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Low-Level Radioactive Waste from Commercial Nuclear Reactors

Volume 4. Proceedings of the Workshop on Research and Development Needs for Treatment of Low-Level Radioactive Waste from Commercial Nuclear Reactors

H. W. Godbee
E. J. Frederick
R. L. Jolley
A. H. Kibbey
B. R. Rodgers

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Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road, Springfield, Virginia 22161
NTIS price codes—Printed Copy: A10 Microfiche A01

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Chemical Technology Division

LOW-LEVEL RADIOACTIVE WASTE FROM COMMERCIAL NUCLEAR REACTORS*

VOLUME 4. PROCEEDINGS OF THE WORKSHOP ON RESEARCH AND DEVELOPMENT NEEDS FOR TREATMENT OF LOW-LEVEL RADIOACTIVE WASTE FROM COMMERCIAL NUCLEAR REACTORS

(Activity KD 01 00 00 0, 00001)

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Manuscript Completed - October 1985

Date Issued - May 1986

Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
operated by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under Contract No. DE-AC05-84OR21400

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ABSTRACT

The overall task of this program was to provide an assessment of currently available technology for treating commercial low-level radioactive waste (LLRW), to initiate development of a methodology for choosing one technology for a given application, and to identify research needed to improve current treatment techniques and decision methodology. The resulting report is issued in four volumes.

As part of this program, a workshop was conducted for determining research and development needs in LLRW treatment. Volume 4, the proceedings of this workshop, includes the formal presentations and both panel and general discussions dealing with such issues as disposal, compaction, and the "below regulatory concern" philosophy. Summaries of individual workshops dealing with specific aspects of LLRW treatment are also presented in this volume.

PREFACE AND ACKNOWLEDGMENTS

Volume 4 of this Low-Level Radwaste Waste (LLRW) Treatment Assessment series represents the summary and proceedings of the Workshop on Research and Development Needs for Treatment of Low-Level Radioactive Waste from Commercial Nuclear Reactors, Arlington, Virginia, August 19-21, 1985. The workshop was organized and conducted by Oak Ridge National Laboratory (ORNL) for the U.S. Department of Energy (DOE), Office of Energy Research. We wish to express our appreciation to Robert G. Rader and George Y. Jordy, DOE, for program assistance, and to Jerre P. Nichols, Engineering Technology Division, ORNL, for supporting this stimulating workshop.

This is a crucial time for the continued development of nuclear energy as a national resource, and the public perception of radioactive waste disposal is an important factor, and perhaps a decisive factor, in this development. The general public must sift through a large mass of information, some of which is quite vitriolic, to discern the reality of the nuclear situation for our country. Accurate discernment may be very difficult, even in the best of situations. Waste disposal and problems associated with waste disposal are important issues within these information-collecting and decision-making processes. The purpose of this workshop was to determine the near- and far-term research and development needs for treatment of LLRW from commercial nuclear reactors. Some of the most knowledgeable people in the field were solicited to attend as leaders, speakers, discussants, and participants. We wish to express our appreciation to the attendees for their assistance and insight into our national R&D needs. This volume contains the results of their collective presentations and discussions on this important national issue.

The assistance of Martha Dawson and Debbie Brown in arranging and preparing these proceedings and discussion summaries was invaluable. The typing assistance of Anne Calhoun and Janice Shannon was also much appreciated. We also appredate the assistance of D. R. Reichle for technical editing of these proceedings.

The workshop planning committee consisted of B. R. Rodgers, Chairman; H. W. Godbee, Technical Program Coordinator; A. H. Kibbey, Technical Program Co-Coordinator; E. J. Frederick, Organization and Arrangements Coordinator; M. K. Bowers, Registration Coordinator; D. S. Brown, Secretary; M. M. Dawson, Secretary; N. C. Cardwell, Conference Officer; and R. L. Jolley, Workshop Coordinator.

We also express our appreciation to the speakers: Bob Rader, Roy Person, Sue Hobart, Charles Koplik, Larry Oyen, and Al Grella; panel discussion mentors: Don Charlesworth, Virgil Autry, Gary Benda, Nancy Kirner, George Kniazewycz, Frank Parker, Lenon Riales, and Sid Wright; and workshop leaders: Mike Thomas, Arlene Kibbey, Roy Post, Sam Clinton, Tom LaGuardia, Sharon Robinson, Radovan Kohout, Ed Frederick, Bob Neilson, and Mike Gilliam. This workshop would not have succeeded without their cooperation and valuable and informative contributions.

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1. PLENARY SESSION

1.1 INTRODUCTION, B. R. RODGERS

Good morning. Welcome to the Workshop on Research and Development Needs for Treatment of Low-Level Radioactive Waste from Commercial Nuclear Reactors. I am Bill Rodgers, the general chairman of the workshop. I would like to take this opportunity to introduce some of the people who are responsible for putting this workshop together.

First of all, I would like to introduce my cochairman, Bob Jolley. Bob has been responsible for overseeing most of the aspects of the workshop and is really probably "the" person to bestow your thanks upon for the job that is being done here. Bob has really worked hard to make this workshop a success.

Next, I would like to introduce the DOE program manager, without whom we could not be having the workshop, because he is sponsoring the project that this workshop is a part of, Dr. Bob Rader.

The technical part of the program, I think, is extremely well balanced in the distribution of the backgrounds of the people who were invited to participate, and, by the way, all of you were invited. We did not send out a general call for attendance. We tried to invite a particular audience that would be balanced, that would interact well in a workshop environment. The person who is the most responsible for this is Herschel Godbee.

Arlene Kibbey is also a technical program coordinator who has worked very hard in this effort. The organization and arrangements coordinator is Ed Frederick. There is a lot of effort involved in getting the organized structure that you will find here today, and Ed is primarily responsible for that.

Norma Cardwell has been instrumental in making all the arrangements for the workshop; Melinda Bowers, our registration person, whom I think you probably have met by now, has also contributed in many ways to the workshop.

I would now like to discuss the major goals of the workshop and the overall assessment that we are doing (Fig. 1).

ORNL WS 42528

MAJOR GOAL OF THE LLW WORKSHOP

- DETERMINE THE NEEDED R&D TO GIVE THE BEST TECHNOLOGY APPLICATIONS

MECHANISM:

OPTIMUM TECHNOLOGY APPLICATIONS MINUS CURRENT TECHNOLOGY APPLICATIONS GIVES THE TECHNOLOGY SHORTFALL, WHICH YIELDS THE R&D NEEDS

Fig. 1. LLRW assessment goals.

The major goals of the technology assessment itself, which is the overall project that we are working on, that the workshop is a part of, is to come up with a matrix of available technologies versus waste streams to aid decisionmakers in matching the best technology to a given waste stream. The second goal is to determine the research and development needs for the most efficient application of technology (Fig. 2).

To aid those overall goals, the major emphasis of the low-level radioactive waste workshop is to determine the needed R&D to give the best technology applications. Being a chemical engineer, I guess I think in terms of equations, so we have a mechanism here in an equation form, and I will try to put it into some words that make sense.

If we knew what the optimum technology applications were, and we subtracted what is currently being done, how current technology is being applied, then we would have what is called a technology shortfall, a gap between current applications and the "best possible" applications. So, today I challenge you to think about what the optimum technology might be for a stream - just let your mind wander a little.

We have recently, within the last couple of months, completed a survey of nuclear reactor operators. The results of that survey give us the current technology applications. We asked the operators what type of technology was being applied and to what stream. Bob Jolley will discuss that in a few minutes. In your packet we have included the results of that survey. We will use this as the base of how technology is currently being applied and, in the workshop, we would like for you to determine if that is a correct application of technology, and if not, what are some things that we should be doing.

Thank you.

Next, I would like to give an opportunity for Bob Rader to say a few words to you and particularly to correct me if I did not state the major goals correctly. Bob has an opportunity for rebuttal to tell you what the goals really are.

ORNL WS 42529

MAJOR GOALS OF THE COMMERCIAL LLW TECHNOLOGY ASSESSMENT

- A MATRIX OF AVAILABLE TECHNOLOGIES VS WASTE STREAMS TO AID DECISIONMAKERS
- THE RESEARCH AND DEVELOPMENT NEEDS FOR THE MOST EFFICIENT APPLICATION OF TECHNOLOGY

Fig. 2. LLRW workshop goals.

1.2 WELCOME, R. G. RADER

Thank you, Bill. I think you got the goals right. We worked long and hard for those.

I would like to welcome all of you here and to emphasize how important we feel your attendance is. First, I should explain a bit about my office and why I am here, and why we are interested in low-level radioactive waste.

I come from the Office of Program Analysis, which is within the Office of Energy Research. Dr. Trivelpiece, who, by legislation, is the chief science adviser to the Secretary of Energy, has the corporate responsibility across DOE for R&D assessment. My office fills that responsibility for him. Every year we try to do a few assessments of the R&D, in particular, areas that need emphasis or need assessments at the moment. We do not bend anybody's arm to do these assessments; we work jointly with the program managers.

The program manager for nuclear energy, or LLRW, is Jeff Smiley — he is here this morning and I think many of you know him. We began working on this assessment almost a year ago, working with Frank Coffman, who was then head of Jeff's office. Bill Voight, who is the current head of the office, is very much behind this effort, also.

A year ago it was discovered that we had two different communities of thought in LLRW. One said that the R&D was already in place, and there was no remaining federal role for R&D. Another one said that was very shortsighted, and we should be looking at what was needed and decide — let the community decide - whether there were R&D needs.

So, in part, that is why you are here today. We labored very hard to get the right people, as Bill said, getting a balance of people, so we can truly represent the community when we come out with the end result of this workshop.

I would encourage you to be candid in your views. I would encourage you to think of what the R&D needs truly are, without regard for whether there is a federal role there or not. We will separate the federal role at the end. There is a need to have long-term as well as short-term

R&D needs expressed. There is, I know, a great deal of thought within the community that there is a lot of economic benefit that could be gained by some short-term R&D, and there is a great deal of R&D that maybe only the federal government will attempt.

But please spread these out and give your thoughts full rein, being as concise as possible within the time frame that Bill has allowed us. Thank you.

1.3 PURPOSE AND SCOPE OF WORKSHOP AND RESULTS OF SURVEY OF COMMERCIAL NUCLEAR REACTORS ON METHODS OF LLRW TREATMENT USED, DISCONTINUED, OR UNDER CONSIDERATION, R. L. JOLLEY

1.3.1 Background Information

Good morning. First I want to acknowledge a person who has been very helpful, the person who is really responsible for the technical content and the flavor of this workshop - Herschel Godbee. Most of you know him through many years of LLRW work. He contributed much to make this workshop successful. Herschel, thank you very much.

I have been in LLRW research for only 1 year. Prior to that I was an environmental chemist. One of the things I perceive clearly as a newcomer to this area is that nuclear energy, which I have been involved with for 30 years, really depends upon waste — what we do with the waste. That seems like the tail wagging the dog, but that indeed is the case. The public perception of waste treatment and safe disposal is very critical at this time. The future of nuclear energy depends upon (1) the ability to make nuclear power plant waste treatment and disposal safe, economical, and environmentally sound, and (2) the public perception of nuclear waste disposal.

It appears that successful LLRW treatment is dependent upon three major factors (and perhaps in this order):

1. good management practices and philosophy;
2. dedicated and motivated personnel; and
3. appropriate and efficient treatment systems.

There are several purposes of this workshop: (1) determine the research and development needs for LLRW treatment; (2) define how we can improve it; (3) identify the problem areas; and (4) establish the research and development (R&D) needs.

We need to develop a priority order of R&D needs, to place this list in some sort of order or ranking. I do not like the word "prioritize," but that is in common vogue now. We also need to prepare a concise statement of the R&D needs, which is necessary for future program planning.

LOW-LEVEL RADIOACTIVE WASTE (LLW) FROM COMMERCIAL NUCLEAR REACTORS: ASSESSMENT OF TREATMENT METHODOLOGIES

[Please mark table with: D - for discontinued; U - for presently using (if a mobile unit indicate by adding M, i.e., UM); C - for considering]

*Mark only the treatment/waste combinations that are applicable. For simplicity of organization parallel construction was used, although it is obvious that certain methodologies are not applicable to all wastes.

Page 1 of 2 pages

TREATMENT METHODOLOGIES	AQUEOUS LIQUIDS	NONAQUEOUS LIQUIDS	WET RESIDUES					DRY WASTES				OTHER
			FILTERS	RESINS	SLUDGES	CONCENTRATES	OTHER	COMBUSTIBLE	NONCOMBUSTIBLE	COMPACTIBLE	NONCOMPACTIBLE	
Removal of water (dewatering)												
Evaporation												
Drying												
Centrifugation												
Filtration												
Reverse osmosis												
Ultrafiltration												
Electrodialysis												
Precipitation												
Coagulation/floc/ sedimentation												
Freeze-thawing												
Other												
Thermal and physicochemical												
Ion exchange												
Distillation												
Incineration												
Wet-air oxidation												
Oxidation/reduction												
Acid-digestion												
Electrolytic processes												
Smelting												
Other												
Biological												
Sorting/Segregation												

Fig. 1. Survey form.

TREATMENT METHODOLOGIES	AQUEOUS LIQUIDS	NONAQUEOUS LIQUIDS	WET RESIDUES					DRY WASTES				OTHER
			FILTERS	RESINS	SLUDGES	CONCENTRATES	OTHER	COMBUSTIBLE	NONCOMBUSTIBLE	COMPACTIBLE	NONCOMPACTIBLE	
Decontamination												
Mechanical												
Chemical												
Electrolytic polishing												
Ultrasonic cleaning												
Other												
Mechanical treatment (VR)												
Dismantlement												
Cutting, sawing, and shearing												
Shredding and grinding												
Baling												
Crushing												
Compaction												
Supercompaction												
Other												
Solidification												
Cement												
Asphalt												
Sorbents												
Glass												
Organic polymers												
Slagging												
Other												
Other Treatment Methods												

PROBLEM AREAS:

RESEARCH AND DEVELOPMENT NEEDS:

Name: _____ Phone Number: _____

Address: _____

Fig. 1 (Continued)

The scope of this workshop is expensive. We are dealing with LLRW treatment only for commercial nuclear reactors. This morning, we will have a general background from the speakers who are experts in their areas. They will discuss waste forms and sources, volume-reduction (VR) technology, regulations, packaging, and transportation. We have a panel of nationally and internationally known experts to discuss the important areas of compacts, de minimis criteria, and disposal. Then, this afternoon and tomorrow, we will have workshops in every area of LLRW treatment.

To provide additional background and information for this workshop and this DOE program, we prepared a survey (Fig. 1) that we sent to 76 reactors, of which 55 are operating reactors. We received 41 responses, which is about 75% of the operating reactors. We think that is a fairly good response. Although the survey was quickly done, we think it is a reasonably good survey. The purpose of the survey was to determine what technologies are used on what streams, and, also, to find out the specific problem areas and research needs of operating reactors. From this survey we developed a matrix of technologies versus waste streams, streams that I will summarize briefly. More detailed summaries of the survey responses, a listing of problem areas and R&D needs, and a listing of responding nuclear reactors are given at the end of this section.

The currently used technologies are summarized in Table 1. The difficulty with presenting summary data is that many technologies have more than one purpose. That is, we are not working with black marbles and red marbles and blue marbles that can be separated neatly in different bags, but technologies are like multi-colored marbles, which can not be divided or grouped neatly. The survey category dewatering, for example, is really treatment of water and includes ion exchange and other water treatments in addition to dewatering per se. Table 1 provides data on the number of process streams to which the "technology" is applied. Clearly, the most used technologies are mechanical treatment (e.g., VR methods like compaction), dewatering (principally ion exchange), decontamination processes, and solidification.

Table 1. Currently used technologies

I — Dewatering	172
II — Thermal, physicochemical	56
III — Biological	0
IV — Sort/segregate	84
V — Decontamination	142
VI — Mechanical treatment (VR)	181
VII — Solidification	121

More reactor operators are considering the use of mechanical VR treatments and solidification than other techniques (Table 2). You can see there is a big emphasis on volume reduction. Several reactor operators have discontinued using dewatering, decontamination, and solidification techniques (Table 3). The treatment of water (dewatering) is summarized in more detail in Table 4. Processes most used are drying, evaporation, and filtration. Ultrafiltration, filtration, and evaporation techniques are being considered most for adoption.

Ion exchange is the most used physicochemical technique (Table 5), but the most consideration is being given to incineration, a very important VR technique.

Most plant operators use several types of sorting/segregation (Table 6). The most used decontamination techniques are mechanical, ultrasonic, and chemical treatments.

Compaction, dismantlement, and cutting and sawing are the most used mechanical treatments (Table 7). Supercompaction and shredding are under most consideration as VR techniques for dry active waste.

In the area of solidification, cement techniques are most used and under most consideration (Table 8). Much consideration is also being given asphalt and organic polymer solidification methods.

I think we have a real challenge today to accomplish everything we would like to see accomplished. Again, I would like to express my appreciation to the planning committee and, principally, Ed Frederick and Arlene Kibbey, long-time members of the LLRW profession, who have contributed much to this workshop.

Our thanks go to all of you for participating in this nationally significant workshop. Thank you very much.

Table 2. Techniques being considered

I — Dewatering	27
II — Thermal, physicochemical	29
III — Biological	0
IV — Sort/segregate	16
V — Decontamination	27
VI — Mechanical treatment (VR)	72
VII — Solidification	48

Table 3. Techniques discontinued

I — Dewatering	19
II — Thermal, physicochemical	3
III — Biological	0
IV — Sort/segregate	0
V — Decontamination	13
VI — Mechanical treatment (VR)	0
VII — Solidification	11

Table 4. Dewatering

Treatment	Use	Con	Dis
Evaporation	38	6	5
Drying	49	1	6
Centrifugation	5	1	4
Filtration	38	6	0
Reverse osmosis	2	3	2
Ultrafiltration	4	8	0
Pcpt/coag/floc/sedim	7	0	0
Other	27	1	2

Table 5. Thermal, physicochemical, biological

Treatment	Use	Con	Dis
Ion exchange	41	2	0
Distillation	11	3	3
Incineration	2	24	0
Electrolytic	1	0	0
Other	1	0	0
Biological	0	0	0

Table 6. Sorting and segregation

Treatment	Use	Con	Dis
Sorting/segregation	84	16	0
Decontamination			
Mechanical	45	4	0
Chemical	24	6	7
Electrolytic	11	10	4
Ultrasonic	38	6	2
Other	24	1	0

Table 7. Mechanical treatment

Treatment	Use	Con	Dis
Dismantlement	24	1	0
Cutting, sawing, etc.	36	3	0
Shredding, grinding	16	29	0
Baling	8	2	0
Crushing	3	0	0
Compaction	74	6	0
Supercompaction	3	30	0

Table 8. Solidification

Treatment	Use	Con	Dis
Cement	47	24	10
Asphalt	9	14	0
Sorbents	19	5	0
Glass	0	0	0
Organic polymers	4	5	1
Slagging	0	0	0
Other	6	0	0

1.3.2 Survey Data

1. Survey responses for used technologies (Fig. 2).
2. Survey responses for considered technologies (Fig. 3).
3. Survey responses for discontinued technologies (Fig. 4).
4. Survey responses for used and considered mobile technologies (Fig. 5).
5. Listing of identified problem areas.
6. Listing of identified R&D needs.
7. Listing of responding nuclear power plants.

LOW-LEVEL RADIOACTIVE WASTE (LLW) FROM COMMERCIAL NUCLEAR REACTORS: ASSESSMENT OF TREATMENT METHODOLOGIES

[Please mark table with: D - for discontinued; U - for presently using (if a mobile unit indicate by adding M, i.e., UM); C - for considering]

*Mark only the treatment/waste combinations that are applicable. For simplicity of organization parallel construction was used, although it is obvious that certain methodologies are not applicable to all wastes.

Page 1 of 2 pages

TREATMENT METHODOLOGIES PRESENTLY BEING USED

TREATMENT METHODOLOGIES	AQUEOUS LIQUIDS	NONAQUEOUS LIQUIDS	WET RESIDUES					DRY WASTES				TOTALS	TOTALS (PLUS MOBILE UNITS)
			FILTERS	RESINS	SLUDGES	CONCENTRATES	OTHER	COMBUSTIBLE	NONCOMBUSTIBLE	COMPACTIBLE	NONCOMPACTIBLE		
Removal of water (dewatering)													
Evaporation	20	2	2	2	2	5	2	1		1	1	38	38
Drying			15	8	5	1		3	3	7	6	48	49
Centrifugation		1		3	1							5	5
Filtration	18	1	2	4	2		1		1		1	30	38
Reverse osmosis	2											2	2
Ultrafiltration	3					1						4	4
Electrodialysis					1	1						2	2
Precipitation													
Coagulation/floc/sedimentation	4	2			1							7	7
Freeze-thawing													
Other			7	11	4	2						24	27
TOTAL												160	172
Thermal and physicochemical													
Ion exchange	30	1		1			2	1				35	41
Distillation	7				1		2					10	11
Incineration		2										2	2
Wet-air oxidation													
Oxidation/reduction													
Acid-digestion													
Electrolytic processes											1	1	1
Smelting													
Other	1											1	1
TOTAL												49	56
Biological												0	0
Sorting/Segregation	5	6	2	1	1			13	13	24	24	89	89

Fig. 2. Survey responses for used technologies.

TREATMENT METHODOLOGIES	AQUEOUS LIQUIDS	NONAQUEOUS LIQUIDS	WET RESIDUES					DRY WASTES				TOTALS	TOTALS (PLUS MOBILE UNITS)
			FILTERS	RESINS	SLUDGES	CONCENTRATES	OTHER	COMBUSTIBLE	NONCOMBUSTIBLE	COMPACTIBLE	NONCOMPACTIBLE		
Decontamination													
Mechanical	2					1		3	9	5	25	45	45
Chemical	2	2	1	1		1		1	2	1	13	24	24
Electrolytic polishing		2				1			1	1	6	11	11
Ultrasonic cleaning	1	2	3	4		1			6	1	20	38	38
Other								3	6	4	11	24	24
TOTAL												142	142
Mechanical treatment (VR)													
Disassembly			1					2	8	4	25	40	40
Cutting, sawing, and shearing								3	6	5	22	36	36
Shredding and grinding								3	3	5	5	16	16
Baling								2	1	5		8	8
Crushing									1		2	3	3
Compaction			2					16	15	39	2	74	74
Supercompaction										3		3	3
Other											1	1	1
TOTAL												181	181
Solidification													
Cement	5	4	6	10	12	9					1	47	83
Asphalt		1	2	2	1	3						9	9
Sorbents	3	6	2	3	1			1	1	1	1	19	19
Glass													
Organic polymers	1			1	1		1					4	4
Slagging													
Other		1	1	2	2							6	6
TOTAL												85	121
Other Treatment Methods												0	0

PROBLEM AREAS:

RESEARCH AND DEVELOPMENT NEEDS:

Name: _____ Phone Number: _____

Address: _____

Fig. 2 (Continued)

LOW-LEVEL RADIOACTIVE WASTE (LLW) FROM COMMERCIAL NUCLEAR REACTORS: ASSESSMENT OF TREATMENT METHODOLOGIES

[Please mark table with: D - for discontinued; U - for presently using (if a mobile unit indicate by adding M, i.e., UM); C - for considering]

*Mark only the treatment/waste combinations that are applicable. For simplicity of organization parallel construction was used, although it is obvious that certain methodologies are not applicable to all wastes.

Page 1 of 2 pages

TREATMENT TECHNOLOGIES PRESENTLY BEING CONSIDERED

TREATMENT METHODOLOGIES	AQUEOUS LIQUIDS	NONAQUEOUS LIQUIDS	WET RESIDUES					DRY WASTES				TOTALS	TOTALS (PLUS MOBILE UNITS)
			FILTERS	RESINS	SLUDGES	CONCENTRATES	OTHER	COMBUSTIBLE	NONCOMBUSTIBLE	COMPACTIBLE	NONCOMPACTIBLE		
Removal of water (dewatering)													
Evaporation	4	1					1					6	6
Drying				1								1	1
Centrifugation		1										1	1
Filtration	1	1		1	1							4	6
Reverse osmosis	3											3	3
Ultrafiltration	6	1				1						8	8
Electrodialysis													
Precipitation													
Coagulation/floc/sedimentation						1						1	1
Freeze-thawing													
Other						1						1	1
TOTAL												25	27
Thermal and physicochemical													
Ion exchange	1					1						2	2
Distillation	3											3	3
Incineration	3	3	1	2	1			8		4	2	24	24
Wet-air oxidation													
Oxidation/reduction													
Acid-digestion													
Electrolytic processes													
Smelting													
Other													
TOTAL												29	29
Biological												0	0
Sorting/Segregation			1	1	1	1		4	4	2	2	16	16

Fig. 3. Survey responses for considered technologies.

TREATMENT METHODOLOGIES	AQUEOUS LIQUIDS	NONAQUEOUS LIQUIDS	WET RESIDUES					DRY WASTES				TOTALS	TOTALS (PLUS MOBILE UNITS)
			FILTERS	RESINS	SLUDGES	CONCENTRATES	OTHER	COMBUSTIBLE	NONCOMBUSTIBLE	COMPACTIBLE	NONCOMPACTIBLE		
Decontamination													
Mechanical								1			3	4	4
Chemical										1	5	6	6
Electrolytic polishing			1					1	1	1	6	10	10
Ultrasonic cleaning									1		5	6	6
Other											1	1	1
TOTAL												27	27
Mechanical treatment (VR)													
Dismantlement											1	1	1
Cutting, sawing, and shearing								1			2	3	3
Shredding and grinding								6	3	13	7	29	29
Baling										1	1	2	2
Crushing													
Compaction			1	1				1	1	2		6	6
Supercompaction								4	4	16	6	30	30
Other											1	1	1
TOTAL												72	72
Solidification													
Cement	2	3	3	5	3	3						19	24
Asphalt	2	1	2	3	3	2						13	14
Sorbents	2	1		1	1							5	5
Glass													
Organic polymers	1	1	1		1	1						5	5
Slagging													
Other													
TOTAL												42	48
Other Treatment Methods										1		1	

PROBLEM AREAS:

RESEARCH AND DEVELOPMENT NEEDS:

Name: _____ Phone Number: _____

Address: _____

Fig. 3 (Continued)

LOW-LEVEL RADIOACTIVE WASTE (LLW) FROM COMMERCIAL NUCLEAR REACTORS: ASSESSMENT OF TREATMENT METHODOLOGIES

[Please mark table with: D - for discontinued; U - for presently using (if a mobile unit indicate by adding M, i.e., UM); C - for considering]

*Mark only the treatment/waste combinations that are applicable. For simplicity of organization parallel construction was used, although it is obvious that certain methodologies are not applicable to all wastes.

TREATMENT METHODOLOGIES THAT HAVE BEEN DISCONTINUED

Page 1 of 2 pages

TREATMENT METHODOLOGIES	AQUEOUS LIQUIDS	NONAQUEOUS LIQUIDS	WET RESIDUES					DRY WASTES				TOTALS	TOTALS (PLUS MOBILE UNITS)
			FILTERS	RESINS	SLUDGES	CONCENTRATES	OTHER	COMBUSTIBLE	NONCOMBUSTIBLE	COMPACTIBLE	NONCOMPACTIBLE		
Removal of water (dewatering)													
Evaporation	4	1										5	
Drying		1		3	2							6	
Centrifugation	1	1		1	1							4	
Filtration													
Reverse osmosis	2											2	
Ultrafiltration													
Electrodialysis													
Precipitation													
Coagulation/floc/sedimentation													
Freeze-thawing													
Other					1	1						2	
TOTAL													
Thermal and physicochemical													
Ion exchange													
Distillation	1	1			1							3	
Incineration													
Wet-air oxidation													
Oxidation/reduction													
Acid-digestion													
Electrolytic processes													
Smelting													
Other													
TOTAL													
Biological												0	
Sorting/Segregation												0	

Fig. 4. Survey responses for discontinued technologies.

TREATMENT METHODOLOGIES	AQUEOUS LIQUIDS	NONAQUEOUS LIQUIDS	WET RESIDUES					DRY WASTES				TOTALS	TOTALS (PLUS MOBILE UNITS)
			FILTERS	RESINS	SLUDGES	CONCENTRATES	OTHER	COMBUSTIBLE	NONCOMBUSTIBLE	COMPACTIBLE	NONCOMPACTIBLE		
Decontamination													
Mechanical													
Chemical									3		4	7	
Electrolytic polishing										1	3	4	
Ultrasonic cleaning									1		1	2	
Other													
TOTAL												13	
Mechanical treatment (VR)													
Dismantlement													
Cutting, sawing, and shearing													
Shredding and grinding													
Baling													
Crushing													
Compaction													
Supercompaction													
Other													
TOTAL													
Solidification													
Cement			1	4		4		1				10	
Asphalt													
Sorbents													
Glass													
Organic polymers						1						1	
Slagging													
Other												1	
TOTAL												12	
Other Treatment Methods												0	

PROBLEM AREAS:

RESEARCH AND DEVELOPMENT NEEDS:

Name: _____ Phone Number: _____

Address: _____

Fig. 4 (Continued)

LOW-LEVEL RADIOACTIVE WASTE (LLW) FROM COMMERCIAL NUCLEAR REACTORS: ASSESSMENT OF TREATMENT METHODOLOGIES

[Please mark table with: D - for discontinued; U - for presently using (if a mobile unit indicate by adding M, i.e., UM); C - for considering]

*Mark only the treatment/waste combinations that are applicable. For simplicity of organization parallel construction was used, although it is obvious that certain methodologies are not applicable to all wastes.

KEY

UM-Using mobile
CM-Considering mobile

MOBILE TREATMENT METHODOLOGIES PRESENTLY BEING USED OR CONSIDERED

Page 1 of 2 pages

TREATMENT METHODOLOGIES	AQUEOUS LIQUIDS	NONAQUEOUS LIQUIDS	WET RESIDUES					DRY WASTES				TOTALS	
			FILTERS	RESINS	SLUDGES	CONCENTRATES	OTHER	COMBUSTIBLE	NONCOMBUSTIBLE	COMPACTIBLE	NONCOMPACTIBLE	UM	CM
Removal of water (dewatering)													
Evaporation													
Drying						UM-1						1	
Centrifugation													
Filtration			UM-3	CM-1 UM-3	CM-1 UM-2							8	2
Reverse osmosis													
Ultrafiltration													
Electrodialysis													
Precipitation													
Coagulation/floc/sedimentation													
Freeze-thawing													
Other			UM-1	UM-1		UM-1						3	
TOTAL													
Thermal and physicochemical													
Ion exchange	UM-4	UM-1		UM-1								6	
Distillation		UM-1										1	
Incineration													
Wet-air oxidation													
Oxidation/reduction													
Acid-digestion													
Electrolytic processes													
Smelting													
Other													
TOTAL												7	
Biological													
Sorting/Segregation													

Fig. 5. Survey responses for used and considered mobile technologies.

TREATMENT METHODOLOGIES	AQUEOUS LIQUIDS	NONAQUEOUS LIQUIDS	WET RESIDUES					DRY WASTES				TOTALS	
			FILTERS	RESINS	SLUDGES	CONCENTRATES	OTHER	COMBUSTIBLE	NONCOMBUSTIBLE	COMPACTIBLE	NONCOMPACTIBLE	UM	CM
Decontamination													
Mechanical													
Chemical													
Electrolytic polishing													
Ultrasonic cleaning													
Other													
TOTAL													
Mechanical treatment (VR)													
Dismantlement													
Cutting, sawing, and shearing													
Shredding and grinding													
Baling													
Crushing													
Compaction													
Supercompaction													
Other													
TOTAL													
Solidification													
Cement	CM-1 UM-6	UM-5	CM-1 UM-4	CM-1 UM-7	CM-1 UM-7	CM-1 UM-7						36	5
Asphalt													
Sorbents													
Glass													
Organic polymers													
Slagging													
Other													
TOTAL												36	6
Other Treatment Methods													

PROBLEM AREAS:

RESEARCH AND DEVELOPMENT NEEDS:

Name: _____ Phone Number: _____

Address: _____

Fig. 5 (Continued)

LLRW SURVEY RESULTS: SPECIFIC PROBLEM AREAS IN LLRW TREATMENT

Twenty-two of 41 responding nuclear plant operators indicated the following problem areas:

1. Permanent system (in Pre-op)
2. In-plant solidification sytem
3. Evaporators
4. Traveling belt filters in radwaste systems
5. Oily waste
6. Wet sludge
7. Stabilization of oil and oily material
8. Filters
9. Low-level resin
10. Oil
11. Sand and rubble
12. Exposure with cleanup when using solidification
13. Contaminated oil
14. Organics
15. Noncompactible liquid stream filters
16. Spent resin sampling
17. Filter disposal methods
18. Cobalt and cesium removal via resins
19. Oil
20. Mercury
21. Liquid scintillation cocktail
22. Waste oil decontamination
23. Solidification of bead resin (10 CFR 61)
24. Solidification of oil and oily materials
25. Stability requirements of 10 CFR 61
26. Burial of waste (1986)
27. Overall volume reduction
28. Resin activity measurement
24. Sludge in waste collection tanks
25. Handling and disposal of liquid scintillation vials (bottles), and aerosol cans
26. Storage space
27. Waste oil — low-level contamination

LLRW SURVEY RESULTS: SPECIFIC R&D RECOMMENDATIONS

Seventeen of 41 responding nuclear plant operators indicated the following R&D needs:

1. Chemical decontamination of the full reactor coolant system (RCS) including fuel
2. Methods for destroying chelates
3. Reduce and/or remove concerns on exotic nuclides, i.e., C-14 for disposal; cost of analysis outweighs benefits or concerns
4. Gamma scan of spent resin storage tank to determine whether solidification is necessary (currently all resins are solidified)
5. Sludge treatment
6. Incineration
7. Decontamination
8. Incineration
9. Removal of fines from liquid waste system
10. Means of regeneration of bead resin such that nearly 100% ion exchange capacity is possible, even if the bed were <20% capacity before regeneration
11. Resin with greater capacity
12. Methods for processing oil
13. Methods for processing mercury
14. Methods for processing scintillation cocktail
15. Methods for analyzing non-LSA
16. Methods for packaging mechanical filter cartridges that exceed waste class "C" or 100 nCi/g TRU
17. Incineration
18. Drying
19. Mobile incineration service
20. De minimis level for release of oil, rubble, sand, and low-level resin
21. TRU low-level analysis
22. Waste stream analysis (10 CFR 61)
23. VR for resins
24. Incineration of DAW and other materials
25. Develop de minimus level for all nuclides

26. Oily waste
27. Wet sludge
28. Contaminated oil treatment and disposal
29. Reliable in-plant solidification system — uncomplicated/low maintenance
30. Economically feasible VR technologies

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1.4 PRESENTATIONS

1.4.1 Future Considerations for Low-Level Waste Treatment, L. S. Person

Future treatment of low-level radioactive waste will most likely be governed by new disposal techniques (including packaging and processing) and must be considered in the light of any changing regulatory requirements. This section will focus on current stability and classification requirements for low-level waste forms and examine how the current criteria (established to ensure stability) must be considered prior to preparing low-level waste forms for disposal.

1.4.1.1 10 CFR 61 "Licensing Requirements for Land Disposal of Radioactive Waste"

- Waste Classification and Waste Form

The most important requirements of 10 CFR Pt. 61 that affect the treatment of low-level waste are requirements on waste form and waste classification. The basic requirements for waste classification are contained in Sect. 61.55 of 10 CFR Pt. 61. This section establishes three classes of waste based on radiological hazard and the radionuclide concentration in the wastes. All three classes of waste (Class A, Class B, and Class C) must meet minimum waste form requirements.

The minimum waste form requirements are contained in Sect. 61.55(a) and include requirements for the minimization of free liquids, the minimization of voids, and the prohibition against the disposal of toxic gases and pyrophoric, pathogenic, or explosive materials. Class A waste that contains lower concentrations of radionuclides must meet the minimum waste form requirements and be segregated from Class B and C wastes at the burial site unless stabilized.

Class B waste is a waste containing higher concentrations of radionuclides than Class A waste and must meet the minimum and stability requirements of 10 CFR Pt. 61. Class C waste has higher concentrations of radionuclides than Class B waste and must be protected against inadvertent intrusion as well as meet the minimum and stability requirements. This protection against inadvertent intrusion may be provided by such means as deeper burial (below 5 m) or construction of long-term barriers.

One way a waste generator can demonstrate waste form stability is by performing the tests described in the Technical Position (TP) on Waste Form. Those tests aid in determining the ability of solidified waste or container materials to be resistant to effects such as radiation exposure, fungal and bacterial growth, burial site loads, and water immersion. The tests described in the TP also help to provide evidence of the waste form's ability to withstand structurally degrading effects over 300 years.

- Achieving Waste Stability

There are several ways stability can be achieved. The waste may contain inherent stability due to its physical form. Thus, metal objects may already dimensionally be stable, and if so, credit can be taken. There are also two alternative methods described in 10 CFR 61 for dealing with wastes that contain liquids. These wastes can be processed to a stable form or placed in an HIC. The volume of drainable liquids should be no more than 0.5% for solidified products and <1.0% for wastes in HICs. In addition, stability can be provided at the burial site. This may be done through processing technology or engineered disposal concepts.

1.4.1.2 New Considerations for Low-Level Waste Treatment

- Decontamination Wastes

In the future, decontamination wastes will consitute a much higher percentage of waste requiring disposal. This will occur in an effort to reduce exposures from the buildup of activation products and sludge in nuclear power plants. These wastes will be composed largely of organic chelating agents, which may complex radionuclides and enhance migration in burial site soils. This will also require greater than normal care in producing acceptable solidification products, as described in BNL A-3253. Other technologies not in wide use have been the subject of recent research, as reported in BNL-NUREG-52699, and may offer acceptable alternatives to solidification alone (e.g., wet air oxidation, incineration, pyrolysis, acid digestion). Some of the treatment methods

may not completely degrade chelating agents or organics, and treatments will need to be provided for residual waste streams.

- Volume Reduction (VR)

  Since many state compacts require VR, there will probably be an increased demand for new VR systems as these compacts are enacted. Additional research will, therefore, be required to ensure safe and effective operation of advanced VR systems and to study the characteristics of the wastes produced.

- Incineration

  Incineration is a very viable option even with the potential for political opposition to obtain state permits. For organic materials, such as scintillation cocktails and decontamination chemicals, it offers a desirable alternative to solidification. Incineration can degrade organic chemicals, remove their hazardous potential, and improve the ability of soils to retain radionuclides. Attempts to incinerate new kinds of wastes may require additional research to ensure process optimization and control.

- Decommissioning Waste

  Decommissioning waste streams are not yet clearly defined. Research needs to be done to characterize waste that would result from the cutting and packaging of hardware, left-over rubble, and other kinds of waste that are generated from decommissioning facilities. This research must be done with an eye toward what will be required by states for disposal as well as optimizing processing.

- Engineered Disposal

  Engineered disposal will be evaluated using similar considerations and criteria in place for conventional shallow-land burial. In some cases, engineered disposal structures may be designed to provide waste stability. Under these conditions, detailed waste stream stability testing may not be needed. Two examples of engineered disposal concepts are provided below.

  - Westinghouse "SurPack"

    The Westinghouse Surepack is a concrete module, or overpack, which can be used to provide stability to resin liners,

solidified wastes, dry active waste, etc. The module is hexagonal in shape and is designed to be stacked and tightly packed in disposal units. Once the waste is placed in Surepack Modules, the void spaces in the modules are grouted with concrete before being closed with a concrete cover having protruding reinforcement bars. The reinforcement bars penetrate into the grout and are stabilized when the grout hardens. These modules could be evaluated as HICs and could provide stability for all wastes shipped for disposal.

- La Centre De La Manche

La Centre De La Manche is a French government owned and operated disposal facility located near Cherbourg, France. The disposal units for this facility are constructed by first excavating a large trench. Once the trench is excavated, a concrete pad is laid. On this pad, wastes are encapsulated with cement to form a large monolith. On top of this monolith lower-activity wastes are stacked to create a tumulus. The entire facility is then covered with 3 m of soil, revegetated, and contoured to the natural surroundings. The design incorporates a special drainage system to control liquids percolating through the facility and to allow monitoring prior to discharge or further processing.

- Potential Requirements for Greater than Class C Waste

In general, a generator must be cognizant of any treatment method that might cause reconcentration of wastes which will change their waste class. He must be able to reasonably quantify his radioactive waste constituents and should have a process control plan to ensure that waste concentrations do not significantly deviate from what is anticipated. For wastes that contain concentrations of radionuclides greater than those listed for Class C, additional requirements are now being identified. These will include additional intruder barriers as well as demonstration that the performance objectives contained in Sect. 61.58, Pt. 61 will be met. These performance objectives include restriction on release of radioactive material to the general public, protection of individuals from inadvertent intrusion, protection of workers, and measures to ensure stability of the disposal site after closure.

1.4.2 Problems Have Solutions, S. A. Hobart

I originally planned to talk about low-level waste forms and sources, but have decided instead to talk this morning on the subject, "Problems Have Solutions."

The purpose of this workshop is to identify areas related to low-level radioactive waste that need research and development, areas where DOE funding could be beneficial.

I was asked to particularly direct my remarks to the subject of LLRW forms and sources. We do not have to look far in that area to find problems. Finding the solutions is more difficult, but there are solutions to be found.

This morning I will restrict my remarks to LLRW generated from commercial nuclear power plants. I will speak on three topics; first, on the identification of forms and sources; second, the current problems related to forms and sources; and third, ongoing activities in search of solutions. I will conclude my remarks by asking each of you to accept a challenge to participate in finding the remaining solutions.

There are two sources of LLRW generated, fission products from leaking fuel elements and activated corrosion products from circulating corrosion scale released by the balance-of-plant systems. The radionuclides circulating in the coolant are removed in purification systems by unit operations such as ion exchange, filtration, and evaporation. These purification systems are the sources of processing waste. Contamination from piping leaks or maintenance activities form the sources of maintenance waste.

If we categorize all the waste produced, we will find four basic forms: (1) liquids and solids, such as evaporator concentrates, decon solutions, and oils; (2) wet solids, such as ion exchange resins, wet charcoals, or wet catalyst filter sludges; (3) dry solids, of which there are not many examples currently, but ash, powder from dryers, and dry resin can certainly fit in that category; and (4) dry active waste (DAW), which is everything else. These are the waste forms, as generated.

There are three classifications of shipments: Type A, Type B, and low specific activity, or LSA (Fig. 1). Types A and B are based on

LLW Packages Have Four CLASSIFICATIONS FOR SHIPMENT

SHIPMENT CLASSIFICATIONS	DISPOSAL FORMS AND PACKAGES
• Type A	Solidified Waste: Drums, Liners
• Type B	Non-Solidified Waste: Liners, HIC's
• Low Specific Activity (LSA)	Compacted Waste: Drums, Boxes

Fig. 1. LLRW classifications for shipment.

contained total quantities of radioactive material; A has the lowest quantity, B is higher. Material having a low level of activity per unit mass, that is microcuries per gram, is labelled LSA. Dry active waste (primarily maintenance waste) generally falls into the LSA category. All that is required of that container is that it be strong tight. Typically, the waste is compacted into 210-L (55-gal) drums or metal or plywood boxes. The rest of the power plant waste (processing waste) is shipped as Type A or B. That waste can be solidified into 210-L (55-gal) drums or disposable liners for casks. Dry powders or moist solids can be shipped in a nonsolidified state in disposable liners for very low levels of radioactivity, or high-integrity containers, known as HICs. Process piping components can usually be disposed of as DAW or in liners (unsolidified). These three forms, solidified, nonsolidified, and compacted wastes, are the three disposal forms of low-level radioactive waste.

To summarize, we have identified the sources of LLRW, that is, fission products and activated corrosion products, removed by the plant purification systems and generated by regular maintenance activities. We have identified the waste forms as generated, liquids and slurries, wet solids, dry solids, and DAW. Finally, we have identified the disposal waste forms, solidified, nonsolidified, and compacted (Fig. 2).

I would like now to address the issue of problems related to LLRW sources and forms. Radwaste became a critical issue for utilities about 7 years ago for two reasons, increasing volumes and rising costs. Volumes were an issue both at the plant level, where the operators were being inundated by waste they could not ship, and at the national level, because the increasing demand and decreasing supply of burial space caused price escalations.

From the utility perspective, the solution to the problem could be addressed by attempting to minimize the waste generated and optimizing the processing of those wastes for disposal. That sounded like a simple approach. It turned out not to be so simple, however. Utilities began implementing this philosophy 5 to 6 years ago. As a result, many new obstacles have developed, preventing the solution of the original problems of increasing volumes and rising costs.

Summary: Radionuclides In Coolant Become LLW

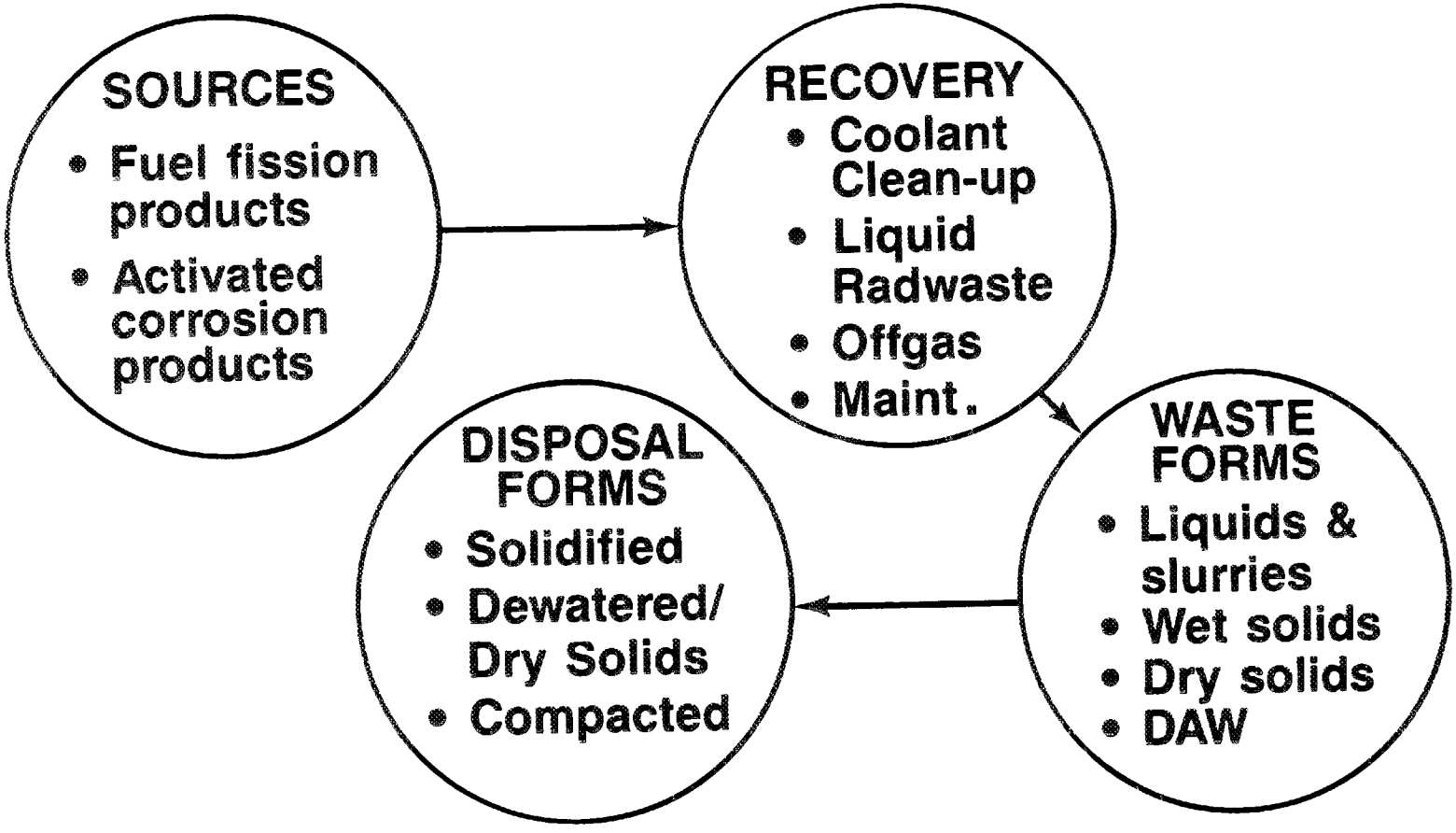

Fig. 2. Radionuclides in coolant became LLRW.

Minimizing waste generated is indeed the ultimate solution to the issue of LLRW. Utilities have shown great initiative in trying to minimize waste at its source. Special waste reduction campaigns have been implemented, entailing publicity and recognition for employees generating waste minimization ideas. Hand-in-hand with those efforts has been an increase in personnel training and the promotion of radwaste awareness site-wide. These efforts have not, however, received as much time or attention as efforts to reduce the volume of waste after it has already been generated. This topic of volume reduction will be covered in more detail by a later speaker. I will indicate here only a summary of the ways that can be used to reduce the volume of generated waste (Fig. 3). Additional compaction, incineration, increased waste loading, and advanced chemical process equipment all involve putting more radioactivity into a smaller volume. The disposal of low-level quantities as uncontaminated waste, also known as de minimis or "Below Regulator Concern" (BRC) disposal, reduces the volume of wastes requiring special handling as radwaste. Some illustrations of volume-reduction equipment that are still considered novel include: shredders, which can be used either in place of compaction or as compactor feed preparation; super-compactors, which take compacted waste and super compress them into "hockey pucks"; dryers and incinerators that have been developed for liquid slurries and combustible shredded material; and waste extruder-evaporators, in which evaporation and solidification occur in the same unit.

Volume reduction is not the ultimate solution, however (Fig. 4). Indeed, implementing these volume-reduction systems has caused us additional problems. The first problem that appeared was with evaporators. We have proven to ourselves that we cannot use fruit juice concentrators to process radwaste. We have also put a bad taste in the mouths of utility operators for any chemical process equipment that is similar in nature. Advanced volume-reduction systems for concentrating waste are costly and are complex to operate. Furthermore, they do not address the real issue of generating the radioactive waste; they only address the political problem of its volume. Personnel radiation exposure is increased with the use of volume-reduction equipment. They are sophisticated systems; therefore, they require more maintenance. The higher

Shipped Waste Volumes Can Be Reduced

- Additional compaction
- Incineration
- Increased Waste Loading
- Advanced chemical process equipment
- BRC (deminimis) waste

Fig. 3. Volume reduction.

VR Solutions Were Not Ultimate Solutions

- Evaporators originally of poor design
- Increased complexity/cost of sophisticated VR systems
- Increased personnel exposure
- Potential for shifting waste package classification
- Potential landfill or plant-area contamination

Fig. 4. Problems encountered in volume reduction.

radionuclide content per drum results in higher radiation fields in storage areas at the plant. Conceivably, waste classification could be altered by putting so much waste in one container that, for instance, LSA waste could become Type A, or Type A could become Type B. This classification shift would result in an increase in cost and time for the utility to dispose of the material. Discarding packing materials before they enter into a radiation zone is prudent. Discarding materials that have been there entails some risk. We have already seen a case or two of contaminated landfills. It is not inconceivable that we could have radioactive snow or rain resulting from burning or contaminated radioactive waste. Therefore, the whole issue of de minimis or BRC disposal is rather open-ended. We do not know what problems will be generated from this practice.

In addition to the technical problems we have created for ourselves in concentrating on volume reduction rather than reduction of waste sources, now there are new problems due to "environmental" factors, that is, factors outside our control (Fig. 5). The current uncertainties with the timing of compacts and decreasing waste volume allocations at existing burial sites raise two issues: how do we continue to reduce volume shipped? and Must we provide on-site storage "just in case"? Another related question is whether states will have the right to force plants to hold incompatible waste forms from hospitals and laboratories in on-site storage facilities. Burial site requirements for waste forms are not uniform: Nevada requires solidification of resins and allows no HICs; Washington allows absorbed liquids and oils, but the others will not. It appears that this situation will only get worse. The requirements of the new compact burial sites are completely unknown. Since state politicians will be involved, it is likely they will be more stringent. In what ways? What kinds of paperwork will be required? What waste forms? What advanced notice of in-transit tracking? How can we prepare now when we do not know for what to prepare? New federal regulatory concerns have arisen. It could be argued that we caused those as a result of putting more radioactivity in each container. So now, how do we best identify the isotopes in that waste? Are scaling factors the answer? Are they in the best interest of either the utility or the public? How do we monitor and predict hydrogen generated from radiolytic degradation of organic

"Environmental" Factors Create Uncertainty

- Burial site availability is uncertain
  - Volume reduction
  - On-site storage
- Burial site requirements inconsistent/unknown
- New regulatory concerns have arisen
  - Isotope monitoring
  - H_2 generation

Fig. 5. Environmental concerns.

materials, such as resins? More seriously, how do we make that waste form stable at the burial site over the long term?

I have just identified many problems that stand in the way of minimizing waste and complying with waste form criteria and would like to return to the theme stated at the beginning of the talk: "Problems do have Solutions." Solutions always require thought, imagination, and creativity. Solutions often require investment of time and money. This last is the area to be addressed by this workshop, that is, identifying areas where DOE funding of R&D would be helpful (Fig. 6).

To be effective, DOE efforts must be coordinated with and complimentary to existing work. This raises the question, however, of what approaches have already been taken for finding solutions. Utilities and service companies are working together to develop computerized methods for waste tracking. As we become more aware of its generation, it becomes much easier to address the issue of reduction at the source. Fuel suppliers have been attempting to provide better fuel, architect/engineers have been attempting to provide better, more corrosion-resistant designs, and utilities have been making an effort to curb DAW generation.

A great deal of effort and money has gone into the area of volume reduction: EPRI has funded surveys of equipment available and the economics of using that equipment; DOE has furnished a grant for development and licensing of the mobile incinerator at Commonwealth Edison. Service companies are starting to provide regional volume-reduction facilities. (I would insert here a reminder, however, that volume reduction may be a political necessity, but it is not the ultimate answer to LLRW. It does generate its own set of problems.)

Utilities have forced the issue of de minimis or BRC disposal. Vendors have done some work on improved low-level monitors, but, basically, we are still taking risks.

Architect/engineers and service companies have provided us with the means of storing waste on-site. Still to be addressed is the prevention of being forced to accept nonplant waste by the states (Fig. 7).

In the area of paperwork, DOE has helped by funding the development of the uniform manifest, and they are funding recertification of 210-L (55-gal) drums, in response to DOT concerns.

Some Work Toward Solutions Is In Progress

- **MINIMIZING WASTE PRODUCTION**
  - In-plant waste tracking
- **MINIMIZING VOLUME SHIPPED**
  - Economics (EPRI)
  - Mobile VR (DOE)
  - Regional VR
  - Enhanced IX loading (EPRI)
- **PREVENTING BRC-RELATED "ACCIDENTS"**
  - Improved monitoring devices

Fig. 6. Progress toward solution of problem areas.

Some Work Toward Solutions Is In Progress

- ON-SITE STORAGE
  Facility design and containers available

- PAPERWORK REQUIREMENTS
  Uniform manifest (DOE)
  Drum certification (DOE)

- REGULATORY CONCERNS
  Waste form verification
  Isotope identification/monitoring
  (EPRI, AIF)
  H_2 generation (EPRI)

- UNIFORMITY OF WASTE FORM REQUIREMENTS

Fig. 7. Further progress toward solutions.

Is there a way of ensuring that the publication of a national manifest will encourage its adoption by compacts, however?

Utilities are working with service companies to develop process control plans that ensure proper solidification. Problems with dewatering and free-standing water remain, however. Some work at TMI was performed using alcohol to dewater resins, but utilities have been hesitant to take the associated risk with implementing that technology.

Although both EPRI and Atomic Industrial Forum (AIF) have funded some work on the estimation of isotopes by using scaling factors, these approaches lead to conservative estimates and do not ensure an accurate accounting of radioactivity placed in the burial trenches. It is doubtful whether grab samples taken midstream can be considered representative of a full liner of waste. Although making an isotopic estimate from a gross gamma dose may be reasonable under normal operating conditions, we know it assuredly is not during special operations such as decontamination. For this reason, more work on improved isotopic monitoring probably needs to be funded. Methods and instrumentation for scanning pipes during waste transfer and 'counting' filled casks have already been pursued through EPRI funding.

EPRI has been funding some work on development of a computer program to predict hydrogen generation from waste. Service companies have developed hydrogen vents on waste containers. We need to ensure that the waste forms will be stable at the burial site, in the burial trench, over the long term. Perhaps the most critical short-term question is, How can we be assured the compact requirements for waste forms will be uniform and reasonable?

In summary, we have identified the sources of low-level radioactive waste and described waste forms and disposal forms (Fig. 8). We have looked at the original LLRW problems of increasing volumes and increasing costs and have discussed the current plant problems with achieving waste minimization. We have examined some current activities aimed at funding solutions and have noted areas where more work appears to be needed.

I want to end with the thought that there is an issue beyond cost-benefit in the search for LLRW solutions, the issue of stewardship. This is the earth on which we live. We have the responsibility of managing radioactive waste to ensure the safety of our world and future generations. We also, however, have the responsibility to convey our dedication

Summary

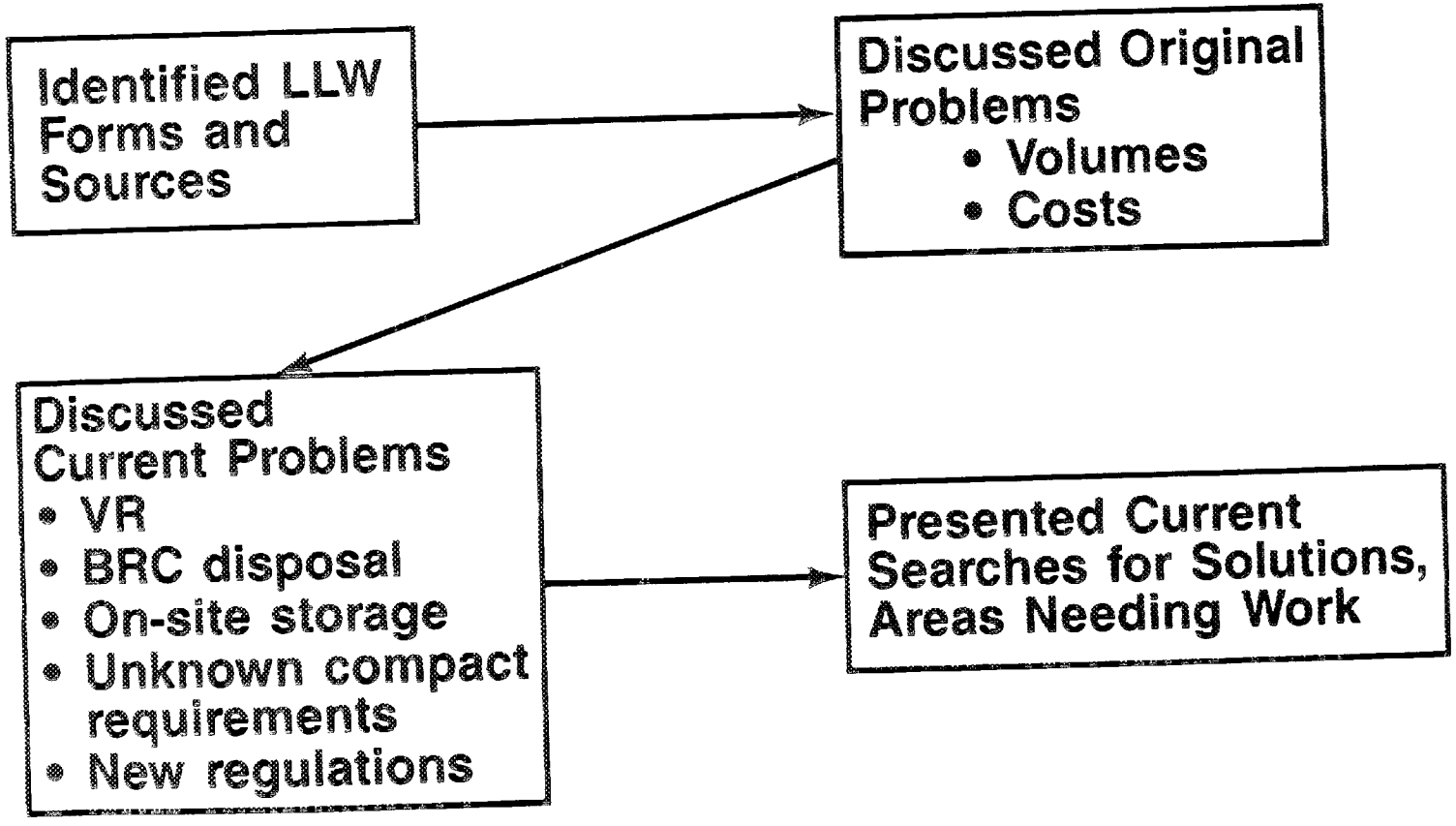

Fig. 8. Summary

for those solutions to the public. By assuaging their concerns, we will not preclude the use of the most environmentally safe energy technology today, nuclear power.

In the interest of encouraging this stewardship, I want to present a challenge to each attendee (Fig. 9). I challenge utilities to continue their pursuit of solutions, recognizing that the primary motivation to date has been economic. I challenge you now to go the extra mile; to dedicate yourself to waste minimization and volume reduction, even in marginally cost-effective situations, for the benefit of the industry. I challenge the architect/engineers and equipment manufacturers to set their sites beyond acceptability; to set standards according to what is best, rather than what is expedient; to focus on the problem, prevention of waste through reduction of fission product release and corrosion product transport. I challenge the regulatory agencies to continue their functions of safeguarding the public. But I further challenge you to instill enthusiasm and vitality into your everyday work, so that the momentum and enthusiasm provided with the passage of the Nuclear Waste Policy Act will continue, and the industry will be encouraged toward progress. I commend DOE and challenge them to follow through on their interest in providing R&D funding for low-level waste. I further challenge you to coordinate your efforts with existing R&D sponsors, such as Empire State Electric Energy Research Center (ESEERCO), EPRI, and AIF, so that the work will be fruitful and complementary.

Finally, I charge every attendee at this workshop to remember that problems do have solutions. The reason we are here this week is to identify avenues leading toward those solutions. Let each one of us go into the workshop sessions committed to use our minds, experiences, and imaginations to identify potential solutions. I assert that the contributions we as individuals make this week may well be some of the most important work of our careers. Let each of us be a part of the solution.

Challenges

- Utilities
- Architect-Engineers/Manufacturers
- Regulatory Agencies
- DOE

Fig. 9. Challenges.

1.4.3 VRTECH and the Volume Reduction Option, C. M. Koplik and M. S. Giuffre

Reducing the volume of radioactive waste generally lowers its burial cost. In some cases the resulting savings can pay for the expenses of volume reduction, including the investment in equipment. The VRTECH code, developed as part of a major EPRI-sponsored study of volume reduction, is used to assess the economics of VR equipment operations. The project team for the study consisted of TASC, Burns and Roe (who provided equipment descriptions), and RAECO (who provided the burial cost models); the results of the study have been published as a five-volume EPRI report, NP-3763.

The VRTECH computer program is a tool for the utility decision maker. TASC analysts designed it to supply the cost information needed by utilities when choosing among waste management options. The program facilitates economic comparisons between alternative waste treatment and disposal systems. It tracks the movement of wastes from generation to burial, determining the costs incurred at each step along the way. By including price escalations and the time value of money in the calculations, VRTECH evaluates all costs on a common basis that may be chosen by the program user.

The time value of money is accounted for by calculating the present value of revenue required (PVRR) for the equipment lifetime. The PVRR is the amount of money that would yield sufficient revenue to pay for all disposal costs during the equipment operating life, if it were all invested at some initial time.

Figure 1 illustrates the process for a calculation made in December 1982 dollars. First, the 1982 cost is calculated for a particular VR option. This is then escalated to determine actual costs over the equipment lifetime. This string of costs is then levelized over the equipment in-service lifetime (assumed here to begin in 1987) and amortized to a single payment. This amount is then expressed in 1982 dollars.

The VRTECH program has three important features that can greatly aid in making effective decisions:

1. flexible program construction;
2. easy, inexpensive sensitivity analysis; and
3. an extensive internal data base.

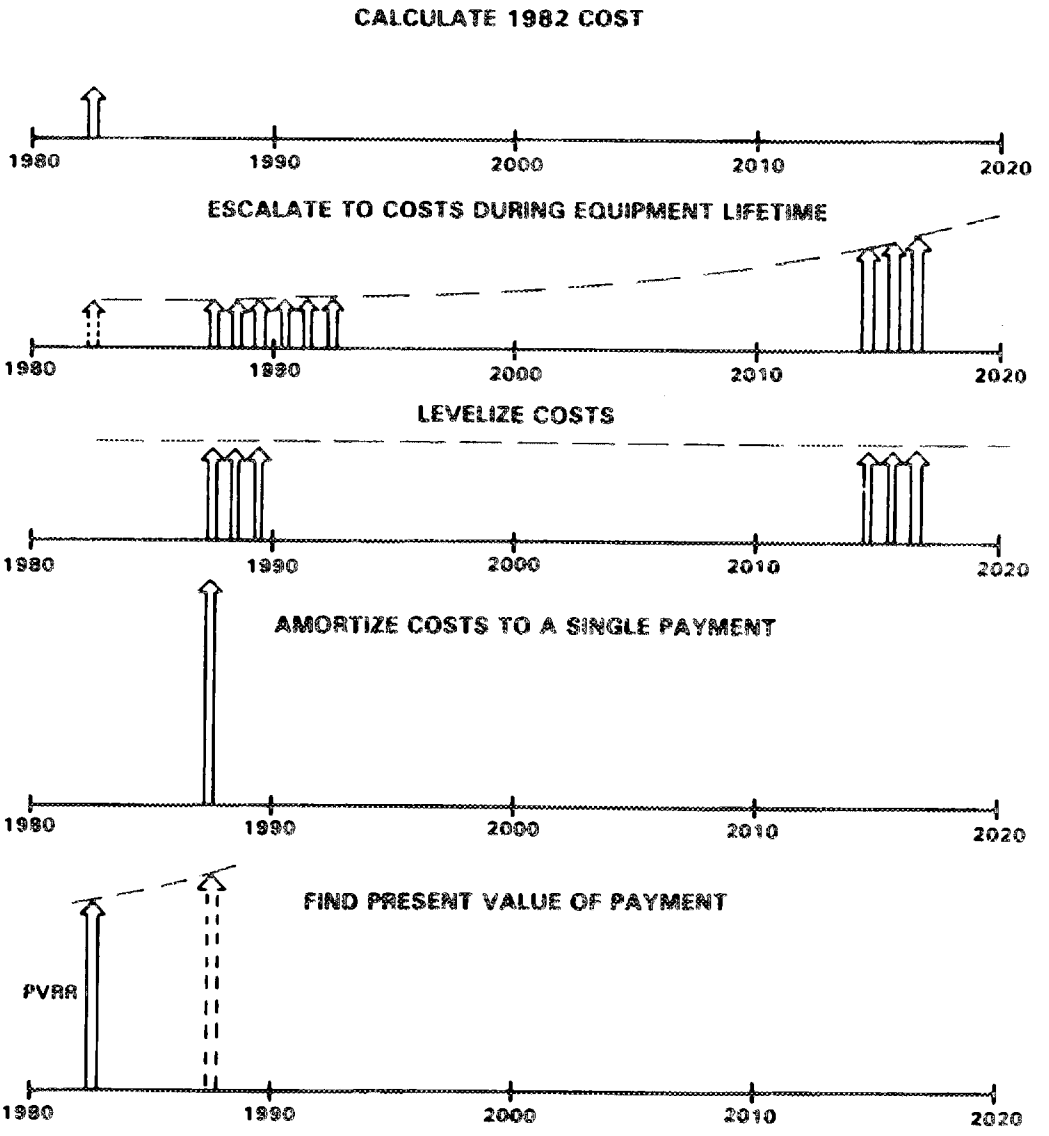

Fig. 1. Present value for revenue required (PVRR) concept.

Modular program construction guarantees that VRTECH can be quickly modified to incorporate the specific design features of any radwaste treatment system. Utility-specific designs or preferences can greatly change the radwaste economic picture. VRTECH incorporates these differences easily and quickly, thereby increasing confidence that the analysis correctly includes all relevant economic factors.

VRTECH greatly facilitates sensitivity analyses. A thorough economic study of a VR option requires hundreds of inputs, including many predictions of the future. The total cost of radwaste disposal is extremely sensitive to these inputs. VRTECH's design allows the swift and efficient evaluation of these sensitivities. In one study, VRTECH evaluated the radwaste disposal costs of over 3000 separate cases in only 3 min of computer time. By examining the sensitivity results, a utility executive can understand the consequences of his decision under a wide variety of potential futures. In this way he can minimize the management risk inherent in radwaste system modifications.

VRTECH contains a large internal data base that includes the latest available information on radwaste generation, VR equipment performance and costs, and burial ground pricing. The radwaste generation data constitutes the best existing compilation of industry experience, including year-to-year variations. The VR equipment costs are extremely useful for initial screening studies. Fourteen VR equipment options are presently included in the VRTECH data base. Each option is described by its radwaste throughput and the complete costs of purchase and installation, as well as the costs of operation and maintenance. The data base allows for calculation of the costs of on-site storage based on the volumes of processed waste and the desired storage period. Several burial ground pricing algorithms are included in the data base, covering the existing sites as well as projected prices for future sites.

TASC is currently developing a PC version of VRTECH, which will soon be available from EPRI. The new code will be much more user friendly than the mainframe version. The trade-off is a slightly smaller internal data base and slower execution. The PC version will be most useful for small-scale investigations, while the mainframe program will be better for large-scale, comprehensive studies.

The following discussion is based on the EPRI-sponsored study mentioned previously (the EPRI Program Manager was M. Naughton). The analysis is presented in two parts. The first part presents the total costs of a hypothetical utility of using each of 14 VR equipment options. Examination of these costs reveals the major benefits and liabilities of each option. In the second part, these observations are amplified based on the results from the entire EPRI study of volume reduction.

The hypothetical utility has twin BWRs, each with a deep-bed condensate polishing system (CPS). The radwaste is shipped 800 miles to a burial site that charges the same prices as Barnwell did on January 1, 1983. The chosen VR option will become operational on January 1, 1988, and the processed waste will be stored on-site for an additional 5 years before shipment. The equipment is expected to operate for 30 years. The utility is considering 14 VR equipment options, including the retention of its present system: a simple compactor, an evaporator, and a solidification system that is operating well. (This latter option is referred to as the "no-VR" case.) All other options involve the purchase of new VR equipment that is either retrofitted into existing structures or placed in a new structure. Table 1 describes the VR options under consideration.

VRTECH requires two kinds of information before it can determine the PVRR, a description of the VR equipment, which was developed by Burns and Roe, Inc., for the EPRI project, and economic input. For the hypothetical case, the inflation rate is 8.5%. All costs escalate at that rate except those for burial, which escalate at 15%. The cost of money to the utility is 12.5%, and its fixed charge rate is 0.2.

Table 2 shows the total PVRR and its major components for the 14 VR options at the hypothetical utility. The table displays the costs for: operations, which include the labor and consumables necessary to operate and maintain the equipment and to drum the processed waste; transportation, which includes trucks, vans, and casks; burial, including dry and wet wastes; total operating expenses, which are the sum of the operating, transportation, and storage costs; and the capital expenditures for the storage facility, as well as for all capital needed to purchase, engineer, and house the VR equipment. These latter capital expenditures are labeled "construction" in the table.

Table 1. Volume reduction options

Case no.	VR technology	Retrofit or new structure	Solidification agent
0	No-VR	Retrofit	Cement
1	High-pressure compactor	Retrofit	-
2	Forced-air incinerator	New	-
3	Fluid-bed dryer/incinerator (no resin incinerated)	New	Dow
4	Evaporator crystallizer	Retrofit	Dow
5	Evaporator extruder	Retrofit	Bitumen
6	Evaporator extruder	New	Bitumen
7	FB dryer/incinerator plus evaporator crystallizer	New	Dow
8	FB dryer/incinerator plus evaporator extruder	New	Bitumen
9	FA incinerator plus crystallizer plus extruder	New	Bitumen
10	Mobile incinerator	New	-
11	Ultra high-pressure compactor	Retrofit	-
12	Fluid-bed dryer/incinerator (resins incinerated)	New	Dow
13	Mobile evaporator	New	Bitumen

Table 2. Costs for twin BWRs (hypothetical case)

VR case	Total operating costs	Transportation costs	Burial costs: Dry waste	Burial costs: Wet waste	Burial costs: Total	Total expenses	Capital costs: Storage	Capital costs: Construction	Total PVRR
0. No-VR	17.6	30.2	69.1	108.3	177.3	225.1	10.2	0	234.2
1. Compactor (R)	16.5	30.1	60.6	108.3	168.8	215.4	9.5	0.2	225.1
2. Incinerator	18.6	29.6	45.0	108.3	153.3	201.4	8.1	19.0	228.5
3. FB incinerator	21.5	27.2	45.0	80.1	125.1	173.8	6.5	33.5	213.8
4. Evap cryst (R)	22.8	29.4	69.1	90.7	159.8	212.0	9.1	6.0	227.0
5. Evap extr (R)	15.7	22.3	69.1	49.9	119.0	157.0	7.1	11.9	175.9
6. Evap extr	15.7	22.3	69.1	49.9	119.0	157.0	7.1	13.6	177.6
7. FB inc + evap cryst	22.7	27.2	45.0	80.1	125.1	174.9	6.5	40.4	221.8
8. FB inc + evap extr	17.9	21.7	45.2	49.9	95.1	134.7	5.0	35.5	175.2
9. Incin, cryst + extr	16.1	21.7	45.2	49.9	95.1	132.9	5.0	40.3	178.3
10. Mobile incinerator	15.8	29.6	44.6	108.3	152.9	198.3	8.0	3.7	210.0
11. Super compactor (R)	14.4	24.6	32.9	108.3	141.2	180.2	8.2	5.2	193.6
12. FB resin incin	21.8	23.6	45.0	64.3	109.3	154.7	5.8	36.1	196.6
13. Mobile evaporation	18.9	26.9	69.1	79.9	148.9	194.7	8.4	5.2	108.3

Note: (R) denotes retrofit.

The "no-VR" case sets the context for the analysis: 75% of the total cost is for burial of the waste, with 45% being for wet waste and 30% for dry. Reductions in burial costs are obviously the major opportunity for savings.

In Case 1, the high-pressure compactor can be retrofitted into the plants inexpensively. The resulting savings of $10M are more than 40 times its cost. The reductions in operations, storage, or dry-waste burial are each more than sufficient to repay the inves ment. This option carries a very low risk: the technology is relatively simple and dependable. Moreover, savings in the first year of operation are enough to cover the capital requirements.

The forced-air incinerator (Case 2) burns compactible trash; the waste volume reduction is much better than with the high-pressure compactor. It produces savings of $24M at the burial site and $2M in storage costs. However, the incinerator is expensive to purchase and install. Consequently, the compactor has a smaller PVRR.

The fluid bed dryer/incinerator is considered in both Case 3 and Case 12. In the former, it incinerates compactible trash and dries concentrated liquids; in the latter, it incinerates resins as well. The projected economic performance is better when resins are also processed. In either case, the technology is expensive to install, and it increases operational costs. Transportation and storage costs are reduced, but the greatest savings occur in burial. In both cases, dry-waste burial costs are reduced by $24M, and wet waste costs are lowered by $44M, if resins are burned, and by $28M, if they are not. If resins are processed, the expected savings over the no-VR case approaches the purchase price, but most of these savings accrue near the end of the equipment lifetime.

Only concentrated liquids are processed with the evaporator crystallizer (Case 4). The VR ratio is relatively low, and the product is solidified with DOW binder, which is very expensive ($260/drum). Consequently, the crystallizer has the highest in-plant costs of all the options. Nevertheless, it produces an overall savings of $8M by lowering the burial costs by $18M. If a less expensive binder were used, this option might appear more economically attractive, even with smaller waste loadings.

The evaporator extruder is considered twice; as a retrofit in Case 5 and in a new structure in Case 6. The added cost of the new structure is $2M. The extruder processes resins, liquids, and sludges. It produces substantial savings in all expense categories and is the only option that can totally pay for itself with savings in operations, transportation, and storage. As an example, $58M is saved at the burial site. The extruder has the smallest total PVRR of all the options considered; it returns its investment within 2 years.

The mobile incinerator, Case 10, is used to burn compactible trash. It combines the excellent volume reduction of the other incinerator systems with a low purchase price. Burial costs are reduced by $16M at an initial cost of only $4M. The payback period on this equipment is fairly short, and, for this reason, the mobile incinerator is a very attractive option.

The super compactor, Case 11, is the only equipment that processes both compactible and noncompactible trash. Consequently, it has the lowest dry-waste burial cost of any of the VR options. Like the mobile incinerator, the initial investment is fairly low, and the payback period is short.

Case 13 is the mobile evaporator, which processes resins and concentrated liquids. The $5M initial investment is the smallest of the wet-waste processors. Although burial cost reductions are almost six times the purchase price, total savings are substantially less than for the extruder.

Cases 7 through 9 are equipment combinations. The two options with extrusion of the wet waste are economically very beneficial. But, in each case, the combination is less attractive than the extruder alone because the incinerators are too expensive to be used for trash only. The combination of the extruder and one of the compactors would be much more economically attractive.

In summary, four of the VR options process dry waste only: the super compactor reduces the volumes of both compactible and noncompactible trash; the high-pressure compactor, the forced-air incinerator, and the mobile incinerator operate on compactible trash only. The forced-air incinerator is much more expensive than the other dry-waste technologies and cannot produce enough savings to overcome this disadvantage. The

high-pressure compactor produces much less savings than the others, but it is so inexpensive to purchase that it becomes a low-risk choice. The mobile incinerator costs about $4M but produces $25M in savings. The super compactor is even better, saving $42M at a cost of only $5M. The economics of the incinerators would likely improve if the combustible portion of the noncompactible trash were segregated and then incinerated.

Four options process only wet wastes: the two extruder configurations, the crystallizer, and the mobile evaporator. They are the most economical group because the wet-waste burial costs are the largest single expense in the no-VR case. The exruder and the mobile evaporator are more economical than the crystallizer. The latter suffers in comparison because it works on only one waste stream, reduces the volume less well, and uses the more expensive DOW binder. The extruder generates large savings at very modest costs.

The five remaining technologies are used on both dry and wet wastes. The two combination technologies with the extruder perform most economically. However, neither are as good as the extruder alone because the incinerator technologies are too expensive to be limited to processing trash. The crystallizer combination does less well. The fluid-bed dryer/incinerator is most economical when resins are incinerated in addition to the processing of trash and liquids. Pairing an extruder with one of the inexpensive dry-waste options would give better results than any of the options considered.

All of the VR options are economically beneficial in the hypothetical case, although VR performs less well in other contexts.

For example, Table 3 displays the present value of costs when twin PWRs replace the BWRs in the hypothetical case. The no-VR results show that both dry- and wet-waste burial costs are significantly reduced: the dry by a factor of 2; the wet by a factor of 7. As a result, wet-waste burial costs are less than one-half of the dry-waste burial costs. In this case, the super compactor is the only option that yields a saving greatly exceeding its purchase price, and the high-pressure compactor is the only option that repays its purchase price within 10 years.

The wet-waste technologies are even less economical. The extruder remains excellent at reducing burial costs, but the saving is only

Table 3. Costs for twin BWRs

VR case	Total operating costs	Transportation costs	Burial costs: Dry waste	Burial costs: Wet waste	Burial costs: Total	Total expenses	Capital costs: Storage	Capital costs: Construction	Total PVRR
0. No-VR	7.8	6.8	35.1	16.2	51.3	65.9	5.0	0.0	70.9
1. Compactor (R)	7.5	6.8	31.2	16.2	47.4	61.7	4.8	0.2	66.7
2. Incinerator	10.2	6.7	23.8	16.2	40.0	56.9	4.4	19.0	80.2
3. FB incinerator	11.6	6.3	23.8	5.0	28.8	46.7	3.7	33.5	83.9
4. Evap cryst (R)	8.7	6.7	35.1	7.1	42.4	57.7	4.5	6.0	68.1
5. Evap extr (R)	9.0	6.2	35.1	3.9	39.0	70.3	4.2	11.9	70.3
6. Evap extr	9.0	6.2	35.1	3.9	39.0	70.3	4.2	13.6	72.1
7. FB inc + evap cryst	12.4	6.3	23.8	5.0	28.8	47.6	3.7	40.4	91.7
8. FB inc + evap extr	12.2	6.1	24.0	3.9	27.8	46.1	3.6	35.5	85.1
9. Incin, cryst + extr	11.7	6.1	24.0	3.9	27.8	45.6	3.6	40.3	89.5
10. Mobile incinerator	8.4	6.7	23.6	16.2	39.7	54.7	3.7	4.3	62.7
11. Super compactor (R)	7.0	3.7	15.2	16.2	31.4	42.1	4.2	5.2	51.5
12. FB resin incin	11.9	6.1	23.8	2.6	26.4	44.4	3.4	36.1	83.9
13. Mobile evaporation	8.2	6.6	35.1	5.4	40.6	55.4	4.3	5.2	64.9

Note: (R) denotes retrofit.

approximately equal to its purchase price. Its payback period is more than 10 years. The mobile evaporator is the most economical option because of its lower purchase price and its efficiency in handling the boric acid wastes from PWRs.

The highly priced technologies all produce $25M in burial cost savings. Unfortunately, this sum is only a portion of their installed cost.

It is clear from this example that the waste generation rate sets a limit on the economic effectiveness of VR equipment by controlling the potential for savings at the burial site. The burial escalation rate has a similar effect on the potential for savings.

As the burial escalation rate changes, the operations, transportation, and storage costs are unaffected, but the burial costs are altered, often greatly, as shown in Fig. 2. It depicts the component costs of the total PVRR for the no-VR case with twin PWRs as the escalation rate varies. The burial costs are less than one-half of the total for a 10% escalation; they grow to almost nine-tenths of the total for a 20% rate.

Table 4 displays the total PVRR for all of the VR options in the twin PWR case for burial escalation rates of 10, 15, and 10%. With a 10% escalation rate, the no-VR case is very nearly the least expensive, and only the super compactor generates an appreciable saving. At 15%, about one-half of the VR technologies produce savings; for three of them the cost reductions are large enough to make purchase a reasonable option. When the escalation rate increases to 20%, the PVRR of every technology option is at least $12M lower than that of the no-VR case.

The critical importance of the burial escalation rate is troublesome to utilities when they attempt to make decisions about what, if any, VR options to purchase. Prediction of the future is always difficult, especially when one must account for complex interactions among all levels of government, the public at large, and private business concerns. Eventually, a utility must deal with this uncertainty both to make a decision and to defend the inclusion of the costs in the rate base.

The EPRI study confirms the importance of the waste generation rate and the burial escalation rate in VR economics. In general, these two

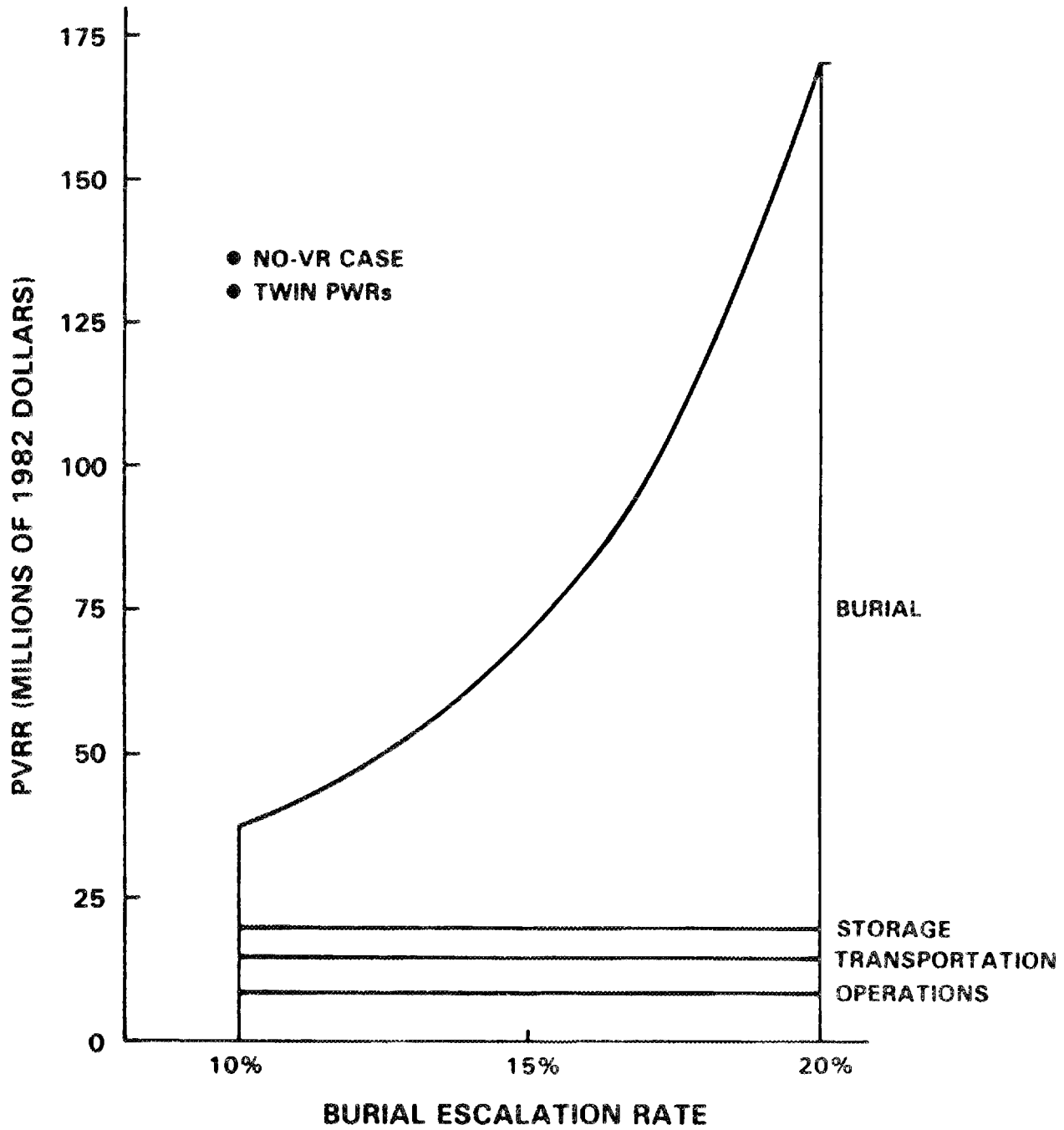

Fig. 2. Effect of burial escalation data of total PVRR.

Table 4. Variation of disposal costs with the burial escalation (twin PWRs)

VR case	Total PVRR (millions of Dec. 1982 dollars) escalation rate		
	10%	15%	20%
0. No-VR	38.1	70.9	170.0
1. HP compactor	36.4	66.7	157.9
2. FA incinerator	54.6	80.2	157.1
3. FB dryer/incinerator	65.5	83.9	139.3
4. Evaporator crystallizer	41.0	68.1	149.6
5. Evaporator extruder	45.3	70.3	145.3
6. Evaporator extender	47.1	72.1	147.1
7. FB dry/incinerator plus crystallizer	73.3	91.7	147.1
8. FB dry/incinerator plus	67.3	85.1	138.5
9. FA incinerator plus crystallizer plus extruder	71.7	89.5	142.9
10. Mobile incinerator	37.3	62.7	139.0
11. Super compactor	31.4	51.5	111.9
12. Resin incinerator	67.0	83.9	134.9
13. Mobile evaporator	38.9	64.9	143.3

factors control burial costs and thereby determine how effective VR can be at reducing expenses. Whenever large volumes of waste are generated, or the costs of burial are rising quickly, volume reduction is likely to produce substantial savings.

However, when waste volume is lower or the escalation rate is smaller, other variables can become important. In particular, some options can effect large enough reductions in the costs of operations, transportation, or storage to repay a large portion of their purchase price (e.g., the extruder in the hypothetical case). Additionally, when burial costs are reasonably low, general economic conditions, such as the cost of money to the utility or the general inflation rate, assume increased importance.

When a utility attempts to decide whether to buy volume-reduction equipment, it must consider a mix of fact and conjecture that leads to an estimate of the economic consequences of purchase. VRTECH is an efficient tool for supplying the utility decision maker with the widest possible range of economic information on the total cost of radwaste treatment options. The code contains an up-to-date equipment data base and specialized economic computer programs. It automatically links together, in a self-consistent manner, all the major aspects of radwaste disposal - from the generation of the waste to its processing, from the transportation of the waste to a disposal site to its ultimate disposal. VRTECH is an example of how systems analysis techniques can be effectively applied to assessing radwaste disposal issues.

The VRTECH code has been used to examine the major variables that affect VR economics. The radwaste generation rate and the burial escalation rate are the dominant variables in VR economics because they jointly determine the cost of waste burial, the largest element in disposal expenses. If burial costs are small, then savings in operation, transportation, or storage costs, as well as the general economic conditions, assume greater importance in VR purchase decisions.

1.4.4 Low-Level Radioactive Waste Regulatory Constraints Affecting Radwaste Processing, L. C. Oyen

1.4.4.1 Introduction

Utilities frequently find that regulatory constraints strongly affect their choice of technology for processing LLRW from nuclear power plants. It is the purpose of the present study to identify such constraints and assess their impact on utilities' LLRW processing choices.

The term regulatory constraint is used in this report to encompass regulations, rules, and procedures that effectively control any or all phases of LLRW managerial activity. These constraints may be issued by agencies of federal, state, or local governments, and, in some cases, non-governmental organizations. The phases of LLRW to which these constraints may be addressed are disposal, processing (including effluent control), storage, and transportation.

1.4.4.2 Computer Data File

The source documents providing background information for this study constitute a rather cumbersome physical file. To simplify access to this information and provide flexibility in sorting and searching this material, a computer file was created. The file is subdivided into four categories: disposal, processing, storage, and transportation. Each regulatory constraint file entry consists of a data sheet, as shown in Fig. 1, which is identified by a unique file location number consisting of the letter D, P, S, or T followed by three digits. This data sheet, T-035, is an example of the 202 constraints compiled for this study and contains basic identifying information on document(s) in the file, such as document title, date, and number, plus two memorandum-type entries. The first of these memos is a description of the important features of the regulatory constraint material in that file. The second memo field contains a statement of the impact that this constraint may have on the choice of radwaste processing techniques.

This file has been set up on a Sperry PC with 640K RAM and two 360K floppy disc drives, using the proprietary code, FRAMEWORK™. Figure 2 shows the T-057 computer output sheet, the computer output sheet for NRC IE Information Notice 84-72.

Two telephone surveys formed the basis for several of the data sheets, especially for state regulations. The first included the "State

Martin Marietta
Project No. 7282-00

LLRW Regulatory Constraints
Review Data Sheet No. TM114
File Location: T035

Document Type: State Transportation Survey

Document Number or Citation: SL - ST23 Document Date: 05-28-85

Document Title: Florida State Transportation Survey and Associated Statutes

Issuing Agency: Florida Dept. of Transportation, Bureau of Weights, and Dept of Health

Governmental Level: State Copy on File (Y/N): Y

Principal LLRW Phase: Transportation Treatment Type:

Secondary LLRW Phases (P, T, S or D):

Compact Region: Southeast State: Florida

Constraint Description: NOTE: APPLIES TO ALL SHIPPERS INCLUDING POWER PLANTS
Florida Administrative Code Sec. 10D-91, (10D-56) Manifest Regulations
Florida Statute Sec. 404.20, Florida Statute Ch. 316 Sec. 316.302 Incorporation of 49 CFR Regulations
Florida Administrative Code Sec.10D-63 (rule) Inspection (filed with general state survey P032)
Florida Statute Sec. 404 Radiation Rules, Florida Statute 381 Sec. 512 Transportation of Radioactive material

1) Gross vehicle weight 80,000 lbs. - graduates lower depending on length and number of axles
2) Dept. of Health and Rehabilitative Services inspects each shipment at site of generation - fee is charged to the producer. (item 5)
3) Manifest required but no permit is required
4) 48 hr. prenotification to Dept. of Health and Rehabilitation Services of any transportation
5) 1.25 $/ft^3 fee for waste shipped (ref. statutes 404.161 filed with P032)

Impact on Treatment: KEYWORDS: VOLUME SURCHARGE, COSTS, NOTIFICATION
Direct impact on processing is minimal as far as packaging of waste form is concerned; however, the Volume Surcharge strongly encourages volume reduction for all wastes transported across the state

Fig. 1. General data sheet.

MARTIN MARIETTA FILE LOCATION : T-057
Project No. 7282-00

DOCUMENT TYPE : IE Information Notice

DOCUMENT NUMBER or CITATION: 84-72

DOCUMENT DATE : September 10, 1984

DOCUMENT TITLE : Clarification of Conditions For Waste Shipments Subject to Hydrogen Gas Generation

GOVERNMENTAL LEVEL : Federal

ISSUING AGENCY : NRC

==========

PRINCPAL LLRW PHASE: Transportation TREATMENT TYPE:

SECONDARY LLWR PHASES (P, T, S, or D): P S D

COMPACT REGION: STATE:

==========

CONSTRAINT DESCRIPTION:

Applies to users of NRC certified shipping casks. Potential exists for the generation of hydrogen or other combustible gases within containers of resins, binders, waste sludge, and wet filters. To prevent reduced packaging effectiveness:

1) For packaging containing substances that could potentially form hydrogen or other combustible gases, it must be determined by test or sampling (representative sampling) that for a period of time twice the expected shipment time:

   a) Hydrogen or combustible gas must be less than 5% by volume of the secondary container gas void if at STP.

   b) If the package could form greater than 5% combustible gas, the void must be inerted to limit oxygen to 5% by volume.

2) For packages containing LSA shipped within 10 days of preparation or venting the sampling program (Item 1) is not required.

NOTE: Shipment time means the time from sealing the container until disposal.

IMPACT ON TREATMENT:

Key words: hydrogen, resins, oxygen inerting, packaging

The full impact of this document has yet to be felt. The requirement to monitor and vent certain packages prior to shipment will impact the design and operation of an interim onsite storage building. Package designs which allow for venting may conflict with disposal site criteria for container handling and integrity. Processing options such as resin drying or incineration may remove the hydrogen gassing concern.

Fig. 2. Computer output sheet.

Transportation Survey," shown in Fig. 3, and the "State Survey" shown in Fig. 4. The information gathered in the state survey for Florida on processing constraints, including the applicable statutes and the impact on LLRW treatment, is summarized in data sheet P032 (Fig. 5).

1.4.4.3 Local Regulatory Information

On the local level, regulatory requirements for constructing and operating facilities to handle LLRW can be separated into three general categories: zoning requirements, building approvals, and miscellaneous permits. If new radwaste facilities are added at a nuclear plant site, a new zoning approval or a modification of an existing zoning approval may be needed. The expenditures of time and effort needed to obtain such approval should not be significant.

The second kind of approval that would typically be needed for radwaste facilities is a building permit issued by the local political subdivision (county, township, village, etc.) in which the plant is located. The building permit would be required for both new facilities and modifications of existing facilities. As with the zoning approval, a building permit would not be considered a major approval in terms of time and effort. Permits may also be required for:

1. review and approval of emissions from an LLRW incinerator or wastewater treatment system to ensure that local regulatory limitations are met;
2. approval for work in a floodplain;
3. approval to transport LLRW within city or county limits; and
4. approval to reroute or waterways at new facilities.

Certain nongovernmental organizations may promulgate their own operating procedures and requirements on users. These are definitely not regulations but are rooted in the regulations and certainly serve as effective constraints upon the power plant operators who use these services.

1.4.4.4 NRC Regulatory Information

The existence of LLRW processing systems in nuclear power plants is required by Title 10, Code of Federal Regulations, Pt. 50, Sect. 50.34A, which sets forth design objectives for equipment to control radioactivity in effluents to the environs. Figure 6, "Hierarchy of Regulatory Constraints Affecting LLRW Processing Choices," includes

LOW-LEVEL RADIOACTIVE WASTE REGULATORY CONSTRAINTS STUDY

STATE TRANSPORTATION SURVEY

1. **Name of State:**

   Florida

2. **Name of Agency:**
   Florida Department of Transportation, Bureau of Weights, and Florida Department of Health and Rehabilitative Services

3. **Contact Person/Phone Number:**

   Bill Mickler 904/488-7920 (Florida DOT)

4. **Has state adopted U.S. DOT requirements?**

   Yes, incorporated by reference

5. **What are the state's requirements for transportation of LLRW:**

   permit requirements: None

   weight limits: Maximum gross weight for trucks 51 ft. or longer is 80,000 lbs. Trucks 50 ft. or less, the weight graduates down. For interstate highways, trucks are weighed to determine the distribution across vehicle axles, while for country roads, the vehicles are inspected to determine gross vehicle weight.

   time restrictions: None

   route restrictions: None

Fig. 3. State transportation survey form.

6. Other restrictions (e.g., escorts, city ordinances, etc.)

The Department of Health and Rehabilitative Services inspects every shipment of LLRW that leaves for a disposal site. The generator (i.e. utility) is charged a fee each time this is done. Manifest requirements must be followed.

7. Statutes, rules and citations:

(for manifest) Rules: Fla. Adm. Code S10D-56 (will be Section 10D-91 sometime in June 1985)

For inspection before transporting: Fla. Stat. Section 404.20 (statute)

Fla. Adm. code Section 10D-63 (rule)

Fla. Stat. Section 404 (Radiation)

Fla. Stat., Ch 381 Section 512 Transportation of Radioactive Material

Fla. Stat., Ch 316 Section 316.302 (Incorporates 49 CFR-Dot Rep)

Fig. 3 (Continued)

LOW LEVEL RADIOACTIVE WASTE REGULATORY CONSTRAINTS STUDY

STATE SURVEY

1. **Name of State/Agency:** Florida Department of Health and Rehabilitative Services, Office of Radiation Control, Radioactive Materials Section

2. **Contact Person:**
Alan Shubert

3. **Phone Number:**
904/487-1004

4. **Does the state have a program for regulating the storage, treatment and disposal of LLRW?**
Florida has been an agreement state since 1964; therefore, Florida's regulations are identical to those of the NRC. In addition, the state of Florida inspects every shipment of LLRW that leaves for a disposal site, and the generator (i.e., the utility) is charged for this. A license would be issued for the handling (storage, treatment) of LLRW by the Department of Health and Rehabilitative Services.

NOTE: The state defers to the NRC with regard to LLRW from nuclear power plants and would conduct its review in conjunction with the NRC review.

Fig. 4. State survey form.

5. **Is a copy of applicable rules and statute(s) available? Citations(s)?**

For storage, treatment, etc.: Florida Statute Sec. 404.0614, Sec. 404.0617
Rules: Florida Administrative Code Sec. 10D-56 (will include manifest requirements) (As of mid-June 1985, Florida Administrative Code Sec. 10D-91.
For inspection before transporting: Florida Statute Sec. 404.20, Forida Administrative Code Sec. 10D-63

6. **What other agencies are involved?**

Department of Environmental Regulation

Air - Clair Fancy 904/488-1344

Water - J. P. Subramani 904/487-0615

7. **What are the standards or limits applicable to emissions from LLRW incinerators?**

The Department of Health and Rehabilitative Services would require a license under the Florida Administrative Code Sec. 10D-56. The rule sets the maximum restricted limitations in a table format that is identical to NRC's 10 CFR 20. Since there are over 150 nuclides, the

Fig. 4 (Continued)

Department of Health could not give the limitation. The Department of Environmental Regulation would require an air construction permit. There are no limitations on TSP for small incinerators; opacity is <5%. (NOTE: Sec. 10D-56 will become Sec. 10D-91 some time in June 1985.)

8. What are the standards or limits applicable to discharges of contaminated wastewater from LLRW treatment facilities (e.g., laundry wastewater)?

The Department of Health and Rehabilitative Services would require a license under Forida Administrative Code Sec. 10D-56 (Sec. 10D-91 by June 1985). The rule sets the maximum restricted limitations from the table in the rule (same as air). The Department of Environmental Regulation, as part of its Power Plant Sitings Certification Application, would require approval from the Water Division. The limitation is 5 picocuries of radiation.

NOTES:

Transportation; Florida Department of Health and Rehabilitative Services looks at all shipments. Information concerning weight limits, time of day, etc., may be obtained from the Florida Department of Transportation, Bureau of Weights. Contact Bill Mickler at 904/488-7920.

Fig. 4 (Continued)

Martin Marietta
Project No. 7282-00

LLRW Regulatory Constraints
Review Data Sheet No. TM086
File Location: P032

Document Type: State Survey

Document Number or Citation: SL - SS08 Document Date: 02-09-85

Document Title: Florida State Survey and Associated Documents

Issuing Agency: Dept. of Health and Rehabilitation Services, Office of Radiation Contrc

Governmental Level: State Copy on File (Y/N): Y

Principal LLRW Phase: Processing Treatment Type:

Secondary LLRW Phases (P, T, S or D): T

Compact Region: Southeast State: Florida

Constraint Description:

1) NRC regulations apply
2) state inspection of all shipment of waste from producer to site
3) state license required for handling facilities that are not considered part of Nuclear Power Plant; the NRC regulations are applied to power plants

Laws, Codes and Statutes

Florida Statute Sec. 404.0614, Sec. 404.0617, Sec. 404.20
Florida Administrative Code Sec. 10D-56, Sec. 10D-63, Sec. 10D-91
Administrative codes cover manifest and inspection procedures
Air quality: no TSP limitation for small incinerators opacity < 5%

Water: limitations based on plant siting certification approval by Dept. of Health water division

4) FDHRS has authority to mandate volume reduction
5) State law has 1.25 $\$/ft^3$ tax on shipped waste to finance inspection programs
6) 48 hr. prior notification to FDHRS required on all shipments

Impact on Treatment: KEYWORDS: VOLUME REDUCTION, TAX,

1) Florida Department of Health and Rehabilitative Services FDRHS has power to mandate volume reduction
2) 1.25 $\$/ft^3$ tax on transportation is incentive to use VR
3) Prior notification and inspection of each shipment could cause scheduling difficulty for LLRW Transportation, increasing costs

Fig. 5. State survey summary data sheet.

with 10 CFR 50.34A other regulations that require the nuclear plants' LLRW treatment systems be described in detail in licensing documents, such as the Safety Analysis Report and the Environmental Report.

For instance, 10 CFR 50.36A requires station technical specifications to limit such effluents to levels "as low as is reasonably achievable" (ALARA), in addition to those concentration limits defined in 10 CFR 20. Somewhat below these in impact is a series of constraints that affect processing primarily through controls on effluents. Another more or less parallel set of constraints, shown on the left side of Fig. 6, affects systems, equipment, or operations more directly. Of the effluent control constraints, 10 CFR 20.106 places very basic requirements on LLRW processing system performance. This regulation ensures that U.S. power plants will follow the recommendations of the International Commission on Radiation Protection by prescribing the maximum radioactivity allowed in plant effluents. Very close to this are 40 CFR 190 and 10 CFR 50, Appendix I, which limit radiation exposure to the public and thereby require that the annual average radioactivity in effluents be small fractions of 10 CFR 20 limits by limiting the allowable exposure to members of the public. Appendix I requires that all effluent treatment techniques be used that can be shown to be cost-effective, assuming a benefit of $1000 per man rem reduction in exposure to the public. Regulatory Guides 1.109 through 1.113 give calculational methods acceptable for the implementation of Appendix I.

Other documents that play a role similar to the Regulatory Guides are NUREG-0016 and -0017, giving the Gale code calculations, and NUREG-0472 and -0473, the standardized Radiological Effluent Technical Specifications (RETS). Both of these reports cover requirements for material to be included in SARs or ERs. Regulatory Guides 1.70 and 4.2 detail the information required in SARs and ERs, respectively. The Standard Review Plans, NUREG-0800, Chapt. 11 state the NRC's approach to evaluating SARs for license applications. Finally, there are several I. E. Notices that bring attention to problems in operating power stations off-gas or gaseous waste treatment systems that could lead to excessive off-site doses.

Those constraints that affect processing more directly are shown on the right side of Fig. 6. At the head of the list, 10 CFR 20.305 and 10 CFR 50.59, along with I. E. Circular 80-18 that interprets 10 CFR 50.59, have a very direct impact on both operating stations and those seeking

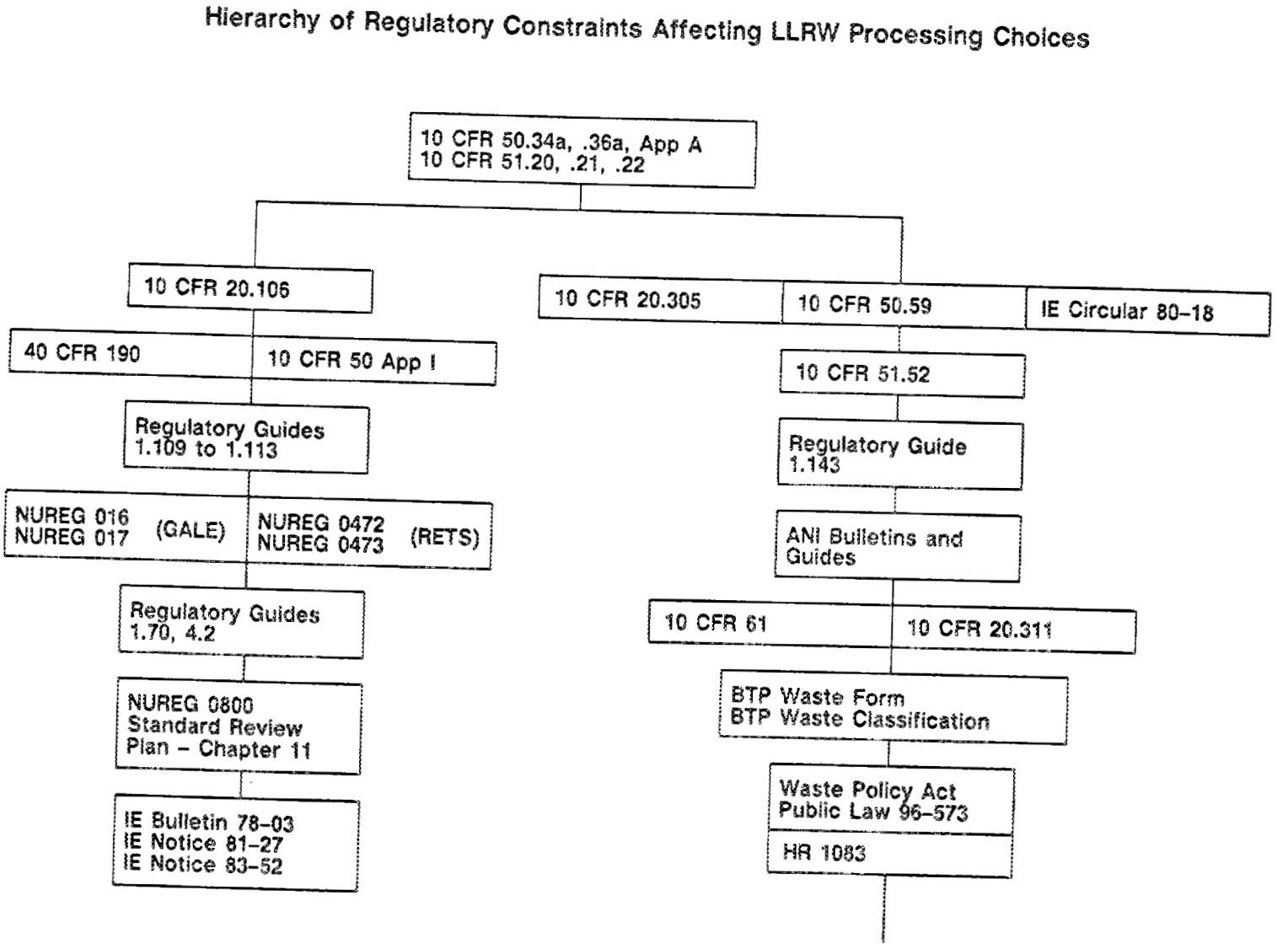

Fig. 6. Hierarchy of regulatory constraints.

Hierarchy of Regulatory Constraints Affecting LLRW Processing Choices

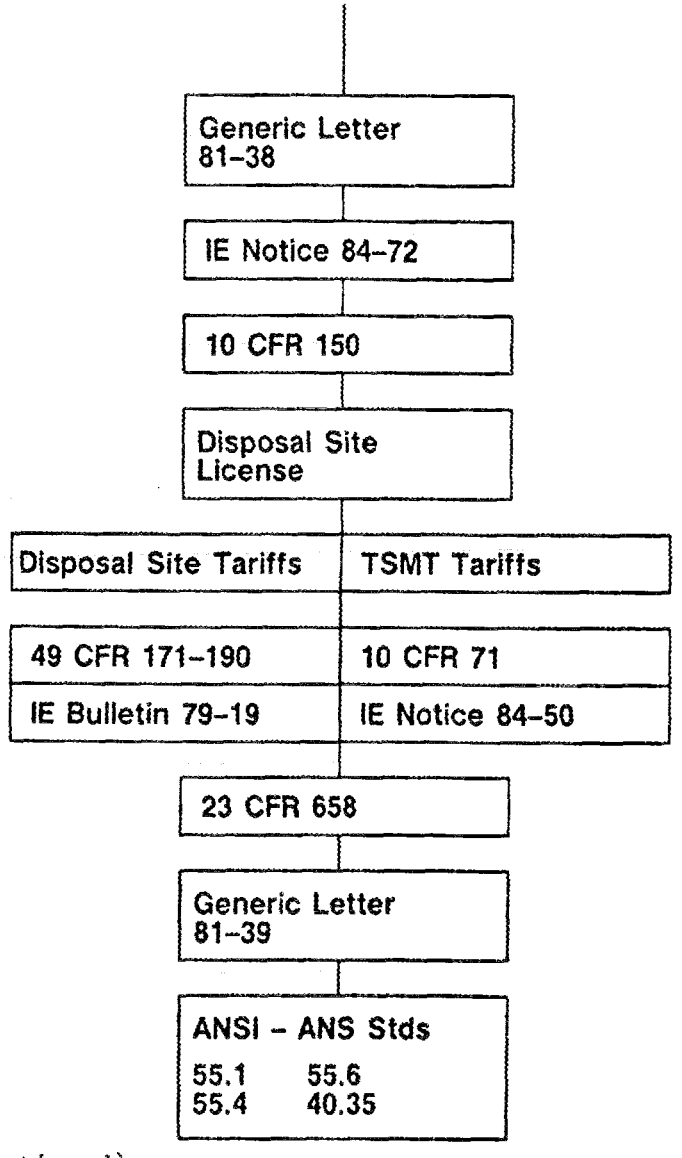

Fig. 6 (Continued)

licenses. Incineration is the only LLRW processing technique singled out for special licensing, being covered in 10 CFR 2.305. Modifications to LLRW processing systems are covered by 10 CFR 50.59.

Almost as prescriptive is the requirement of 10 CFR 51.52 that only solid LLRW be shipped from power plants for disposal. Here, as in the RETS, dewatered resins may be considered "solid."

One of the broadest impacts on LLRW processing is produced by Regulatory Guide 1.143. This Regulatory Guide offers "design guidance" for all LLRW processing systems. It covers tanks, pumps, piping, processing equipment, and the structures housing them. It specified design codes and standards for materials, welding, and testing. It specifies seismic requirements for equipment and structures, and it defines the boundaries of the LLRW systems. I. E. Circular 80-18 requires that 10 CFR 50.59 analyses show adherence to Regulatory Guide 1.143, therefore applying this Regulatory Guide to operating stations.

Just below Regulatory Guide 1.143 on Fig. 6 are listed the bulletins and guidelines issued by American Nuclear Insurers (ANI). The ANI bulletin on "Radwaste Systems Using Combustible Materials/Components" specifies generally acceptable fire protection systems for insurance purposes. The ANI also has bulletins covering other specific systems.

The biggest constraint in the disposal section, and perhaps the constraint that currently is effecting several processing choices, is 10 CFR 61, titled "Licensing Requirements for Land Disposal of Radioactive Materials," and its companion 10 CFR 20.311. The specific requirements on radioactive waste classification and the waste form required to meet 10 CFR 61.55 and 61.56 are detailed in two Branch Technical Position Papers. They may serve as bases for new Regulatory Guides. These requirements are specific and prescriptive and have contributed to the decision, made by many utilities, to contract for mobile solidification services from vendors who already have approved process control programs.

The Low-Level Waste Policy Act of 1980 (Pub. L. 96-573), and its probable amendments as contained in House Resolution (HR) 1083, will make many changes in LLRW disposal procedures and in the choice of solidification and volume-reduction techniques for the wet LLRW. At the same time, this law has heightened interest in volume reduction, especially of the dry

active waste (DAW). It has also encouraged planning for at least three central facilities to provide contract volume reduction services for power plant DAW.

This law has also spurred interest in on-site storage of LLRW for 3 to 5 years, because it sets a deadline of December 31, 1985, for shipment of waste to an existing disposal site, if the plant is not within that region. The final approved HR 1083 and senate bills will probably keep the three disposal sites open until 1993, provided the other compacts license and build disposal sites. Plants outside of the sited regions will have to pay an increasing surcharge for disposal privileges. Six compacts have been ratified by their member states and have been submitted to Congress for approval. These compacts involve 33 states in groups ranging in size from 2 states to 8 states. Congressional approval of these compacts must await final disposition of HR 1083. Texas is not planning to join a compact, but is developing its own LLRW disposal program as a few other states may also do.

In NRC Generic Letter 81-38 details of some of the requirements for interim LLRW on-site storage structures are presented. However, there are gaps in the guidance supplied by this letter, leaving utilities somewhat uncertain as to the usefulness of plastic, high-integrity containers (HICs) as storage vessels. They have been approved for burial, but their use for long-term storage has not been subjected to regulatory review.

A transportation constraint in the form of I. E. Notice 84-72 places some severe constraints on LLRW packages containing dewatered resins. This notice requires venting of certain packages that might develop flammable mixtures of gases. To avoid the storage and transportation complications attendant upon such venting, solidification and possibly drying of resins may become favored.

Most disposal sites are licensed by the states as a result of 10 CFR 150, which regulates "Agreement States." Consequently, the existing sites all have state licenses, and they all differ from each other in ways that certainly affect processing.

Costs are always important constraints, and those reflected in the disposal site tariffs for Barnwell, Hanford, and Beatty and the Tri State Motor Transport Co. (TSMT) transportation tariffs quite frequently determine processing decisions, such as whether to use drums or liners, ion

exchange processing, or evaporation. The transportation constraints contained in 49 CFR 171-190, 10 CFR 71, 23 CFR 658, and various state regulations have little impact on processing.

In I. E. Notices 79-19 and 84-56, quality assurance (QA) requirements for packaging are detailed. Processing must be compatible with license packaging requirements, state routing, and time-of-day scheduling, or tax requirements may affect some cost-benefit decisions. Generally, the impact of transportation constraints on processing is minimal, although the I.E. Notice 84-72 on gas venting of packages before transportation may be an exception.

Generic Letter 81-39 states the volume-reduction policy of the NRC, which views volume reduction as a two-step process. The first step is to reduce the volume of the waste generated through administrative controls or procedures. The second step would be the installation of advanced processing equipment to achieve greater volume reduction, especially in LLRW streams not amenable to administrative controls.

The American National Standards Institute (ANSI-ANS) Standards 55.1, 55.4, 55.6, and 40.35 provide requirements for the design of solid, gaseous, liquid, and volume-reduction systems for LLRW processing. They codified good engineering design, but had little impact on the choice of radwaste processing.

1.4.4.5 Summary

There have been over 200 regulatory constraints identified in this study, primarily addressing disposal, processing, storage, or transportation of LLRW. Currently, the major constraint on the choice of technology for processing of radwaste is the disposal constraint, 10 CFR 61, adopted in 1982. Future constraints will probably be developed from the Waste Policy Act of 1980 and the formation of the waste disposal compacts.

1.4.5 Overview of Nuclear Materials Transportation, A. W. Grella

This presentation is really not an overview of radioactive material transportation, but an overview of transportation as it relates to one specific type of material, low specific activity (LSA) material. It is the predominant type of material that fits into the low-level waste category.

I want to discuss how LSA is regulated, setting forth the requirements. But I first want to review the general scheme of regulations. I do not want to spend a lot of time on that, but I do want to conclude by discussing what I see as a future change in the regulations that is probably inevitable. It has not been formally proposed, as yet, but it will affect transportation of LSA materials and, quite likely, impact on R&D needs in this area.

As you know, there are two major agencies that regulate transportation, the U.S. Department of Transportation (DOT) and the U.S. Nuclear Regulatory Commission (NRC). Each has statutory authority. Because of this, we have historically worked through a Memorandum of Understanding to avoid overlaps and duplication.

Basically, the regulations for the United States as well as the rest of the world are based on the International Atomic Energy Association (IAEA) safety standards (Safety Series No. 6, 1973 edition). In 1983, both DOT and NRC amended the domestic regulations to conform to these 1973 IAEA standards.

In 1980 the IAEA then began convening the first of three advisory groups (1980, 1982, 1983) to develop another series of changes. This resulted in the 1985 edition, which has now been published. Within the next 5 years or so, most of the countries of the world, including the United States, will undoubtedly be conforming their regulations to this 1985 edition.

Later, I want to end with a brief discussion on the changes in the 1985 edition that affect LSA waste, which very probably will be the pattern on which the domestic proposals are also made, possibly next year, to change LSA regulations in the United States. The DOT regulations, as you know, are in Title 49 of the Code of Federal Regulations, the "Hazardous Materials Regulations." NRC has its regulations in Title 10, Pt. 71,

"Packaging and Transportation of Radioactive Material." Both standards were substantially revised in 1983 to conform to the 1973 international standards.

Table 1 is a list of the main headings of the DOT and NRC regulations. For transportation purposes of radioactive materials, there is a large category of materials that is not regulated, of low regulatory concern, labeled "de minimis." But, for purposes of transportation, these materials, that do not exceed 2 nCi/g, are not regulated.

I have found, down through the years, that this de minimis definition is often overlooked. Materials have been shipped as regulated materials for purposes of transportation when they actually did not have to be. That is not to say, however, that they are not still regulated for purposes of burial or disposal.

We get into a system of regulation now in which we use terms called A_1 and A_2, which I will explain. Moving upward from the de minimis definition, we have limited quantities or radioactive devices that are limited in terms of fractions of A_1 and A_2 values (e.g., usually 10^{-3} times these values). Then we have Type A quantities and Type B quantities. Very broadly, Type A quantities have limited contents, such that you never exceed 1000 Ci. Type A packages have to withstand only normal conditions of transport, as defined. The package-approval process is a self-approval process, since you are not required to get regulatory approval for a Type A package (e.g., the DOT specification 7A).

Type B packages have to withstand severe accident conditions, and there are very few specification packages listed in the DOT regulations. When you are not using one of those, it becomes a tailor-made-approval situation, where the package design has to be approved by the NRC before it can be used.

Therefore, except for the de minimis definition, these others are limitations on package activity (i.e., total activity in a package). The de minimis activity is a limit on specific activity. Also limited in this fashion is the category of LSA, which is an extremely important one, particularly in the transport of low-level radioactive wastes, which will be developed further as we go on.

Going back to the definition, materials that do not exceed 2 nCi/g are not regulated for purposes of transportation. This same value is

Table 1. Sources of federal regulations

Main headings	
Title 49, U.S. Department of Transportation's "Hazardous Materials Regulations," Pts. 100-178	
49 CFR 106	Rulemaking Procedures
49 CFR 107	Hazardous Materials Program Procedures
49 CFR 171	General Information, Regulations and Definitions
49 CFR 172	Hazardous Materials Tables and Hazardous Materials Communications Regulations
49 CFR 173	Shippers—General Requirements for Shipments and Packagings
49 CFR 174	Carriage by Rail
49 CFR 175	Carriage by Aircraft
49 CFR 176	Carriage by Vessel
49 CFR 177	Carriage by Public Highway
49 CFR 178	Shipping Container Specifications
Title 10, U.S. Nuclear Regulatory Commission	
10 CFR 71	Packaging and Transportation of Radioactive Material

Note: Pursuant to 10 CFR 71.5(7) NRC licensee shippers are directly subject to 49 CFR shipper requirements.

quoted in the international regulations and in all of the statutes upon which domestic regulations are based.

Under the A_1/A_2 system, there is a list of some 250 nuclides in the regulations, each having an A_1 and A_2 value. Table 2 gives a few examples from that list, with A_1 being essentially material that is in special form, and A_2 material being material in nonspecial or normal form. Form is very important for the more radiotoxic materials, but, essentially, special form materials are a radiation hazard only if they escape from the package.

Nonspecial form or normal form materials are both a radiation and contamination hazard if they escape from the package. So, if you think of special form, you think of A_1; if you think of nonspecial form or normal form, think of A_2. In the regulations, there is a table of radionuclides in which the A_1 and A_2 are listed for each nuclide. So, as an example, if you are interested in how much activity you can ship for ^{60}Co, you look up

Table 2. Type A package quantity limits for selected radionuclides

Radionuclide	Element and atomic number	A_1(Ci) (special form)	A_2(Ci) (normal form)
^{14}C	Carbon (6)	1000	60
^{137}Cs	Cesium (55)	30	10
^{99}Mo	Molybdenum (42)	100	20
^{235}U	Uranium (92)	100	0.2
^{226}Ra	Radium (88)	10	0.05
^{201}Ra	Lead (82)	20	20
^{60}Co	Cobale (27)	7	7

the A_1 value, 7 Ci, and the A_2 value, 7 Ci. This happens to be a nuclide where the limits are the same.

For most materials, the A_1 number is higher than the A_2 number. But, in any case, neither value will ever exceed 1000 Ci. Since the contents are so limited, the package must only withstand normal conditions for transportation. As I pointed out earlier, when package activity is limited to fractions of these values, then you have the so-called quantities or excepted quantities, which are excepted from specific packaging, marking, and labeling requirements. Generally speaking, if you do not exceed 0.001 of these A_1/A_2 values, you have a limited quantity. You do not have to have any specified packaging; it must only be a strong-tight package. The same is true for excepted instruments or radioactive articles, gauges, and electron tubes that contain a radioactive source as a component part.

Under DOT regulations, the LSA category is limited solely on a specific activity basis. As shown in Table 3, the maximum activity of the material is related to the A_2 value.

Originally, an LSA material was conceptualized as one that was inherently safe. The models used to develop the specific activity limits mainly considered ingestion or inhalation of up to 10 mg of materials, without exceeding the recommended radiation protection limits.

However, over the years, the concept has been extended. For example, if you take materials that are limited to 0.3 nCi/g, when the A_2 value

Table 3. LSA category limitations based on DOT regulations

If the A_2 of the radionuclide is:	The maximum activity per gram of material is:
$\leq$0.05 Ci	0.0001 mCi
$>$0.05 to 1.0 Ci	0.005 mCi
$>$1.0 Ci	0.3 mCi

exceeds 1 Ci, and if you have enough grams of that material in a package, you then have a package that requires heavy shielding and has high radiation dose rates associated with it. It is "not so low" in "low specific activity."

Under DOT regulations, all that is required for LSA materials is a strong-tight package. This is not the case with NRC regulations, which go considerably further in specifying the type of packaging that is required for this "not-so-low" LSA. It is for such materials that there will very likely be future changes, based on international changes, aimed at placing more limitations on shipment of this kind of material.

Again, regarding package limitations, Type A is anything less than or equal to A_1 or A_2. Anything exceeding that is called a Type B quantity, for which you need Type B accident-resistant packaging. Type A packaging must only withstand normal conditions of transport. In DOT regulations, there had been a category called large-quantity radioactive material, which is now known as highway-route control quantity and is a multiple of 3000 A_1 of A_2, or 30,000 Ci, whichever is least. These are the quantities wherein the DOT routing rules apply or the NRC requirements require notification of the governor of a particular state to which a shipment is going. We are talking mainly about spent fuel in this category. In addition, Type A packaging must only withstand normal conditions, but Type B must also withstand accident conditions.

Thus, for Type A packages, shipments involve mainly industrial-type packaging. A very important scheme of regulation here is that the DOT specification 7A, which is the only specification authorized, is a self-approval process, wherein the user of this package has to document and

maintain on file how the package was assessed to meet these conditions. The user does not go to NRC or DOT for approval, if the user is shipping a DOT specification 7A Type A package.

The vast majority of materials shipped in this category are radiopharmaceuticals, such as technetium-molybdenum generators. Now, when you get into Type B, it is a different "ball game" in terms of the performance of the package. It has to meet severe accident conditions, which are detailed in sequence in Pt. 71. The Type B packages have to meet these so-called "torture tests," as listed in Table 4.

Table 4. Type B packaging tests

1.	A 30-ft free drop onto an unyielding surface.
2.	A puncture test which is a free drop >100 cm (>40 in.) onto a 15-cm (6-in.)-diam steel pin.
3.	Thermal exposure at 1475°F for 30 min.
4.	Water immersion for 8 h (for fissile materials packaging only).

Generally, if you are not using one of three or four DOT specification packages that are listed in the regulations, you have to go to NRC with an application demonstrating how your package meets these conditions. If NRC is satisfied with such demonstrations, they issue you a certificate for the package. Any other NRC-licensed shipper can use the same NRC-certified package under a general license under P. 71. There is a directory of certified packages (NUREG-0383) which lists annually the NRC-certified packages.

Under the scheme of regulations, the DOT also authorizes transportation of packages that are certified by DOE for its own use and that of its contractors. These are authorized for use under DOT regulations. Therefore, two different approval authorities exist for Type B packages: DOE-approving packages for DOE and its contractors; and the NRC-approving packages under Pt. 71 for use by NRC licensees.

Type B packages include a broad range of sizes and shapes, such as small radiography packages, right on up to large spent fuel casks.

In the LSA category, if you exceed the LSA concentration limit and you have a straight Type B quantity in your package, then you need a straight Type B package. There are several certified waste packages that are used for shipping radioactive wastes at Type B activity levels.

As for LSA, which does not exceed the activity concentration limits, then under DOT regulations, all you need is a strong-tight package. Such packages must be shipped in exclusive-use vehicles. There are no specific standards for a strong-tight package other than it must not leak under normal conditions of transport.

A lot of material, mainly the DAW type, is shipped in strong-tight packages, drums, and boxes.

Under DOT regulations, if you are shipping a less-than-truckload amount of LSA material, it is pretty much like shipping a Type A package. Most LSA material is shipped this way, in exclusive-use vehicles, where there are a specific number of requirements that have to be followed. Most importantly, regarding packaging under DOT regulations, all that is needed is a strong-tight package. The other DOT requirements include such things as placarding the vehicle, monitoring contamination and radiation limits, marking the outside of the package "radioactive LSA," and providing written instructions for maintenance of exclusive-use shipment controls.

The "certified Type A package for LSA exceeding Type A" is a package that is used for shipping LSA and has been certified by NRC as Type A. As you recall, Type A packages are a self-approval process under DOT regulations, that is, when you are limited to no more than a Type A quantity of total activity in a package.

But you may also remember that if you have enough grams of materials at this concentration of 0.3 mCi/g or less, you have a package with a fair amount of total activity and an activity which exceeds, really, a Type A quantity. Then if you look at 10 CFR Pt. 71 requirements, you find that you need something more than just a strong-tight package. If you are an NRC licensee shipper, and you have enough grams of material that you exceed what would otherwise be a Type A quantity under DOT regulations

(which is a Type B quantity), then the NRC requires that the package be certified as Type A. The bottom line of this interesting anomaly is that if you have a Type B quantity of LSA radioactive material, you must use at least a certified Type A package, and, additionally, it must be certified by NRC and may not be a self-approved DOT specification 7A Type A package.

If you look at the NRC container directory (NUREG-0383), there are some 20 designs listed that are certified Type A packages. A vast majority of the power reactor fuel cycle materials, such as spent resins, filters, and that kind of material, are shipped in these NRC-certified Type A packages. Many of these designs involve an inner, disposable HIC as a liner. Such an HIC liner is used as the means of stabilizing the waste form for purposes of 10 CFR Pt. 61 requirements. So, as you can see, the NRC goes considerably further than DOT in requiring at least a certified Type A package when you have a Type B quantity of LSA.

That is the thrust of the concern over LSA that has been considered and deliberated by the IAEA the last 4 years. It has resulted in some finalization of amendments to the international regulations (IAEA Safety Series No. 6, 1985 Edition) that are aimed at limiting the hazard from unshielded LSA materials and establishing more precise packaging requirements.

The Appendix contains excerpts of the pertinent paragraphs from the 1985 regulations. One can look at these to get some idea of the thrust of what the changes are going to be. Basically, I believe that the future proposals into the United States will be to limit the package activity of the contents of LSA material such that, when unshielded, without any packaging, the resulting radiation level would not exceed 1 rem/h at 3 m.

If you calculate some of the activities of filters and resin liners and determine their unshielded activity and dose rate in the existing outer package, you can see what some of the impact might be if this kind of change takes place in the regulations.

It is something that everybody ought to think about. In particular, watch what we regulators are proposing to do to you in any Notices of Rulemaking on LSA. At the present time, DOT has a study that is being performed by Sandia Laboratories. It is a cost-benefit study of the impact of these kinds of changes. I believe they will be citing the results of this study in any proposed rulemaking.

1,4.5.1 Excerpts from IAEA Safety Series No. 6 (Regulations for the Safe Transport of Radioactive Material)

Definition of LSA

Low specific activity material

131. Low specific activity (LSA) material shall mean radioactive material which by its nature has a limited specific activity, or radioactive material for which limits of estimated average specific activity apply. External shielding materials surrounding the LSA material shall not be considered in determining the estimated average specific activity.

LSA material shall be in one of three groups:

(a) LSA-I

(i) Ores containing naturally occurring radionuclides (e.g., uranium, thorium,), and uranium or thorium concentrates of such ores;

(ii) Solid unirradiated natural uranium or depleted uranium or natural thorium or their solid or liquid compounds or mixtures; or

(iii) Radioactive material, other than fissile material, for which the A_2 value is unlimited.

(b) LSA-II

(i) Water with tritium concentration up to 1 TBq/L (20 Ci/L); or

(ii) Other material in which the activity is distributed throughout and the estimated average specific activity does not exceed 10^{-4} A_2/g for solids and gases, and 10^{-5} A_2/g for solids.

(c) LSA-III

Solids (e.g., consolidated wastes, activated materials) in which:

(i) The radioactive material is distributed throughout a solid or a collection of solid objects, or is essentially

uniformly distributed in a solid compact binding agent (such as concrete, bitumen, ceramic, etc.);

(ii) The radioactive material is relatively insoluble, or it is intrinsically contained in a relatively insoluble matrix, so that, even under loss of packaging, the loss of radioactive material per package by leaching when placed in water for 7 d would not exceed 0.1 A_2; and

(iii) The estimated average specific activity of the solid, excluding any shielding material, does not exceed 2×10^{-3} A_2/g.

Definition of SCO

Surface contaminated object

144. Surface contaminated object (SCO) shall mean a solid object which is not itself radioactive but which has radioactive material distributed on its surfaces. SCO shall be in one of two groups:

(a) SCO-I: A solid object on which:

(i) the non-fixed contamination on the accessible surface averaged over 300 cm^2 (or the area of the surface if less than 300 cm^2) does not exceed 4 Bq/cm^2 (10^{-4} $\mu Ci/cm^2$) for beta and gamma emitters, or 0.4 Bq/cm^2 (10^{-5} $\mu Ci/cm^2$) for alpha emitters; and

(ii) the fixed contamination on the accessible surface averaged over 300 cm^2 (or the area of the surface if less than 300 cm^2) does not exceed 4×10^4 Bq/cm^2 (1 $\mu Ci/cm^2$) for beta and gamma emitters, or 4×10^3 Bq/cm^2 (0.1 $\mu Ci/cm^2$) for alpha emitters; and

(iii) the non-fixed contamination plus the fixed contamination on the inaccessible surface averaged over 300 cm^2 (or the area of the surface if less than 300 cm^2) does not exceed 4×10^4 Bq/cm^2 (1 $\mu Ci/cm^2$) for beta and gamma emitters, or 4×10^3 Bq/cm^2 (0.1 $\mu Ci/cm^2$) for alpha emitters.

(b) SCO-II: A solid object on which either the fixed or non-fixed contamination on the surface exceeds the applicable limits specified for SCO-I in (a) above and on which:

(i) the non-fixed contamination on the accessible surface averaged over 300 cm^2 (or the area of the surface if less than 300 cm^2) does not exceed 400 Bq/cm^2 (10^{-2} $\mu Ci/cm^2$) for beta and gamma emitters or 40 Bq/cm^2 (10^{-3} $\mu Ci/cm^2$) for alpha emitters; and

(ii) the fixed contamination on the accessible surface averaged over 300 cm^2 (or the area of the surface if less than 300 cm^2) does not exceed 8×10^5 Bq/cm^2 (20 $\mu Ci/cm^2$) for beta and gamma emitters or 8×10^4 Bq/cm^2 (2 $\mu Ci/cm^2$) for alpha emitters; and

(iii) the non-fixed contamination plus the fixed contamination on the inaccessible surface averaged over 300 cm^2 (or the area of the surface if less than 300 cm^2) does not exceed 8×10^5 Bq/cm^2 (20 $\mu Ci/cm^2$) for beta and gamma emitters, or 8×10^4 Bq/cm^2 (2 $\mu Ci/cm^2$) for alpha emitters.

General Provision for LSA and SCO

Industrial packages

311. The total activity in a single package of LSA material or in a single package of SCO shall be so restricted that the radiation level specified in para. 422 shall not be exceeded, and the activity in a single package shall also be so restricted that the activity limits for a conveyance specified in para. 427 shall not be exceeded.

Requirements and Controls for Transport of LSA and SCO

422. The quantity of LSA material or SCO in a single package or object or collection of objects, if appropriate, shall be so restricted that the external radiation level at 3 m from the unshielded material or object or collection of objects does not exceed 10 mSv/h (1 rem/h).

423. LSA material and SCO which is or contains fissile material shall meet the applicable requirements of paras. 479, 480, and 559.

424. Packages, including tanks or freight containers, containing LSA material or SCO shall be subject to the provisions of paras. 408 and 409.

425. LSA material and SCO in groups LSA-I and SCO-I may be transported unpackaged under the following conditions:

(a) All unpackaged material other than ores containing only naturally occurring radionuclides shall be transported in such a manner that under conditions likely to be encountered in routine transport there will be no escape of the contents of the conveyance nor will there by any loss of shielding;

Industrial Package Requirements

Package

134. Package shall mean the packaging with its radioactive contents as presented for transport. Package and packaging performance standards, in terms of retention of integrity or containment and shielding, depend upon the quantity and nature of the radioactive material transported. Performance standards applied are graded to take into account conditions of transport characterized by the following severity levels:

- conditions likely to be encountered in routine transport (in incident-free conditions),
- normal conditions of transport (minor mishaps), and
- accident conditions of transport.

The performance standards include design requirements and tests. Each package shall be classified as follows:

(a) Excepted package is a packaging containing excepted radioactive material (see paras. 418–420) that is designed to meet the General Requirements for All Packagings and Packages (see paras. 505–514).

(b) (i) Industrial Type 1 (IP-1) is a packaging, tank, or freight container containing LSA material or surface contaminated object (SCO)(see paras. 131, 144, and 426) that is designed

to meet the General Design Requirements for All Packagings and Packages (see paras. 505—514).

(ii) Industrial package Type 2 (IP-2) is a packaging, tank, or freight container containing LSA material or SCO (see paras. 131, 144, and 426), that is designed to meet the General Requirements for All Packagings and Packages (see paras. 505—514), the requirements of paras. 515—517 if carried by air, and, in addition, the following Specific Design Requirements: (i) for a package, see para. 519, (ii) for a tank, see paras. 521—522, and (iii) for a freight container, see para. 523;

(iii) Industrial package Type 3 (IP-3) is a packaging, tank, or freight container containing LSA material or SCO (see paras. 131, 144, and 426), that is designed to meet the General Requirements for All Packagings and Packages (see paras. 505—514), the requirements of paras. 515—517 if carried by air, and, in additioin, the following Specific Design Requirements: (i) for a package, see para. 520, (ii) for a tank, see paras. 521—522, and (iii) for a freight container, see para. 523.

(b) Each conveyance shall be under exclusive use, except when only transportating SCO-I on which the contamination on the accessible and the inaccessible surfaces is not greater than ten times the applicable level specified in para. 122; and

(c) For SCO-I where it is suspected that non-fixed contamination exists on inaccessible surfaces in excess of the values specified in para. 144(a)(i) measures shall be taken to ensure that the radioactive material is not released into the conveyance.

426. LSA material and SCO, except as otherwise specified in para. 425, shall be packaged in accordance with the package integrity levels specified in Table 5, in such a manner that, under conditions likely to be encountered in routine transport, there will be no escape of contents from packages, nor will there be any loss of shielding afforded by the packaging. LSA-II material, LSA-III material and SCO-II shall not be transported unpackaged.

427. The total activity of LSA material and SCO in any single conveyance shall not exceed the limits shown in Table 6.

Table 5. Industrial package integrity requirements for LSA material and SCO

Contents	Industrial package type[a]	
	Exclusive use	Not under exclusive use
LSA-I[b]		
Solid	IP-1	IP-1
Liquid	IP-1	IP-2
LSA-II		
Solid	IP-2	IP-2
Liquid and gas	IP-2	IP-3
LSA-III	IP-2	IP-3
SCO-I[b]	IP-1	IP-1
SCO-II	IP-2	IP-2

[a]See para. 134.
[b]Under the conditions specified in para. 425, LSA-I material and SCO-I may be transported unpackaged.

Table 6. Conveyance activity limits for LSA material and SCO

Nature of material	Activity limit for conveyances other than by inland waterway[a]	Activity limit for a hold or compartment of an inland water craft[a]
LSA-I	No limit	No limit
LSA-II and LSA-II non-combustible solids	No limit	100 A_2
LSA-II and LSA-III combustible solids, and all liquids and gases	100 A_2	10 A_2
SCO	100 A_2	10 A_2

[a]The concentration limit for tritium in liquid form, specified in Table 1, does not apply.

1.4.5.2 Discussion

DR. RODGERS: Al, I did you a bit of a disservice. I think the programmer for the timer malfunctioned, and it did not really go off at twenty after. So, luckily, we have some extra time now. I think it worked out really well, except for the fact you had to rush a little; it allows us to open the floor for questions. We have about 8 minutes, so I will open the floor for questions to any speaker who has spoken this morning; not just to Al, because many times we were rushed and did not have enough time for questions after the other talks.

DR. MALLORY: I am Chuck Mallory, Westinghouse Hittman, with questions for Al. How can you justify these more stringent LSA regulations based on the safety record over the last 13 years?

MR. GRELLA: That is a good question. I think that is one of the things being addressed in the DOE study by Sandia, a cost-benefit analysis. As I tried to point out, there has been a concern on the part of NRC about this kind of material. That is why we had this requirement for 10 to 15 years, requiring that the packages be at least certified Type A packages for what are otherwise Type B quantities.

DR. MALLORY: As I recall, in 13 years there have been only two releases of material from those kinds of packages.

MR. GRELLA: Actually, there have not been many incidents in which the package has been in an upset. There have been several and, to my knowledge, no LSA package, such as a cask, has breached. But, again, it is a good question. It is certainly something that we as regulators have to address in a proposed rule.

DR. NEILSON: Bob Neilson, EG&G, Idaho. I would like to direct a question to Larry Oyen. Would you care to discuss briefly the implications, if any, of RCRA on radioactive waste dispposal?

MR. OYEN: The RCRA requirements may have an impact, perhaps, on incineration in some locations, depending on how the state and local regulations may want to interpret the RCRA. We have not thought so far that it would be a major impact yet, because there have not been any cases that we are aware of that would cause problems.

DR. NEILSON: The reason I mentioned that is, speaking to some of the people from Oak Ridge, I understand that RCRA is threatening to affect their operation there at the burial site.

MR. OYEN: You mean at the disposal site versus at the power plant? I was referring to the power plant.

DR. WALDEN: Joe Walden of Alabama Power Company. I direct my question to Mr. Grella. The commission cannot give a waste generator a de minimis level, cannot agree upon anything from oil to DAW to any medium. On the other hand, we have a wide gap of disparity, I would think, when we have a commission that also tells us that 2 mCi/g as a shipper is not regulated. Could you tell us what the phrase "not regulated" means?

MR. GRELLA: In terms of the value you just mentioned, it is 2 nCi/g, and it is an activity below which the material is not regulated at all, for purposes of transportation. It is essentially not radioactive. As I said, that only applies to transportation. There is an anomaly in that it is still probably regulated for other purposes. This, I think, stresses the need and importance of establishing limits below regulatory concern for licensing purposes.

A good corollary of that is what was done by the commission about 3 years ago in essentially deregulating or establishing a limit for ^{14}C and tritium in certain forms, levels below which they were not of regulatory concern. In this case, you effectively had a regulation that said you do not have to worry about these things for purposes of radioactivity.

Well, the DOT regulation on transportation values existed at 2 nCi/g, and no consideration was given by one to the other. So we had the situation in which this material became deregulated for purposes of disposal and possession, but it was still regulated for purposes of transportation. As a practical matter, all this meant that you needed a shipping paper. But, that is not always the way it was handled in specific situations by burial grounds. The DOT recently published a final rule to bring the two regulations together. They have deregulated, for purposes of transportation, the activities of tritium and ^{14}C that NRC had deregulated earlier.

It was a good example of where the difference between the purposes of the regulations really did not give a lot of help. I could not agree with

you more. Giving you a personal opinion, there is a real need to establish some limits for other materials that are below regulatory concern. It is all well and good to say a material is not regulated for the purpose of transportation, but if you have still got a problem getting rid of it, it does not do you any good, does it?

DR. WALDEN: It would appear that the problem would be on the other end, the receiver of the material, who wanted to declare it be handled as a radioactive following the guidelines that you just gave us.

DR. RODGERS: Any more questions?

Thank you very much. I would like to ask all the speakers to make sure they provide copies of their slides to either Ed Frederick, Bob Jolley, or me, or any member who has a little "Committee" tag on. We do intend to include the slides that are provided, along with the transcript, for all attendees.

Thank you very much for your attention. We are going to have a break right now.

1.5 PANEL DISCUSSION (SESSION 1), B. R. RODGERS

1.5.1 Introduction to Workshop Panel Discussion, D. H. Charlesworth

This panel is aimed at giving us the opportunity to broaden the scope of discussion beyond the immediate topics of the workshop sessions. In addition to the workshop's focus on waste treatment, it would be appropriate to discuss, for example, disposal methods, operating procedures, the effects of the establishment of the state compacts, and de minimis criteria. We should, however, remember that our overall aim is to identify problems that need R&D work in order to advance LLRW technology and to put the industry in a better position in 5 to 10 years, or even 25 years, from now.

Examples of some questions which you might wish to explore are:

1. Waste treatment — What is its aim? — optimum technology application? — better economics? — safety? — efficient land use? — Where should the facilities be located? — local to the source? — centralized? — mobile?
2. Disposal — Does the disposal step have the major effect on treatment specification, or are the major considerations related to waste characterization, packaging, transport, or storage?
3. State Compacts — The increased number of sites will involve smaller scale operations and a variety of site characteristics, disposal methods, regulations, and fee structures. How does this variety impact on treatment needs?
4. De minimis — Creation of a de minimis category will mean two separate smaller waste streams under different jurisdictions and with different characterization needs. How will it affect the benefits of treatment?

From the above, it seems that we should have no trouble filling the panel's time slot today. If we do run out of time before you have the opportunity to raise your topic of choice, please remember there is time scheduled for a continuation with the panel tomorrow morning.

1.5.2 Remarks of V. R. Autry

I appreciate this opportunity to participate in this workshop and present some of the views and suggestions concerning the treatment and disposal of LLRW. We feel very strongly that the treatment of waste should be approached from a technical standpoint and applied universally to all generators, but with strong consideration of the environmental factors affecting each disposal site.

Prior to promulgation of Pt. 61, the disposal-site states historically set standards for the treatment and disposal of waste, with conditions incorporated into the licenses issued to the different disposal facilities. Of course, this is still the case. However, certain elements of the new Pt. 61 are mandated in these licenses to ensure consistent land disposal and standards in waste classification.

Methods of treatment and containment of wastes, such as solidification media and systems, and HICs were reviewed and approved on a case-by-case basis by the states. Although successful, it was very difficult for us to accomplish this because of staff limitations.

As we learned more about the properties of radioactive waste and solidification media, additional requirements were necessary to ensure environmental protection. Of course, as the volumes of radioactive waste grew, the numbers of vendors and treatment systems and methods also increased, and this, of course, compounded our problems in trying to review all these proposals.

In order to comply with the requirements of Pt. 61 and the facility license, it became necessary for guidance and standards to be devised that could be applied universally to all waste generators. The NRC's branch technical position on waste forms was developed for this purpose and, of course, in concurrence with the sited states.

Along with this came a joint review by the NRC and the states of process-control programs, solidification media, methods, and HICs. At this point in time, the state and NRC both jointly reviewed these for final approval.

The NRC's branch technical position on waste forms has established numerous standards with general criteria for determining radionuclide concentrations in waste, in classifying waste, as well as in establishing

standards for proper waste stabilization. We feel at this point, however, that specific methods and guidance should be established to accurately determine the radionuclide concentrations in waste.

This is especially true for the Class C waste and more so for irradiated reactor components. In addition to improving radionuclide accountability in waste streams, we also recommend possible research and development studies for LLRW to answer some of the following questions, which are posed by numbers of persons dealing with the compacts, political persons, and other technical people.

The first question we would like for someone to at least approach is, What are the increased radiological hazards for handling and disposing of wastes that have been subjected to volume reduction (e.g., compaction and incineration)? We do not have very much material on this question today.

Obviously, there are some advantages to volume reduction, which increases the longevity of burial sites by saving burial space. However, where is the break point? When such activities create a higher concentration of waste, it results in increased occupational exposure during handling and higher potentials for migration in the burial environment.

Other effects from waste reduction should also be considered, such as radionuclide discharge to the environment during incineration, increased transportation exposures, and accident scenarios.

The second question is, based on handling and disposing of incinerator ash, residual, and similar wastes at burial facilities, What concentration limits should be established that would require waste stability, for example, solidification or increased containment?

The advent of incinerators and other waste-treatment methods produces small particulates, which pose handling problems at burial facilities. There is also an increased potential for environmental surface contamination as a result of handling and transportation accidents.

An in-depth study of this situation may help to determine at what concentration level these waste forms should be solidified and require increased containment.

The third question is, What would be an acceptable concentration for chelating agents contained in waste disposed in burial environments? At

the Barnwell site, which has a humid environment, there have been many numbers approached as to what percentage of chelating agents would be reasonable for disposal there. However, there has been much discussion about this, and each compact now, especially in the Southeast, will be faced with ever-increasing burial of waste-containing chelating agents. Of course, this is recognized as a means to increase migration, or the potential to increase migration.

Although compact approval is pending in Congress, the proposed legislation, as written, would have various effects on the host states. We feel that the LLRW disposal technology will not be compromised by the compact. However, the allocation scheme proposed, especially the requirement for the three host states to divide the "pie" among themselves, will have significant effects.

Administering the allocation program, with its numerous variables, will require considerable management. Also, there is a need for information systems for the host states, the compact commissions, the burial sites, and the federal agencies and many of their contractors. A national data base system should be established, and I understand that there is work toward this end now being done.

Under current practices, regulatory or otherwise, considerable quantities of materials that contain insignificant levels of radioactivity or are often overshadowed by their toxic properties are disposed at licensed facilities. Radiation levels and concentration of radionuclides alone should not be a basis for determination, but, also, the individual radiotoxicity of nuclides should be analyzed.

There are other considerations, regulatory restrictions, and political and public perceptions that have a tremendous bearing on regulatory decisions. However, when approached reasonably and logically and evaluated for health risks versus benefits, a significant amount of low-level radioactive wastes can be disposed by other means than licensed radioactive disposal sites.

1.5.3 Remarks of G. A. Benda

When Herschel asked me to speak about the perspectives of R&D, and what they would be in the next 5 or 10 years, I came up with two specific conclusions, source elimination and new disposal site economics.

Being in Projects Development, I deal quite a bit with the public and in politics. If you remember back in 1977 and 1978, when South Carolina Governor Dick Riley was wondering why South Carolina was taking 68,000 m^3 (2.4 million ft^3) of waste, the industry was being questioned on its volume-reduction plan, and everybody started thinking in terms of volume.

This has continued today in the compacts; everybody thinks of volume reduction and the economics associated with volume. If you start listening now, concerning new site development, with the environmental groups, and the public, there is a new word cropping up, "curie or source reduction" or source elimination.

Today, there are several environmental groups that are taking the stance, that (1) Class B and C waste should go to high-level waste sites, not low-level waste sites, and (2) source or curie reduction, or, more importantly, source elimination, should also be looked at. In 5 to 10 years from now, our major R&D effort may be finding methods not to produce as much radioactive material.

The second factor, in considering governmental R&D efforts, is economics. We now have 12 or 13 compacts, depending on the day of the week, the month, and the person with whom you are speaking. We continually talk about the volume in those compacts, but no one has done an interactive impact study in each compact. For example, if we estimate that the disposal price in a certain compact is \$2020/m^3 (\$60/ft^3) because of higher technology costs, replacement costs, public relations costs, etc., how much volume do you think you will generate at that new calculated price?

You then take that volume of material, go back and refine the study, and find that now your cost is \$5300/m^3 (\$150/ft^3) because of having less volume over which to spread your cost base. There exists a continuous spiraling effect of disposal price and volume. We have not yet been able to relate to our public and our legislators what our final cost of disposal will be in the proposed 12 or 13 compacts.

It seems to me that the two prime future R&D efforts in the next 5 to 10 years should be source elimination and analysis of disposal site economics.

1.5.4 Remarks of Arvil Crase

I am pleased to be on the panel this morning and to present some of our views that we believe need some further consideration. I would like to talk for just a moment on some of the activities that US Ecology is involved in other than the two shallow land disposal sites, Beatty, Nevada, and Richland, Washington.

We are currently very involved in the design, construction, and hopeful operation of an incinerator. This incinerator is designed to handle DAW and some liquids. We have applied for a license to the state of North Carolina and, if successful, we believe this will be the first commercial incinerator in the United States. It is not a big unit. We would like to cooperate with DOE and other agencies and institutions as this incinerator is developed, so that the technology can be spread to other interested parties. We are very interested in having DOE work with us on this particular project.

We are also involved in site development. As Gary Benda has already said, we do not know exactly which way we are going to go, as a company, with new sites because of the uncertainty of the compacts and compact language. The situation is very simple. There is no state that has come forth other than, perhaps, Pennsylvania, and said, "We're going to have a site." Once this happens, then the companies such as Chem-Nuclear, US Ecology, and others, will certainly be very involved in siting. We will need help from modeling for the sites.

There are very few data, other than the supportive data that came out on the preceding 10 CFR Pt. 61. It seems like the data are cut off at that point in time. I certainly will echo Gary Benda's concern about costing in a particular compact region.

During 1984, for instance, the Southeast region generated just a little over 28,000 m^3 (1 million ft^3); the Rocky Mountain region, in which our Beatty site is located, generated 280 m^3 (10,000 ft^3); and the Northwest region generated ~3400 m^3 (120,000 ft^3). Now, in one month's time, we take in ~3400 m^3 (120,000 ft^3) at the Richland site.

So, logically the costs could be higher by a factor of 10. I believe this affects the institutional generators much more than it would a utility. The immediate increase in the cost of disposal of waste to a

medical facility results in immediate higher patient costs. This is spread over a more narrow base. That affects economics associated with the existing scheme of compacts and could be very, very severe, especially in the Rocky Mountain and Central regions, which generate $\sim$2000 m^3 (71,000 ft^3). Much more work needs to be done on the economics of siting under the present scheme of compact layout.

The biggest thing that we need help on today is the issue of dual regulation between EPA and NRC, the mixed-waste issue. This is going to surface very shortly. It will, again, affect basically institutional generators.

On November 8, 1985, US Ecology will no longer accept scintillation fluid in any form. Now, where does it go? Regulated or deregulated, it does not matter. We, as a burial site operator, cannot conform to retroregulations as they are written and handle readioactive waste. We cannot morally subject our employees to opening containers to verify waste forms and the chemical constituents thereof.

I am not sure that there is a radiochemistry lab in the country that could perform this analysis for us. It also involves a retromanifest. It also involves dual lining in trenches. We urgently need a definition of mixed waste and who regulates what.

We firmly believe the NRC is the regulatory agency for radioactive waste, in whatever form. There are other agencies that disagree with that.

Virgil Autry touched on chelates. Is that a mixed waste? What mixed waste forms do utilities generate? Are there heavy metals on resins? Are there heavy metals in other waste streams? What waste forms are you generating that will potentially come under mixed waste and retroregulations? We think it is a big issue, and we urgently request DOE to consider this area.

1.5.5 Remarks by N. P. Kirner

Thank you. I will start out giving an advertisement for my sister agency in the state of Washington, the Department of Ecology. It provides staff for the compact negotiation process and heads up the Northwest Interstate Compact. The department recently issued a document on procedures for contacting the Northwest Compact. You might want to contact the Northwest Compact if you are interested in ensuring disposal capacity after January 1, 1986. The person to talk to is Elaine Carlin, and her phone number is (206) 459-6244. I will take business cards or requests for copies of the procedures for contacting the compactor, if you would like us to send one to you.

I would briefly like to amplify some of the remarks that Virgil Autry and Gary Benda made regarding volume reduction. It is very possible that we will still receive the same activity of wastes, only in a smaller package, once the compacts are ratified.

In doing so, the states may have done themselves a disservice by increasing their hazardous legacy, since hazard is generally proportional to the concentration of the waste. More specific guidance is needed for waste classification.

I want to spend most of my time, however, on the issue of orphaned waste. Currently, there are several categories of waste that have no home, which I call orphaned wastes. One of those is, in normal parlance, Class D waste, that is, greater than Class C. It is somewhere between high-level waste, which is not defined by EPA, and low-level waste. Neither the state of South Carolina nor the state of Washington will receive greater than Class C waste without additional information regarding the safety of that classification for shallow land burial.

I also want to caution people who may rush onto the bandwagon of de minimis or below-regulatory-concern (BRC) waste. Please be sure there is an alternate place to put the waste once it has been deregulated. Liquid scintillation vials are a perfect example of how a quick fix fell short. There was one actor, the NRC. There needed to be coordinated regulatory actions by about about three actors, NRC, EPA, and DOT. Three years following NRC action, DOT finally agreed that this specific waste is nonradioactive for transportation purposes. Meanwhile, EPA, for the most

part, has not embraced this waste stream as being allowable to its RCRA-regulated disposal sites.

The same regulatory confusion could happen with some of the waste streams now being proposed for classification as BRC, such as slightly contaminated oils from nuclear power plants.

I want to touch significantly on mixed waste, especially on the definition of what is a mixed waste. This is an issue currently impacting both federal and commercial operations, Oak Ridge and the Hanford Reservation. Low-level radioactive waste facilities are falling under regulation from both RCRA agencies and Atomic Energy Act agencies. The low-level waste disposal operator in Washington has been notified to either submit a Part B application by November 8, 1985, or to submit a closure plan by November 8, 1985. As I understand, the disposal site operator has chosen the closure plan.

According to the definitions being considered among the federal agencies, mixed waste could encompass as much as 95% of the waste that is currently generated, or it could encompass as little as 3%. Some rudimentary studies have been done under contract to the NRC by Brookhaven National Laboratory. I believe more information is needed, especially from the small medical generators.

The small generators, of which there are about ten times more than utility generators, do not have to appear to have the large economic base to meet the more demanding regulations concerning mixed waste.

How should one dispose of mixed waste? Is pretreatment necessary? Possibly incineration is the answer. The costs of incineration have not been borne out to be advantageous, but what is the cost of not being able to dispose of the waste at all?

There was some discussion about making the Washington and South Carolina licenses identical. If this happens, there will probably be more orphaned waste. Chelating agents and volatile organic liquids fall into that category. I look, again, to incineration as perhaps a pretreatment alternative.

Both institutional and technical information and solutions are needed. By institutional, I mean regulatory and legal actions that are needed. Both institutional and technical sectors must work together to

solve the problems facing LLRW disposal. It is a chicken-and-egg problem. You cannot have the technical solution without the institutional solution or institutional body having confidence in that technical solution. I go back to my favorite acronym, and that is CORCOBS — "Cooperative," everybody working together, "Open," no false or hidden agendas, "Responsible," neither overregulation nor underregulation, "Communication On Both Sides."

1.5.6 Remarks by B. G. Kniazewycz

The last time I spoke on a DOE panel was in 1977, and that dealt with low-level waste. At that time, I was a major advocate of volume reduction, the big-dollar items, the $50 million retrofits. Today, though, I think we have a different challenge, and one that, unfortunately, is sort of a deja vu. We have a new series of plants coming on-line, a new series of operators, and the same problems we had in the 70s.

Plant operations are not optimized. The consciousness level of management, while undoubtedly higher than before, is still not at a level where we can say the unit operations in the plants are optimized, the source terms are minimized, the equipment runs well, and we have gotten the maximum "bang-for-the-buck" for the money that has already been spent.

I think the challenge that we face right now is identifying those plants that are operating well, those plants that do not release water, those plants that, instead of disposing of 280 m^3/month (10,000 ft^3/month), dispose of 10,000 ft^3/year, and taking that operational information and determining why they operate the way they operate, bring this experience to bear to the whole industry, allowing the whole nuclear industry to reevaluate its priorities and its operating philosophy.

In the same vein, though, we have seen a lot of improvements. We have seen volume reduction of DAW waste and have seen a lot of improvements in this area. As a consultant, I have seen this improvement in numerous operating plants. I think what we have seen, though, at the same time, is not the same effort on a more complicated problem, involving unit operations such as the water systems, the resin systems, the evaporators, and the filters.

We have a number of good examples out there, but I think, with close to 100 plants on line within the next 5 years, you are going to see a situation in which we have to go back to the waste source, and I think that is the key item.

At the same time, I will say that DOE has sponsored some research. Our own company has received a grant to evaluate and develop means of recycling boric acid in a power plant, cleaning it up to such a state that we can reuse it instead of disposing of it as a solidified waste.

I think we need to look at a lot of the experience in Japan and some of the other areas, reexamine the effectiveness of the unit operations that exist today, and reevaluate why some organizations (plants) can operate very well, whether it be a combination of personnel training, organizational direction, better procedures, or better people, and really take that into consideration.

I think if research is being looked at, we should look at the waste source. I think that it is obvious that, at the tail end of the plant, a lot of effort is being done. A lot of the comments here identify more areas for R&D. But I think we are doing ourselves a major disservice without bringing the 80 plants on-line now up to their optimal operations and gaining the volume reduction at that end.

1.5.7 Remarks of F. L. Parker

I had intended to talk about needed research, based upon my experience in radioactive waste management. However, I learned only this morning that the problem became critical only in 1977, and so the knowledge that I gained in the prior 25 years, I guess, is not particularly applicable.

Therefore, I will talk about detailed, specific work that I and my students are involved in at the present time. I do this consciously, because there are excerpts in your packets of three excellent publications that have good lists of work under way and research needed. The three are: A State of the Art Report on Low-Level Radioactive Waste Treatment (ORNL/TM-7427 by Herschel Godbee and Arlene Kibbey); The Low-Level Radioactive Waste Treatment Technology Manual, DOE/LLW-13TC; and The DOE Hazardous Chemical Defense Management Program Technology Review Report: Currently Available Technology, DOE/HWP-4.

I want to acknowledge the assistance that the DOE has provided us in a pilot internship program on decontamination and decommissioning at Vanderbilt University. We have five students on summer work assignments at the present time, two at the Savannah River Plant, two at Bechtel National, and one at Westinghouse Hittman. Parenthetically, I might say, if you have any bright students who are interested in a master's degree in this area, get in touch with me.

In addition, if you would like to sponsor one of our students during their internship next summer, also let me know, and if you are interested in the program, in general, we have a colloquium on their experiences this past year, the first year of the program, September 19 at our university.

Some of the things I have to say we have heard already, but I will repeat them. It is obvious to everyone attending this meeting that low-level waste is defined by 10 CFR 61 and high-level waste by the Nuclear Waste Policy Act, with a large gap of uncertainty about what to do about the wastes between Class C waste and high-level waste.

There have been a number of comparisons made between the requirements of 10 CFR 61 and the RCRA for land disposal. However, similar comparisons between 10 CFR 61 and 40 CFR 191 — I can say that, since it was just issued — have not been made.

I have suggested, somewhat facetiously, but maybe not totally so, that first raffinate wastes from reprocessing plants, from which most of the long-lived nuclides have been removed, should be classified as an RCRA rather than a high-level waste, so that the waste can be stabilized near the ground surface, rather than being put into deep-mined geological repositories.

These problems, about which I am only partially joking, reflect the difficulties inherent in this type of classification. It would be much better, in my view, and the NCRP has echoed this, or vice versa, if the determination of method of waste disposal were risk based. However, this approach would require much more information about the retention of radioactive materials in their solidified forms, their movement through the environment, and their speciation.

This proposal should also allow variances by which certain categories of waste could arbitrarily be classified in the same way as 10 CFR 61 does now. To do the risk-based analysis then, the retardation of important radionuclides, combined with the nonradioactive materials, in the various rocks and soil types would need to be determined.

One of our big problems right now, which has already been mentioned earlier, is the lack of ability to quickly and inexpensively characterize wastes both for their radioactive content and hazardous chemical content. This lack is inhibiting the cleanup and disposal of wastes at these sites.

Particularly troublesome is the lack of a screening methodology for chemical wastes. The method should be simpler than testing for every priority pollutant, which is required now. At a particular site that is being decommissioned, of which I am familiar, there is an enormous volume of construction material that will now go to a licensed burial ground simply because there is no rapid method of separating the radioactive from nonradioactive materials — half of it is just construction material, which could easily be disposed of in a municipal waste facility.

For liquid wastes, even if the hazardous chemical wastes were identified, their separation to a high degree from radioactive waste is required to avoid having them classified as mixed wastes.

Now turning to some work that we are doing, in decontamination and decommissioning of nuclear facilities, we find that concrete frequently needs to be decontaminated. Most of the methods in use today are brute-force methods, such as hydroblasting and scabblers. Both are difficult to accomplish and spread polluted material about. They may even cause further penetration of the contaminants into the concrete.

It would be useful to have a chemical method that would be specific for, say, cesium and strontium and would not take other elements into solution. We are searching for such chemical methods.

Now, I want to list the work that the interns are doing this summer, just to give you an idea of the kind of research that is going on. One of my students at the Savannah River Plant is writing a smart computer program using artificial intelligence to operate a plutonium incinerator. Another one of my students, also at the Savannah River Plant, is looking at simple and safe methods of capping piping as it is cut, so that it prevents the scattering of contamination. The same students are trying to determine the effects of such variables as temperature, pressure, and volume on the efficiency of hydroblasting.

Another one of my students, at Westinghouse Hittman, is looking at the injection of grout into an existing burial ground to see if it can stabilize the contents. They are trying different grout formulations. In addition, she is helping to design the advanced disposal demonstration facility for that site.

One of the students at Bechtel National is looking at the removal of oil and the breakup of emulsified oils from mixed waste, so that they can then classify the remainder as radioactive waste, and they can bury it. Another student at Bechtel is searching for quick chemical segregation methods for these mixed wastes and is also testing the field effectiveness of various alpha monitoring techniques.

1.5.8 Remarks of L. J. Riales

TVA has five nuclear units in commercial operation, one awaiting a license, and three additional units under construction. The three units at Browns Ferry produce ~3300 m^3 (116,000 ft^3) of low-level radwaste per year. The two units at Sequoyah produce a total of 820 m^3 (29,000 ft^3) per year. The first of our Watts Bar units should also start up next year with the second unit starting up in 1987. We currently ship about two-thirds of our waste to Richland, Washington, with the other one-third going to Barnwell, South Carolina.

We have been carefully following the new congressional legislation and its effect on TVA. House Resolution 1083 will have the following effects on TVA plants:

1. All shipments to Richland, Washington, will have to be discontinued, with TVA using Chem-Nuclear's Barnwell facility exclusively.
2. TVA plants will have new allocations based on plant type and license date.
3. Browns Ferry's current waste generation rate exceeds its allocation in the 1986–1989 time period by 28% and by 35% in the following 3 years.
4. Sequoyah's current waste generation rate exceeds its 1986–1989 allocation by 14% and its allocation for the following 3 years by 22%.
5. Watts Bar exceeds its allocation by an average of 15%.

In order to ensure that TVA radwaste disposal operations are not adversely affected, we have looked at a variety of processing and storage options. It is obvious that massive volume reduction is required and that the place to start is at the origin of the waste. Increased employee education, recycle, and waste segregation are being used to stop unnecessary waste generation at the source.

At Sequoyah, we are working through EPRI to develop a licensing submittal for NRC that would allow us to take all trash with a specific activity of <2 nCi/g to a local sanitary landfill. The submittal is complete and will hopefully go to NRC by next month.

We are also considering equipment additions at each plant site to reduce trash volumes. A shredder/box compactor has been purchased for

Browns Ferry, and one has also been purchased for Sequoyah, to be installed in a new DAW processing building. Similar equipment may also be purchased for Watts Bar.

After a successful demonstration of the Westinghouse Hittman mobile supercompactor at Browns Ferry, we have sent out a request for quotes for a similar system to compact drums of trash. We are also considering other mobile services to reduce our trash volume. We have been approached by regional volume-reduction facilities that use supercompaction and incineration to reduce waste volumes.

In the remaining months of 1985, the plants are trying to get rid of as much backlogged waste as possible, including some material in the spent fuel pools that may be difficult to get rid of later.

Both Browns Ferry and Sequoyah have above-ground concrete storage modules that are licensed for up to 5 years of storage. With currently built modules, Browns Ferry can store almost 1 year of generation, and Sequoyah can store about a 3-year production of waste. Because of the difficulty of using these modules, TVA plants are considering the purchase of on-site storage containers for waste storage. These steel and concrete containers can be used to hold liners, drums, and boxes and may be licensed for 5-year storage under 10 CFR 50.59. Their low cost, availability, and simplicity make them more attractive than additional concrete modules.

Another R&D program currently underway at TVA is the design, fabrication, and testing of our own HIC. Our design comes in three sizes to fit TVA casks. We currently have a request for quotes out for the fabrication and testing of prototype containers. Production of these containers will depend upon the results of the prototype tests and a determination of cost-effectiveness versus vendor-supplied HICs.

1.6 GENERAL DISCUSSION (SESSION 1)

DR. CHARLESWORTH: Thank you very much, Lenon. Now is the time to put the rest of you to work. I will remind you that we are aiming for identifying R&D needs, but our instructions are to consider not only treatment, but disposal, the effects of compacts, and de minimis criteria, and I am sure other related topics are equally appropriate.

MR. KOPLIK: Chuck Koplik, TASC. Just a comment, not addressed to anyone in particular, concerning the effect of volume reduction on the economics of the compact site.

I commented this morning, but maybe should add a more on the study we did for Houston Power and Light. We evaluated the proposed Texas closed site and its effects on Houston Power and Light if it greatly increased its waste volume reduction. This increased volume reduction would economically affect other users, the major effect being that costs could well go up, quite sizably. In particular, the medical community, and possibly other reactors as well, would be affected.

The other supportive comment I wanted to make was in relation to the discussions of mixed waste. We have looked at that issue briefly for the state of Massachusetts by doing a survey of all the sources of LLRW produced in Massachusetts. The real focus on the problem in Massachusetts, in terms of mixed waste, was in the medical community and on its generation of toluenes. There was very little problem as far as nuclear plants were concerned. So, I just offer those comments in relation to the things people were talking about this morning.

DR. CHARLESWORTH: Thank you. Are there comments from people on the panel?

DR. RODGERS: I would like to just expand on that a little bit, because it ties in with what was said by Chuck Koplik. We have discussed the fact that the cost is going to increase, which a number of people have felt was a definite possibility. Can we look at why it increases, instead of just assuming that it is going to increase? Why will it increase? What are the causes? Is it necessary that it actually increase, or is there some way that we can get around it? I suppose that Arvil Crase and Gary Benda have some good reasons as to why it is going to increase. I think all of us would like to find some ways around those reasons, so

let's see if we can get at the underlying factors and elucidate them a little bit.

MR. BENDA: Let's look more specifically at a disposal site and especially for new sites in a smaller region. The major cost is fixed; it is not a variable dependent on the volume. No matter how much volume may go to that site, you still have a large fixed cost. This really impacts states with small volumes of waste. In a "small" state like Texas, which now has ~3400 m^3 (120,000 ft^3), which is volume reduced to 2000 m^3 (70,000 ft^3), the variable costs change slightly, but the personnel needed for environmental monitoring, for regulatory interface, for truck unloading, which will still be coming in once a week, does not drastically reduce. Therefore, you still have those large operational and development fixed costs and a very high disposal price.

DR. RODGERS: You have fixed costs, but you can put more material in the same space if it is concentrated. In other words, the life of the site will be longer if you have a smaller volume coming in, and your fixed costs will be spread out over a longer period of time.

MR. BENDA: Except that in my Texas example, and in a lot of other compacts, they are saying that their site will only last 20 years because of political and public relations reasons.

DR. RODGERS: Regardless of how much you put into it?

MR. BENDA: Regardless of how much you put into it, a 20-year maximum lifetime is predicted.

DR. RODGERS: Is that going to be necessary every time we have a site?

MR. BENDA: Well, it is a political factor. It is happening in every compact discussed right now; even California put a 20-year lifetime on its site.

DR. RODGERS: What if you have smaller sites, then?

MR. BENDA: No, it is not. Besides, when you buy land, you usually have to buy large sections of it at a time for a large or small site. Even if you are given the chance to buy it by a willing seller, no one is going to sell you just 40 acres.

DR. RODGERS: Will you have to go to different disposal techniques in order to account for the increased radioactivity? Will such a disposal technique increase the cost of the operation?

DR. CRASE: Let me answer that. It is US Ecology's opinion that shallow-land burial that we conduct in Nevada and Washington will not be publicly acceptable. There will have to be some enhanced engineering of current technology in order to make it publicly acceptable, and yes, that will increase the cost. For instance, the various types of entombments (while we certainly do not believe it to be necessary in an arid region) will probably be required by the public and, therefore, will increase the cost of disposal.

DR. RODGERS: Won't that be required regardless of the volume reduction?

DR. CRASE: No, sir, I do not believe so. One of the other things that raises costs is that we have not formally agreed (for the Beatty, Nevada site) as to what should be the amount of the perpetual care and maintenance fund, how many millions of dollars should it be?

We can say in the state of Washington that it is something like $8-9 million. It may be in that range or considerably less at the Nevada facility. So, if that site has a definitive life placed on it by the compact region, and if US Ecology must have in place $20 million for closure, which comes in at 280 m^3 (10,000 ft^3) a year, simple economics tells you that burial cost is going to be astronomical.

What, then, does this do to those facilities (e.g., Dr. Post at The University of Arizona) which use that site? What is the cost going to be to that institution? They are going to do everything possible to generate as little waste as possible. Then the cost goes further. This is an operating site, that is, a current operating site. What will the situation be for the new sites that come along? That is where the work really needs to be done.

DR. CHARLESWORTH: Any other comments from panel members?

DR. BUELT: Jim Buelt from Battelle, PNL. Nancy, I hear you, Gary, and others on the panel deemphasize volume reduction, basically from the standpoint that the same activity in a smaller package is not an improvement in waste isolation. Do you consider the improvement of the waste

form, coupled with the volume-reduction process, a significant incentive for volume-reduction processes?

MS. KIRNER: Let me go back. I think I was misunderstood if that is the thrust that you got from that statement. I said that, generally, the hazard level increases as the concentration increases, and if that is the case, if the hazard increases, according to 10 CFR 61, as soon as you exceed the Class A concentration limits, then you do have to start dealing with waste-forms stability requirements.

It would also extrapolate back, going down the scale, that if 80% of your waste was, say, half of the Class A limit, and 20% was over, then people started volume reducing and you flip-flopped (a very simple scenario here), you just flip-flopped the proportion of Class A to higher half versus lower half, you now get 80% in the higher half of the class as opposed to 20% in the lower half. I think your site has a greater potential for hazard.

DR. BENDA: Let me clarify my previous comments on volume reduction. From my perspective, I support volume reduction all the way, but for small compacts, we should be looking at two scenarios, one before the new sites are developed and the other after site development. On the second scenario, after the site is developed, and you are in a small region, you need to assess the volume-reduction impact of all the generators in that compact.

Like the Texas scenario, it may be better for Houston Light and Power and Texas utilities to each pay 40% of the site, no matter what volume-reduction method they want to use, because eventually, through all types of price increase and volume recalculation, they will be paying for that site anyway.

My second clarification on volume reduction focuses more on curie reduction. Curie reduction, or source elimination, is the new environmental movement. Much of the public is asking the industry why waste is generated in the first place.

Therefore, you see more and more legislators being pressured by the public to force the industry not to produce it at all. The R&D is needed at power plants to compare the curies they produced this year with the total in previous years and answer public opposition and environmental groups' concern.

DR. GOULD: Al Gould with Florida Power and Light Company. I just have a comment, not directed at anybody in particular. I think, in many ways, by focusing on volume we have created a more significant dilemma for the country, and certain volume-reduction or waste-minimization practices are very viable and should be accomplished, some are not so viable, and some may even be detrimental in other areas.

One way to reduce volumes is to cut out the demineralizer and eliminate it as a source of waste. What will result though, are higher radiation levels in the power plants and higher concentrations in the effluent. So, we should be thinking about the kinds of volume reduction that we are attempting to do.

But the real comment I wanted to make relates to a recent trip to Germany during which I visited a nuclear power plant, the Nekarwestheim Power Plant. In West Germany there is no shallow-land burial and no low-level waste disposal at all - all their material is stored on site. They ship to a regional nuclear research center, where it is volume reduced either by compaction, incineration, or an appropriate process. It is then packaged, most often solidified, and returned to them.

I would like to suggest that volume reduction on an individual utility basis is not the way we should be looking at this. We should be looking at volume-reduction centers similarly, except rather than returning the waste to the utilities for storage, or to the generators, it should go into the ground from the centers.

I further submit that these regional centers ought to be coupled to the burial sites. Some of the states may not agree with me, but that would give them total control, a total waste-management center, and they would not have to be concerned about increasing classification from C to above C, or from B to C, or from A to B, if it were not necessary. As everything came in, it would be volume reduced, as appropriate for the waste form and type, and then placed in the ground out the back door.

MS. KIRNER: I have a comment on that. I would only like to add that we did consider the application of one volume-reduction supercompactor adjacent to the state of Washington's existing LLRW disposal site from an overall waste-management scheme. We were looking at the reasonableness of having the volume-reduction center 3000 miles away from where most of the waste is generated. So, you have to also put your disposal center in that

regional area. Please do not think in terms of the West will take it and the East continues to produce it.

DR. GOULD: No, but within the framework of the compacts, we are talking about five or seven sites now, so we are talking about reasonable transportation issues.

DR. KOHOUT: I am Radovan Kohout from Ontario Hydro. I would like to expand a little bit more on the volume-reduction issue, although I may be repeating what has been said already here. If you take a look from the viewpoint of the people who run the disposal sites, it is a simplistic approach. The dilemma, should we recommend volume reduction or should we not, does it mean an economic savings for the utility or does it not?

But from the viewpoint of the producers of the waste, we all know that some sort of treatment of waste is necessary. But we are treating the waste, first of all, for a number of reasons, one of them being that we are converting the waste into a more stable form, perhaps into the form that is more compatible with the criteria of the disposal site. Unfortunately, we do not know the criteria of future disposal sites. But we do know that we have to treat the waste, to convert it into something. If we can volume reduce it at the same time, that is fine.

At this workshop we are trying to focus on outlining the R&D needs for a low-level waste treatment and, on the other hand, we are asking if we really need volume reduction. I would suggest that, for the practical sake of this workshop, we agree that volume reduction needs to be further developed, along with the treatment method. We should then schedule another workshop after we hear from the disposal sites what the criteria and, if possible, the costs are for disposal. Do we have land burial? Most likely not. We will have some sort of engineered structures.

We may have to have engineered containers that go into the ground and may possibly be retrievable, and then we may start to worry about volumes. I am from Canada, and we have practiced on-site storage since we started the nuclear program.

We do understand that once you introduce engineered structures into storage, retrievable storage, or retrievable disposal, you start to worry about volume. We have developed about the fifth generation of storage structures, engineered storage structures, which are very inexpensive,

yet we still feel that volume reduction is a very important segment in our waste management.

DR. CHARLESWORTH: Are there any comments, especially on storage versus disposal?

DR. CRASE: I would like to comment on that. It is uncertain to US Ecology as to what waste form will be acceptable in certain compact regions or the site that would be in that region. For instance, in a very humid area, such as New England, what is the waste form that will be required of the operator on the site, and what are the conditions? What will the license say is an acceptable waste form?

I would be very cautious, if I were a utility, in preparing waste in any fixed matrix for storage and aiming it for ultimate disposal at a site that has yet to be designated, with uncertainty as to what waste form will be acceptable. We can assume that it would certainly meet Pt. 61; however, the additional burial site requirements may cause some problems for waste that is placed in storage.

DR. CHARLESWORTH: Perhaps it is the chairman's prerogative here to raise a question. Storage is often defined in two different ways. One definition has to do with the intent to retrieve the waste and do something else with it, which is perhaps the context that is used here. The other approach is that storage is defined as being there forever and ever.

Is there anything but storage going on at the present time? Do we really expect to walk away from any site?

DR. BENDA: I disagree when you say "walk away" with 10 CFR 61 and the institutional control and the long-term closure requirements, as it is not walking away. The disposal sites operating today are not going to be dug up and moved 200 or 300 years from now. There is no intent by any operator or any regulator, that I know of, that the intent of 10 CFR 61 is to "walk away." It is not like Ontario Hydro, which is, as you mentioned, producing short-term and long-term storage.

DR. PARKER: That may not be the present intent, but we are certainly familiar with some of the D&D sites that have been declared cleanup and certified as clean, and now they are being dug up and transported some place else. We certainly do not know what the future is going to bring.

I am somewhat reminded of Mencken's comment that nobody ever went broke underestimating the taste of the American public.

The same thing, I think, is true about certification and treatment of waste. Nobody will ever go broke treating the waste to the highest extent possible. I think that is what we are seeing in France, and I think eventually we are going to see the same thing here.

DR. RAMSEY: I am Bob Ramsey with Nuclear Energy Services. This discussion is very interesting. I think there is one term that we are not using that we should use more carefully or use to good advantage, and that is "immobilization." We talk a lot about the treatment of waste, the processing of waste, the solidification of waste, and the volume reduction of waste. All these are process treatments, but the real management that occurs when we process and treat the waste is to immobilize it, so that it will not become a self-dispersing article in the environment.

It is very important, I think, when we look at volume reduction, that we look at it realistically. What it does is save money in terms of using what we have defined as a scarce resource, and that is burial space. Another burial space should not be a scarce resource — we do have to use it very carefully — but certainly we are not using volumes of shallow land to give us any great concern about how much that volume is.

It is attendant upon us, however, to preserve that, to have what was mentioned today, stewardship of burial of material. The ultimate question of what happens to a burial ground is well known - it ceases to be managed. That will be its fate, and when it ceases to be managed, it then has to take care of itself against the rigors of whatever nature does with the materials that have been invested in it.

That is the real stewardship, to understand what nature does with the materials that are put in the ground and make sure that we make the best use of nature's own intent, to immobilize those materials and not have them emerge again as a threat or a hazard to the future. When we talk about processes of immobilization and processes of volume reduction, I would like to suggest that we focus on this issue of immobilizing, encasing, or doing whatever is necessary in the waste, so that we can, indeed, abandon the material without management, because that is going to be its ultimate fate.

I would like to raise again one other point or question for Mr. Crase. Arvil talked about the US Ecology incinerator, which raised the issue of the ash that is generated. I think Nancy also mentioned the question as to ash being a dispersible material and, therefore, being less safe than it would be in its normal circumstance. Is there any plan to incorporate in your incineration immobilization of that material in order to provide an improved form at volume reduction?

DR. CRASE: Under present conditions, where we would use the Washington facility for disposal of the ash, there would be no requirement to immobilize it. However, under the Southeast Compact, the ash could go to the Barnwell site and it would be required to be immobilized, solidified, for example. Ironically, our studies have indicated that if we go ahead and solidify it, we get a further 5% reduction.

DR. PARKER: I would like to return to this question of storage versus disposal. I mentioned in my remarks about using a risk-based classification. One of the things that Bob just mentioned struck me. We have not talked about changes of the risk with time, so we are not talking about having a waste that is going to sit there for thousands of years, as with high-level wastes, but we are talking about low-level wastes at this conference, so we can look very easily at how that risk is going to change over time, if you know what is in the waste. It means, for a relatively short period, we have to guarantee the integrity of these sites.

DR. AUTRY: I would like to comment on that. One of the first things I mentioned is we are looking at short-lived isotopes; however, we need better definition of these. We are aware that often waste is misclassified and the true content and nature of this waste are not always described.

Returning to this gentlemen's statement about a philosophy of ensuring immobilization of waste, South Carolina has tried to do this for many years, ensuring that waste is immobilized and, when placed in our environment, that it will remain where it is placed and will not migrate.

DR. PARKER: I guess I still have some trouble with that kind of definition, having no waste migrate. To not have a single atom migrate is an impossible task, and if we required that of any other aspect of human activity, we would shut down civilization. Thus, I think we ought to talk

about, again, what the risks are. Some small fraction migrates, as a matter of fact, every time we breathe radioactive material migrates. So, I think we have to be very careful when we talk about migration, because we need to talk about the quantity and, again, the risks that are involved.

DR. WILLIAMS: Paul Williams of Stock Equipment Company. We are talking VR, and we are talking up to 12 burial sites in this country. My own opinion, in looking at a number of projections of the quantity of LLRW in the future, is that the economies and the surcharges put on the burial sites are going to go a long way to accomplish the volume reduction.

As George had indicated, in the utility industry there has been a good bit of improved management, and waste quantities at individual plants are almost universally coming down. We all know that in the past 10 or 15 years the hospitals and other medical facilities have gone to a total disposal, throwaway economy in this area, and, most probably, as the disposal costs go up, this, of course, can be reversed.

I would like to address a question to the panel as to just how much waste there will be in the next 10 years versus that generated today, to attempt to tell us all a little bit how big the problem really will be.

DR. CRASE: Let me give some background to that, Paul. The nation's waste volume peaked at ~1100,000 m^3 (4 million ft^3) a little over 3 years ago, and since that time it has decreased. Statistically, there is very little difference between the waste volume generated in 1983 versus 1984.

We at US Ecology believe that volume reduction and other techniques to reduce the amount of waste delivered to the burial sites is offsetting the growth. In other words, with the new plants that are coming on, which generate probably 30% of the amount that the older plants generated at the same time in their operating history, we see a real growth of about 3% a year.

That is what we are predicting, but my predictions have not materialized because the market has continued to drop over 3 years. The amount of waste delivered to burial sites has decreased.

There is, however, a difference between waste generated and waste delivered for commercial disposal. This represents another market for the processors or vendors who provide services to reduce waste volume. But we do not see growth over 3% a year in this area.

DR. BENDA: I would add one more exception to that, and I think Arvil would agree, that there are some sites, such as superfund sites, which have to be cleaned up. This waste is already here and must be added to that volume estimate.

DR. KNIAZEWYCZ: I think that is another point to add, too. Many of the plants are becoming 10 to 20 years old, and they still have not totally complied with post-TMI required retrofits. At several facilities that we have worked at, we have seen a lot of concern about waste resulting from significant rebuilding or retrofitting of the facilities, and I think that that needs to be reflected in this waste question.

It is not at all unusual to see some of the plants with a lot of carbon steel piping, and so forth, in them removing that and chipping a lot of concrete. I think when that is reflected, you may see another waste blip or two, definitely, over the next 10 years.

I think we will also see a situation where there still would be some additional problems associated with a lot of the water-treatment systems at these plants, where they are slowly degrading, where the condenser performance is a problem, or where the demineralizer systems themselves are causing some problems.

In addition, the one other area that we have seen a concern about is the area of water chemistry and the requirements by several vendors to enhance their water quality and, in particular, reduce silica.

So, I think that these raise a number of questions that definitely are potential waste problems to industry.

DR. BENDA: I would like to ask Arvil a question. Do your projections hold true if the Udall amendment goes through, and the $10.00 tax goes on?

DR. CRASE: I have not addressed that issue, and I doubt if anybody in the company has looked at projections for future volume based on those surcharges of from $350 to $2100 per cubic meter ($10.00 to $60.00 a cubic foot).

DR. CHARLESWORTH: How about decommissioning wastes? Are they in your estimates?

DR. CRASE: No, they are not. I have recently seen, perhaps many of you have, a DOE survey of utilities as to what the future holds at the end

of the operating period of time. If my memory serves me right, there are many, many locations, perhaps half, at which a decision has not been made and, therefore, we would not have a complete projection.

DR. MALLORY: Chuck Mallory, Westinghouse Hittman. This is for either Virgil or Gary. At the beginning of this year, 1985, the rate schedules at Barnwell were changed to remove the radiation surcharge, leaving just a volume surcharge and a curie surcharge. Has this resulted in increased surface radiation on the packages, and have you noticed any difference in the exposure of your personnel?

DR. AUTRY: I have not, through our inspections, noted much difference whatsoever as opposed to before the radiation surcharges. It possibly has been reported less on paperwork, but we have not noticed it as far as our inspection program. Of course, South Carolina has nothing to do with setting rates whatsoever. This is entirely each company's own prerogative to do that.

DR. BENDA: Chuck, I do not know how our exposure level per month has changed, but I can find out for you.

DR. MALLORY: It would encourage people to use dewatered HICs rather than solidify the waste. I was wondering if that trend has been observable. The dewatered container would have a higher surface radiation, and where it was solidified, a lower surface radiation would be found.

DR. BENDA: Is the surcharge that much different between the technologies of dewatering and solidification?

DR. MALLORY: It was a major factor in the disposal costs until the beginning of the year.

DR. BENDA: I will find out as far as our exposure . . .

DR. MALLORY: I think a more general concern that we ought to consider at this workshop is how to use rate structures and surcharges to achieve our objectives.

DR. AUTRY: I think surcharges right now are more of a penalty that certain states are going to have to pay for their failure to grasp the low-level waste problem and, of course, it will be passed on to the citizens as rate payers. That is my understanding of surcharges mandated in the compact legislation. We do not know who is going to get this money from these surcharges, or what it is going to be used for. It certainly

could be used in some of our environmental programs. As we see it, it is just a penalty.

DR. CHARLESWORTH: We are down to the final minute, and it is appropriate that Bob Jolley have it.

DR. JOLLEY: I do not know whether it is appropriate or not. But I was reminded by what Frank Parker said, quoting from the sage of Baltimore, H. L. Mencken, that there is an additional quote which goes along with our current complex problems. He wrote that most people think that all complex problems have a simple solution. And then he added the statement, "but it is usually wrong."

DR. CHARLESWORTH: Our time has run out for today. We will have some of the panel back tomorrow, and I hope, over the workshop time, you will be thinking of more discussion that would be useful. I would like to take this opportunity to thank all the members, and particularly those who will not be around here tomorrow to receive a second round of thanks.

DR. RODGERS: Let's give the panel a hand. That is very, very interesting. Thank you very much. The plenary session is adjourned.

1.7 PANEL DISCUSSION (SESSION 2), C. H. CHARLESWORTH

DON CHARLESWORTH: We have had lots of opportunity in the workshops to get down to specifics. This is the opportunity to put it all together. We had a good session yesterday discussing some of the other factors that weren't going to be touched upon in the workshops. I hope that new ones have arisen and that the ones left over from yesterday are still in your mind. We have some members of the panel here to help the discussion along. Do we have any comments or questions or discussion related to the entire low-level waste system?

RAY ISAACSON: Ray Isaacson, Rockwell Hanford Operations, Richland, Washington. Overall, I thought that the workshop was very good and very well prepared. I think that there is one issue we skirted in the workshops, having only talked about it in a peripheral way, and that is the actual disposal itself. The land disposal of LLRW is one issue that is unresolved. States have been slow in responding, as they were supposed to have established their compacts by January 1986, which they have not done. The three sites we had when that law was passed are still there. They are the only sites in the United States that are accepting LLRW and, of course, they have made a lot of changes with respect to what they will accept. Of course, that is going to be impacted further by the RCRA, which we talked about in the panel, and yet we have not addressed that issue in this workshop. I would hope that we could give some more attention to discussing the needs for establishing burial ground technology and practices. What is needed in that area? Again, I don't think we have addressed that. At Hanford, where we have a rather arid environment, we still have questions as to whether or not precipitation infiltrates and percolates to the water table, thus potentially carrying materials to the water table. The state of Washington is now involved in our total waste management practices, looking over our shoulder at the chemical hazards, along with LLRW. And so, there is a full series of issues related to the burial ground practices that I don't believe we have addressed adequately in the workshop. I would encourage us to give that some attention, if time allows.

DR. CHARLESWORTH: Thank you. Is there comment on that from the panel?

DR. RODGERS: I guess I'd just like to ask Arvil, What kind of burial ground technologies do you see coming in the future? What help might you need in developing various technologies? I would also like to ask, What is the effect of the compact system going to be on US Ecology? Do you plan on moving into the various compact regions with a burial situation? And, if you are going to establish new burial sites, if the compact arrangement gets started, and you are going to move in and establish new sites, what have you learned and what do you need to go through that process?

DR. CRASE: Those are good questions, for which I wish I knew all the answers. Let me answer the last question, first. We believe that after the compacts are in place, there will be a great effort exerted by a number of companies to become involved in siting. And, generically, we can't say exactly what we need because we don't know how certain compacts are evolving. Many may take the approach that Texas has, in which the compact will be sited by the compact commission and then maybe even operated by the commission, requiring a lot of engineering support. And, in that particular case, I think that those groups will need a lot of direction because they will lack experience such as we and Chem Nuclear have. We are involved in siting nearly as much as Chem Nuclear in South Dakota; but, of course, we bid on the California projects in accordance with their regulations or specifications, which left a lot to be desired. But we believe that in the East and in the Southeast, and, by the way, that's an issue that very few people are addressing, while we do have an operating site at Barnwell, where is the next site in the Southeast because that site is on a time-specific schedule too? That other technology will have to be employed. It may not be necessary to employ a lot of the advanced technology that we see such as entombment and engineered barriers, except to ensure public acceptability. And, of course, in the arid areas, we see that there is still a lot of studying going on and a lot of concern around the Hanford reservation as others began to get involved, particularly the EPA, as to the real characteristics of that site. And perhaps there will be a further need for more modeling at this site or the other. We are very interested in siting in Pennsylvania. However, in some cases you can move too fast. The Pennsylvania people

need to get their regulations into place and make the siting situation possible. In the central states, the way the compact reads is that any vendor can come in and put in a site, and then the site selection process will be made. Now, I don't know of too many vendors who want to put in a site of $7-15 million, or whatever the costs might be, and run risk of not being selected. But that's the way the language is. With respect to compacts, it appears to us that a state will have to take the lead within the a compact, will have to take the lead, will have to be designated as a state. The Southeast Compact had a meeting or has scheduled a meeting to discuss siting and where the next site will be. Maybe if that meeting has been held, someone has some information on what decisions, if any, were made and what criteria were developed. At the present time, with the sites operating as they are, we do not see need for advanced study. But bear in mind that in these arid sites, because of the lack of availability of groundwater, not much work has been done with respect to movement of radioactivity through the soils. In Nevada, the nearest groundwater is 110 m (360 ft) deep, and on the Hanford reservation that's on the order of 90 m (300 ft) down.

DR. RODGERS: Where do you feel that there is more need?

DR. CRASE: I think the need is for future siting. We are already there, and it's more a preventive thing or to provide information to respond. But in the arid region in California, where perhaps a site will be located, even though it is engineered you still have to answer the questions under Pt. 61, as to what effect it has on the water table, where the water table is, and how it gets there?

DR. RODGERS: Are most of the new sites going to have a collection mechanism for water? Is water going to be in contact with the waste itself and be collected and treated in some manner before release to the environment?

DR. CRASE: I believe that would be required in a site. However, we question the necessity of it in an arid region site. But certainly in the humid regions, this procedure is still used. But again, there is the question of the validity of the system versus the need, and versus public acceptance. If the waste form is a solid, and we actually have a negative evaporation rate in the desert, what is the concern about collecting 100%

humidity when you don't have standing water in the trenches? But if it is required, of course, we put it in. It's our site and your money. Does that answer your question or get us started?

DR. RODGERS: Do you think there is any technology needed in terms of liners?

DR. CRASE: There has been a lot of study on trench liners, synthetic liners, and so forth. About 30 to 40% of our business is in the chemical disposal area. We operate an RCRA-authorized site in Texas and also the Nevada site, part of it being a chemical disposal facility. We just within the past month completed a disposal unit or trench at our Texas site using the new synthetic liner. We found that there has been a substantial amount of information and data put together on synthetic liners for chemicals. I do not know, and couldn't answer with any authority, whether or not that technology has been applied to radioactive waste, or if it need be.

DR. RODGERS: There are a number of cases in which the technology in the hazardous chemical area is, I think, a little more advanced, primarily because it has been applied for a longer period of time. In some cases, such as the usage of liners, if we start considering for low-level radioactive waste at some point in the future, there will be a lot of information available from the hazardous waste analogy. I firmly believe that there are a number of analogies in the chemical waste industry that can be applied to low-level waste disposal, handling, and treatment, and as you noted, in the handouts we included a lot of technologies that have never been applied to low-level waste or never considered as an application to low-level waste. They were primarily chemically hazardous technologies. We put those in there for a particular reason, hoping that people would take a look at them and see if there were possible applications to low-level waste. Most of them just haven't been considered before.

Frank, you are doing a lot of research at Vanderbilt - I think you mentioned five projects the other day - where do you see the R&D needs in this area? I know you are involved in preparing proposals, and so forth, and you must have some pretty good idea of what the R&D needs are.

DR. PARKER: Let me consider your first question on liners. I will make a comment rather than answer it. I wonder whether putting in liners

is really not technically the wrong thing to do in the humid East. The biggest problem for most of these sites that have had difficulties has been the bathtub effect, and a liner only exacerbates that problem. I certainly believe in good water control, such as putting in tight covers and diverting surface waters, and all that. But some of the material in the East is certainly going to leak out sometime or other. The amount may be very small, but what you would like to do is to get the water out of the disposal pits as quickly as possible. The liners have exactly the opposite effect, they retain the water.

DR. RODGERS: That's true, if you are just trying to prevent the intrusion of water, but a lot of times liners are used as a collection mechanism, and then you go to a sump. So, if the water gets in there, it is collected, treated, and released. Obviously, there is more than one use for a liner.

DR. PARKER: Then, the liner should be some distance below the site so that it doesn't back water up into the site. I think, even on that basis, I would not be too thrilled about it, because eventually people are going to walk away from the site, and then you will exacerbate the problem by building up water in the system if the liner lasts that long. I don't think they are going to last that long, I might say. But assuming that they would last that long, I don't think it's going to work the way you want it to work. It's going to be just the opposite, keeping water in after the site is abandoned.

We have been looking more at the movement of materials in the environment, such as movement of materials through liners. We have done a lot of work on hazardous chemical waste too. We found that a number of chemicals go through clay liners even faster than water does. Basically, it's a chromatographic system, except that it moves the waste through faster than the water. Another area that has had only a brief mention here, but certainly is a problem in chemical hazardous wastes (I think it may also become a problem in radioactive waste), is vapor transport of material to the surface of the ground.

DR. RODGERS: Is that due to a continuing reaction of waste materials placed there?

DR. PARKER: Yes, and from the organics.

DR. RODGERS: Where would the vapor come from? From the fact that things are still reacting underneath the surface and producing vapor? Vapor is not there initially.

DR. PARKER: It's also because you have biological activity, which is breaking down the material as well. So I think you need to look at transport just as is done for radon. You need to do the same thing now for a lot of these organics as well and determine the distances that you need for moisture and vapor containment just as was done for radon control. That kind of information is still pretty well lacking.

Another area that needs research work is risk-based design. I think the mistake that the agencies make, both EPA and NRC, is they treat low-level waste disposal sites the same as reactors, as if there are going to be 100 waste disposal sites. Actually, I think that there will only be about 6 or a dozen sites, at most, till the end of the century. It seems to me to have a generic rule for so few sites is a mistake, as it wastes a lot of time, and it really is not applicable to any specific site.

If you look at the high-level waste standards that EPA has just promulgated, and you look at their models, you see they have nothing to do with reality whatsoever. If you have to have a generic model, theirs is about as good as it needs to be. I think it's a mistake to have a generic model when you will only have one or two repositories by the end of the century. However, EPA is going to be coming out with regulations for low-level wastes sites based, I would guess, on a generic model. I think doing a risk-based analysis for each specific site would tell you how much reliance you have to place on the waste form and the packaging and how much credit you can take for the geology, taking into account the lifetime of those wastes. The discussion seems to assume that the wastes are going to last forever, which we know is not true. We don't need a package that's going to last 10,000 years, as is required for high-level waste. The activity is going to be at miniscale levels in a much shorter period of time. That could be factored into a risk-based system.

We have been particularly interested in research. We have not worked very much on the treatment, although I think its important, but we have just not done it.

RAY ISAACSON: I couldn't help but react to a couple of things. When we get into the transport effect, one area that we have forgotten,

apparently, is that water behaves under capillary flow pretty effectively and efficiently. Again, to illustrate the example, in one of our cribs at Richland we found that nitrate crystals were forming on the surface of the ground due to the capillary flow and evaporation at the surface. So when you are speaking of vapor transport, this is a factor too. In one of our experiments we have found that all of the incident rainfall over a period of a year, under a high-rainfall year, one of our once-in-10-years rainfalls, that moisture penetrated to a depth of about 5 m (15 ft) with subsequent evaporation from that depth back to the surface, with no apparent infiltration below that. Capillary transport and evaporation to the surface is an effect in the desert region that has been ignored, as far as I can see, from all my reviews of the literature and other studies. Even in the high-rainfall areas, you should also have evaporation, and, while your liners may serve to increase the bathtub effect, you also need to look at the evaporation potential and the capillary transport potential. I think, in summary, I am still saying that we do not yet know enough about the behavior of moisture in the soils and how it transports wastes from our burial sites. I think this is going to be a very important factor when we start selecting sites for disposal, whether it be in the humid East or the arid West. I find that the work of Dr. Karos Cartwright at Illinois has been very good in terms of engineered barriers, looking at infiltration barriers, but again, that's only a very limited study. At Hanford I find that our knowledge of the infiltration effects in that area, while we know perhaps more than has been known in the past, is lacking in terms of the transporting effects. So again, I would plead that we look at the research needs for burial sites in terms of how they behave with the various types of waste forms that we are considering.

DR. JOLLEY: I would like to have us explore de minimis for them. Maybe you have done that in your individual workshops. My questions relate to: (1) whether or not it can be practically achieved; (2) whether or not our monitoring devices are sensitive enough that we can sort and segregate and be assured that we have a de minimis waste; (3) whether or not the public would ever accept it; and (4) whether or not we really feel it is achievable as a concept?

DR. CHARLESWORTH: We will now accept comments from the floor.

UNKNOWN: Have we defined the concept?

DR. CHARLESWORTH: I am only familiar with the Canadian situation in which de minimis currently is related to, not unrestricted disposal of the material, but to restricted other disposal. That is, that you are not saying it is out of regulation, you are saying it passes from one to another. Thus, it's not so low a number that it has to be safe under any condition. Now, what is the current direction of thinking in the United States?

BILL HOLCOMB, EPA: I can say something about de minimis or what EPA is calling Below Regulatory Concern (BRC). There are several studies going on, and EPA, for one, is considering BRC as a viable option for the unregulated disposal of wastes with "minimal" or only "suspected" concentrations of radioactivity. We hope to propose a BRC standard next year in conjunction with a low-level waste standard. I know NRC is also quite interested in the idea of a de minimis or BRC standard. They mentioned it in their draft 10 CFR 61. In talking with some of the NRC staff, a generic rule from NRC would probably take 5 years to produce while there are provisions in the NRC rules to go in for a stream by stream exemption. That's probably the best method that the utilities or any other facilities could approach. For instance, somebody mentioned the waste oils petition at NRC now. A petition like that would probably take a year to act on by the NRC. Another exemption is the biomedical rule they did a few years ago. Otherwise NRC is sitting back and waiting for EPA to come out with its BRC standard and, if you will, for EPA to take the heat on the comments from the public, which may view the idea of taking radioactive wastes and declaring them nonradioactive as not in its best interests. But we are taking the approach that if we have done an analysis and determined a level below which regulation is not warranted, then as a concept the BRC level has a potential to improve environmental protection through focusing the expenditure of resources on the more significant impacts.

UNKNOWN: What have you come with and when do you think you are going to come up with it? Can you speak on that?

DR. HOLCOMB: I can't tell you what we've come up with, as we're still in the analysis state.

UNKNOWN: You haven't said anything about the worst that God gave us, or doubling that or anything.

DR. HOLCOMB: Many people want us to look at background and to take a percentage for the BRC level. We don't want to look at it that way. We want to look at the waste stream, the activity involved, and the interactions with other waste streams and do a comprehensive analysis.

UNKNOWN: You want details about every individual stream?

DR. HOLCOMB: No. I will say that we hope to publish our proposed rule sometime early in 1986. I hope that everybody takes the opportunity to comment because the comments are taken seriously and will be considered by the agency.

UNKNOWN: Will it be buried in the Federal Register?

DR. HOLCOMB: No. We will also have public meetings around the country to discuss the proposed standards.

UNKNOWN: There will be, but it is difficult to attend these.

DR. HOLCOMB: It is very laborious to get out a standard. We try to balance what the general public and the industrial section perceive and how the federal government agencies involved with NRC implementing the standard perceive the other standard.

DICK CURTIS: Those are generalizations; who is giving you the input? I am working in the quality assurance and equipment management area. I have worked in the radiation protection area, and I have a problem with how long it's taking to establish a de minimis limit for regulatory control of radioactive waste.

DR. HOLCOMB: Who knows how long it's going to take. I just came from an AIF meeting where they are looking at investigating possible de minimis waste streams from utilities in an effort to make proposals to NRC to exempt certain waste streams. We are all looking at the various waste streams and looking at the impact on the public in terms of radiation exposure. Because once you exempt, deregulate, or determine a waste is ready to throw out, you are going to throw it anywhere you want. No one is going to control it afterward. It's going to end up in a sanitary landfill, the county dump, or somebody's backyard in a hole. You want to make sure the public is safe. You want to make sure that the public is not going to be down on you every day pounding on you not to do that. It's possible that the public is not going to accept it either. When some county finds out that you are throwing stuff in a local landfill that was

classified as radioactive a week ago and is now no longer radioactive, what kind of public pressure will this bring?

DR. CURTIS: Yes, it's radioactive, and it's going to go in right next to the fly spray that's got the label on it, but let's get some relative risk information into the decision and pick a number of value.

DR. HOLCOMB: That's true. I don't deny that there's a misbalance between chemical risk and radioactive risk in the way people are perceiving them. There is also a vast difference between the chemicals that are regulated and the way they regulate radioactive materials.

DR. RODGERS: Bill, while you're up, could you please fill us in on EPA's role? It looks like EPA is getting into the radiation regulation act more and more these days. Is that really the case? Are you going to be pretty active in the area of regulating radioactive materials in the future?

DR. HOLCOMB: It depends on how the budget goes, which is on a year-to-year-basis. It also depends on what money OMB decides they can allow us to have. We just finished the high-level waste standard, which took 9 years to do. Once we had a court order, it took several months to finish it up. We did standards on the mill tailings and now there is concern, both congressionally and publicly, of the radon problem they are having in Pennsylvania and other states. They would like to see some sort of guidance on how to control it.

UNKNOWN: Who told you?

DR. HOLCOMB: The people, writing to their congressmen or writing to the states. The states are concerned. The states are having a big problem, in Pennsylvania, New Jersey, and New York, about what to do about all these houses that have so much radon involved that the people living there are at a greater risk for getting cancer within a few years.

DR. RODGERS: Bill, as you get into the regulation of radioactive materials more and more, do you see any conflict with NRC? How are you going to determine whether you should stop and they should start, or vice versa?

DR. HOLCOMB: We have already had this conflict, and we lost. No, there is a very definite dividing line between EPA and NRC authorities, unless Congress, in a specific law, requires EPA to do something different.

DR. RODGERS: Would you define that for us?

DR. HOLCOMB: We only work on generally applicable environmental radiation standards outside a facility's boundary or fence line. NRC has complete jurisdiction over the licensing and inside the fence line. We're talking radioactive materials, not mixed waste yet. NRC also implements all of EPA's environmental radiation standards. EPA has no implementation powers. We only issue the standard. NRC has to implement it and see that it is carried out. It's sort of a two-step process.

DR. RODGERS: It seems to me when you say you control something right up to the fence, that you're almost, indirectly, forcing someone inside the fence to accept the same thing.

DR. HOLCOMB: In a sense, yes. You're saying don't release so many curies to the environment past this fence line, and that forces NRC to say, "OK you guys, you can't let it get out, you have to do something with it. You have to control it."

DR. RODGERS: Concerning the area of mixed waste, I know that there was a DOE-EPA committee studying who should be regulating mixed waste and trying to go about getting an adequate definition for mixed waste. Can you tell us what the progress of that is?

DR. HOLCOMB: I have no idea what is going on there. DOE-EPA and NRC-EPA are working on memoranda, and that's strictly between DOE and NRC and the hazardous waste people in EPA. Unfortunately, in the past there has not been a lot of communication between "hazardous" people and the "radioactive waste" people at EPA. They don't seem to understand our philosophy, and we don't understand their philosophy, and its kind of hard to get together sometimes. So there is not much I can say.

DR. CURTIS: We got off the de minimis topic, but I think it's important to note that the budget was identified as a means of exerting come control over the decisions that are made in the regulatory area.

DR. JOLLEY: I'd like to insert a further comment or question. Let's assume that we can define de minimis as the normal background activity, a number that would be very low. And let's assume that the public accepts it, which, in my way of thinking, may be quite questionable in view of public perception of nuclear energy now and radioactivity in general. Can we expect the ordinary utility to have the expertise to count low-level activity well? Is instrumentation available? Is it too expensive? Some

of the low-level activity counting that we do at ORNL, for example, is done in underground facilities, very well shielded. Of course, this is to get down to very, very low levels and may not be needed. But, is there a need to develop instrumentation, economical instrumentation that is good for this purpose?

DR. CURTIS: I think whole-body counting equipment, such as the type that has been advanced by Lou Helgeson, is an example. He's got a quickie counter system, and I'm sure that with a little additional shielding and maybe a couple of bigger detectors you will be able to identify levels that even the public would accept since we're walking around with some levels of radioactivity in us.

DR. JOLLEY: Dick, you seem to be knowledgeable about it. Could you give us a level of cost of that type of instrumentation?

DR. CURTIS: No. I can't address how much Lou Helgeson charges for his quickie counter but I know that DOE has been shielding large detector crystals and measuring the radioactivity in things for a long time.

UNKNOWN: It's quite expensive.

DR. CURTIS: If you can avoid having to pay $\$2100/m^3$ ($\$60/ft^3$) to dispose of some stuff, it will probably be cost-effective to have a room that you can pass known "low-level waste" through and demonstrate that it is "de minimis." Somebody in the industry is trying to sell shielded boxes containing detectors in which you put a bag and say that it is low enough. I don't know the costs of these either.

UNKNOWN: The easy part of the problem is coming up with the money that is cost-effective, but setting the limits is difficult.

DR. CURTIS: Take the radioactivity in God-given granite or uranium in sand and start from there - I don't know why the regulators don't start from there.

PAUL WILLIAMS: Regarding low-level radioactive waste - we are in the same position as the nuclear power industry with one exception, namely:

1. Institutionally and politically our creditability is questioned.
2. Anything "nuclear" is an emotional rather than a factual issue.
3. The exception, in my opinion, is that positive actions are occurring regarding nuclear power and high-level radioactive waste. "Lessons learned" are being applied, Quality Assurance (QA) has become a

positive norm through utility, Institute for Nuclear Power Operations, and the NRC actions, and the industry is doing a better job of publicizing the facts.

In the LLRW area, we are more fractured technically, politically, and institutionally. Many regulations have been issued but not enforced, and the various methods of shipping and storing waste as presently used are difficult to support because of limited technical data.

No utility will invest its money in a new nuclear system or radwaste system when the utilities cannot reasonably predict the final cost or the long-term viability of equipment under fluid regulations, tight financial situations, and means available to "get by" without capital or minimal expense. The "what if" scenarios regarding radwaste equipment as it relates to regulations have forced designers to build almost unlimited flexibility into the equipment which, of course, escalated the price.

Under the above circumstances, I suggest that R&D efforts should be directed at defining criteria for long-term disposal of LLRW. These criteria should meet technical, institutional, and political needs. The criteria should be frozen and enforced, providing the utilities and waste generators a reasonable time to comply. We can then proceed rationally to settle the LLRW question.

Yes, the ultimate criteria will probably end up with a fair amount of "overkill" from a technical standpoint, and it will not be easy to accomplish. However, in my opinion, this will provide a relatively low-cost solution, perceived by most to be effective. It will certainly be less expensive and more effective in the long term than present practice; namely, most radwaste systems do not meet the criteria necessary at the time of plant initial operation, hence capital budgets are wasted.

JOE WALDEN: I have a couple of comments to make. I haven't been exposed to the DOE staff except for this meeting and a few occasions in Oak Ridge. It looks like most of the DOE R&D money and efforts are directed at trying to determine that we need to improve technologies. I think some of the R&D money should be directed toward selling the fact that the present technology of landfill techniques, the present technology of transportation, and items of this nature, are adequate and that we have gone far enough and we don't have to go any further in improvements (e.g.,

changing regulations). We need to get down to the real issues such as de minimis, which is the bottom line that will give us this 30 and 35% that Udall says we must obtain in shallow-land burial reduction. The second comment I have to make is that a couple of the speakers on the panel implied or were preconditioning us to accept the fact that there is an economic breakpoint in regard to cost vs volume reduction. They were trying to get us to go back to our management to say that no matter what we do, we can't save any money by implementing volume reduction. I think we ought to go on record, as an industry, saying that we don't go that way. We have been working toward volume reduction for 5 to 6 years, and we are making some gains in that area. To publicly say, as an industry, that we don't need volume-reduction improvements is irresponsible.

DR. CRASE: We're not singling out utilities or anyone. What we're simply saying is that, as the volume of waste delivered to a burial site continues to go down, the price will go up, rest assured, because of the fixed cost and such things as corporations requiring a profit. And then on top of this, I think that one of the areas facing disposal sites, at least at U.S. Ecology, which is a matter of much concern, is what the value of perpetual care and maintenance fee should be and what it should take to close a site. We know what we think it will take. Now, we could reduce your price by $\$2/ft^3$ if Washington would not assess us additional perpetual care and maintenance. The fund is almost $10 million, and they are wanting $22. Now, how in the world can you spend $22 million in a desert site? But those are the kinds of things that have to continue, they have to get their share, the 33% gross revenue. Although the volume goes down, the economic level for US Ecology is fairly constant. Understandably, it won't take as many people, as much excavation, and things like that, but the fixed costs go on. The licensing fee is required, whether you bury one barrel or 1 million barrels, although that's also negotiable. Now I can't say it doesn't save you money to volume reduce because everybody knows that it will. Oh yes, it'll save you internally, but I don't know what the break-even point is. For instance, if all of you people who were reducing, compacting, etc., didn't compact waste and our volume doubled, maybe I'd reduce prices. I don't know, but all I do know right now is that it is happening, and these are the factors. However, it certainly should not be implied that you can't save money by reducing volume.

BOB RAMSEY: I would like to comment on this paradox of the pricing of burial. The fact seems to be that the more burial space you have, the more expensive it gets. This is because there is only so much waste for burial, and more burial grounds are likely to wind up underutilized and, hence, cost more. One of the limitations on burial space is based on time. Time has been set by some of the states as their criterion for accepting a limited inventory of waste. The limit is not necessarily physical. The burial ground may have a physical capacity for an extended time in the future. The time limit reflects the fact that the real barrier to accepting additional waste and perpetuating the usefulness of a site already dedicated to land burial is political. I believe that we have to overcome the same political limitations to get new sites. It is physically possible to find new sites that are equally acceptable as the ones we are using, so there is no physical basis for scarcity of sites. The very same political problem that limits the time available to use our existing burial grounds must be solved to site new ones. Because extending the political acceptance of the sites already in existence is easier and more efficient, we should do everything possible to extend their lifetime by conserving their burial capacity. I do not want to pursue the issue too much, but this reasoning of a politically imposed time constraint as opposed to physical constraint is going to lead to too much burial ground capacity, and this raises the problem of how to justify disposing of volume-reduced waste in burial space that has to cover large fixed costs regardless of the volume buried. I conclude we have to use the best technology to reduce volume and conserve the resource of existing burial space as well as immobilize the waste to ensure continued acceptance of disposal.

DR. CHARLESWORTH: Well, we've reached 12 o'clock, but Bob was looking for a response.

DR. PARKER: I don't want to respond to that, but could I talk about two other research items? We have talked a great deal about public perception. Recently, New York City announced that it had plutonium in the drinking water, and that didn't seem to excite the public very much. I think it would be very useful to look into why you can announce you have plutonium in your public water supply and it doesn't seem to bother anybody and, yet if you have it in a burial ground 500 miles away, people get

terribly excited about it. I think that phenomenon really deserves to be addressed.

UNKNOWN: Somehow, I think that the statement came out that it's not much different than the water level that's acceptable.

DR. PARKER: But that's what we say all the time about what comes out of the waste burial grounds.

UNKNOWN: But in the same news articles. . . .

DR. PARKER: But why do you get such good press on that topic, such relatively unbiased covereage, rather than the ABC type, you know the fire-unleashed type?

UNKNOWN: Excuse me, as a New York City person, maybe I can put it into perspective a little bit. What was causing people even more concern at that point was that 10% of the New York City water supply was being pulled out of the Hudson River because of our drought conditions. And so, it was a matter of extent to comparative risks.

DR. PARKER: Yes, but the word plutonium just a few years scared the devil out of people, and the National Council of Churches said. . . .

UNKNOWN: That's right, the New York City Health Commissioner said that these levels were extremely low, and he was being believed,.

DR. PARKER: But why?

UNKNOWN: The one thing that we thought was very interesting in New York City was that the director of the NYC Office of Radiation Control, who has been the major opponent to things like transportation through the city, has not been heard from.

DR. PARKER: They must have sent him out of the country.

The comment deals with something I've noticed in the literature distributed here. We have catalogues of things that can be done, that are being done, yet we really don't have a critical analysis of how well these techniques work. I think such analysis would be worth funding. In addition, it would pinpoint the research that needs to be done or could be done that would really make a quantum difference. I think that it's that kind of meta-analysis that would be extraordinarily useful, and I think that it's been missing.

DR. CRASE: Let me make just a comment about the gentlemen who talked about the existing site. We are probably at one-fifth capacity at

Richland; I think we have used a total of ~18 acres out of 100. The Nevada facility, of course, Nevada is about 87% BLM land anyway, surrounds us in all directions as far as the eye can see. I can't speak for Barnwell, but we certainly support your approach that if it were politically acceptable this country can get by with one site.

CHUCK ALLEN: I would like to thank you for the opportunity to participate in this year's workshop. I felt the broad cross section of participants, representing industry, academia, government, and the labs, resulted in some very worthwhile exchange of opinions and ideas.

One of the areas of concern we have at HEDL is with high-gamma wastes. Our studies and experience with spent FFTF fuel assembly components and other waste forms indicate that these types of wastes could become very costly to handle, package, certify, shop, and store. This will be even more true if some of the criteria mentioned at the conference (i.e., 1 rem/h max at 3m) are imposed by the NRC. HEDL would be very interested in participating in a study to address issues, criteria, and technology in this area. We already have significant programs underway addressing spent fuel transportation, but we feel a need to look at the whole issue from generation and treatment through transportation, storage, and disposal.

The above issues, as well as the areas of "orphan" wastes, class D wastes, mixed wastes, etc., should be addressed and resolved.

DR. RODGERS: Don, isn't Canada going toward a minimum number of sites, while we're going toward a larger number of sites on a regional basis? Would you give us some benefits of the Canadian experience?

DR. CHARLESWORTH: Yes, certainly our Atomic Energy Control Board, which is our regulatory body, has made it known that the fewer sites the better, as far as their input into the situation, and we are also pushed in that direction because the scale of operation is small enough that the less you subdivide it the more economically viable it is. But beyond that, I think what is just as important for us is that existing sites can be operated. New sites are very hard to come by, and so I'd go along with Bob Ramsey's point that the more we can get out of existing sites, the better.

Okay, I guess I ended up being the last speaker and would like to thank the audience. . . .

2. SUMMARIES OF SPECIAL WORKSHOPS

2.1 WORKSHOP A: REMOVAL OF WATER FROM NUCLEAR POWER PLANT LOW-LEVEL RADIOACTIVE WASTES, M. M. THOMAS, LEADER, AND ARLENE H. KIBBEY, RECORDING SECRETARY

The five sequential workshop sessions on the removal of water from nuclear power plant waste streams focused on two distinct areas of concern. The first area of interest was purification of various waste streams where the primary purpose is to permit recycling. The second area of concern was the removal of water as part of conditioning a waste stream for solidification or other form prior to ultimate disposal.

With regard to treating waste streams for possible recycle, several issues were identified for potential research and development.

1. Specific radionuclide concentration. The techniques currently used employ materials and/or equipment that have a high selectivity for specific ions or compounds. The result is a divided waste stream with one portion being radiologically detoxified and therefore suitable for recycle or routine release. The remaining portion contains the contaminants in concentrated form. At present, both ion exchange and hyperfiltration are used to effect such separations. However, there is some concern over the radiostability and quality control of materials, hydrogen generation, the suitability of applying these techniques to economically high-value streams such as reactor coolant, and compatibility with currently used waste solidification media (i.e., long-term waste form stability).

In the future, the concentration of specific radionuclides has the potential for converting current waste materials into resources for use in by-product programs.

2. Analytical procedures and equipment. Plant operators need quick, accurate capabilities for performing a wide variety of trace contaminant analyses, especially for reactor coolant. There is a growing recognition that both purified fresh (makeup) water and treated reactor coolant contain traces of contaminants that adversely affect long-term reactor performance, which, in turn, can influence waste generation.

3. Multiple-unit operations. The performance of traditional water purification equipment, such as evaporators and ion exchangers, can be dramatically affected by upstream unit operations. There is a need to identify and quantify this synergism in an effort to improve overall system performance at lower cost.

4. Fundamental chemistry. There is a basic lack of understanding of the fundamental chemistry of the various liquid streams in a nuclear power plant. This lack of accurate information has resulted in misapplication of existing technology, poor long-term plant performance, and higher costs in both actual dollars and in radiation exposure to workers.

In the area of removal of water from waste prior to ultimate disposal, the following concerns were identified.

1. Waste-form stability. There is insufficient knowledge of the effects of water on long-term waste-form stability. Specific issues are the integrity of the monolith, gas generation, freeze/thaw resistance (especially during interim on-site, above-ground storage), and leachability performance. A scientific basis is needed for deciding how much water (or other constituent) is appropriate for optimum long-term stability.

2. Basic chemistry. Just as in the case of precise, in-plant, fundamental chemistry, there is a paucity of data to support waste burial site regulators and operators in developing appropriate restrictions or requirements on waste form and disposal practice. Maximum use of existing performance requirements is often not realized because of the lack of knowledge of the basic chemistry involved.

3. Ion exchange resins and high-integrity containers (HICs). Disposal policies on waste resins are not well founded on accurate scientific data. Information gaps exist with respect to:

a. the long-term stability and/or degradation of resins,

b. the effects of water on biodegradation,

c. the correctness of high-efficiency dehydration of resins for volume reduction, with due consideration to the fact that they will be placed in containers that are not gas tight and then buried in soil saturated with moisture,

d. the ability to nondestructively verify the water content of packaged resins,

e. the long-term compatibility of HIC materials with spent resins, and

f. the lack of a firm chemical data base to support the design of advanced resin drying systems and integration with solidification systems.

4. System or process integration. Much needs to be done to properly develop new equipment and procedures for nuclear waste treatment. However, power plants, in general, have insufficient time, manpower, and financial resources to carry out the detailed studies and tests that are required. There is also a need for greater integration of technology development that will require the following:

a. definition of the desired end products or products acceptable for long-term disposal,

b. development of the chemical and engineering basis for selecting appropriate dewatering technologies,

c. examination of existing technology for applicability and adaptability, and

d. cooperative development and sharing of resources among the federal government, the utilities, and equipment vendors. It is clear that neither the utilities nor equipment vendors have the resources necessary to support fundamental research and prototype development under current market conditions.

While some workshop participants maintained that the necessary processing technology was already in place and that all LLRW problems are purely social and political, the majority agreed that there are significant data gaps, and there is a definite need to put LLRW processing on a firmer scientific basis. At the same time, all would likely agree that the problems are most definitely solvable with a straightforward commitment of appropriate resources. The biggest need is for the nuclear industry, with government support, to seize the initiative and abandon its present reactive posture.

A thorough review and evaluation of past operating experience was suggested as the basis for planning future R&D. Several problem areas that are peculiar to nuclear power plants were cited for group consideration and discussion. Some have been long-standing problems for which attempts have been made at, at least, partial solutions. There are

now considerable, albeit uncatalogued, data on materials and equipment performance, maintenance costs, the adequacy of plant and process design, and the identification of unanticipated factors, that have had bearing on the success or failure of nuclear as an energy option. Are we using this backlog of information to its fullest advantage in controlling waste generation and final disposal? Many participants thought that DOE should be the appropriate arbiter.

Sometimes new techniques for solving old problems or doing routine tasks more efficiently give rise to new questions that may require answers involving unknown variables. Hints of many such questions surfaced during the workshop sessions pertaining to the removal of water from LLRW. The most important points of discussion are presented in the following sections.

PURIFICATION OF WATER AND RELATED CLEANUP MATERIALS FOR RECYCLE

Quick, accurate procedures for the determination of traces of such organic contaminants as oils, hydrocarbons, and glycols in raw (make up) water and in recycle water at power plants are not available. The development of such procedures could have a high economic payoff since an agressive recycle program [i.e., ~38,000 L/month (~10,000 gal/month)] is extremely expensive. Optimization of evaporator design (materials of construction, instrumentation, etc.), together with improved performance attained by operators, might achieve higher decontamination factors (feed-to-condensate concentration ratios) that would permit greater volumes of water to be recycled. Basic engineering studies on evaporator design would prevent misapplication and therefore minimize waste generation in the long run.

The removal of specific ions (e.g., Cl^- from boric acid evaporator bottoms at PWRs) could often make recycle possible instead of disposal, depending on the economic trade-offs. Special tailored resins may make specific ion removal feasible, but R&D is needed to understand and utilize the mechanisms involved. The usefulness of new products, such as organic resins bonded to glass, should be investigated.

Ion exchange, in general, has not been well understood and optimized at nuclear power plants. More study is needed to improve the predictability of the ion-exchange behavior of the various ionic species found

in plant streams. The chemical forms of the ions, as well as the radiostability and the limits of resin quality assurance, should be examined. The effects of aging of resins in a nonradioactive environment have not been fully evaluated, especially with regard to changes in capacity and/or selectivity.

Filtration is widely used for stream cleanup in nuclear power plants. However, improved methods are needed for determining and comparing the decontamination factors obtained by filtration.

Since the advent of 10 CFR 61, the frequency of changeout of the filter cartridge has significantly increased. To avoid the expense of having to stabilize and ship Class B waste, many plant operators have elected to change cartridges while they remain in the lower Class A category. There are filter cartridges in some plant locations, however, that make a Class A changeout impractical. If a way could be found to reuse or recycle filter cartridges, a great economic benefit would be experienced by the utilities. The R&D work required in such an undertaking would probably be so extensive that it would require the cooperative effort of the federal government.

Hyperfiltration can augment evaporation. Although it has a low decontamination factor (DF) for Cs, the DFs for other elements are much higher, thus allowing for good separations in some applications (perhaps applicable in Cs/Sr separation). Hyperfiltration technology that was developed at ORNL is being tested at SRL. More research should be done on the in-place chemistry of the waste streams where it is applied.

Reverse osmosis (RO) has been used successfully for the separation of boron from silica in power plant process streams. However, other applications have resulted in two (rather than one) radioactive streams. A question regarding the potential for effective use of RO in power plants remains unresolved. This may be worthy of more investigation.

THE PRESENCE OF WATER IN WASTES SENT TO INTERIM STORAGE AND FINAL DISPOSAL

The effects of water in waste forms that are sent to interim storage or final disposal need better identification. Also needed is a scientifically based definition of the acceptable lower limit for water content (the 1% currently used is an assumed design value). In the past, a

1½-year effort was put into the development of internal screens for dewatering resins in liners; a residual water content as low as 0.02% was achieved. Is this sufficient?

The development of nondestructive means to measure the water content of packaged waste is needed. The adequacy of the practice of lowering a probe into a container is questionable, since containers that have been "dewatered" still often develop "puddles." The retention of water during transport should be looked at to determine the causes of water separation; it may be a function of time, temperature, shock, some other variable, or a combination of these.

Some questions that need definitive answers are:

1. Is low-temperature drying of resins adequate; and how much drying is necessary?

2. Does it make sense to dry resins beyond the normal atmospheric moisture content, especially if they are placed in containers that are not gas tight and are buried in moisture-saturated soil? Will the in-leakage of water cause swelling and pressure buildup that could rupture the container?

3. How much influence do "internal" and "external" water in packaged resins have on radiostability and biological degradation of both the resin and the container? How much does it contribute to gas generation?

4. Rockwell has a skid-mounted, mobile resin dryer that should be in the final design stage early next year (1986). They are willing to test it under actual plant operating conditions, and Sacramento Municipal Utility District (SMUD) may be willing to volunteer participation in such a test at Rancho Seco nuclear power station. Would DOE cooperate?

5. Since thermal removal of water from waste (or waste streams) is very energy intensive, would the use of microwave drying techniques be applicable and economical?

6. Could solar drying of resins be used?

7. How do the end-products of resin breakdown in radiation fields affect the integrity of HICs?

8. Waste that is treated with a "super-compactor" yields some free liquid. The nature of this "juice" needs to be identified and its effect on containers determined. Is it toxic or corrosive?

9. To what extent is hydrogen gas generated during transport of nuclear wastes, especially spent resins? Should packages be vented (or not) for safety?

10. How adequately can hydrogen generation in packages be controlled by catalysts?

11. What is the diffusion rate of hydrogen through various types of packages, including HICs?

Additionally, a data base on dewatered spent resins should be developed. Among useful items that should be included are density and chemical loading. The correlations that have been established between the TMI-2 resins and those from normal power plant operations should also be incorporated.

The economic viability of various methods of waste immobilization need unbiased study, perhaps at a university. Task studies should be done to establish safety criteria. A definition of acceptably safe solids is needed to answer questions such as:

1. Do ion exchange resins really need to be solidified (i.e., incorporated into a monolithic matrix)?

2. Are iron filings useful as an immobilization medium?

It is known that some substances occurring in waste streams (e.g., borates, chelating agents, some ions, such as sulfate and chloride) can affect the solidification process in some media. Quantitative correlations based on the chemistry of the various solidification mechanisms should be established.

Waste immobilization must include consideration of the waste container itself. A question has been raised as to the suitability of the new HICs for use in the interim storage of wastes. It is known that they are degraded by ultraviolet (UV) radiation, but the length of time involved has not been precisely determined, and the actual shelf life of new HICs has not been established. Covering these containers with black bags has been suggested as a means of prolonging the shelf life, but the effectiveness of this method needs evaluation. Apparently, once in the ground, there are ~25 years of experience that indicate that HICs will perform satisfactorily. However, in view of the relatively short life of HICs exposed to light, NUS Corp. is taking them off the market and is

recommending solidification of waste in polymer or packaging in "supermetal" containers. The cost of substituting other materials for polyethylene in HICs should be determined.

Ceramic containers for nuclear wastes have been suggested, but since most radioactive wastes are not as "bad" as many chemical wastes, such drastic treatment may be unwarranted. If scientifically based release limits, and not political advantage, are the deciding factors, ceramics would be useful for containing LLRW in only a small number of exceptional cases.

The use of gas-tight containers for "super compacted" wastes, which become dehydrated in the compaction process, needs evaluation. Such wastes may reabsorb water from the air with subsequent swelling that could rupture the container. New "High-G" centrifuges also are capable of producing such waste forms; some unsolved problems may be associated with the transfer of the waste solids from the High-G machine to an HIC.

Volume reduction of wastes already generated has become a major goal in recent years due to the fear that burial space will soon be unavailable. Recently, it has been recognized that a more critical evaluation of volume reduction is needed, especially with attention to the trade-offs involved in small-volume, high-activity vs larger-volume, low-activity solids. Exposure, transportation, and burial ground costs are among the items that must be considered. Where is pumping and/or centrifugation preferable to incineration in the light of these considerations?

Limitations on the uses of incineration for the volume reduction of power plant wastes need to be defined, especially for resins. The incineration of high-activity resins could cause a maintenance nightmare, and the incineration of low-activity resins can, in the end, create high-activity radiation fields. (The use of pyrohydrolysis in this application may be a viable alternative, and our Canadian colleagues are looking at this possibility.)

The VRTECH systems analysis program, developed by TASC, is designed to do economic evaluations of several volume-reduction options for any type of LWR plant. The economic factors considered are capital and

operating costs for the alternative VR technologies; burial costs, with a range of potential escalation rates; and storage and transportation costs. The evaluations are aimed at obtaining representative costs and at identifying dominant cost factors. There are situations where volume reduction may not be economically advantageous. One must consider the effects of 10 CFR 61 on waste classification and the associated transportation requirements as well as burial costs. In handling reactor wastes, ^{60}Co, ^{134}Cs, and ^{137}Cs are the main considerations. Although it is not now included in the VRTECH model, the feasibility of vitrification as a means of volume reducing LWR low-level wastes may be worth study. Salt dewatering may also have useful application.

The TVA once thought that incineration would put radioactive resins into the most stable form but public resistance precluded further study. It is felt that full-scale demonstrations would help with understanding some of the lesser-known technologies. For example, more development work is needed to study such aspects as cleaning, corrosion, and maintenance. The uncertainties in studies of such magnitude make them too risky for a utility to undertake on its own. Since more R&D will not make some methods work, more thought should be directed toward the end application. Frequently, a good technology is improperly applied. The application of various technologies to the jobs to be done should be examined to determine if an appropriate technology exists. The DOE should support private industry financially so that the R&D needed to solve the problems of the nuclear industry could be performed.

It is almost impossible to write specifications tight enough to cover all possibilities. It should be noted that Japan has R&D centers with full-scale equipment for testing, which eliminates "cutting corners" that so often lead to inferior results. Recently, TVA has been successful in getting only foreign bidders on jobs. This has created the feeling that DOE needs to work more closely with the industry as a whole.

Plant-specific functions and problems need study. Also, the synergism that could occur in the nuclear industry through combining wastes from different origins for use in new applications (e.g., food or sewage irradiation) should be encouraged. In the role of "integrator,"

the DOE should make use of universities to review the literature and determine if some processes that were rejected as inadequate or unimportant in the past may now be useful because of changed conditions.

The effects of freeze/thaw on wastes in interim storage and the adequacy of present waste forms under a variety of conditions including engineered storage should be studied. The trade-offs in the "French Approach" to LLRW disposal should be evaluated. It is expensive, but for the French, the problem is energy -- not waste! Money is spent up front on central facilities, which makes the waste controllable. The French method should be brought to the attention of the U.S. public to show that it can be done. Additionally, risk analyses need to be made with regard to many power plant operations that the general public perceives as dangerous (this could include near-surface land disposal).

Beyond the present state-of-the-art, new technologies should be developed so that they are ready and operable if or when called for by regulators. Where proven technologies already exist, a strong federal policy is needed to optimally utilize them. Perceived needs now may be different in the future due to changes in regulations or jurisdiction. For example, leachability indexes for some isotopes are not required at present, but there is no assurance that they will not be in the future, or agreement states may have more rigid requirements than now exist under NRC regulation. On the other hand, easing of regulations on the release limits for some chemical constituents in the waste (e.g., H_3BO_3) could make formerly rejected treatment methods acceptable.

There is a need for definition of BRC (i.e., "de minimis") waste. Currently, the DOT value of 2 nCi/g is being used by TVA and others because another definition is lacking. Clarification of what is required regarding uniformity of shipping manifests is also needed. The burial grounds feel that the present requirements are sufficient. They do not feel that they should be responsible for chemical surveys. It is true that they cannot answer all specific questions about the wastes disposed of at their sites because the shippers are not required to list some information that would answer these questions. For example, utilities are not required to report the plutonium content of their low-level radioactive wastes. The utilities often feel that too much is required of them

already. For instance, the activity on spent demineralizer resins is concentrated in bands, but the overall dose reading on a container does not reflect this. This tends to make the reading estimates given on the shipping manifests too high, and they are charged accordingly. More efficient ways of package scanning should be developed to alleviate the problem. In the same vein, spent filter cartridges can be solidified in HICs, but this is not LSA waste. An overweight Type B cask, which is restricted to holding only four cartridges, would be required for shipment. Any shielding that is used may not be included when averaging the overall activity. New regulations or cheaper handling methods should be developed for spent cartridge filter shipments.

Clearly, solutions must be found for the technical, legal, and purely social and political problems that overshadow the entire nuclear industry at this time. In the present situation, the utilities have been forced into survival planning.

2.2 WORKSHOP B: THERMAL, PHYSICOCHEMICAL, AND BIOLOGICAL TREATMENT, R. G. POST, LEADER, AND S. D. CLINTON, RECORDING SECRETARY

2.2.1 Overview

The scope of the workshop was modified during the discussions. In essence, the scope includes biological and chemical treatment of waste. Because of its relationship to the systems, we considered ion exchange to be a unit operation for consideration. Electrolysis was limited to the recovery or precipitation of ionic species.

The purposes of the treatment options for low-level radioactive waste are:

1. volume reduction,
2. immobilization, and
3. reduction of hazards due to nonradioactive materials.

The workshop believed that the order of importance for decision making is:

1. regulatory requirements,
2. political and public perceptions (note that regulatory requirements are responsive to public perceptions),
3. economic optimizations, and
4. meeting of technical and operational requirements.

The state of technology on the different unit operations was not a consensus opinion. Commercial systems for nuclear plants are restricted to ion exchange and incineration (with incineration, the operation is just beginning). Those processes ready for commercialization include smelting, electrolysis, and acid digestion, with oxidation-reduction very close behind. Wet-air oxidation appears to be a feasible process but requires more pilot plant demonstration. The workshop groups could find no utility for biological processes.

The problems delineated below may only be partially resolved by additional research and development. An overriding concern of the groups was the unknowns in regulatory and economic factors, particularly with regard to the waste acceptance criteria and charges to be assessed by the state compacts operating the future disposal sites.

The problem areas are:

1. high capital costs for incineration and other such chemical unit operations,

2. technical factors,
   a. operationally safe designs,
   b. chlorides and other off-gas pollutants,
   c. certain chemical and biological hazards, and
   d. capacity limits imposed by nonradioactive salts.

Possible solutions for problems associated with incinerators are:

1. Establishing regional systems that have economic and operational advantages which are not yet quantitatively defined. Designing cheaper units means compromising the off-gas system, which reduces the flexibility to handle a wide variety of radioactive waste. This may be alleviated by reducing or eliminating waste that has undesirable off-gas components.
2. Assessing maintenance and consequent radiation exposure levels.
3. Evaluating alternate systems. These include: (a) acid digestion, which may accept some waste not suitable for incinerators but does not permit HCl-producing waste,and it is difficult to process volatile organics; (b) glass incinerator, which may have better control for handling chlorides but costs must be proven; (c) oxidation/reduction, which has an unknown flexibility, but it should handle chlorides; and (d) wet-air oxidation, which should handle all waste materials, but the process equipment has not been proven.

Solutions for special problems were discussed by workshop participants. Not all of the special problems have been identified, but the following provide examples:

1. Disposal of electrolytes from electrolytic decontamination processes. Electrolytic deposition of the radioisotopes appears to be a natural choice.
2. Surface contamination from metals. Removal may often be accomplished by smelting.

In conclusion, most of the work that needs to be done involves engineering studies and evaluations. Laboratory and pilot plant studies of acid digestion, glass incineration, oxidation/reduction, and wet-air oxidation should be continued to prove their utility in handling off-gas pollutants (hence, a variety of radioactive waste) and establish the cost of the system.

2.2.2 Workshop Discussion

2.2.2.1 Ion Exchange

Ion exchange is the only unit operation discussed in Workshop B that is being used currently for the treatment of LLRW in the nuclear reactor industry. Areas for research and development include:

1. pretreatment of liquid waste streams (more control on the contaminants introduced in the feed water);
2. optimization of ion exchange resins (development of resin beads with higher loading capacities);
3. split-stream processing;
4. improved capacity for mixed wastes containing hazardous chemicals; and
5. regeneration of resins, which may create more LLRW volume; however, regeneration may simplify ultimate resin disposal.

The final disposal of resins is an ongoing problem and needs some attention. Possible solutions are: (1) solidification, or (2) disposal in an HIC after dewatering. Economic incentives for volume reduction are becoming less important, and there is some question about stabilizing mixed wastes such as filters and spent resins in the same container. One suggestion for reducing spent resin volumes by a factor of 2 was to use microwave heating. Apparently, the dried resin will still retain fission products. One participant suggested that a regional regeneration station might be economically desirable for spent resins. The dewatered resins containing LLRW would be shipped to the regeneration station and recycled back to the nuclear facility.

2.2.2.2 Acid Digestion

Acid digestion with hydrogen peroxide has essentially no off-gas problems and requires no addition of salts. The process has been greatly simplified over the original concept and can be operated remotely with no moving parts. Operation is thermally stable with no chance for runaway conditions. A wide variety of waste streams can be handled, including resins, combustible solids, sludges, and some hazardous chemicals. Due to corrosion problems, the system is not compatible with phosphates and fluorides. The economics have been defined, and the process has been satisfactorily demonstrated for TRU wastes and resins. Despite these positive aspects, no utility was willing to invest in a unit for its LLRW

streams. The unit operation may have merit in a regional disposal facility for handling spent ion exchange resins. A portable system may also be feasible with the acid-digestion residues solidified in glass.

2.2.2.3 Biological Nitrate Removal - Cellulosic Biodegradation

The workshop participants seemed to be in agreement that biodegradation was not a cost-effective process for commercial nuclear power facilities. A possible incentive for chloride wastes was downplayed due to the use of chlorides as a wood preservative (chlorides do not biodegrade).

2.2.2.4 Electrolytic Processes

Although the unit operation was generally believed to be too costly, the concept received some attention as a means of decontaminating special equipment items. The process works well with simple geometries but creates a large volume of liquid LLRW. After decontamination, the electrolytic solution could be recycled by plating the contaminant on an inert material.

2.2.2.5 Incineration

Besides ion exchange, incineration appears to be the only process with an immediate future in the nuclear industry. Incineration will be practiced at two nuclear power plants in the very near future; however, most participants seemed content to take a wait-and-see type of response. A general consensus seemed to be that incineration would not be cost-effective for a single utility but might be useful in a regional waste disposal facility. Although incineration may prove to have application, the process may not be compatible with all waste materials. Besides the high capital cost and materials compatibility, most participants were concerned about the selection of an off-gas treatment system and the resulting LLRW scrub solution. Maintenance considerations (high radiation exposure to operators) was another concern, and simplicity of operation was a key for nuclear application. Areas for more research and development include the disposal of hazardous chemicals (RCRA) and the final waste stability achieved by the particular incineration process (i.e., vitrification). The controlled-air incinerator seemed to be the choice of more participants than any other type with the present state of technology.

2.2.2.6 Oxidation/Reduction

Chemical oxidation and reduction processes did not appear to create any significant interest among the participants. The idea of converting one waste stream form to another may be beneficial in the disposal of ion exchange resins. Treatment with hydrogen peroxide to convert resins to a liquid form could result in a more favorable operation for ultimate disposal (i.e., evaporation).

2.2.2.7 Smelting

Although smelting has been used for isotope separation and removing uranium contamination from scrap metals, there appears to be no economic incentive for advancing this technology in the nuclear power industry.

2.2.2.8 Wet-Air Oxidation

A major advantage of this process is that no off-gases are generated; however, more development will be required for nuclear power application. Advantages of the relatively low-temperature process (100 to 300°C) include the potential for handling chloride wastes and ion exchange resins. The process requires only the addition of air, and the resulting solutions could be further treated by more proven methods, such as evaporation.

2.2.3 General Impressions

A strong feeling from the workshop is that the nuclear power utilities need to improve their image to the general public. Regulatory requirements are dictated by political forces that are driven ultimately by public opinion. Technology controlled by public influence cannot advance. The nuclear industry should invest in more public relation activities to make its product more acceptable to the general population.

The following concerns do not fall into any particular category or order but seemed to underly much of the workshop discussion:

1. desire for a greater loading capacity for ion exchange resins;
2. great concern for the disposal of ion exchange resins;
3. incentive for the recycle of more materials used during processing;
4. concern about the disposal of chelating agents and nonradioactive hazardous chemicals;

5. efficient volume reduction, which may result in a waste classification greater than Class C;
6. process that exchanges one waste stream for another with no overall benefit;
7. addition of chemicals to the waste processing scheme;
8. sharing the waste disposal costs of a regional processing facility;
9. volume-reduction cost incentive that may disappear due to a fixed cost recovery required by the burial facility; and
10. need to identify processes that minimize miscellaneous by-product wastes.

In conclusion, the workshop seemed to satisfy a pressing need for improving the handling and ultimate disposal of low-level radioactive wastes common to all nuclear power facilities.

2.3 WORKSHOP C. SORTING/SEGREGATION AND DECONTAMINATION, T. S. LaGUARDIA, LEADER, AND S. M. ROBINSON, RECORDING SECRETARY

2.3.1 Summary

The major problems of the utilities in the area of sorting, segregation, decontamination, and decommissioning seem to be associated with mixed wastes. In addition to the problems created by conflicting regulations concerning the treatment and disposal of RCRA wastes and LLRW, there is an inability of utilities to detect, sort, treat, and dispose of these wastes. Research should focus on eliminating RCRA wastes from the waste streams, developing instrumentation to detect and sort RCRA wastes from radioactive material, and providing processes to treat the mixed wastes that cannot be separated.

Most problems associated with processing radioactive materials by themselves is restricted to a few broad areas. The main problems that arise in sorting and segregating radioactive materials are due to a lack of automated equipment which can accurately detect radiation at the de minimis levels and reliably separate materials. None of the decontamination processes presently used adequately meet desired performance criteria; most produce large amounts of secondary waste that are often classified as hazardous materials. Therefore, research in this area should focus on producing alternative processes, developing readily disposable solvents, improving recycling methods, and developing stablization and disposal methods for existing decontamination wastes. Problems that must be addressed before decommissioning power plants include providing adequate burial space for LLRW and disposal methods for "intermediate" waste.

Several generic problem areas were identified in the work shop which impact all aspects of LLRW processing and future research. These include the utilities' need for nonconflicting policies and better-defined guidelines from regulatory agencies. The basis for many of the existing regulations should be reexamined using recent data in an attempt to relax current policies on treatment, transportation, and disposal methods. There is a need to standardize calculation and modeling methods within the industry. Research is needed to determine the life expectancy of existing

shipping/storage containers and develop methods of prolonging their lifetime. There is a need to train power plant operators to minimize waste generation at the source and to provide dedicated, better-trained personnel to operate waste disposal plants. There is also a lack of technology transfer among DOE, EPRI, and the utilities and among the utilities themselves.

2.3.2 Mixed Wastes

The utilities have major problems with the treatment and disposal of mixed wastes. Even though segregation of mixed wastes will probably simplify processing and disposal, conflicting regulations regarding the disposal of RCRA wastes and LLRW make it imperative that hazardous wastes be eliminated or segregated from radioactive materials before processing for disposal. An initial study is needed to determine which presently used materials generate RCRA-type wastes and to assess the currently available materials and processes that could be substituted to eliminate these wastes. Additional research needs to focus on eliminating hazardous materials from the waste streams by producing nonhazardous substitutes, developing regenerative or purification processes to allow recycling of problem materials, and determining when the initial use of such materials can be eliminated or minimized. In this particular area, research needs to focus on the elimination of hazardous chemical solvents and chelating agents from decontamination solutions and PVCs from the work environment.

If alternative materials or processes cannot be found, efficient, simple recycling and/or concentrating methods should be developed to reduce the volume of the materials that reach the waste stream. Current processes, such as distillation, tend to be expensive and complicated. There will then be a need to develop methods for detecting, sorting, and segregating the remaining RCRA materials from radioactive materials. Such techniques as microscopic examination or mass spectroscopy may be required to detect asbestos, particulates, and hazardous chemicals, while automated chemical and/or physical separation processing may be necessary to separate the materials. Alternative processes need to be developed to treat the mixed wastes which cannot be eliminated by the above processes.

2.3.3 Sorting/Segregating

Existing instrumentation for measurement at high radiation levels appears to be adequate in most areas, but its repeatability and

reliability need to be proven. Production-scale, automated equipment that can accurately detect radiation down to the de minimis levels and sort "noncontaminated" and radioactive materials needs to be developed. Most of the present equipment either cannot adequately detect low levels of radiation or are hand-operated devices.

There appears to be a need to study the costs and benefits, including ALARA considerations, of sorting for specific applications. Examples include assessing the need to develop instrumentation such as metal detectors or x-ray devices on a production scale for sorting feed material for incinerators, compactors, and shredders.

Simple, reliable instrumentation is also needed to detect inadequate processing before disposal. Nondestructive tests with proven reliability are needed to detect liquids in disposal containers that contain dewatered resins and solidified wastes.

Research is needed to develop localized, portable ventilation systems to trap contamination at the source. This will prevent cross-contamination of areas and reduce decontamination waste volumes.

2.3.4 Decontamination

Many decontamination processes are presently used by utilities, but all of them tend to have problems. The existing decontamination methods should be assessed, and comparative results for each method should be made available to the utilities for use in selecting processes for particular applications. New processes are also needed which are capable of removing low levels of contamination and which produce small volumes of easily disposal secondary wastes.

The chemical processes tend to produce large volumes of contaminated solvents that fall into the catagory of mixed wastes described above. Particular problems associated with decontamination solvents include a lack of available regenerative processes, data concerning the effects of concentrating solutions for disposal, and adequate solidification and disposal processes especially for solutions containing organics. Since decontamination solvents vary considerably in composition, utilities need to know their standard formulations in order to be able to specify the chemical composition when ordering solvents from vendors, thus eliminating unnecessary contaminants, such as chlorides, from their systems.

Chelating agents are particularly hard to deal with since their burial regulations are extremely strict. Research in this area should address limiting the migration of the materials after disposal and reducing the incoming waste streams by methods suggested for mixed wastes. Research to determine when chelating agents are not needed in processes to eliminate percipitation of dissolved contaminants, such as straight runs of pipe, could also reduce future generation of these problem wastes. The ranking of the relative mobility of chelating agents would be useful for determining their applicability for specific processes and for determining the necessary isolation distance needed in the burial ground.

Research could also be focused on developing nonchemical decontamination processes. There is a need to develop nondestructive decontamination of painted surfaces, eliminating the need to remove paint and coatings from the base metal. The compatibility of high-pressure, water-jet grit materials, such as glass beads, aluminum oxide, and borated grit, with reactor materials needs to be determined. Decontamination of the grit material by such methods as ultrasonic cleaning also needs to be evaluated.

2.3.5 Decommissioning

Research is needed to address the required burial ground space for decommissioning wastes. The waste volume generated by decommissioning is estimated to be up to 19,000 m^3 (25,000 yd^3) per 10000-MW reactor. Suitable methods of disposing of type D waste (greater than type C) must also be determined. The current criteria and basis for essentially excluding it from LLRW burial grounds need to be examined. Such techniques as probabilistic risk assessment (PRA) methods may be used to assess comparative risks.

Research is needed for assessing the amount of fuel-failure debris (TRU wastes) distributed throughout primary and secondary systems. Analytical models that have been verified by direct measurements are needed.

2.3.6 Changing of Regulations

There is a definite need of the utilities to have more precise, well-defined regulations and guidelines from the regulatory agencies. One of the most important issues that needs to be addressed is the separation of

RCRA and LLRW regulations, including the removal of conflicting policies for all aspects of treatment and disposal of mixed wastes. Precise guidelines for the disposal of hazardous wastes such as PVCs, resins, celluosics, and chemicals, need to be developed, which could be equivalent to 10 CFR 61 for radioactive waste disposal. There may also be a need for a research effort to determine the controlling hazard in mixed wastes that cannot be separated for disposal purposes. The upper limit for "de minimis" levels of radioacitivity also needs to be defined.

The bases for existing regulations need to be reviewed to determine if they can be made more practical by using better assumptions than those which were available at the time the initial guidelines were established. Research projects may be required to provide the data needed to make the assumptions more realistic. As an example, leach data could replace the conservative assumptions used to determine disposal criteria, possibly resulting in less strict burial ground requirements for class A, B, and C wastes and intruder dose criteria.

Existing regulations should also be examined to determine if they should be rewritten for typical and special wastes generated by utilities. If regulations are based on atypical, worst-case operations, reanalyzing the assumptions using realistic data for normal operating conditions may produce less stringent regulations for typically generated wastes. Actual tests may also be required to prove that policies could be changed for standard operations. An example cited in the workshop is to determine if ensuring inertness of resin shipment casks to prevent generated hydrogen gas from creating explosive or combustible mixtures is necessary for standard resin shipments as well as for special cases such as resins generated in the Three Mile Island cleanup.

There is a need to establish consistent guidelines for many measurement and calculation procedures. Many current methods are not consistent and therefore reduce the reliability of reported values. Examples include standardizing algorithms for waste characterization and calculations for activation of vessels and internals.

2.3.7 Container Development

Current HICs are only certified for 5 years when placed in a storage facility prior to final disposal. Research is needed to determine the

life expectancy of existing containers, the factors that cause degradation, and the need for better designed containers. The program may need to include determination of the environmental controls needed for storage facilities to prolong container life.

2.3.8 Training and Plant Operation

Many of the waste disposal problems could be minimized by properly training plant operators. Power plant operators should be trained to minimize waste generation at the source and should be aware of proper sorting and segregation procedures. Periodic training should be reinforced with on-site awareness programs, such as posters and briefing sessions. Dedicated, well-trained crews should also be used to operate waste disposal facilities.

2.3.9 Technology Transfer

The discussions during this workshop plainly indicated that there is a lack of technology transfer among DOE, EPRI, and the utilities and among the utilities themselves. There is a definite need for the utilities to have a data base that lists all the processes presently or previously used to treat and dispose of LLRW. It needs to include an unbiased summary of the method's capabilities and problems, the location of the plant, and a contact for detailed information. It does not need to include background information or detailed descriptions of the processes.

2.4 WORKSHOP D. MECHANICAL TREATMENT AND VOLUME REDUCTION, R. KOHOUT, LEADER, AND E. J. FREDERICK, RECORDING SECRETARY

Workshop D focused on assessment and identification of R&D needs, both near- and long-term, of the following treatment processes:

- compaction (low- and high-pressure),
- sizing (or size reduction) - cutting, shearing, shredding, and
- dismantlement.

The above are processes that are, in essence, purely mechanical. In addition, we also addressed, as instructed, filtration of liquids and gases, which appeared to be somewhat different in nature from the main topics listed above. The reason for inclusion of the filtration process was its nature of mechanical removal of particulates from the process stream, along with the fact that there was no coverage of this process by other workshop groups. Last, but not least, in the workshop we tried to dissociate ourselves from the existing technology and treatment processes, and search instead for voids and non-existing technologies that would help to minimize these voids. The detailed listing of our findings will be derived from the transcripts of our workshop. In the 15-min time frame that I have available now, I can only highlight the workshop recommendations as follows:

1. Low-pressure, in-drum compaction may require optimization of antispring-back provisions, but the vendors themselves should be competent to do so.
2. Baling does not appear to be widely utilized. Baling into rectangular metal containers rather than cardboard boxes would be an improvement.
3. High pressure of supercompaction would deserve a development effort to modify the machinery to yield a rectangular end-product, to optimize storage, transportation, and disposal efficiency.
4. An R&D effort should be launched to fully investigate impact of supercompaction on mobility of radionuclides and other chemical constituents in land burial disposal.
5. Sizing (size reduction) involves a number of technologies (e.g., plasma arc cutting, shearing, sawing, shredding). There are a number of problem-specific dedicated systems being used in the industry. It

is recommended to review and assess the generic technologies and tooling, including their adaptability to remote control applications, and identify needs for development of new technologies. As an example, hydro lasers, using high pressure water jets with/without abrasives, should be assessed for suitability for radioactive applications. Shredders should be developed for underwater operation to control radiation and contamination.

6. A generic study on dismantlement/decommissioning should be carried out, forecasting types of materials to be dismantled, processed, handled, and transported for disposal. The study should identify dismantling logistics and necesary technologies, both existing and required. This may lead to R&D efforts in certain areas to acquire, and then demonstrate, new technologies. Some of the new technologies may be used, as they are developed, in partial decommissioning projects and major refurbishing projects.
7. A review of applicability of simple, one-purpose (man-like) robotics to do work in radiation area should be carried out, with assessment of collective dose-reduction potential to plant operators.
8. A generic study on volume reduction should be undertaken regarding compatibility of miscellaneous DAW and other materials with available mechanical treatment processes. The study should define optimum processes for individual materials. To maximize the overall VR, a suitable substitute material for PVC should be identified and tested. A feasibility study on destruction of PVC materials (e.g., by using microwave technology) should be undertaken and then suitable technology developed.
9. A survey of filtration practices (e.g., filtration media section, crud bedding capacity, method of filter replacement) in radioactive process stream treatment should be undertaken, to enable optimization of radioactive crud removal from nuclear plant process systems.
10. The ALARA principle shall be incorporated as a consideration in all R&D and also design/development work.

In closing this brief overview, I would like to thank all workshop participants for their ingenuity and efforts.

2.5 WORKSHOP E. SOLIDIFICATION, R. M. NEILSON, LEADER, AND T. M. GILLIAM, RECORDING SECRETARY

2.5.1 Introduction

The session on solidification was chaired by Robert M. Neilson, Jr., EG&G Idaho, Inc., and cochaired by T. Michael Gilliam, ORNL. Discussions were lively and initially represented a diversity of opinions from the participants. However, as discussions progressed, there was a remarkable consistency among the participants as to the fundamental needs in the area of solidification. These needs fall within three general categories: (1) improving existing operations, (2) understanding these operations, and (3) determining the adequacy of these operations. It should be noted that not all of these needs require major new R&D initiatives. These needs are highlighted in the following section.

2.5.2 Highlights of Solidification Needs

In the area of improving existing operations, the following suggestions were made:

1. Improve chemical characterization of waste streams and analytical screening protocols in response to RCRA.
2. Expand capability to obtain representative waste samples for analysis and testing.
3. Develop techniques for waste form verification testing at the reactor site. Potential remedial actions need to be evaluated in the event that a drum fails this verification testing.
4. Initiate a comprehensive study on solidification of problem wastes, such as decontamination wastes and oils contaminated with PCBs and new wastes, such as incinerator ash.
5. Improve container-filling techniques (i.e., increase packing efficiency).

In understanding and improving waste-form performance, it is necessary to:

1. Perform long-term stability testing of waste forms.
2. Develop a fundamental understanding of the mechanisms affecting radionuclide retention and stability for existing waste forms.
3. Determine the effects of chemically hazardous components in mixed waste on waste-form performance.

4. Apply information obtained to the development of improved waste forms and in support of licensing for new sites.

To promote system integration, it would be advantageous to:

1. Compile and disseminate existing solidification data (DOE, vendor, utilities).
2. Assess current low-level radioactive waste management practice with regard to compliance with RCRA.
3. Determine de minimis levels for radionuclides in LLRW and hazardous components in mixed waste.
4. Conduct sociological studies of public perception of LLRW disposal practices to provide guidance to cost-benefit analysis.
5. Perform waste disposal system optimization studies (e.g., waste form, container, disposal site, engineered barriers) to verify minimum requirements.
6. Develop additional experimental data as required to support the previous task.

2.5.3 Discussion of Solidification Needs

It should be noted that the following discussions refer, in all cases, to existing commercial reactor waste streams. The use of the word "generic" implies "common to more than one generator."

2.5.3.1 Improving Existing Operations

- Improve chemical characterization of waste streams and analytical screening protocols in response to the Resource Conservation and Recovery Act (RCRA).

Typically, waste streams are analyzed only for those radionuclides that are germane to NRC classification (i.e., A, B, or C). These analyses need to be expanded to include chemical constituents of concern under RCRA. However, performing these analyses as specified in 40 CFR 261 is not only expensive but, in many cases, is not feasible in the presence of significant amounts of radioactivity. Consequently, there is a critical need to: (1) develop analytical techniques that can safely measure RCRA constituents in waste streams containing significant amounts of radioactivity and (2) develop analytical screening techniques that can address classes of compounds and hence reduce analytical costs.

- Expand capability to obtain representative waste samples for analysis and testing.

At present, grab samples are used to test solidification media. This testing encompasses both selection of the solidification media and QA/QC for a selected process. As such, there is little documentation to support the fitness of the grab samples. In many cases, this leads to a solidification selection study based on an unrepresentative waste sample and/or a significant rejection rate of solidified product. Consequently, a sampling technique needs to be developed that addressses: (1) the necessary statistics to document the representative nature of the sample, (2) radiation exposure hazards, and (3) existing storage tank designs.

- Develop techniques for waste-form verification testing at the reactor site. Potential remedial actions need to be evaluated in the event that a drum fails this verification testing.

At present, there is no adequate technique that can be applied to solidified drums at the reactor site to verify compliance with performance criteria. Compliance verification is limited to laboratory-scale tests that are not necessarily adequate, as discussed earlier. Field-verification testing is left to the discretion of the disposal site operator, with rejected drums being sent back to the reactor site. This is inefficient and costly and increases transportation risks. Consequently, there is a need to develop a verification technique that can be applied to sealed drums at the reactor site. In conjunction with this development effort, there needs to be a study to determine appropriate remedial action for drums that fail verification testing.

- Initiate a comprehensive study on solidification of problem wastes, such as decontamination wastes and oils contaminated with PCBs and new wastes, such as incinerator ash.

At present, solidification development efforts on new or problem wastes are left to each waste generator or to commercial solidification vendors. The former invariably involves duplication of effort and increased costs, while the latter places the generator's liability in the hands of a vendor's proprietary data. Consequently, there needs to be a comprehensive, coordinated, solidification development effort for these generic waste streams.

- Improve container-filling techniques.

In the past, little attention has been given to optimizing utilization of drum space. With disposal costs per cubic meter steadily rising, inefficiencies in space utilization are beginning to translate into significant costs. Consequently, there is a need to develop techniques that increase packing efficiencies. This development effort should not only address packing efficiency of the drum but improved process control of transferring grout into the drum.

2.5.3.2 Understanding and Improving Waste-Form Performance

- Perform long-term stability testing of waste forms needs.

The NRC requires demonstration of long-term stability for Class C wastes. Although relatively short-term stability tests (which can be performed at the reactor site) are presently specified, it was agreed by all participants that there is no substitute for long-term tests. Such tests are costly for the generator and involve a significant duplication of effort. Consequently, there needs to be a coordinated study on the long-term stability and leachability of generic solidified products.

- Develop a fundamental understanding of the mechanisms affecting radionuclide retention and stability for existing waste forms.

At present, radionuclide retention and stability are determined by measurements of Leachability Index and compressive strength. Defending the extrapolation of these measurements to predict long-term performance and stability has not proven successful in the public arena. Consequently, a fundamental study is needed to understand and document the mechanisms of radionuclide retention and the chemistry of the solidification process. Such a study would provide the data base necessary to determine and define long-term performance and stability.

- Determine the effects of chemically hazardous components in mixed waste on waste-form performance.

The study suggested that these needs be expanded to include mixed waste. Chemical constituents of concern under RCRA are known to affect the chemistries of most cement-based solidification processes. Consequently, to truly understand the solidification process, wastes containing these constituents must be addressed.

- Apply information obtained from the above to the development of improved waste forms and in support of licensing for new sites.

With the present dependency on measurements such as Leachability Index and compressive strength, the public perceives that higher numbers are better and, in many cases, necessary. Therefore, improved waste forms and multiple barriers are required due to the political environment. Information obtained provides the data base to determine the adequacy of existing waste forms. Conversely, it provides the data base for waste-form improvement if it is determined to be needed.

2.5.3.3 System Integration

- Compile and disseminate existing solidification data (DOE, vendor, utilities)

Although a significant amount of pertinent research on solidification is being performed (by DOE, vendors, utilities, etc.), the results of the research is not always known to the appropriate users. There is a critical need for a centralized clearing house for data pertaining to solidification of LLRW.

- Assess current low-level waste management practice with regard to compliance with RCRA

Present LLRW management practices adhere to NRC requirements, and there is a need to assess the impact of RCRA requirements on these practices. In many cases, RCRA requirements may be incompatible with the ALARA concept. Where these incompatibilities are identified, the appropriate course of action needs to be identified.

- Determine de minimis levels for radionuclides in LLRW and hazardous components in mixed waste.

At present, there are no de minimis levels for radionuclides or RCRA hazardous constituents. As a result, significant quantities of waste are being solidified, which may not be necessary. Definition of de minimis levels would eliminate this cost.

- Conduct sociological studies of public perception of LLRW disposal practices to provide guidance to cost-benefit analyses.

Although cost-benefit analyses have been performed in the past, they have not included public perceptions. Sociological studies of public perception need to be performed to provide this input. This effort would provide guidance in determining where research in benefit improvement should be focused.

- Perform waste disposal system optimization studies (e.g., waste form, container, disposal site, engineered barriers) to verify minimum requirements.

A system optimization study needs to be performed that would identify disposal options available to meet the overall objective. Such a study would, for instance, define conditions in which waste form improvements may eliminate the need for additional migration barriers. However, the major use of this study would be as a tool to assess the effects of cost-saving options on overall performance. For example, considerable effort is being directed at volume reduction primarily to save costs. However, little effort is being directed at the effects of concentrating waste streams on solidification processes and their performance.

- Develop additional experimental data as required to support the previous task.

This optimization effort will invariably identify gaps in the existing data base. In order to use the optimization effort as a tool subject to public review, these gaps must be addressed.

2.5.4 Impressions

Although the needs discussed above appear to address a variety of issues, in reality they address two themes discussed time and time again in the session: costs and public perception. The greatest concerns of the participants were to (1) reduce costs of existing processes and (2) deal with public perception. It was generally agreed that the quickest, most efficient, and most cost-effective means of dealing with these issues is a centralized R&D effort (such as by DOE) on generic wastes and processes. Models, soothing words, etc., have their place, but the time has come to bite the bullet and generate hard data.

APPENDIX A: PROGRAM FOR LLRW WORKSHOP

PROGRAM FOR LLRW WORKSHOP

RESEARCH AND DEVELOPMENT NEEDS FOR TREATMENT OF LOW-LEVEL RADIOACTIVE WASTE FROM COMMERCIAL NUCLEAR REACTORS

Crystal Gateway Marriott Hotel
Arlington, Virginia
August 19-21, 1985

Monday, August 19, 1985

8:00-9:30 pm	Registration and Hospitality

Tuesday, August 20, 1985

8:00 am	Warm-up: Coffee and Sausage/Biscuits
8:30 am-12:30 pm	Plenary Session
8:30 am	Introduction, Bill Rodgers, ORNL
8:35 am	Welcome, Bob Rader, DOE,
8:40 am	Scope of Study and Purpose of Workshop, Bob Jolley, ORNL
8:50 am	Low-Level Radioactive Waste, Roy Person, NRC
9:10 am	LLRW Forms and Sources, Sue Hobart, EPRI
9:30 am	LLRW Volume Reduction Technology: VRTECH Model, Charles Koplik, The Analytical Sciences Corporation (TASC)
9:50 am	LLRW Regulatory Constraints, Larry Oyen, Sargent and Lundy
10:10 am	LLRW Transportation, Al Grella, NRC
10:40 am	----- BREAK -----

11:00 am — Panel Discussion on LLRW Treatment, Disposal, and the Effects of Compacts and de minimus Criteria

Don Charlesworth, AECL, Chalk River (Moderator)
Virgil Autry, State of South Carolina
Gary Benda, Chem-Nuclear Systems
Nancy Kirner, State of Washington
George Kniazewycz, KLM Engineering
Frank Parker, Vanderbilt University
Lenon Riales, Tennessee Valley Authority
Sid Wright, USEcology

12:30 pm — Workshops on LLRW Treatment: Methodology and Expectations, and Introduction of Workshop Leaders and Recording Secretaries, Herschel Godbee, ORNL

Workshop A: Removal of Water (Dewatering)
Leader: Mike Thomas, Black and Veatch Engineering Consultants
Recording Secretary, Arlene Kibbey, ORNL

Workshop B: Thermal, Physiochemical, and Biological Treatment
Leader: Roy Post, University of Arizona
Recording Secretary: Sam Clinton, ORNL

Workshop C: Sorting/Segregation and Decontamination
Leader: Tom LaGuardia, TLG Engineering
Recording Secretary: Sharon Robinson, ORNL

Workshop D: Mechanical Treatment (VR)
Leader: Radovan Kohout, Ontario Hydro
Recording Secretary: Ed Frederick, ORNL

Workshop E: Solidification
Leader: Bob Neilson, EG&G Idaho
Recording Secretary: Mike Gilliam, ORNL

12:35 pm — LUNCH (free time)

2:00 pm Individual Workshops

Workshop A:	Group 1
Workshop B:	Group 2
Workshop C:	Group 3
Workshop D:	Group 4
Workshop E:	Group 5

3:00 pm Individual Workshops

Workshop A:	Group 2
Workshop B:	Group 3
Workshop C:	Group 4
Workshop D:	Group 5
Workshop E:	Group 1

4:00 pm Individual Workshops

Workshop A:	Group 3
Workshop B:	Group 4
Workshop C:	Group 5
Workshop D:	Group 1
Workshop E:	Group 2

5:00-6:00 pm Relaxation and Debriefing Period

Wednesday, August 21, 1985

8:00 am Warmup: Coffee and Sausage/Biscuits

8:30 am Individual Workshops

Workshop A:	Group 4
Workshop B:	Group 5
Workshop C:	Group 1
Workshop D:	Group 2
Workshop E:	Group 3

9:30 am Individual Workshops

Workshop A:	Group 5
Workshop B:	Group 1
Workshop C:	Group 2
Workshop D:	Group 3
Workshop E:	Group 4

10:30 am -----BREAK-----

11:00 am	Parallel Sessions I. Preparation of Workshop Summaries II. Critique of Panel Discussion
12:00 N	LUNCH (free time)
1:30-3:00 pm	Plenary Session
1:30 pm	Workshop Leader Reports: Assessment, Problem Areas, and Development Needs A (15 min) B (15 min) C (15 min) D (15 min) E (15 min)
2:45 pm	Workshop "Summary" and Wrap-up, Bill Rodgers, ORNL
3:00 pm	Workshop Adjournment

APPENDIX B: ATTENDEE LIST

ATTENDEE LIST

WORKSHOP ON RESEARCH AND DEVELOPMENT NEEDS FOR TREATMENT OF RADIOACTIVE WASTE FROM COMMERCIAL NUCLEAR REACTORS AUGUST 19-21, 1985

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148. George H. Warrier, Carolina Power & Light, Rt. 1, P. O. Box 327, New Hill, NC 57562
149. Westinghouse Materials Co. of Ohio, Attention: Reports Library, P.O. Box 398704, Cincinnati, OH 45239
150. Paul C. Williams, Vice President, Nuclear Systems Sales, Stock Equipment Company, 16490 Chillicothe Road, Chagrin Falls, OH 44022
151. Robert H. Wolle, Southeast Compact Commission, Murray Lane, Rt. 3, Brentwood, TN 37027
152-153. Technical Information Center, U.S. Department of Energy Oak Ridge, TN 37831