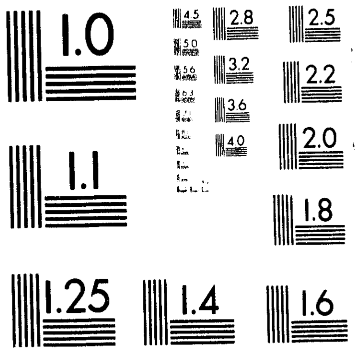
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SAND93-0054
Unlimited Release
Printed October 1993

Distribution
Category UC-721

Status of Waste Isolation Pilot Plant Compliance with 40 CFR 191B, December 1992

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ABSTRACT

Before disposing of transuranic radioactive waste at the Waste Isolation Pilot Plant (WIPP), the U.S. Department of Energy (DOE) must evaluate compliance with long-term regulations of the U.S. Environmental Protection Agency (EPA). Sandia National Laboratories (SNL) is conducting iterative performance assessments (PAs) of the WIPP for the DOE to provide interim guidance while preparing for final compliance evaluations. This paper describes the 1992 preliminary comparison with Subpart B of the *Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes* (40 CFR 191), which regulates long-term releases of radioactive waste. Results of the 1992 PA are preliminary, and cannot be used to determine compliance or noncompliance with EPA regulations because portions of the modeling system and data base are incomplete. Results are consistent, however, with those of previous iterations of PA, and the SNL WIPP PA Department has high confidence that compliance with 40 CFR 191B can be demonstrated. Comparison of predicted radiation doses from the disposal system also gives high confidence that the disposal system is safe for long-term isolation.

ACKNOWLEDGMENTS

The authors wish to recognize the technical reviews of this report by David Gallegos and Andrew Peterson (6342) of Sandia National Laboratories.

PREFACE

This SAND report is a reproduction of the identically titled paper published in:

American Nuclear Society and American Society of Civil Engineers. *High-Level Waste Management: Proceedings of the Fourth Annual International Conference in Las Vegas, NV, April 26 - 30, 1993.* American Nuclear Society, La Grange, IL; American Society of Civil Engineers, New York, NY.

STATUS OF WIPP COMPLIANCE WITH EPA 40 CFR 191B

DECEMBER 1992

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ABSTRACT

Before disposing of transuranic radioactive waste at the Waste Isolation Pilot Plant (WIPP), the United States Department of Energy (DOE) must evaluate compliance with long-term regulations of the United States Environmental Protection Agency (EPA). Sandia National Laboratories (SNL) is conducting iterative performance assessments (PAs) of the WIPP for the DOE to provide interim guidance while preparing for final compliance evaluations. This paper describes the 1992 preliminary comparison with Subpart B of the *Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes* (40 CFR 191), which regulates long-term releases of radioactive waste. Results of the 1992 PA are preliminary, and cannot be used to determine compliance or noncompliance with EPA regulations because portions of the modeling system and data base are incomplete. Results are consistent, however, with those of previous iterations of PA, and the SNL WIPP PA Department has high confidence that compliance with 40 CFR 191B can be demonstrated. Comparison of predicted radiation doses from the disposal system also gives high confidence that the disposal system is safe for long-term isolation.

INTRODUCTION

The United States Department of Energy (DOE) is developing the Waste Isolation Pilot Plant (WIPP), located in 255 million-year-old bedded salt in southeastern New Mexico, for disposal of transuranic wastes generated by defense programs. The DOE must first evaluate compliance with the Environmental Protection Agency's (EPA) *Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes* (40 CFR Part 191),[1] and with the *Land Disposal Restrictions* (40 CFR Part 268)[2] of the *Hazardous and Solid Waste Amendments* to the *Resource Conservation and Recovery Act*. The *National Environmental Policy Act* (NEPA)[3] requires all agencies of the federal government to prepare a detailed statement on the environmental impacts of "proposed major federal actions affecting the quality of the human environment." In compliance with the NEPA, an additional supplemental environmental impact statement (SEIS) is planned prior to permanent disposal.[4] This paper addresses the present status of WIPP compliance with Subpart B of 40 CFR 191 and an evaluation of long-term safety of the WIPP.

Subpart B of 40 CFR 191 was vacated by a Federal Court of Appeals in 1987 and is undergoing revision; by agreement with the State of New Mexico[5] the DOE will continue to evaluate repository performance with respect to the standard as first promulgated until a new version is available. The *Waste Isolation Pilot Plant Land Withdrawal Act*,[6] which mandates specific actions before the Test Phase for the WIPP can begin, requires the EPA to repromulgate the regulation before May 1993. The approach to 40 CFR 191B and the resultant methodology reported here have not been modified to reflect the EPA's efforts to develop a new Subpart B. The Containment Requirements in Subpart B of 40 CFR 191 set limits on the probability that cumulative radionuclide releases to the accessible environment during the 10,000 years following decommissioning of the repository will exceed certain limits. As defined in the standard, the accessible environment is "(1) the atmosphere; (2) land surfaces; (3) surface waters; (4) oceans; and (5) all of the lithosphere that is beyond the controlled area" (191.12[k]).[1]

To comply with the requirements of 40 CFR 191B, performance assessments (PAs) must construct a modeling system that can adequately simulate all realistic future states of the repository that might result in radionuclide releases. Because the regulatory limits are probabilistic, PAs must accurately reflect variability and uncertainty within all factors that contribute to the simulation, including variability in material properties, probabilities of future human actions, and uncertainties inherent in the conceptual and numerical models that simulate reality. In keeping with the strategy of the WIPP Project Headquarters for achieving a compliance decision,[4] the WIPP PA Department has completed three annual PAs evaluating preliminary compliance with 40 CFR Part 191, Subpart B.[7-16]

This paper summarizes the present status of WIPP PA.[14-16] All PA results to date are preliminary and cannot be used to determine compliance or noncompliance with EPA regulations governing long-term performance. Only the long-term performance of the disposal system is addressed.

INADVERTENT HUMAN INTRUSION

PAs for 40 CFR 191B presently concentrate on inadvertent human intrusion during exploratory drilling for resources, which has been demonstrated by past analyses[17,18,10-12,19] to be the only event likely to lead to radionuclide releases close to or in excess of regulatory limits. Future drilling technology is assumed for these analyses to be comparable to technology presently in use in the region around the WIPP.

If the waste-disposal panels are penetrated by an exploratory borehole, radionuclides may reach the accessible environment by two principal pathways. First, some radionuclides will be transported up the borehole directly to the ground surface. Second, additional radionuclides transported up the borehole will migrate into overlying strata and may be transported laterally in groundwater to the subsurface boundary of the accessible environment.

Most releases at the ground surface will be in the form of particulate waste entrained in the drilling fluid, including components from cuttings (material removed by the drill bit), cavings (material eroded from the borehole wall by the circulating drilling fluid), and spallings (material that enters the borehole as the repository depressurizes). For convenience, these particulate releases are collectively referred to in performance-assessment documentation as cuttings. For the 1992 calculations, results referred to as cuttings include cavings but do not include spallings. If important, spallings will be included in future PAs when models and data are available. Release of radionuclides dissolved in brine that may flow up the borehole to the ground surface both during drilling and after degradation of plugs has not been included either in past PAs or in the results presented in this volume. Preliminary analyses of releases by these mechanisms will be included in later PAs.

Subsurface releases of radionuclides following lateral transport in groundwater are believed most likely to occur in the Culebra Dolomite Member of the Rustler Formation overlying the repository. For analysis purposes, subsurface transport is assumed to occur only in the Culebra, maximizing the potential for releases by this pathway.

Figure 1 illustrates a representative intrusion scenario. In the scenario, a borehole penetrates the repository and a hypothetical pressurized brine reservoir in the underlying Castile Formation.

COMPUTATIONAL MODELS

The primary computer programs used in the computational models for the 1992 preliminary PA (Figure 2) reflect improvements in the conceptual and numerical models used in the 1991 and previous PAs and permit the replacement of simplifying assumptions with more realistic models. Three of the most significant improvements in 1992 are discussed here.

The 1992 calculations mark the first time the effects of salt creep have been explicitly included in PAs. Salt will deform over time by creep in response to a pressure gradient, and, if the repository remained at atmospheric pressure, lithostatic stresses would cause it to close almost completely within 100 years.[20-22] Gas will be generated within the repository by degradation of the waste, however, and pressure within the repository will rise to elevated levels that will retard complete creep closure and may perhaps partially reverse the process. In 1991 no model was available to describe the coupled interaction of creep closure and gas pressurization, and the performance-assessment calculations used a simplifying assumption that porosity within the disposal region would remain constant through time. The 1992 calculations use output from the geomechanical code SANCHO[23] to define the porosity of the waste as a function of pressure. Although this method does not represent a full coupling of creep closure and gas generation, the modeling improvement allows the PA to evaluate the importance of changing void volume in the repository.

The method used to incorporate spatial variability in the transmissivity field in the Culebra has been modified significantly from that used in 1991. WIPP PA now uses an automated inverse approach to calibrate a two-dimensional model to both steady-state and transient pressure data, generating multiple realizations of the transmissivity field.[15,24] Seventy calibrated fields were sampled for use in the 1992 PA.

Radionuclide transport in the Culebra Dolomite, which had been simulated using

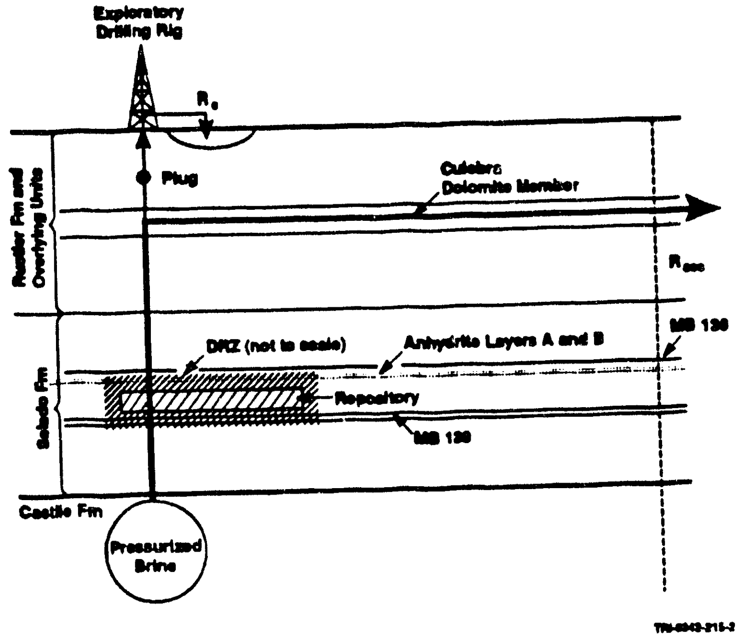

Figure 1 - Conceptual model for an intrusion scenario in which a borehole penetrates the repository and a hypothetical pressurized brine reservoir in the underlying Castile Formation. Arrows indicate assumed direction and relative magnitude of flow. R_c is the release of cuttings and eroded material. R_{acc} is the release at the subsurface boundary of the accessible environment. Illustrated plugs are assumed to remain intact for 10,000 years.

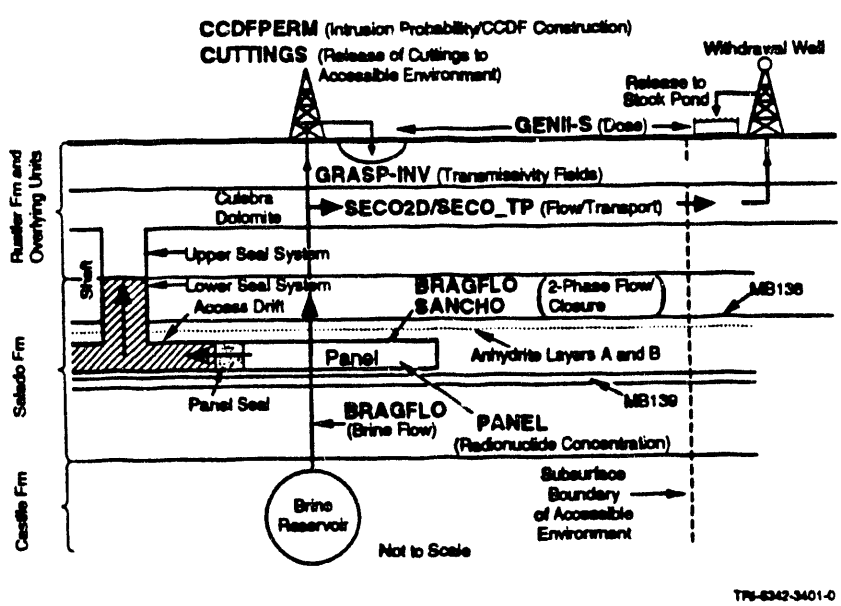

Figure 2 - Major codes used in the 1992 performance assessment.

STAFF2D[25] in the 1991 PA, is now simulated by the SECO-TP code.[16] SECO-TP is a dual-porosity model in which advective transport is allowed only in fractures, and diffusion of solute occurs into the rock matrix surrounding the fracture. The fracture system is idealized as planar and parallel, and each fracture wall may be coated with a layer of clay of uniform thickness and porosity. The model is capable of simulating both physical retardation by diffusion and chemical retardation by sorption in both clay fracture linings and dolomite matrix.

PROBABILITIES OF SCENARIOS

Preliminary PAs for the WIPP prior to 1990 considered a fixed number of human intrusions with fixed and arbitrary probabilities.[17,26] The 1990 preliminary assessment[7] compared performance assuming fixed probabilities for intrusion events with performance estimated assuming that intrusion through the repository follows a Poisson process (i.e., intrusion events are random in time and space) with a rate constant, λ_o. The 1991 assessment[10,11] included a probability model based on the Poisson assumption and also included effects of variable activity loading within the waste-disposal panels with boreholes intersecting waste of five different levels of radioactivity.[13] Based on guidance in Appendix B of 40 CFR 191, a maximum of 30 boreholes/km^2 were allowed in 10,000 years.

The 1992 preliminary PA marks the first use for the WIPP of external expert judgment to estimate the probability of future intrusion. Teams of experts from outside the WIPP Project were selected and organized into two panels to address (1) the nature of future societies and the possible modes of intrusion, and (2) types of markers and their potential effectiveness in deterring intrusion.[16] The judgments elicited from these panels were used to construct an algorithm describing possible changes in the Poisson rate constant, λ_t, with time.[16] The 1992 preliminary PA presents results calculated both using the 1991 time-invariant formulation and the time-dependent formulation based on external expert judgment. Both formulations used the same representation for variable activity loading within the waste-disposal panels used in the 1991 PA.[13] The time-dependent formulation, which included the deterrence effect of markers, resulted in significantly fewer intrusions than the time-invariant formulation.

RESULTS OF THE 1992 PERFORMANCE ASSESSMENT

Results of the 1992 PA are consistent with the conclusion made in previous preliminary comparisons that performance estimates for the WIPP lie below the limits set by the Containment Requirements of Subpart B of 40 CFR 191.[7,10] As illustrated in Figure 3, consideration of alternative models for the probability of human intrusion and radionuclide transport in the Culebra Dolomite provides insights into the relative impacts on performance of specific components of the natural barrier system and institutional controls at the WIPP.

The uppermost CCDF in Figure 3, labeled "Total, Single Porosity + Cuttings, λ_o" and calculated using the single-porosity (fracture only) and constant λ models, represents an estimate of the performance of the disposal system with very little contribution from the natural barrier provided by retardation in the Culebra Dolomite and no contribution from the potential institutional barrier that could be provided by passive markers, as required by the Assurance Requirements (191.14).[1] For the modeling system and data base used in 1992, the mean CCDF for this case lies below the EPA limits.

The segments of a CCDF shown with a dotted line and labeled "Total, Discharge from Borehole + Cuttings, λ_o" display performance with <u>no</u> contribution whatsoever from retardation in the Culebra Dolomite. This CCDF is unlike others shown in this figure in that releases are not calculated at the accessible environment and therefore is not suitable for comparison, preliminary or otherwise, with the Containment Requirements. The curve displays releases directly into the Culebra Dolomite (with cuttings also included) from boreholes occurring at 1000 years and therefore provides an estimate of total releases if subsurface transport to the accessible environment were instantaneous and complete. Instantaneous and complete transport is physically unrealistic, and this curve is displayed only for the purpose of comparison with the curve described in the previous paragraph, which was calculated using the single-porosity and constant λ models. The two curves are identical for most of their lengths. The differences between the curves are caused by radioactive decay during transport, and the single-porosity transport model in effect allows all sufficiently long-lived radionuclides that enter the Culebra Dolomite to be transported to the accessible environment within the 9000 years following intrusion.

The CCDF in Figure 3 labeled "Total, Dual Porosity + Cuttings, K_d=0, λ_o" represents an estimate of the performance of the disposal system if physical retardation by diffusion into the pore volume of the Culebra Dolomite is included as a part of the natural barrier system. The area between the first and second CCDFs is a measure of the potential regulatory impact of including physical retardation. Similarly, the next CCDF in Figure 3, calculated using the dual-porosity, K_d≠0, and constant λ models, represents an estimate of the performance of the disposal system if both physical and chemical retardation in the Culebra Dolomite are included in the natural barrier system. The location of this third curve is determined entirely by cuttings releases.

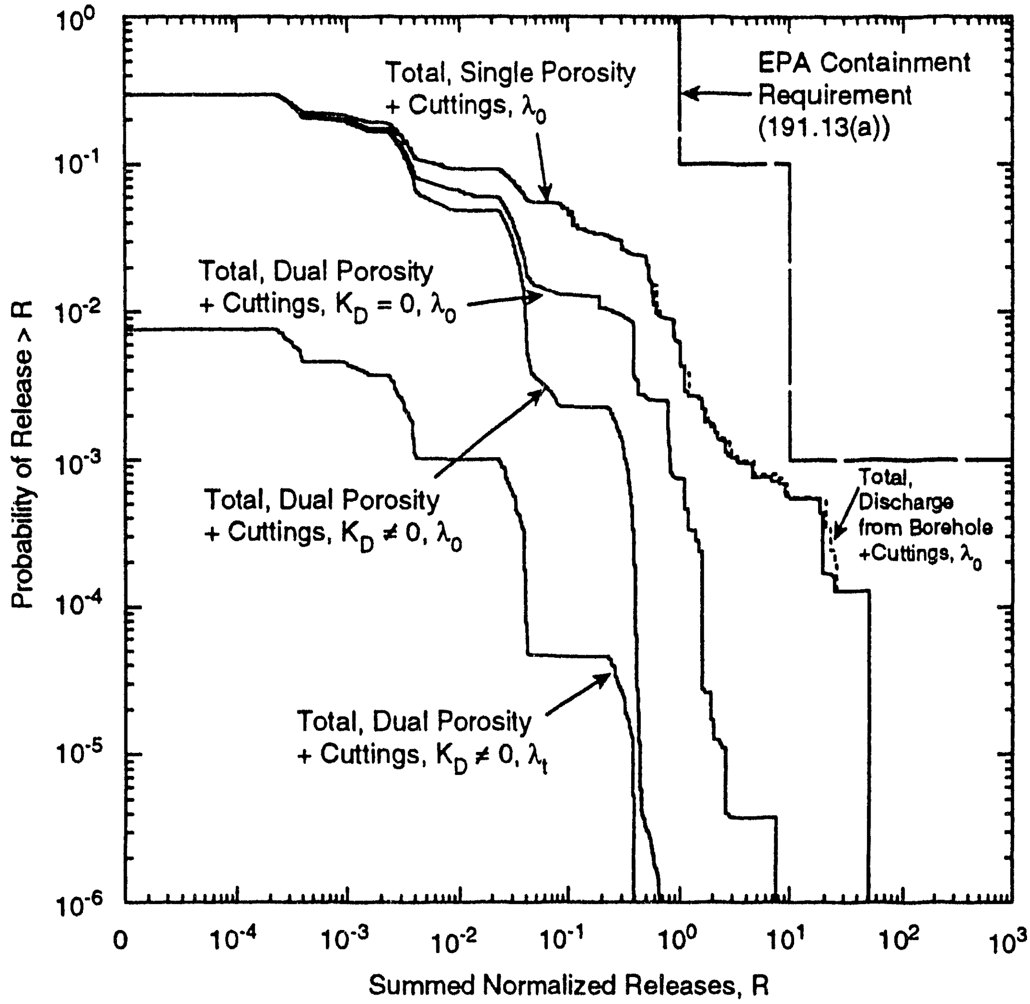

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Figure 3 - Comparison of mean CCDFs for total (cuttings plus subsurface) releases from intrusions occurring at 1000 years showing the impact of including specific components of the natural and institutional barrier systems. Both curves shown for $K_d \neq 0$ are dominated completely by cuttings releases. Summed normalized releases are displayed using an inverse hyperbolic sine scale, which differs from a logarithmic scale only in the interval between 0 and 10^{-4}.

The final CCDF in Figure 3, calculated using the dual-porosity, K_d=0, and time-dependent λ models, shows the effect of including expert judgment on the efficacy of passive markers in reducing the probability of human intrusion. This final CCDF, also determined entirely by cuttings releases, was calculated using what the WIPP PA Department believes at this time to be the most realistic conceptual model for the disposal system, based on models and data available in 1992. As indicated previously, results are preliminary, and none of the curves shown in Figure 3 are believed sufficiently defensible for use in a final compliance evaluation.

CONCLUSIONS

Significant improvements in the 1992 PA modeling system over that used in previous years[26] were the simulation of waste-generated gas and two-phase (brine and gas) flow modeling in the repository; the use of geostatistically generated transmissivity fields in the Culebra Dolomite Member; the use of a Poisson model with time-varying drilling intensities to determine scenario probabilities; the inclusion of a preliminary analysis of potential effects of climate variability on flow in the Culebra Dolomite; and the inclusion of the effects of salt creep (closure and inflation of waste panels) Processes not included in the analyses reported in the set of documents comprising the 1992 PA that could have a significant effect on performance are fracturing in the anhydrite interbeds, and spalling into an intrusion borehole. Important uncertainties that have not been assessed and included in the 1992 PA[14-16] are conceptual uncertainties in many parts of the system, both in non-Salado and Salado natural barrier systems and within the engineered barrier system. Effects of subsidence due to potash mining were not included in the scenario analyses. WIPP PA has a high level of confidence that the net effect of including these refinements will not change the overall conclusions (major conclusions 1 and 2 below) of the 1992 analysis but will provide additional confirmation for those conclusions.

Major conclusions that can be drawn from the 1992 preliminary PA for the WIPP are as follows:

1. PA analysts have high confidence that compliance with Subpart B of 40 CFR 191 can be demonstrated.
2. By comparison with doses from other common sources and ICRP recommendations, PA analysts have high confidence that the facility is safe for long-term isolation.

These two conclusions, and therefore demonstration of compliance with 40 CFR 191B and determination of the long-term safety of the disposal system, are conditional on completion of those portions of the WIPP Test Phase Plan[27] that are shown to be important for PA, to confirm that reality lies within the range of uncertainty used by PA.

Analyses supporting these conclusions indicate that, with regard to 40 CFR 191B, the direct release of radioactive material at the ground surface during borehole intrusions dominates the estimates of cumulative 10,000-year releases. Important uncertain parameters include the rate of future intrusion, the permeability of future borehole fill, and the diameter of future boreholes. An important assumption used in calculating these direct releases is that present-day drilling technology persists for 10,000 years. Other parameters for which uncertainty has a relatively large impact on cumulative radionuclide releases include permeabilities of the anhydrite and halite of the undisturbed Salado Formation, radionuclide solubilities in repository brine, radionuclide retardation in the Culebra Dolomite, and parameters used in the assumed dual-porosity model for radionuclide transport in the Culebra Dolomite.

ACKNOWLEDGMENT

This is Sandia National Laboratories report SAND93-0054C. Work was performed for the United States Department of Energy under Contract DE-AC04-76DP00789.

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6341	Sandia WIPP Central Files (100)
6342	D.R. Anderson
6342	Staff (30)
6343	V. Harper-Slaboszewicz
6343	Staff (3)
6345	R.C. Lincoln
6345	Staff (9)
6347	D.R. Schafer
6348	J.T. Holmes
6348	Staff (4)
6351	R.E. Thompson
6352	S.E. Sharpton
6400	N.R. Ortiz
6613	R.M. Cranwell
6613	R.L. Iman
6613	C. Leigh
6622	M.S.Y. Chu
6641	R.E. Luna, Acting
7141	Technical Library (5)
7151	Technical Publications
7613-2	Document Processing for DOE/OSTI (10)
8523-2	Central Technical Files

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