to input data not allowed for by the other specific fields.

Manually extracted data flowed into a temporary computer file called Text Editor and Corrector (TECO) stored in a PDP-10 computer. After editing of the temporary printout, TECO file contents were then transferred to a permanent and numbered computer file called Automated Data Set Editing Program (ADSEP).[5] The records were numbered automatically and sequentially by the computer as entered.

The computer personnel directly involved with the mechanization of Part 70 docket files are in the Information Services and Operation Section of the Information Center Complex (ICC) of the ORNL Information Division and consist of two groups: the Data Processing Group and the Production Group.

ORNL–DWG 79-19687

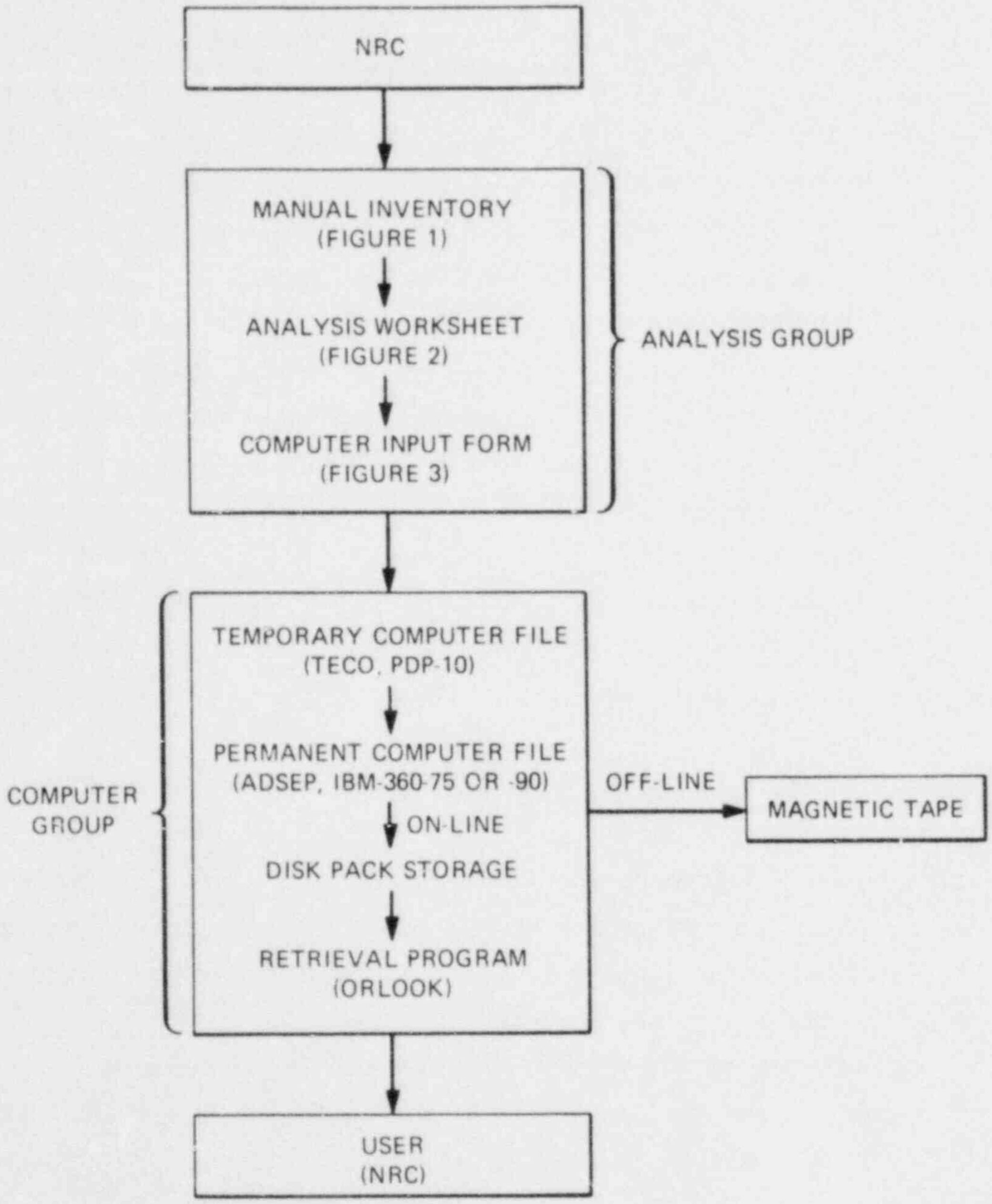

Fig. 8. Flow sheet for the computerization process.

Table 1. Data fields for computer input

Computer field	Information contained
DOC NO	Docket number
BOX	File box number where docket located
FOLDERS	Number of file folders included in the docket
ANALYSTS	Initials of analysts evaluating the file
ORGANIZ	Name of licensee
ADDRES A	Primary address of licensee
CITY A	Primary address of licensee
ZIP A	Primary address of licensee
STATE A	Primary address of licensee
SITE A	Primary location of licensee's operation with source material
REGION	NRC Region number
LIC A	Primary license number
EXPIR	Expiration date of licensee
EFF	Effective beginning date of licensee
ISOTOP	Identity of radioisotope licensed
ENRICH	Percent enrichment of each nuclide
QUANTY	Quantity of source material authorized
UNIT	Mass unit associated with quantity
PURE EQ	Equivalent amounts of pure nuclides
LIC YRS	Total license operation years
CHEM	Chemical form(s) of nuclide(s)
PHYS	Physical form(s) nuclide(s)
OPERTN	Operation conducted under specific license
COMENT	Discretionary comment by analyst
CROSSRF	Cross-reference to other license or docket number
LIC B	Secondary license number
WASTE TY	Waste type(s) involved in above 2 licenses, i.e., whether sludge, scrap, etc.
DISPOSAL	Whether on- or off-site, by burial, holding tank, pond, incineration, sewer, etc.; if off-site, to whom and/or where, and is this new site identified in another docket?
TRM SRVY	In those few cases where a definitive termination survey could be identified, this field was used, and might consist of an AEC or consultant survey

2.5 Editing

All computer printout editing was done by the DOSAR Group. Emphasis was on errors such as micrograms instead of kilograms and on the records for questionable dockets, that is, dockets given final categorizations of No or Un. Any given docket record was subjected to two editings, and questionable dockets to three for both technical and input errors. The first editing was of the TECO printout; the second for the ADSEP printout; and the third for record changes made after group-analysis of those docket records retrieved as questionable.

2.6 Quality Assurance

From the foregoing sections much of the quality control in effect can be inferred. As cited in Sect. 2.3, the main mechanical tools for quality assurance were the control forms used and the multiple editings referred to in Sect. 2.5.

Ultimate quality assurance is based on the quality and consistency of the criteria used. The criteria used rest upon accepted national and international standards as given by the *Code of Federal Regulations* on Energy (10 CFR), the National Council on Radiation Protection and Measurements (NCRP), the Environmental Protection Agency (EPA), the International Atomic Energy Agency (IAEA), and the International Commission on Radiological Protection (ICRP). The NCRP and ICRP standards in turn are based upon analysis and modeling of the original research literature.

A potential weak point in the methodology is that an original categorization of OK by an analyst removed that docket from further consideration other than editing; that is, from being subjected to group-analysis. There is the possibility that a different analyst might not have OK'd the docket in question. To minimize this potential error, criteria were conservative and analysts tried to err on the conservative side as well, when applying the criteria, and in a few cases by consulting with each other. That initial categorizations were on the conservative side is suggested since about one-half of those dockets initially categorized as No or Un, and therefore coming before the group for group-analysis, were recategorized as OK.

The main source of potential error by the computer personnel was the possibility of misplacing or otherwise failing to enter into the TECO computer file one or more data sheets. To eliminate this potential error, the number of sheets in a given production batch listed on the DPC form (Fig. 4) was checked by the inputter, spot checked by the supervisor, and checked by an analyst when comparing original input forms against temporary computer file printouts. Another quality assurance check was inherent in the frequent accessing of the ADSEP file to obtain printouts for group-analysis, for statistics for monthly reports, and for data on questionable sites and to check on dockets for the NRC. Observed inconsistencies were checked and corrections or procedural changes sometimes made as a result.

3. DATA EXTRACTION AND COMPUTERIZATION

3.1 Data Fields for Computer Input

In consultation with the NRC, a combined analysis work sheet/computer input form on a single sheet was designed and improved while in use. Figure 3 shows the type information now in the computerized Part 70 file. Information extracted from the docket folders and associated notebooks and reports filed with the docket folders was placed in the computer via the fields shown and defined in Table 1. The docket number (DOC NO) for Part 70 dockets did not exceed 999, but for compatibility with Part 30, Part 40, or other federal or state docket files, a XXXX-XXXXXX-XX (4-6-2) format was selected. The first four digits allowed for the Part (30, 40, 50, 70, etc.), the additional two spaces for future use if desired, such as coupling of NRC dockets with state file numbers. The next group of six digits allows for docket numbers in excess of 9999, since Part 30 dockets exceed this number. The third set of two digits was not used consistently, but would allow for designating up to 99 license amendments, or to differentiate supplementary (S) from main (M) folders if desired in the future. This 4-6-2 numbering pattern for docket numbers is the same as that used for the license numbers (LIC A), (LIC B) of Parts 70 and 40. In the case of special nuclear material export licenses, XSNM, all four of the digits in the first digit subfield are used. See DOC No, LIC A and CROSRF A in Fig. 3.

The box number (BOX) remains useful so long as docket folders are preserved and stored in their original boxes, serving as a convenient file location for physical retrieval of original docket folders. In addition, it was a useful field while the computer file was in construction.

The licensee(s) (ORGANIZ) associated with a given site tend(s) to change over the years. Occasionally, as many as three different organizations, not necesarily different licensees, were associated with a given docket number. When in doubt, an additional name was entered in this field to facilitate future cross-referencing between dockets. For further information on computer fields and search methods for this file see refs. 6 and 7.

3.2 Data Extraction from Docket Files

Part 70 dockets were concerned primarily with the production, storage and disposal of partially or fully enriched ^{235}U, and with the use of plutonium, often in sealed form such as Pu-Be neutron sources. Part 70 dockets also involved storage of both unirradiated and irradiated reactor fuel elements for and from research and power reactors. The usual restriction on storage and/or use of irradiated fuel elements was that they remain sealed, such a license authorizing "possession only" of the thousands of curies of by-products and of the plutonium contained within the sealed elements. Part 70 licenses dealt most commonly with ^{235}U and secondarily with plutonium; primarily with civilian licensees and secondarily with military licenses, all unclassified, but some dockets restricted for proprietary reasons.

The basic tool for data extraction was the analysis/input form (Figs. 2 and 3). Data extracted for computer preservation was limited to the defined computer fields, for example, the elements and/or radionuclides involved, quantities, degree of enrichment, types of operations carried on at the site, and manner of waste disposal or storage.

Special attention was paid to forms documenting shipments of waste to off-site recipients, to inspection reports, to license applications and issued licenses, to correspondence when it seemed to be indicative of a potentially unsafe situation, and even to blueprints to estimate magnitude or complexity of operations.

Difficulties sometimes encountered in extracting unambiguous data are varied and sometimes subtle. One example may suffice. A key factor in site evaluation is to know whether *all* radioactive waste left the site by closedown date. A basic document bearing on this question was ambiguous in that the printed form asked for documentation that waste *would* be shipped out, rather than a factual statement that all waste *had* been shipped out, and that no more radioactive material would be permitted to come on the site prior to closedown. For some sites, there is inadequate documentation [e.g., for sites that operated before the advent of formal licensing procedures or where data may exist in folders not received at ORNL, such as main (as against supplementary) folders, retired folders, or classified folders]. Some of these uncertainties can be cleared up by the NRC; others may require radiological surveys to generate missing data.

3.3 Generic Data Summaries

3.3.1 Docket distribution by NRC region

The United States is divided into five NRC regions (Table 2). A search of the Part 70 computer file gave the distribution of dockets by region (Table 3). Of the Part 70 dockets, 36% were associated with Region 1, 12% with Region 2, 18% with Region 3, 13% with Region 4, and 21% with Region 5. (A few dockets were associated with more than one region.) Of the questionable dockets (No or Un category), 48% were

Table 2. States located in the defined NRC regions

NRC region	State
1	ME, VT, NH, MA, CT, RI, NY, PA, NJ, DE, MD
2	VA, WV, KY, NC, TN, SC, GA, FL, AL, MS
3	OH, IN, MI, WI, MN, IL, MO, IA
4	AR, LA, TX, OK, KS, NB, SD, ND, MT, WY, UT, NM, CO, ID
5	WA, OR, CA, NV, AZ, AK, HI

Table 3. Docket distribution by NRC regions

Region	Dockets	Category					
		2No	2Un	1No	1Un	2OK	1OK
1	249	3	6	12	6	116	106
2	81	1	0	1	1	28	50
3	122	2	4	3	3	41	69
4	89	1	1	1	0	31	55
5	143	1	1	7	3	61	69
Totals							
By region	684[a]	8	12	24	13	277	349
By category	667[b]	8	11	23	12	270	343

[a]More than 668 dockets are retrievable by the field (REGION) because a few dockets were assigned to more than one NRC Region.

[b]The true number of dockets in the Part 70 computer file by manual accounting is 668. One docket, No. 70-132, not categorized, was referred to 70-165, but the two dockets did not seem to be connected.

Note: By (CATEGORY) count, 54 dockets were questionable (No or Un). Fewer than 54 sites are involved because some sites are associated with more than one docket.

from Region 1, 5% from Region 2, 21% from Region 3, 5% from Region 4, and 21% from Region 5. Eight and one-tenth percent (54/667) of the dockets were questionable (Table 3).

3.3.2 Docket distribution by state

As of April 5, 1977, there were 25 agreement states (Table 4) that had entered into agreements with the NRC to assume certain radioisotope licensing responsibilities within the state. As of each agreement date, many of which are noted in the docket (and computer) records, jurisdiction for the sites in question passed from NRC to the state for those activities of intra-state nature. Responsibility for many of the questionable sites identified in this study has passed to a particular agreement state.

The total number of docket references by states, obtained by searching on the combined fields (STATE A), (STATE B), and (STATE C), is tabulated in Table 5. About 16% of the records were for California, followed by about 13% for New York. Ohio, Massachusetts, and Pennsylvania came next, each accounting for about 5% of the total records. All other states were 4% or less, with Hawaii, Nebraska, and West Virginia having no special nuclear material dockets.

3.3.3 Distribution of license codes

In theory, all Part 70 license numbers would bear the prefix code SNM for special nuclear material, except that export licenses are differentiated by XSNM. About 17% of the license numbers bore identification prefixes other than SNM or XSNM. Sometimes a second license was involved, usually a by-product license; or no license number was assigned, as for a pre-docket system folder. Distribution of license codes are presented in Table 6.

3.3.4 Distribution of license expirations

Of particular concern to the NRC were licenses expiring before 1966. Consequently, the computer file was searched to determine the

Table 4. Agreement states as of April 5, 1977[a]

Alabama	Mississippi
Arizona	Nevada
Arkansas	Nebraska
California	New Hampshire
Colorado	New Mexico
Florida	New York
Georgia	North Carolina
Idaho	North Dakota
Kansas	Oregon
Kentucky	South Carolina
Louisiana	Tennessee
Maryland	Texas
	Washington

[a]Brodsky, A. B., Editor, *CRC Handbook of Radiation Measurements and Protection 1*, 6-9, CRC Press, West Palm Beach, Florida (1978).

Table 5. Docket distribution by states

State	No. of Part 70 docket records	State	No. of Part 70 docket records
Alabama	6	Montana	1
Alaska	1	Nebraska	0
Arizona	4	Nevada	6
Arkansas	4	New Hamsphire	4
California	105	New Jersey	18
Colorado	14	New Mexico	6
Connecticut	10	New York	86
Delaware	2	North Carolina	11
District of Columbia	26	North Dakota	2
Florida	7	Ohio	38
Georgia	7	Oklahoma	9
Hawaii	0	Oregon	9
Idaho	2	Pennsylvania	33
Illinois	27	Puerto Rico	2
Indiana	4	Rhode Island	3
Iowa	3	South Carolina	6
Kansas	8	South Dakota	1
Kentucky	5	Tennessee	13
Louisiana	7	Texas	22
Maine	1	Utah	5
Maryland	29	Vermont	2
Massachusetts	37	Virginia	15
Michigan	27	Washington	17
Minnesota	11	West Virginia	0
Mississippi	5	Wisconsin	5
		Wyoming	1
		Total	667

Table 6. Distribution of license codes in the Part 70 dockets

License code	No. of licenses
SNM[a]	558
No. license	59
XSNM[b]	14
0022[c]	9
0041[d]	8
DPR[e]	7
SMB[f]	2
Other (by difference)	11
Total	668

[a]SNM = special nuclear material.

[b]XSNM = special nuclear material for export.

[c]0022 = a by-product material code (Part 30).

[d]0041 = a by-product material code (Part 30).

[e]DPR = license for SNM in power reactors.

[f]SMB = users of both uranium and thorium for manufacturing purposes.

distribution of special nuclear material licenses by date of expiration (Fig. 9).

The first two licenses to expire in the NRC docket system were in 1956. Maximum licenses expirations were in 1968 when 67 licenses expired. When all licenses in a given docket expired prior to 1966, a prefix "2" was placed in the (CATEGORY) field; when one or more license in a docket expired in 1966 or later, the prefix "1" was used.

3.3.5 Types of operations

The type or types of operation connected with License A (LIC A) of a given docket can be retrieved by remote terminal using the field (OPERTN A). Prime use of OPERTN A or OPERTN B, by the analysts was to aid in initial screening and final categorization; however, this field will give a semiquantitative picture of the operation t [illegible] or which Part 70 licenses were issued (Table 7).

About 19% of the licenses went to educational institutions, especially for sealed Pu-Be neutron sources, and to a lesser degree for research reactors. Only 0.7% of licenses involved hospitals. Manufacturing, including fabrication, but excluding fuel-element fabrication, accounted for about 4% of the licenses, with fuel-element fabrication accounting for 5%. Manufacturing (17), fabrication (19), fuel-element fabrication (40), processing (2), and testing (59) gives a total of about 19% industrial type licenses. At least 3% of the licenses involved power reactors, and 12% related to storage, notably of fuel elements. These percentages are correspondingly higher on the basis of records (668) as against types of operations (816).

4. SCREENING AND CATEGORIZATION RATIONALE

There are numerous attempts in the literature to set up some kind of hazard index for radionuclides (see Table 8). These particular indices relate to the ICRP maximum permissible concentration (MPC) concept for air and water.[8] Our present concern is restricted to uranium, thorium, and a few transuranics such as americium and plutonium and

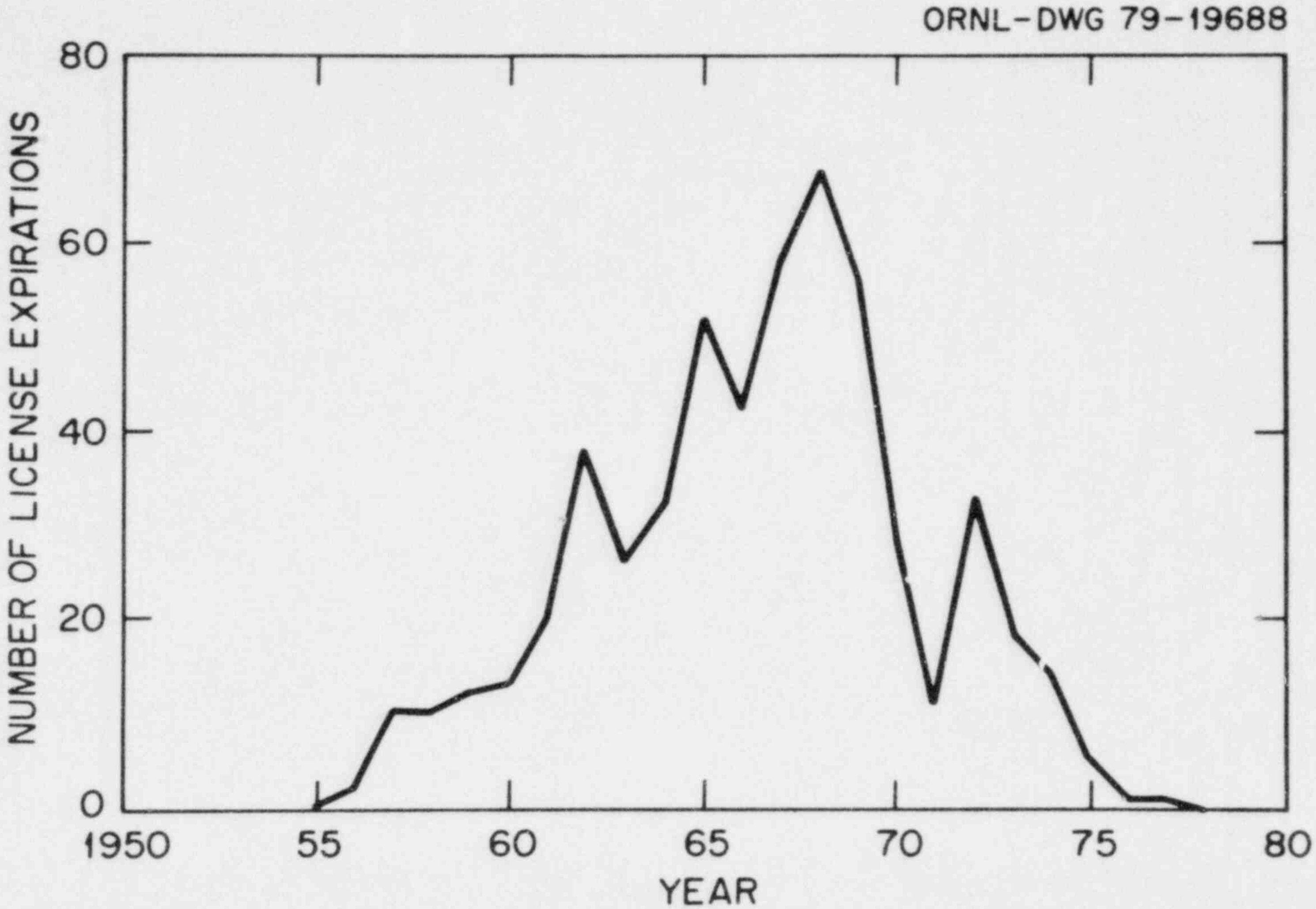

Fig. 9. Number of Part 70 license expirations as a function of time.

Table 7. Operation type at site

Code	Type of operation	No. of records
Ed	Educational institution	157
R&D	Research and development (usually industrial)	112
Sto	Storage	97
Anl	Analytical use	72
Ind	Industrial	57
Test	Testing (usually industrial)	59
FEF	Fuel element fabrication (FEF)	40
Subcr	Subcritical assembly	39
Reac	Reactor (research)	37
Pow	Power reactor	28
Exp	Export	28
Pro	Processing	20
Fab	Fabrication (other than FEF)	19
Imp	Import	18
Mfg	Manufacturing (other than FEF or Fab)	17
Crit	Critical assembly	7
Hos	Hospital	6
Dist	Distributor	3
Total		816

Table 8. Some hazard indices for radionuclides[a]

Symbol	Hazard index	Definition	Interpretation
Q	Quantity of radioactive material	Waste inventory (or waste released)	Comparison of waste inventories
MPC	Maximum permissible concentration	10 CFR 20	Relative hazards of radionuclides
HM	Hazard measure	HM = Q/MPC	Volume of air or water to dilute Q radionuclides to one MPC
HMI	Modified hazard measure 1	HM1 = D/D2 D = exposure, D2 = exposure limit	Ratio of anticipated exposure to allowable limit
HM2	Modified hazard measure 2	$HM2 = Q(a/MPI_{water} + b/MPI_{air})$	a = fraction of Q released to water; b = fraction of Q released to air
HM3	Modified hazard measure 3	$HM3 = \int_{t}^{t+d} (Q(t)/MPI)dt$	Number of MPI in environment versus time
PHM	Potential hazard measure	$PHM = P \frac{Q.1}{MPI.\lambda}$ P = probability of reaching man, λ = decay constant	Risk of releasing Q versus time
HI	Hazard index	$HI = \frac{Q}{MPC(V)}$ V = entrained volume	Number of MPC's per unit volume
HA	Hazard available index	$HA = \log_{10}HI + \log_{10}TF$ TF = transport factors	HI with pathway transport efficiency included

Table 8. (Cont'd)

Symbol	Hazard index	Definition	Interpretation
T	Isolation time	$T = -\frac{1}{\lambda} \ln \frac{MPC\ V_f}{A\ L}$	Time nuclides must be held to reduce concentrations to one MPC
RTI	Relative toxicity index	$RTI = \frac{(Q/MPC)\text{waste}}{(Q/MPC)\text{ ore}}$	Ratio, HI of waste to HI of U ore mined to generate the waste

[a]Hazard indices listed in this table are discussed in detail in J. Greenborg, W. K. Winegardner, P. J. Pelto, J. W. Voss, J. A. Stottlemyre, I. A. Forbes(a), J. B. Fussell(b), and H. C. Burkholder, *Waste Isolation Safety Assessment Program Scenario Analysis Methods for Use in Assessing the Safety of the Geologic Isolation of Nuclear Waste*, PNL-2643 (1978), with references to the original literature on each.

their respective daughters. Concern is further restricted to present and future population exposure; not to former occupational workers at sites no longer operative.

For purposes of the present Part 70 project, it was felt that radiotoxicity should be one screening criterion but that it should be modified by other factors of considerable importance. Some of the other factors are

(1) quantity of material licensed and quantity left on the site after shutdown;
(2) containment of radionuclides;
(3) type of process or operation conducted;
(4) waste management and disposal procedures employed; and
(5) type of material being handled, whether dispersible or non-dispersible.

The fractional environmental transport problem was bypassed by assuming that any contained nuclide on the site could eventually leave the site over a short enough time period so as to pose a potential human intake problem. Likewise, the fractional human uptake problem was bypassed by assuming that all of any nuclide intake to the body would be retained indefinitely, giving maximum dose and therefore maximum likelihood for harm. These and other conservative assumptions lead to some site categorizations which are unduly conservative; however, documentation in some cases is sufficiently meager so as to counterbalance this effect.

4.1 Hazard Factor

A hazard factor (HF) was considered that would (a) relate the radiotoxicity of a radionuclide to ^{226}Ra for which the most human data have been accumulated; (b) relate the toxicity of a radionuclide to natural uranium, meaning the natural uranium isotopes plus the daughters produced from these uranium nuclides; and (c) compare the quantity of radionuclide in question to the 150-lb calendar-year limit [10 CFR 40.22(a)] of uranium or thorium allowed responsible parties without special license. The specific desire was to relate the radiological hazard of special nuclear materials, especially ^{235}U and ^{239}Pu, to the source materials, primarily uranium and thorium ores and processed forms of uranium and thorium. The relative hazard approach taken includes that of Morgan et al.[9] in which a relative hazard factor obtained by the method of Duhamel and Lavie[10] was plotted against specific activity in curies per gram. The relative hazard of ^{226}Ra was taken as one (RH = 1).

The hazard factor was derived from:

(a) specific activities of radionuclides,

(b) ICRP maximum permissible concentration,

(c) MPC ratios with natural uranium plus daughters, and

(d) weight ratio of ^{235}U to 150 lb of natural uranium.

These separate factors were combined multiplicatively, reducing to the simplified equation:

$$(\mathrm{HF}) = \frac{(\mathrm{SA}_x)\,(\mathrm{MPC}_{\mathrm{Ra}})}{(\mathrm{MPC})_x} = \frac{(\mathrm{SA}_x)\,(3\mathrm{E}\text{-}11)}{(\mathrm{MPC}_x)} , \qquad (1)$$

where

SA_x = Specific activity of radionuclide x, expressed in µCi/mg;

MPC_{Ra} = Maximum permissible concentration in air (40 hr/wk) of soluble ^{226}Ra when bone is taken as the critical tissue, expressed in µCi/ml, occupational life time of 50 years;

MPC_x = Maximum permissible concentration in air of soluble nuclide x, when bone is taken as the critical tissue, or of insoluble nuclide x when lung is taken as the critical tissue, expressed in µCi/ml, for an occupational lifetime of 50 years, but taking 168 hr/week exposure.

To determine the hazard of any given special nuclear material relative to natural uranium plus its daughters, the hazard of the latter relative to ^{226}Ra was given a value of one, which is equivalent to dividing all HF values of radionuclides (x) of interest by the HF value of 7.08E-6 for natural uranium. For example, the relative hazard for ^{238}U is

$$\text{RH for } ^{238}\text{U} = \frac{1.96\text{E-7 } (^{238}\text{U})}{7.08\text{E-6 (nat-U)}} = 2.8 \text{ E-2} . \qquad (2)$$

Since 68 kg of natural uranium (maximum) qualifies for a general license (i.e., exempt from special licensing), the equivalent mass of special nuclear material of equal hazard (relative to natural uranium) would be 68 divided by the RH, or for ^{238}U, the value 2.4E+3. These hazard factors have been determined for the nuclides of interest in the Part 70 dockets. To conform to arbitrarily chosen screening factors (SF) of OK for less than 100, Un for values between 100 and 1,000, and No for values in excess of 1,000, the factor 100/68 was used with the quantity (kilograms) of special nuclear material involved for the docket in question (Table 9).

Derivation of the HF as a combination of the parameters (a) specific activity, (b) MPC of ^{226}Ra, (c) MPC of nat-U, and (d) weight of radionuclide to give a screening factor of 100 relative to 150 lb (68 kilograms) of source material (e.g., natural uranium in ore) is summarized as follows:

$$\text{HF} = \frac{\dfrac{(\text{SA}_x)\ (\text{MPC}_{\text{Ra}})}{(\text{MPC}_x)}}{\dfrac{(\text{SA}_{\text{nat-U}})\ (\text{MPC}_{\text{Ra}})}{(\text{MPC}_{\text{nat-U}})}} \times \frac{100}{68}$$

$$\text{HF} = \frac{100(\text{SA}_x)(\text{MPC}_{\text{nat-U}})}{68(\text{SA}_{\text{nat-U}})(\text{MPC}_x)}$$

Table 9. Relative hazard factors

Nuclide	S.A. in mCi/kg	$(MPC)_a$ Type	$(MPC)_a$ ($\mu Ci/cm^3$) (168^a hr./wk)	Hazard Relative to Ra-226 (168 hr./wk)	Hazard Relative to Nat. U + Daughters	OK ≤kg	NO ≥kg	Hazard factor OK = 100
U-Nat. U-238+U-235+ daughters	4.85E+0	L(I)	2×10^{-11}	7.08×10^{-6}	1	68	1,000	1.5
U-Nat. Processed U-238, U-235, U-234	7.007E-1	L(I)	5×10^{-11}	4.09×10^{-7}	5.8×10^{-2}	1.2×10^{3}	1.7×10^{4}	8.4×10^{-2}
U-238	3.366E-1	L(I)	5×10^{-11}	1.96×10^{-7}	2.8×10^{-2}	2.4×10^{3}	3.6×10^{4}	4.1×10^{-2}
U-236	6.43E+11	L(I)	4×10^{-11}	4.73×10^{5}	6.7×10^{10}	1.01×10^{-9}	1.5×10^{-8}	9.8×10^{10}
U-235	2.16E+0	L(I)	4×10^{-11}	1.58×10^{-6}	2.2×10^{-1}	3.1×10^{2}	4.5×10^{3}	3.3×10^{-1}
U-235 Enriched	4.3 E+0	L(I)	4×10^{-11}	3.14×10^{-6}	4.4×10^{-1}	1.5×10^{2}	2.3×10^{3}	6.5×10^{-1}
U-234	6.27E+3	L(I)	4×10^{-11}	4.58×10^{-3}	6.5×10^{2}	1.0×10^{-1}	1.5	9.5×10^{-2}
U-233	9.73E+3	L(I)	4×10^{-11}	7.10×10^{-3}	1.0×10^{3}	6.8×10^{-2}	1.0	1.5×10^{3}
U-232	2.14E+7	L(I)	9×10^{-12}	6.94×10^{1}	9.8×10^{6}	7×10^{-6}	1.0×10^{-4}	1.4×10^{7}
Pu-242	3.82E+3	B(S)	6×10^{-13}	.19	2.6×10^{4}	2.6×10^{-3}	3.8×10^{-2}	3.8×10^{4}
Pu-241	9.91E+7	B(S)	3×10^{-11}	9.65×10^{1}	1.4×10^{7}	5.0×10^{-6}	7.3×10^{-5}	2.0×10^{7}
Pu-240	2.28E+5	B(S)	6×10^{-13}	1.11×10^{1}	1.6×10^{6}	4.3×10^{-5}	6.4×10^{-4}	2.3×10^{6}
Pu-239	6.15E+4	B(S)	6×10^{-13}	2.98	4.2×10^{5}	1.6×10^{-4}	2.4×10^{-3}	6.2×10^{5}
Pu-238	1.72E+7	B(S)	7×10^{-13}	7.17×10^{2}	1.0×10^{8}	6.7×10^{-7}	9.9×10^{-6}	1.5×10^{8}
Th-Nat. Th-232 + daughters	1.103E+0	L(I)	10^{-11}	3.22×10^{-6}	4.6×10^{-1}	1.5×10^{2}	2.2×10^{3}	6.7×10^{-1}
Th-Nat Processed Th-232, Th-228	2.21E-1	L(I)	10^{-11}	6.45×10^{-7}	9×10^{-2}	7.5×10^{2}	1.1×10^{4}	1.3×10^{-1}
Th-232	1.10E-1	L(I)	4×10^{-12}	8.03×10^{-7}	1.1×10^{-1}	6.0×10^{2}	8.8×10^{3}	1.7×10^{-1}
Th-230	2.02+4	L(I)	3×10^{-12}	2.0×10^{-1}	2.8×10^{4}	2.4×10^{-3}	3.6×10^{-2}	4.1×10^{4}
Th-228	8.21E+8	[illegible]	2×10^{-12}	1.20×10^{4}	1.7×10^{9}	4×10^{-8}	5.9×10^{-7}	2.5×10^{9}
Ra-226	1.0E+6	B [illegible]	2.9×10^{-11} (40 hr. wk)	1	1.4×10^{5}	4.8×10^{-4}	7.1×10^{-3}	2.1×10^{5}
Po-210	4.50E+9	[illegible](I)	7×10^{-11}	1.88×10^{3}	2.7×10^{8}	2.6×10^{-7}	3.8×10^{-6}	3.9×10^{8}

$$HF = 6.06E\text{-}6\ \frac{(SA_x)}{(MPC_x)}$$

Two specific examples will illustrate how HF's were derived for purposes of obtaining screening factors for individual radionuclides (see Table 9).

Example 1: HF for enriched (100%) ^{235}U

$$HF_{^{235}U} = 6.06E\text{-}6\ \frac{(SA_{^{235}U})}{(MPC_{^{235}U})} = 6.06E\text{-}6\ \frac{4.3E\text{-}6}{4E\text{-}11} = 6.5E\text{-}1$$

Example 2: HF for ^{239}Pu

$$HF_{^{239}Pu} = 6.06E\text{-}6\ \frac{(SA_{^{239}Pu})}{(MPC_{^{239}Pu})} = 6.06E\text{-}6\ \frac{6.15E\text{-}2}{6E\text{-}13} = 6.2E\text{+}5$$

4.2 Operation Factor

Because hazard factors based upon MPC's have their limitations, the need was felt for balancing the toxicity figures for radionuclides administered to animals under artificial conditions with some measure of the operation or process that was conducted with due respect for operational experience. Toxic radionuclides when properly contained are not an actual hazard. Some industrial operations are more likely to produce a long-term environmental hazard than others. It is not possible to quantitate on paper the contribution of operation types to human hazard as readily as laboratory toxicity studies of which MPC's are more or less a direct result. We used the following arbitrary scale from an IAEA report.[11]

Type of operation	Operation factor
Storage (dry or wet)	0.01
Wet and simple operations	0.1
Normal chemical operations	1
Wet and complex	10

4.3 Containment Factor

An additional factor of concern was whether the radioactive material was isolated from the biosphere. In general, sealed sources under license are considered to be contained, and justification for reducing the potential hazard is that the material can not be readily released for human contact. A containment factor (CF) of one was used for all cases except sealed sources when a CF = 0.1 was used. An example of the application of this factor would be sealed Pu-Be neutron sources under license.

4.4 Total Screening Factor

A screening factor was the product of the HF, the operation factor, the CF, and the quantity in kilograms of special nuclear material. Determination of screening factors is illustrated in the example below.

Example 1: Sealed Pu-Be neutron sources

Plutonium (Ci)	Plutonium (kg)	Hazard factor	Operation factor	Containment factor	Screening factor	Tentative category
1	0.006	6.2E+5	0.01	0.1	0.37	OK
10	0.160	6.2E+5	0.01	0.1	99	OK
20	0.320	6.2E+5	0.01	0.1	198	Un

Example 2: Unsealed enriched uranium

^{235}U (kg)	Hazard factor	Operation factor	Containment factor	Screening factor	Tentative category
1	3.3E-1	0.01	1	.003	OK
10	3.3E-1	1	1	3.3	OK
100	3.3E-1	10	1	330	Un
1000	3.3E-1	1	1	330	Un
10000	3.3E-1	1	1	3300	No
100000	3.3E-1	0.01	1	330	Un

The total screening factor (TSF) is the sum of the individual screening factors. The TSF's varied from essentially zero to more than 10^6.

TSF		No. of records
<10		235
10 - 99		278
100 - 999		117
≥1000		38
	Total	668

The 155 records with TSF ≥100 represent 23% of the Part 70 computer file. These records were subject to group-analysis.

4.5 Tangible Factors in Categorization

The attempt at deriving a semitheoretical basis for initial categorization of docket folders was tempered by the physical form of the nuclide, which is frequently directly related to the containment question and of course the intended use. A generic categorization was compiled after enough dockets had been analyzed to see the evolving pattern, and thus be able to apply the generalizations as tabulated in Table 10.

A tangible factor such as a 10 CFR criterion can change and further amendments can be expected.[12] Docket 70-1008 is a case in point because Appendix C of Part 20 was amended May 22, 1970, to reduce the quantity of ^{235}U that may be buried in soil by a factor of 5,000 (from 50 μCi to 0.01 μCi), of which a single burial may consist of up to 1,000 times this specified value in Appendix C.

In general, it was not possible to apply these and other detailed criteria post facto except in obvious cases such as the cited docket 70-1008 where specific data were given. Presumably, lack of specific data meant compliance. Inspection reports were the chief source of specific data. This underlines the future need for more specific data by which to measure compliance with decommissioning criteria, that are economically reasonable and yet adequate to ensure protection of the public health. Since criteria in turn can be no better than the scientific data upon which they are based, it is essential that more animal pathology and human epidemiology studies be designed specifically for criteria needs.

Table 10. Generic categorizations

Nuclide	Physical form	Quantity	Sealed	Category	Note
Pu	Plated alpha sources	μg	No	OK	1
Pu	Pu-Be neutron sources	160 g	Yes	OK	2
Pu	Variable (R&D)	Variable	No	Variable	3
Pu	Variable (processing)	kg	No	No	4
Pu, U, FP's	Irrad'd fuel elements	kg	Yes	Variable	5
U-235	Fission counters	μg	Yes	OK	6
U-235	Variable (R&D)	g	No	OK	7
U-235	Unirrad'd fuel elements	kg	Yes	OK	8
U-235	Variable (processing)	kg	No	No	9
Other	Other	Variable	Yes/No	Variable	10

Notes:

1. Any amount of plutonium greater than 1 μg should be discarded eventually in such manner, form and location as not to exceed 10 ng per gram of material, above which it becomes transuranic waste to be kept separate from other radioactive wastes. Dockets involving microgram amounts of plutonium were cleared unless obviously irresponsible handling was suggested.

2. Few if any Pu-Be neutron sources exceeded 160 g (10 Ci). The minimum critical mass for plutonium in aqueous solution is about 500 g. All Pu-Be sealed sources under license with periodic leak testing, not exceeding 160 g total, combined or separate, per docket, were categorized OK on the assumption that constant and competent supervision under license is continuing where there is no docket documentation to indicate that proper disposal (transfer to another docket) has been made. This may or may not be a valid assumption. Pu comes under accountability control.

3. Unsealed plutonium in milligram quantities, used by responsible parties under license, probably OK, barring an unusual situation. Plutonium in gram quantities, sealed or unsealed, is a matter of some concern if there is possibility of human error, carelessness, unusual events such as accident, bankruptcy, break in inventory control, etc. Kilogram quantities of plutonium automatically should require reinvestigation of current situation (i.e., a continuing or periodic inspection basis).

4. Former processing of plutonium in gram and kilogram amounts deserves special attention, and unless there was recent and adequate documentation, such amounts were categorized No. The exception would be when evidence is strong that all of the plutonium left the site, and on-site plutonium residual had been reduced to ICRP permissible levels, and 10 CFR specification.

5. Irradiated fuel elements licensed for storage are OK only to the extent that none are leaking, which can be assured only through continuous monitoring.

6. Microgram amounts of ^{235}U were considered not much more hazardous than ^{238}U, when compared to ^{233}U and ^{234}U. It is unlikely (because of environmental dilution) that microgram amounts of uranium isotopes would be inhaled or ingested in undiluted form from microgram amounts under license.

7. Unsealed sources involving gram quantities of ^{235}U, under an R&D-type license considered OK.

8. Kilogram amounts of ^{235}U in sealed, unirradiated fuel elements under license considered OK.

9. Former processing of kilogram amounts of ^{235}U need reinvestigation where documentation was incomplete or unsatisfactory.

10. Other nuclides such as ^{241}Am, ^{210}Po and by-products were found infrequently in Part 70 dockets. Large quantities (grams to kilograms) need to be checked carefully, especially for radiological half-lives much in excess of 1 year, when categorized No or Un.

4.6 Intangible Factors in Categorization

The objective of this project was the practical one of separating dockets into safe and unsafe categories (i.e., of insignificant vs significant potential radiological health hazards to present and future populations) in the United States. Such a task cannot be divorced entirely from the scientific philosophy of what constitutes a "potential radiological health hazard," especially since regulations are changing.

The analysts were constantly faced with making judgments, for example, whether to apply an operation factor of one for a normal chemical operation or a factor of 10 for a wet and complex operation. In many cases there can be no clean-cut distinction. The screening factors call for a determination of the quantity of material and that in itself was difficult. Do you assume the licensed quantity, the licensed quantity times the number of years in operation, the quantity shown on material inventories, or none because a dated statement from a company executive affirmed they had never received material despite a license to do so?

Voluntary and involuntary risk to members of a population must therefore be balanced against direct and indirect benefits received by the general public and in terms of the economic costs involved. Our background thinking did not give primary emphasis to cost, or even to benefits. However, others using this report will need to do so. To the extent that the analysts were able to postulate a near-background situation for a given site, they tended to OK the site. It is important to bring up the issue of intangible factors in categorization since unconscious bias can affect categorizations where judgment has to be based on a mixture of subjective and objective factors.

4.7 Qualifications of Analysts

The analysis group included four individuals with diverse backgrounds in radiochemistry, industrial toxicology, health physics, and environmental science.

One of the analysts had over two years experience supervising the electromagnetic separation of uranium isotopes and more than 28 years experience in the field of radiochemistry. The experience in radiochemistry included:

1. isolation of micro quantities of promethium and neptunium from irradiated nuclear fuel;

2. measurement of the neutron capture cross-section and other physical constants for many of the fission products; and

3. development of analytical procedures for the analysis of soil and natural waters for ^{226}Ra, ^{230}Th, and ^{210}Pb from uranium milling sites.

Another analyst had over 15 years experience in health physics, industrial toxiciology, and related work. He also had five years experience in the construction and use of computerized data bases.

The third analyst had over 12 years experience in health physics and was certified by the American Board of Health Physics. His experience included participation in the Department of Energy's Formerly Utilized Sites - Remedial Action Program to characterize the radiological status of excess properties. He had also been involved in studies to develop decommissioning criteria.

The final analyst had a biological background and was pursuing an advanced degree in ecology. She was familiar with methods and instruments for field investigations in environmental science. She also had experience as an information systems specialist.

Collectively, the analysis group had the depth and breadth of training and experience required to address the wide variety of special nuclear material applications encountered in the terminated docket files. This group was adequately qualified to evaluate the potential for residual radiological health hazards that could exist at sites which had licenses to handle special nuclear material.

4.8 Ultimate Categorization

In view of the many theoretical and practical limitations upon any categorizing scheme that attempts to evaluate the potential radiological health hazard of a parcel of land with its fixed assets thereon (such as buildings), and its materials underneath (such as water, minerals, and buried waste), the ultimate categorization must be subjective, tempered with whatever objective facts the existing state-of-the-art can offer at a point in time. Hard, verifiable facts are far fewer than opinions, beliefs, theories, and feelings. A low-risk environment is achievable within certain technical and socioeconomic limits and population needs; a risk-free environment is not. Based on the limited data available in the docket files, we have made site categorizations. Followup will be needed on the questionable sites. If new information becomes available on those sites categorized OK, it may be necessary in some cases to reconsider such sites; the number of such, however, will probably be few if any. Conditions for safe use of radionuclides will continue to be a controversial subject until the biological effects of ionizing radiation are completely understood, including the basic mechanism of cancer induction.[13]

4.9 Limitations on Screening and Categorizing

In addition to routine processing errors at ORNL, some errors occurred during prior handling of the dockets, before arriving at ORNL. For example, some correspondence on the Dow Chemical Company intended for docket folder 70-1033 was found in a National Lead Company docket folder 70-1034. All material in 70-1019, transferred to 70-750, was located; but all material transferred from 70-1025 to 70-25 was not. In these few cases, one analyst might have categorized an empty docket as OK since it contained no adverse information about the site, while another might have categorized it as Un on grounds that adverse information might exist elsewhere for that docket. Problems of this type were resolved by group-analysis and re-input as group-analyzed dockets.

5. SUMMARY AND CONCLUSIONS

A total of 668 docket folders initiated by the AEC to control the licensing of special nuclear material, notably ^{235}U and plutonium isotopes, have been analyzed and categorized. From these dockets, 54 questionable sites have been identified with respect to their potential radiological health hazard to members of the general population. Categorization was based upon such factors as types and quantities of special nuclear materials entering, leaving, and remaining at the site, so far as could be ascertained from the available records. Documents examined included license applications, licenses issued and renewed, inspection reports, material transfer forms, correspondence, maps, blueprints, radiological surveys, and so forth.

A combined analysis worksheet and computer input form was designed for extracting, analyzing, and submitting essential data from the docket folders to a computer file that would meet NRC needs.

Those sites identified as questionable can serve as the starting point for NRC investigation. In some cases a visit, or a radiological survey, may be needed to generate missing data needed to clear the site or to clean it up for restricted or unrestricted use.

It is concluded that some dockets represent sites that can be returned to public use, while others may represent potentially serious problems that need attention, a few of which may require considerable expense to clean up for unrestricted use.

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