CARD No. 43
Passive Institutional Controls

43.A.1 BACKGROUND

Assurance requirements were included in the disposal regulations to compensate in a qualitative manner for the inherent uncertainties in projecting the behavior of natural and engineered components of the WIPP for many thousands of years (50 FR 38072). Section 194.43 incorporates one of the assurance requirements in the Compliance Criteria. Passive Institutional Controls (PICs) are defined in Section 191.12 as "(1) Permanent markers placed at a disposal site, (2) public records and archives, (3) government ownership and regulations regarding land or resource use, and (4) other methods of preserving knowledge about the location design, and contents of a disposal system." The advantage of PICs is that they require little or no human intervention to convey the message to potential intruders that they should not disturb the site (Taylor, 1993).

Because changes in language, technology, and political institutions cannot be predicted over thousands of years, PICs and their messages cannot be assumed to last in perpetuity. For this reason, neither the disposal regulations nor the compliance criteria require that PICs be shown to be effective for 10,000 years (Response to Comments Document for 40 CFR Part 194, p. 15-12). In addition, there is no guarantee that a person will obey an admonition not to disturb the site, even if he or she has read and understood it. EPA therefore intends that PICs serve only to avert "unintentional" intrusions into the repository (e.g., resource exploration resulting from lack of knowledge of the presence of radioactive waste). The Agency also intends that PICs be designed to survive as long as possible using available technology and materials.

43.A.2 REQUIREMENT

(a) "Any compliance application shall include detailed descriptions of the measures that will be employed to preserve knowledge about the location, design, and contents of the disposal system. Such measures shall include:

(1) Identification of the controlled area by markers that have been designed and will be fabricated and emplaced to be as permanent as practicable."

43.A.3 ABSTRACT

DOE must submit a description of the markers that will be placed at the WIPP site to warn future generations of the presence and hazards of radioactive waste. The markers must be as permanent as is practicable using current technology. EPA expected that DOE would discuss the schedule for implementation of markers in the CCA.

DOE proposed to build an elaborate system of markers at the site. Granite monuments would be placed on the surface around the WIPP Land Withdrawal perimeter[1] and also the repository footprint. A tall, earthen berm would encompass and protect both the monuments at the repository and a granite information room. Magnets and metal trefoils would be enclosed in the berm structure to give it a distinctive signature in magnetic or radar surveys. Small markers and duplicate granite information rooms would be buried in or near the footprint. All markers except the berm would be inscribed in several languages with warning messages of varying complexity. DOE proposed to test materials and messages until approximately 100 years after closure of the WIPP, at which time the marker system would be put in place.

EPA reviewed the descriptions provided by DOE to determine whether the markers could be considered as permanent as practicable. The Agency contacted quarries to discuss the design and develop an independent cost estimate. EPA also reviewed DOE's schedule for completing the markers.

43.A.4 Compliance Review Criteria

To comply with Section 194.43(a)(1), DOE must submit a design for markers that identify the WIPP site and convey information about the disposal system's design and contents. Such a design should describe individual markers in detail and be supported by information demonstrating that the markers were as permanent as practicable. Permanence refers to the markers' ability to withstand both natural and human-initiated forces that could reasonably be expected to occur at the site. Markers need not be designed to withstand catastrophic, low-probability events, such as nuclear war or a comet strike, since any attempt to do so would undoubtedly strain the practicability of the design. Practicability refers to DOE's ability to emplace markers using currently available resources and technology.

In addition to describing markers that will be fabricated and emplaced, DOE was expected to provide a time line for implementing the markers. EPA measured DOE's commitment to the design by the level of detail proffered in the CCA regarding markers and the actions that DOE expects to take during the period of EPA's regulatory authority (approximately 35 years).

43.A.5 DOE Methodology and Conclusions

Chapters 7.3.3.1.1 and 7.3.3.3 and Appendices PIC and EPIC contain the information supporting DOE's compliance with this requirement. Appendix PIC contains marker descriptions and the basis for the selection of specific markers and designs, while Appendix EPIC describes the potential failures considered in the design. Subsequent to its submission of the CCA on October 29, 1996, on January 21, 1997, DOE submitted a revision of Appendix EPIC (Revision 1, dated November 14, 1996, with Addendum dated December 6, 1996). See the discussion under Section 194.43(b) in this CARD for further information about potential

[1] The WIPP Land Withdrawal perimeter encompasses an area of 16 square miles. DOE refers to this territory, which was placed under DOE's authority by the 1992 WIPP Land Withdrawal Act, as the "controlled area."

failures for markers. In addition, DOE submitted supplemental information relevant to the marker design with a letter dated February 7, 1997 (Docket A-93-02, Item II-I-07, Enclosure 2e), referred to henceforth as "the 2/7/97 supplement." This supplement clarifies statements in the CCA concerning implementation of markers, as discussed under EPA Compliance Review below.

DOE's development of PICs was informed by historical expert panels. DOE convened two groups of experts, the Futures Panel and the Markers Panel, to examine the issues involved with designing an effective system of permanent markers. The Futures Panel identified the characteristics of possible future societies and assessed the likelihood that inadvertent human intrusion into the WIPP would occur. At the conclusion of their efforts, the Futures Panel prepared a report entitled "Expert Judgment on Inadvertent Human Intrusion into the Waste Isolation Pilot Plant" (Hora et al., 1991).

Subsequently, DOE tasked the Markers Panel with designing a marker system for the WIPP site. The Markers Panel also identified types of messages, message content, and types of media that would be appropriate for conveying information to future generations. The information to be conveyed included the location of the disposal system, the presence of dangerous waste material, and the potential consequences of intrusion. The Markers Panel prepared a report entitled "Expert Judgment on Markers to Deter Inadvertent Human Intrusion into the Waste Isolation Pilot Plant" (Trauth et al., 1993). The report examined a variety of configurations and materials and concluded that a highly redundant system, comprised of natural materials and incorporating massive structures with messages and graphics of varying complexity, offered the greatest likelihood of endurance. DOE noted that the Markers Panel was under no restrictions regarding the scope of their considerations (i.e., they were not told to consider such factors as cost and effort in recommending a design).

DOE developed the conceptual design for the proposed markers based on the general recommendations of the Markers Panel, along with other considerations such as feasibility and cost. A description of the design requirements and design criteria that DOE used to develop the conceptual design for the markers is included in Section III of Appendix PIC (pp. 17-23). The conceptual design for the PIC markers included the following elements:

- A berm surrounding the repository footprint.
- Sixteen monuments at the perimeter of the repository footprint to identify the outer boundary of the subsurface disposal system.
- Thirty-two monuments at the perimeter of the controlled area to define the Land Withdrawal Act Boundary.
- Thousands of small buried markers, randomly spaced and distributed across the repository footprint.
- An information center located above ground at the center of the repository footprint.

- Two buried storage rooms, located within the southern section of the berm and halfway between the berm and the hot cell to the north.

DOE's overall concept was to construct redundant markers with messages of varying complexity. DOE provided a detailed description of the conceptual design for the messages and the rationale for the design in Section IV (pp. 24-40) and Appendices 2 and 3 (pp. 108-123) of Appendix PIC. The four levels of message complexity used in the design (p. 24) are:

- Level I—Something made by humans is present. The message is the physical form of the marker itself. (All markers)

- Level II—Danger. Something dangerous is buried here and no digging or drilling should be conducted in the vicinity of the disposal system. (Monuments and buried markers)

- Level III—Danger. Basic information (in seven languages) about the WIPP, such as location, design, and contents. (Monuments)

- Level IV—Danger. Detailed messages (in seven languages) about the WIPP disposal system, including tables, figures, maps, and diagrams. (Information center and buried rooms)

In addition, Level V documents such as the CCA itself will be kept in record centers and archives (see discussion under Section 194.43(a)(2) in this CARD). Level V messages are considerably more complex than may be practically captured in stone. The markers proposed by DOE in Appendix PIC are described below.

Berm

The purpose of the berm surrounding the repository footprint is to provide a Level I message and to outline the surface footprint of the repository with a massive structure. The berm will have a trapezoidal cross section and a rectangular outline that is slightly larger than the actual repository footprint. The long side of the berm will be oriented in an east-west direction. The outer dimensions will be 874 meters (2,870 feet) by 720 meters (2,360 feet), and the inner dimensions will be 814 meters (2,670 feet) by 660 meters (2,165 feet). The overall height of the berm will be 10 meters (33 feet) above ground surface. The width of the berm at the base and at the ground surface will be 30 meters (98 feet), and the width of the flat top of the berm will be 4 meters (13 feet). The outer side slope of the berm will be 1.3 horizontal to 1.0 vertical. The total volume of the berm will be approximately 750,000 cubic meters (975,000 cubic yards).

To provide a solid base for the berm, approximately 10 feet of surficial soil will be excavated so that the base of the berm will rest on the top of the caliche layer. The inner core of the berm will consist of salt excavated during construction of the repository, since it is a fill material that will be readily available in large quantities. The salt core will be protected by an approximately 2-3 meter (5-8 feet) thick layer of caliche. The caliche will be graded such that 30 to 40 percent of the material will be classified as fine-grained (i.e., material that will pass through a number 200 sieve). The caliche will be compacted to decrease permeability. Above

the caliche will be a layer of riprap to protect the compacted caliche from wind erosion and provide a drainage layer for precipitation. The outer layer of the berm will consist of a mixture of riprap and native soil designed to support vegetation and minimize erosion. DOE did not specify the final combination of soil types and riprap sizes for the outer layer.

To decrease collection of precipitation in the enclosed area of the berm, drainage paths will be built at approximately 100 meter (328 foot) intervals. The drainage paths will consist of riprap-filled trenches 3 meters (10 feet) wide through the berm base below the surface. Large permanent magnets buried at intervals in the berm will give the structure a distinctive magnetic signature. These magnets will measure approximately 1 meter (3.2 feet) long and 0.5 meters (1.6 feet) square in cross-section and will produce a signal detectable with current airborne detection equipment. Metal trihedrals buried in the berm will provide a distinctive radar-reflective signature. The trihedrals will have facets measuring approximately 0.9 meters (2.9 feet) on each side and will be encased in concrete to extend their effective lifetime and to reduce their likelihood of being salvaged.

Repository Footprint Perimeter Monuments

The purpose of the repository footprint perimeter monuments is to provide a ground-level outline of the outer boundary of the subsurface disposal system and to provide a surface for inscribing Level II and Level III messages that describe the waste, the size of the area where digging and drilling should be prohibited, and the depth at which waste is located. DOE proposed to place 16 monuments, evenly spaced, along the inside perimeter of the berm.

Each monument will consist of two granite monoliths joined by a 1.5 meter (5 feet) long tendon, with a buried truncated base, 6.7 meters (22 feet) high, including the tendon, and a 7.6 meter (25 feet) high right prism that will be 1.2 meters (4 feet) square. The upper stone will weigh approximately 36.4 metric tons (40 tons), and the base stone will weigh approximately 59.1 metric tons (65 tons). The granite monuments will be quarried and fabricated and then shipped by rail to the site, where they will be erected. The base stone will be set 1.5 meters (5 feet) into the caliche layer to provide a stable base. Each face of the monument will be polished to shed water.

Each of the monuments will be inscribed with Level II and Level III messages in seven languages: the six official United Nations languages (English, French, Spanish, Chinese, Russian, and Arabic) and Navajo. In addition, each footprint monument will be inscribed with a diagram depicting two concepts. The first concept will illustrate the danger of digging or drilling into the repository and releasing radioactive and toxic waste. The second concept will illustrate the decay of radioactive material over many thousands of years.

The written messages will be inscribed at the top of the monuments in three languages on three sides of the monument. The top of the fourth side will contain diagrams. One diagram and written Level II and Level III messages in four languages will be inscribed on the buried portion of the monuments. The precise location of the individual translations on the monuments will vary so that copies of all translations are located both above and below ground.

Controlled Area Perimeter Monuments

The purpose of the controlled area perimeter monuments is to provide a ground-level outline of the location of the controlled area boundary and to provide a surface for inscribing a Level II message that cautions against drilling or mining in the controlled area. DOE proposed to place 32 monuments, evenly spaced, around the perimeter of the 41 square kilometer (16 square mile) controlled area.

The dimensions of the controlled area perimeter monuments will be the same as for the repository footprint perimeter monuments. The top of a monument will be inscribed with "Danger" and a message not to drill in the controlled area. The message will be in three languages on three of the sides of the monument. The two diagrams illustrating the danger of digging or drilling into the repository and the decay of radioactive material over time will be inscribed on the top of the fourth side of the monument. The "Danger" warning will be repeated in the remaining four of seven languages on the buried portion of the monuments in the area 1.5 - 3.6 meters (5 - 12 feet) above the bottom of the monument. The precise location of the individual translations on the monuments will vary so that copies of all translations are located both above and below ground.

Small Buried Markers

The purpose of the small buried markers is to provide a Level II message warning against digging or drilling in the area that would be unearthed by individuals attempting to drill or mine within the repository footprint. DOE proposed to bury several thousand small markers, constructed of three different materials (granite, aluminum oxide, and fired clay), at random intervals over a range of 0.6 to 1.8 meters (2 to 6 feet) below the ground surface, within the repository footprint, and in the berm. The lateral spacing between the buried markers will also be random, with a range of 4.6 to 12.2 meters (15 to 40 feet). DOE chose this spacing to increase the likelihood that several markers would be unearthed during preparation of a site for drilling. Each buried marker has a Level II warning message in one of the seven languages used on the monuments.

Information Center

The purpose of the information center is to provide a surface for inscribing a Level IV message regarding the location and design of the disposal system and the dangers of the radioactive and toxic waste buried therein.

The information center will be composed of granite slabs and erected at the geometric center of the repository footprint. The foundation of the information center will be prepared by excavating the native soil down to the caliche layer, then filling the excavation back up to the ground surface with compacted caliche. The information center will have four exterior walls and seven parallel interior information walls, but no roof, in order to permit observation of the messages in natural light. The overall dimensions of the structure will be 12.2 meters long by 9.8 meters wide by 3.0 meters high (40 feet long by 32 feet wide by 10 feet high). The dimensions of the interior information walls will be 5.2 meters wide by 2.1 meters high (17 feet wide by 7 feet high). These dimensions exclude the 1.5 meters (5 feet) of each wall that will be buried in the compacted caliche to support the structure.

Level IV messages will be engraved on both sides of the seven granite information walls. Tables, figures, diagrams, and maps will be engraved on the interior sides of the exterior walls. The interior walls will be spaced close together to minimize wind and water erosion. The ground surface near the information center will be graded so that precipitation drains away from the structure.

Buried Storage Rooms

The purpose of the buried storage rooms is to provide a surface for inscribing a Level IV message regarding the location and design of the disposal system and the dangers of the radioactive and toxic waste buried therein. One storage room will be buried within the center of the southern section of the berm. The second storage room will be buried 160 meters (525 feet) north of the berm on a line between the information center and the hot cell.

The overall dimensions of the buried storage rooms will be 11.9 meters long by 6.7 meters wide by 4.9 meters high (39 feet long by 22 feet wide by 16 feet high). The exterior walls, base, and roof of the storage rooms will be formed by granite slabs with a minimum number of joints. The conceptual design calls for the individual exterior structural walls, floor, and roof to be comprised of single granite slabs joined only at the perimeter. The slabs will be joined by fitting the pieces into slots cut in the granite slabs to eliminate the need for mortar, grouts, or metal fasteners that could degrade over time.

Seven granite slabs, 3.7 meters wide by 3.0 meters high (12 feet wide by 10 feet high), will be emplaced within the buried storage room to create interior walls for text. The internal walls containing Level IV messages will be fitted into slots in the base slab, the roof slab, and one outside wall. After the room is erected, the excavation will be backfilled. The entrance to the room will be a plug in one wall measuring 0.6 meters (2 feet) at the inner minimum diameter and weighing approximately 725 kilograms (1,600 pounds). The plug will be tapered so that the diameter of the face of the plug that faces the inside of the room is smaller to prevent the plug from falling into the room.

Tables, figures, diagrams, and maps will be engraved on the interior sides of the exterior walls. Each of the seven interior message walls will be engraved on both sides with messages in seven languages. Both sides of the interior message walls and the interior sides of the exterior walls will have a granite veneer with duplicate information engraved underneath. The location of the buried storage rooms will be documented in the records located off site in archives and record centers (see discussion under Section 194.43(a)(2) below) and in the on-site information center.

DOE Conclusions

In Chapter 7.3 (p. 7-64), the CCA concludes that the program described in Appendix PIC will fulfill the requirements of Section 194.43 and that, “The permanent marker system. . . is the best system of passive institutional controls for permanently marking the system” (p.7-66).

43.A.6 EPA COMPLIANCE REVIEW

EPA reviewed information concerning the marker design as contained in Chapter 7, Appendix PIC, Revision 1 of Appendix EPIC (dated January 21, 1997), and the 2/7/97 supplement. EPA evaluated DOE's statements regarding (1) the permanence of the design, (2) the practicability of the design, and (3) implementation of the design. As stated in the Compliance Application Guidance (CAG), EPA expected DOE to provide a time line for implementing the markers. EPA also considered the manner in which the messages on the proposed markers preserve knowledge about the location, design, and contents of the disposal system. In the Response to Comments Document for 40 CFR Part 194, EPA stated, "The EPA recognizes that [a] message is more likely to endure and be understood if it is conveyed in multiple languages and on durable materials. The EPA will consider such factors in its evaluation of DOE's plan to implement PICs" (RTC, p. 15-2).

Permanence of the Design

DOE discussed how the markers were designed for endurance in Sections III, V, VI, VII, and VIII of Appendix PIC. Information regarding the proposed markers' potential failures and how they were addressed in the conceptual design is provided in Appendices EPIC.5 and EPIC.6. This CARD discusses endurance and potential failures of the proposed markers under Section 194.43(b) below.

Practicability of the Design

EPA required DOE to show that the proposed markers are as permanent as practicable (i.e., able to be completed using currently available resources and technology). In general, the types of markers proposed by DOE appear practicable, although labor and resource intensive. The materials to be used (granite, salt, caliche, aluminum, and clay) are commonly available and of low economic value (materials of high economic value are less desirable because they may encourage removal and/or destruction of markers) (See Trauth, pp. F-92 to F-97). However, while the CCA contained detailed information about certain aspects of the marker system (particularly the berm), the CCA did not directly address some basic questions that arose about the feasibility of other features of the design. For example:

- How much time and money will it cost to fabricate and construct the proposed markers?
- Can granite be quarried and constructed as required by the design?
- Did DOE consult quarries, and what did the Department learn from them?
- Are the engraved messages practicable?

In a letter dated December 19, 1996, EPA asked DOE to provide evidence that "in proposing the overall PICs design as practicable, it gave serious consideration to the amount of time, human effort, and money likely to be required to implement the major aspects of the design" (Docket A-93-02, Item II-I-01).

DOE's response, the 2/7/97 supplement, stated that a number of quarries were contacted to obtain order of magnitude cost estimates for the fabrication of components, and that inquiries were made as to the availability of riprap and caliche in the local area. On the basis of its inquiries, DOE concluded that materials are available, that three years are sufficient to construct the marker system, and that the cost of the markers in current dollars is $75 million (Docket A-93-02, Item II-I-07, Enclosure 2e, p. 15).

To confirm DOE's estimate, EPA undertook an independent estimate of the cost of fabricating and constructing the principal markers—the berm and the monuments. Using information provided in the CCA, EPA obtained a very broad cost estimate in 1997 dollars for construction of the berm and the fabrication, transport, and erection of the granite monoliths used to mark the repository footprint and the perimeter of the controlled area (EPA, 1997).

EPA obtained information about the berm's geometry from Chapter 7 (Figure 7-15) of the CCA and Figures VIII-1 and 2 of Appendix PIC. The Agency calculated the volume of materials required to construct each of the component layers of the berm and assessed the cost of related construction activities, such as clearing and grubbing the land, hauling the various materials, and backfilling/placing and compacting materials. EPA derived construction costs related to the berm from the R.S. Means Heavy Construction Cost Data (11th Annual Edition, 1997). EPA estimated the cost of constructing the berm to be approximately $40 million dollars (EPA, 1997).

EPA contacted the Cold Spring Granite Company of Cold Spring, Minnesota, to obtain estimates of the costs related to fabricating and engraving the granite. Cold Spring Granite Company was one of the quarries mentioned as a contact by DOE in the 2/7/97 supplement. The costs related to shipping the granite monoliths to the site and erecting them were obtained from Cold Spring Granite Company, OMNI Transportation Services, and the Means Cost Guide. EPA estimated the cost of fabricating, engraving, shipping, and erecting the 48 granite monuments to be approximately $28.25 million dollars (EPA 1998).

EPA's estimate of the costs associated with the berm and monuments totaled $68 million in current dollars. This estimate did not include the cost of fabrication and erection of the granite information center and the buried storage rooms or the cost of production and emplacement of the small buried markers. As a result, EPA concluded that DOE's estimate of $75 million for all PICs was probably too low.

Neither the CCA nor the 2/7/97 supplement specified the substance of DOE's inquiries to individual quarries. The supplement stated only that 10 quarries were contacted "in determining the size and configurations of large granite monoliths which can be quarried. . . [I]t was determined that rectangular components were much easier to fabricate, when considering such large sizes, than are curved components" (p. 8).

EPA contacted two of the granite quarries identified by DOE to confirm that it is possible to fabricate the proposed monuments. Representatives of Cold Spring Granite Company and Keystone Granite Company of Elberton, Georgia informed EPA that only a few quarries are able to quarry and fabricate large granite structures. They also stated that DOE's two-piece monuments could be quarried but would be difficult to construct using current

fabrication capabilities, and that a five-piece design would be more feasible. Both sources stated that it would not be possible to engrave and handle the pieces without expanding conventional fabrication techniques, due to the weight and length of the pieces.

Given that two of the quarries expressed reservations about fabricating pieces with the dimensions proposed by DOE, it appears that DOE's design merits further explanation of why it is practicable. DOE did not provide documentation, in the form of either correspondence with quarries or technical literature citations, showing that the granite monoliths for the monuments and slabs for the rooms could be:

- ♦ Quarried (cut and removed from the ground) without cracking due to tensile stresses from handling or isostatic rebound.

- ♦ Engraved on the scale required by the design.

- ♦ Transported to the site, given the weight and dimensions of the monoliths and slabs and the capacity of existing rail cars and rail lines.

- ♦ Loaded, unloaded, and erected without cracking based on the capacity of available equipment.

- ♦ Successfully joined.

According to Appendix PIC, DOE intends to evaluate such features of the system as consolidation of the salt core, performance of the railroad spur at the WIPP site, construction techniques, chemical interaction of materials, and procurement of materials. DOE clarified in the 2/7/97 supplement that such review and testing, with certain exceptions (see "Implementation of the Design" below), will take place during the WIPP's operational period. Thus, any determination that DOE has complied with this criterion must be conditioned on DOE satisfactorily addressing each of the factors enumerated above during the operational period. If EPA determines that DOE has not demonstrated that these factors have been satisfactorily addressed, EPA will be constrained to find that DOE has departed from the basis on which EPA determines compliance. Any such departure would subject the certification to modification, suspension, or revocation pursuant to Section 553 of the Administrative Procedure Act (Section 194.4; see also RTC, p. 15-12).

Appendix PIC discusses some of the alternative designs for markers that DOE considered and the reasons why they were rejected. For example, Sections X-XIII of Appendix PIC describe designs for the berm that were suggested by the Markers Panel and explain why DOE found them to be impractical. Section V of Appendix PIC explains why DOE selected the particular shape, design, base material, and placement of the proposed monuments. Section V also discusses why deep markers and various subsurface means of interfering with drilling were found impractical. EPA considered DOE's judgment in these areas to be reasonable and well-founded. Specifically, EPA agreed that the alternative markers described in Appendix PIC, such as the menacing earthworks concept described in Section XII and the steel plates and dye described in Section V, are much more difficult to implement and are likely to be less effective than the proposed measures.

Implementation of the Design

The CCA contains numerous statements indicating that DOE intends to make unspecified changes to the conceptual design for PICs after the WIPP ceases operation (see for example Sections I.B (pp. 4-6), VI (pp. 66-67), and IX (pp. 74-77) of Appendix PIC). Figure 7-16 of the CCA indicates that the PICs markers will not be built until the year 2083. Section IX of Appendix PIC provided a brief description of some of the subjects that may be evaluated during the testing program, but generally did not provide details concerning the actual data needs to be filled, the types of tests that will be conducted to obtain the data, or the performance criteria that will be used to evaluate the data.

EPA requested clarification of DOE's implementation of PICs in the December 19, 1996 letter to DOE (Docket A-93-02, Item II-I-01):

> The Department must provide more explicit information in support of its proposed design and schedule for implementation of PICs. At a minimum, this information should include: which steps DOE can and cannot accomplish during the operational period and the reasons why; the rationale behind the timing of the various stages of implementation; [and] specific actions that DOE will take to test PICs, when those actions will occur, and what DOE expects to learn by testing—especially in terms of how testing could lead to substantial modifications to the conceptual design.

EPA made this request because virtually all aspects of PIC implementation would not be completed until well after EPA's authority to approve the design had elapsed (see pp. 7-81 to 7-85 of the CCA). Also, public commenters expressed concern that the PICs eventually employed by DOE could be substantially different from those approved by EPA, or perhaps would never be employed at all. In the case of site markers, the CCA stated that the following steps would be taken:

- Design and test marker concepts and materials—1996-2083 (87 years).
- Construct test berm—1998-2005 (7 years).
- Monitor performance of test markers and berm—2005-2083 (78 years).
- Test comprehension of marker messages—2018-2023 (5 years).
- Develop final design of markers—2083-2090 (7 years).
- Construct all markers (this phase presumably incorporates all quarrying, fabrication, and emplacement)—2090-2093 (3 years).

DOE's response to EPA's request for clarification, the 2/7/97 supplement, did not alter these dates. The 2/7/97 supplement instead explained the rationale for stages of implementation and identified discrete activities during the operational period of the WIPP. The 2/7/97 supplement made the following commitments related to the markers (pp. 4-6):

- After certification, DOE will study environmental effects on existing granite monuments near the WIPP and will locate sources of caliche and riprap. (EPA noted that, had these steps taken place prior to submittal of the application, they might have been used to support the proposed design).

- DOE will submit plans for the test berm, including magnets and radar reflectors, in the first recertification application. The test berm and test monuments will be built prior to the second recertification application.

- Plans for testing message comprehension will be submitted in the fourth recertification application. Testing will take place prior to the fifth application.

The 2/7/97 supplement also made the following statements in regard to the testing of markers (pp. 6-8):

- Marker materials and configurations, but not dimensions, may change as a result of testing.

- The test berm will be studied to determine the ideal ratio of materials, effective vegetation cover, optimum consolidation of the salt core, etc.

- The condition of other granite monuments in the WIPP's vicinity, as well as data gained by observing the effects of erosion and weathering on test monuments, could lead to substantial changes to the composition and configuration of monuments.

- Any refinements of the design to be undertaken during the operational period will be submitted to EPA in recertification applications for approval.

DOE's argument in the CCA and the 2/7/97 supplement is that testing will identify modifications to the design needed to strengthen confidence in its ability to endure. DOE also argued that the protracted testing period will permit DOE to take advantage of any future developments in technology that also may strengthen confidence in the design. As stated in the 2/7/97 supplement:

> [I]f in the future, materials are developed which duplicate the environmentally stable characteristics of granite and the fabrication and installation of the permanent marker components can be accomplished with this new material at a lower cost, then the DOE will have to give serious consideration to its use. Similarly, if during the planned decades of testing the granite monuments, data is [sic] obtained suggesting modifications to the planned configurations that would have significant effects on the monuments [sic] durability without the expenditure of a disproportionate amount of funds, then it would only be responsible for the

> DOE to evaluate appropriate changes to the design and make those changes which are prudent and cost effective (p. 2).

The former argument, that testing could strengthen the design, appears reasonable in the case of the berm (including the magnets and radar reflectors), although DOE did not discuss why seven years are required to construct a test berm segment and only three years are required to construct the entire marker system. The benefit of testing the other markers is less clear, since DOE's treatment of the subject is considerably less detailed than that for the berm. The CCA contains virtually no discussion of testing of the small buried markers and buried rooms, apart from a short paragraph in Appendix PIC (pp. 76-77). Testing of surface granite structures is discussed in somewhat greater detail, particularly in the 2/7/97 supplement, which states, "Data regarding the durability of the granite material and the effects of weathering on the engraved lettering and diagrams will be used to refine the final design" (p. 7). However, given that granite is said to be "one of the most durable rocks currently used for building construction," neither the CCA nor the 2/7/97 supplement adequately demonstrates that thirty or so years of exposure could reveal such dramatic changes to the surface of markers as to warrant "substantial changes in the configuration of the monuments and the information center" (p. 7).

In addition, Appendix PIC references a conversation between DOE and a Carlsbad memorial distributor that revealed watering in cemeteries accelerates the weathering of memorial stones. DOE concluded that testing was necessary because memorial stones are not reliable indicators of the effects of weathering:

> Therefore, any judgments made with respect to the effects of weathering due to local conditions would be biased by the artificial watering phenomenon. To provide for a more accurate assessment of the environmental effects on granite at the WIPP site, granite monuments made from materials from multiple quarries within the U.S. will be engraved and emplaced at the WIPP site during the disposal phase (p. 77).

This approach to testing the monuments is not represented elsewhere in DOE's discussion of implementation. Also, it appears to contradict a statement in the 2/7/97 supplement (p. 4) that DOE will "survey stone monuments within a 150 mile radius of the WIPP to evaluate the environmental affects [sic] on various types of granite (blue, gray, black, etc.)."

Even considering the time it would take to complete a limited amount of research into local granite monuments and experimentation with berm strata, there does not appear to be any practical reason why DOE could not be prepared to fabricate and emplace all markers once the WIPP is decommissioned. While EPA recognizes the basic utility of testing, DOE has not adequately explained why any testing that would take place after the operational period is either necessary or adequate to support the practicability of the proposed design. In other words, DOE did not identify a compelling reason why EPA should permit the design to be modified after closure.

EPA questioned DOE's conclusion that the proposed markers represent "the best system of passive institutional controls for permanently marking the system." In treating the design as a final product that would be implemented essentially as proposed, EPA could not identify a basis

for comparison that would enable the Agency to determine whether DOE's design was in fact "the best." Rather, EPA considered whether the proposed conceptual design incorporated the best currently available technology and knowledge (see "Practicability of the Design" above).

EPA considered DOE's second argument—that DOE should expect to incorporate future technological developments in the marker design—to be rational but irrelevant. As EPA stated in its 12/19/96 letter to DOE, "EPA cannot certify an undefined 'final design' as it may exist 100 years in the future. EPA considered it more appropriate to assume for the purpose of certification that the conceptual design that is proposed is the same one that will be implemented." In other words, EPA's proposed certification decision concerning the markers was based on the markers as they are described in the present CCA, not as they may be in the year 2090. EPA stated in the Response to Comments Document for 40 CFR Part 194,

> With respect to PICs, EPA must be satisfied that the measures described by DOE in the application will actually be implemented as planned. To further ensure that DOE fulfills all commitments made in the compliance application, any activities which depart from the basis on which EPA determines compliance will subject any compliance certification to modification, suspension, or revocation, as described in Section 194.4. Among other things, Section 194.4 states that any modification (or change in condition) of the certification is to be conducted in a public rulemaking. A rulemaking re-opening the initial certification would also be subject to judicial review (p. 15-12).

EPA's regulation of the WIPP presently extends only through the facility's 35- to 40-year operational period, therefore EPA will not be able to enforce commitments made by DOE past the point of closure. For this reason, EPA requires DOE to identify any changes to the design prior to closure.

Messages

DOE describes the messages (including text, diagrams, tables, etc.) to be conveyed by the markers in Chapter 7.3.3.1.1 and Section IV and Appendices 2 and 3 of Appendix PIC. DOE's separation of messages into different levels of complexity and distribution of messages over different markers is appropriate because it emphasizes brevity and redundancy. The messages provided in Appendix PIC adequately describe the location, design, and contents of the disposal system. Also, DOE proposed a mix of verbal and non-verbal messages to account for future difficulties related to language.[2]

What is less clear, however, is the extent-which DOE intends the messages in Appendix PIC to represent the messages that ultimately will be engraved on markers. The 2/7/97 supplement states that "the diagrams accompanying the Level IV message on pages 115-122 of Appendix PIC are not anticipated to change except to reflect actual conditions as they exist at the

[2] Experts have recommended that potential confusion related to incomprehension of written language can be alleviated by varying their complexity and combining them with non-verbal messages (e.g., iconic drawings). See, for example, HITF 1984, pp. 41-53.

time of engraving. . .” (p. 5). DOE did not specify which diagrams may change. It appears, for example, that Diagram 2 (Generalized Geologic Cross Section) would not have to be updated at all, while Diagrams 7 (World Map of Waste Disposal Sites) and 8 (Longitude and Latitude of Disposal Sites Relative to the WIPP) at this point in time are purely hypothetical and so presumably could look very different or perhaps may not be used at all. However, revisions should be acceptable as long as they do not depart significantly from the type of information conveyed by the proposed messages.

Text messages also are subject to change. For example, Chapter 7.3.3.2, Section IX of Appendix PIC, and the 2/7/97 supplement indicate that DOE intends to test messages prior to fabricating and engraving the markers. DOE plans to test the comprehensibility of messages among a cultural cross section of the U.S. population. Testing will consist of presenting subjects with messages in their native languages. The results of testing will be used to refine messages and possibly the method of presentation.

Presenting messages in various languages to native speakers could be a useful means of evaluating the comprehensibility of the messages in the present, provided that such testing is guided by clearly stated goals and accomplished through a carefully controlled process. (EPA noted that there is no guarantee that messages will be understood by potential intruders in the future. This CARD discusses comprehensibility of the proposed messages under Section 194.43(b) below). The CCA indicates in Figure 7-16 that message testing will be conducted from 2018 through 2023 but does not describe in detail the purpose the testing will serve, how it will be accomplished, or the criteria that will be used to evaluate the resulting data and determine whether revisions of messages are required.

Also, neither the CCA nor the 2/7/97 supplement explains why five years of testing is necessary, or why 2018-2023 is the appropriate time to undertake testing. Nevertheless, because those years fall within the operational period of the WIPP, EPA and the public would have the opportunity to review both DOE’s plan for testing and the results of testing in a recertification application.

Appendix PIC states that “the engraving of such a large quantity of letters and characters to provide the messages in different languages will offer a unique challenge to both the supplier and the DOE’s QA program” (p. 101). EPA noted that it is very important that messages be subjected to quality control to ensure that they are free of errors.

Finally, EPA noted that several of the diagrams (see Diagrams 1 through 4, in particular) are very complex graphically, and the CCA does not contain documentation showing that they may be adequately represented by the granite medium.

43.B.1 REQUIREMENT

(a) “Any compliance application shall include detailed descriptions of the measures that will be employed to preserve knowledge about the location, design, and contents of the disposal system. Such measures shall include:

(2) Placement of records in the archives and land record systems of local, State, and Federal governments, and international archives, that would likely be consulted by individuals in search of unexploited resources. Such records shall identify:

(i) The location of the controlled area and the disposal system.

(ii) The design of the disposal system.

(iii) The nature and hazard of the waste.

(iv) Geologic, geochemical, hydrologic, and other site data pertinent to the containment of waste in the disposal system, or the location of such information. and

(v) The results of tests, experiments, and other analyses relating to backfill of excavated areas, shaft sealing, waste interaction with the disposal system, and other tests, experiments, or analyses pertinent to the containment of waste in the disposal system, or the location of such information."

43.B.2 ABSTRACT

DOE must identify the archives and record centers to which it plans to submit information that identifies the location, design, and contents of the WIPP. DOE must identify information repositories that would likely be consulted by individuals in search of information about natural resources near the WIPP. EPA expected that DOE would either present detailed plans for the preservation of records, or indicate in the CCA when such plans would be developed during the WIPP's operational period.

The CCA identified a set of documents that DOE intends to submit to archives and record centers. DOE proposed to send documents made with archive-quality ink and paper to a large number of repositories, with priority given to those repositories local to the WIPP and commonly consulted for land ownership information, as well as a host of national archives. DOE proposed to finalize the list of recipients during the operational period and ship the documents shortly after closure.

EPA reviewed the information provided by DOE to determine whether the proposed documents addressed the required topics and whether the archives and record centers targeted by DOE were likely to be consulted by individuals in search of unexploited resources. EPA also considered DOE's schedule for implementing the measures associated with record preservation.

43.B.3 COMPLIANCE REVIEW CRITERIA

DOE must identify the local, State, and Federal archives and record centers, as well as international archives, to which it plans to submit the information identified in Section 194.43(a)(2)(i-v). EPA expected DOE to identify repositories that would likely be consulted by individuals in search of information about natural resources near the WIPP. EPA also expected DOE to identify the records it plans to preserve. In addition, DOE should consider the form(s) in which materials would be stored, and the likelihood that those materials would be maintained

in a reliable manner (CAG, p. 58). EPA also indicated that DOE should submit a time line for the implementation of record keeping measures and should identify the practices employed by repositories for maintaining records and making them accessible to the public. EPA expected to see the same level of commitment to implementing record storage as was demonstrated to emplacement of markers (see "Compliance Review Criteria" under Section 194.43(a)(1) above).

43.B.4 DOE METHODOLOGY AND CONCLUSIONS

The information supporting DOE's compliance with this requirement is found in Chapter 7.3.3 and Sections XIV and XV of Appendix PIC. Appendix PIC identifies materials to be archived and potential repositories for those records. Also, DOE submitted additional information relevant to Section 194.43 in the 2/7/97 supplement. Appendix PIC draws several distinctions between archives and record centers:

- ♦ Archives maintain more stringent control over indoor environments, access to documents, and storage media (e.g., paper, microfilm) than do record centers.

- ♦ Record centers typically are more functional in purpose than archives, and individuals explicitly interested in information on resources are more likely to consult record centers.

- ♦ Record centers maintain a smaller volume of documentation than archives.

<u>Documents to be Placed in Archives and Record Centers</u>

Chapter 7.3.3.1.2 (p. 7-77) and Section XIV of Appendix PIC (p. 93) identify specific documents and/or types of documents to be archived in accordance with Section 194.43(a)(2)(i-v). These documents include:

- ♦ Final Safety Analysis Report and addenda (i-iv).

- ♦ Final Environmental Impact Statement and Supplemental reports (i-iv).

- ♦ RCRA Permit (i-v).

- ♦ Compliance Certification Application (i-v).

- ♦ Environmental and ecological background data before and during the disposal phase (iv).

- ♦ Records of the waste containers' contents and location in the disposal system (iii).

- ♦ Drawings defining the construction and configuration of the repository and shafts (ii).

- Drawings, procedures, and design reports describing waste emplacement and repository closure (v).

- Detailed maps describing the exact location of the repository (i).

- Design information for PICs (ii).

Many documents on this list will not be in final form until the WIPP is decommissioned, while others depend on actions taken by regulatory agencies.

Appendix PIC states that "a smaller volume of documentation" with a focus on "location, design, and hazards information" will be sent to record centers (p. 95). The CCA does not specify which documents DOE will send to record centers, but suggests that they will be taken from the above list. Appendix PIC also states that DOE plans to develop a summary document that will be more accessible (in terms of both scope and general comprehension) and readily stored than the voluminous records listed above (p. 92). The CCA does not specify the content of the summary document beyond that it will contain basic information about the location, design, contents, and hazards of the disposal system.

Proposed Archives and Record Centers

Sections XIV and XV of Appendix PIC provide a list of the archives and record centers which are proposed for the storage of WIPP-related documents. DOE has yet to initiate whatever arrangements are necessary to complete the transfer of documents to repositories (the CCA does not specify what these arrangements entail; see "EPA Compliance Review" below). Appendix PIC (p. 94) identifies the following archives as potential repositories:

- National Archives and Records Services.

- State Archives of New Mexico and Texas.

- National archives of nations with nuclear weapons and/or power plants (see p. 124 for list).

- Archives of the United Nations.

- National archives of nations with natural gas and/or petroleum resources (see p.125 for list).

According to the 2/7/97 supplement (p. 12-13), DOE assigned priorities to archives according to the likelihood that persons would consult them if they were interested in oil, gas, and mineral resources in the Delaware Basin and/or the southwestern United States. DOE intends to pursue arrangements with the following archives first:

- U.S. National Archives—Washington, D.C., Southwest Region, Rocky Mountain Region.

- State Archives of New Mexico and Texas.
- Zuni Indian Archives.
- National Archives of Australia, Belgium, Canada, China, France, Germany, Great Britain, Japan, S. Korea, Kuwait, Mexico, Norway, Russia, Saudi Arabia, Taiwan, Venezuela.

Appendix PIC (p. 95) identifies the following record centers as potential repositories:

- Libraries of the 50 States.
- Libraries of cities within 150 miles of the WIPP with populations exceeding 15,000.
- U.S. Nuclear Regulatory Commission.
- The 53 Federal Regional Depository Libraries.
- Bureau of Land Management (BLM).
- Library of Congress.
- Defense Mapping Agency.
- International Boundary Commission.
- Federal Highway Administration.
- New Mexico State Highway Department Planning and Research Division, Cartography Section.
- One-Call System of notification of underground utilities.
- Carlsbad offices of the BLM, Bureau of Mines, and Bureau of Reclamation.
- Federal records center serving New Mexico.
- Hobbs and Artesia offices of the New Mexico Oil Conservation Division.
- Libraries of New Mexico Institute of Mining and Technology, New Mexico State University, University of New Mexico, and Texas A&M University.

As stated in the 2/7/97 supplement (p. 13), DOE intends to pursue arrangements with the following record centers first:

- Hobbs and Artesia offices of the New Mexico Oil Conservation Division.
- Carlsbad offices of the BLM and Bureau of Reclamation.
- Libraries of Carlsbad, Artesia, Hobbs, and Roswell.
- New Mexico State Library.
- Library of Congress.
- Libraries of New Mexico Institute of Mining and Technology, New Mexico State University, University of New Mexico, Texas A&M University, University of Colorado at Boulder, and Texas Technical University.
- Denver Public Library.

DOE Conclusions

In Chapter 7.3 (p. 7-64), DOE states that the program described in Appendix PIC will fulfill the requirements of Section 194.43. DOE also states, "Written documentation will include information on the location, design, and disposal contents and hazards, as well as stipulations on allowable land uses" (p. 7-64).

43.B.5 EPA Compliance Review

DOE discussed its approach to preserving records primarily in Sections XIV and XV of Appendix PIC and in the 2/7/97 supplement. Information concerning the endurance and comprehensibility of records over time and potential failures associated with archives is provided in Appendices EPIC.5 and EPIC.6. This CARD discusses endurance and comprehensibility of records under Section 194.43(b) below.

EPA evaluated information regarding records in accordance with the criteria described above. EPA's review focused on the following questions:

- Do the proposed records incorporate the information required by Section 194.43(a)(2)(i-v)?
- Does DOE propose to send records to local, national, and international archives and record centers that are likely to be consulted by individuals in search of unexploited resources?
- To what extent does DOE show its proposal to be reasonable and practicable? For example, does DOE describe the practices employed by repositories to maintain records and make them accessible to the public?

In regard to the first question, EPA determined that the 10 documents or types of documents (see Chapter 7, p. 7-77) that DOE proposed to archive sufficiently incorporate the information required in Section 194.43(a)(2)(i-v). In addition, EPA also requires DOE to archive recertification applications, unless the information in them will be captured by other documents. Appendix PIC (p. 93) unnecessarily includes the RCRA No Migration Variance Petition and Determination on the list. The National Defense Authorization Act for Fiscal Year 1997 (Public Law 104-201) exempted the WIPP from the RCRA requirements pertaining to the No Migration Variance decision. The RCRA No Migration Variance Petition was not listed in the 2/7/97 supplement.

In regard to the second question, EPA found that archives and record centers identified as potential repositories may be expected to be consulted by individuals in search of information about resources near the WIPP for several reasons: they are either public institutions or accessible to the public; they contain public records; and they are likely to retain information about unexploited resources. In specific cases, such as offices of the BLM, consultation of leases and maps by individuals interested in resource exploration is already an established practice.

Chapter 7.3.3.1.2 of the CCA indicates that DOE targeted certain archives and record centers because they represented one of the following:

- A nation engaged in oil and gas exploration and exploitation.
- A nation with the potential to generate radioactive waste.
- A local governmental organization whose records are consulted by individuals engaged in oil and gas exploration and exploitation.
- A [U.S.] National Archive.
- A regional library.
- A keeper of public records ("a public [sic] funded location").

EPA considered these factors to be reasonable for conducting an initial screening; however, it appeared that DOE did not attempt to narrow the list of potential sites even further. According to Chapter 7, "DOE intends to submit WIPP records to over 100 archives nationally and internationally" (p. 7-79). This statement apparently incorporates both archives and record centers; if not, the list of potential repositories meeting DOE's criteria grows even longer with the addition of record centers. In addition, DOE did not assign priorities among the many potential repositories listed in the CCA. For example, Appendix PIC.5 lists natural gas and/or petroleum producing nations destined to receive WIPP records. There is no discussion of whether these nations would choose to or are even appropriate to store WIPP records. Also, the CCA did not discuss the quantity of documents that local and university libraries, which have limited shelving and/or funding, are likely to accept. DOE also did not provide any information in the CCA regarding practices that repositories employ to maintain records and make them accessible to the public.

EPA asked DOE to clarify its approach to preservation of records in a letter dated December 19, 1996, which stated, "The Department must provide. . . evidence that DOE, in proposing the design as practicable, gave serious consideration to the amount of time, human effort, and money likely to be required to implement the major aspects of the design." (Docket A-93-02, Item II-I-01) Following this request, DOE submitted a supplement to the CCA that prioritized but did not exclude any of the proposed repositories (see "DOE Methodology and Conclusions" above). EPA determined that DOE's prioritization is reasonable because it generally targets those archives and record centers most likely to be consulted first by individuals seeking resources in the Delaware Basin.

Neither the CCA nor supplementary information contained detailed information concerning the "amount of time, human effort, and money likely to be required" to print records and place them in the proposed archives and record centers, although Appendix PIC does state that the Federal Government may incur some long-term financial obligations to ensure retention of records (p. 94). EPA therefore conducted its own independent estimate.

EPA contacted A.B. Hirschfeld Press of Denver, Colorado, to obtain cost estimates for printing and shipping documents. EPA assumed that, in accordance with Section XIV of Appendix PIC (p. 92), the records will be printed on archival quality paper meeting or exceeding the requirements of National Archives and Records Administration Bulletin Number 95-7 or ANSI/NISO Z39.48-1992 (or latest version), Permanence of Paper for Documents and Libraries. In addition, offset printing will use an oxidizing, carbon black ink with a buffered fountain solution (pH >5.5) or equivalent. EPA also assumed that there would be a total of 100 sets of documents submitted to various archives and record centers, based on the statement that DOE will ship documents to at least 100 repositories. Finally, EPA assumed that each set would be composed of 50 volumes of information, with 100 pages per volume (a total of 500,000 pages).

The estimate that EPA received from Hirschfeld Press for printing and shipping 100 sets of documents was approximately $85,000. EPA recognizes that the conclusions to be drawn from this estimate are limited, especially since the amount of material that DOE proposes to send is presently indeterminate. Nevertheless, given that the CCA—consisting of the October 29, 1996, submission and additional supplementary materials required by EPA to constitute a complete and technically sufficient application—alone is approximately 100,000 pages, the prospect of shipping dozens of copies of the CCA and other sizeable documents suggests that it could be fairly costly, though only a small fraction of what the markers are likely to cost.

The U.S. National Archives indicated to EPA that there would be no cost to DOE for the storage, use, and preservation of documents. There does not appear to be any reason to believe that DOE would incur charges from similar repositories for acceptance of records.

In regard to the third question—to what extent does DOE show its proposal to be reasonable and able to be implemented?—EPA examined the arrangements that DOE may be expected to make with all of the national and international archives and records centers identified in the CCA as potential repositories for WIPP records. Chapter 7 described the procedure followed by National Archives staff upon receipt of a document and noted that "the state [sic] of New Mexico Archive and the Canadian National Archive were also contacted and their practices are similar to those employed by the U.S. National Archives" (p. 7-79).

Otherwise, DOE did not attempt to identify the practices employed by each archive and repository for maintaining records and making them accessible to the public.

A letter from EPA to DOE, dated December 19, 1996, requested additional evidence that DOE "gave serious consideration to the amount of time, human effort, and money likely to be required to implement the major aspects of the design." DOE provided supplemental information in a letter dated February 7, 1997, that responded:

> Nationally it has been found that those archives, record centers. . . which have been contacted in the course of. . .developing the Passive Institutional Controls design. . . have been receptive to supporting the DOE's intent of preserving WIPP information. There may be differences in the quantity of material acceptable to individual locations but at least some material will be acceptable to all. Internationally the DOE believes that the information. . . will serve as an incentive for foreign archives to accept. . . information. . . When considering that the DOE would provide at least some of the material translated into the particular country's technical language or finance the translation as defined in any agreement reached, there are strong arguments for accepting information (p. 14).

EPA did not consider DOE's response to be an adequate demonstration that archives in general, and international archives in particular, would accept and maintain information sent to them. In an attempt to address this issue independently, EPA contacted the National Archives of the United Kingdom, Canada, Australia, and Mexico. The national archives of the United Kingdom and Canada informed EPA that they do not normally accept documents from other nations but would entertain written requests. The National Archives of Australia accepts only documents pertaining to Australia. Various Mexican organizations, including the National Archives of Mexico, were contacted but no single "best" repository was identified. This cursory investigation demonstrated to EPA that the negotiation of agreements with the National Archives of other nations is almost certain to be more complicated than was suggested by DOE. Thus, any positive certification determination must be conditioned on DOE satisfactorily demonstrating that the relevant records can be archived in some international archives, as required by the criterion.

Third, EPA reviewed DOE's approach to implementing the proposed record keeping measures. Chapter 7.3.3.3 and Figure 7-16 indicate the following steps will be taken:

- ♦ Establish filing system for records—2003.
- ♦ Collect information related to WIPP operational period—2003-2033 (30 years).
- ♦ Collect information related to implementation of institutional controls—2033-2090 (57 years).
- ♦ Arrange for receipt at repositories and translate records—2023-2034 (11 years).

- ♦ Develop summary document—2033-2034 (1 year).

- ♦ Distribute records to repositories—2035.

- ♦ Collect information related to post-closure period—2083-2093 (10 years). and

- ♦ Distribute records related to post-closure period to repositories—2093.

DOE's 2/7/97 supplement did not substantially alter these dates, but added that DOE intends to audit repositories within two years of the distribution of records (2037) and every 15 years thereafter until active institutional controls cease (100 years from the time of disposal). This measure was mentioned in Appendix PIC (p. 94) but not in Chapter 7. The purpose of the audits is to verify the retention and retrievability of documents.

The supplement makes the following commitments related to record keeping (pp. 5 to 6):

- ♦ The filing system for documents will be established in 2003. EPA will receive a description of the system and DOE's efforts to make documents comport with the system in the second recertification application (2007).

- ♦ DOE will submit a plan for soliciting the participation of specific archives and record centers in the fifth recertification application (2022).

- ♦ The WIPP summary document will be prepared and sent to EPA at the conclusion of site restoration (i.e., decommissioning).

- ♦ After closure of the WIPP, DOE will send EPA a yearly report concerning the status of record distribution. DOE also will send EPA the results of its audits.

EPA considered it reasonable for DOE to refrain from preparing and distributing materials to be archived until the Department has complete and final information about the disposal system and its contents, which will happen only upon closure. EPA noted that the process outlined by the CCA, though clearly just a general plan at present, would enable DOE to ship records to targeted locations soon after the WIPP ceases operations and would allow EPA an opportunity to review DOE's activities during the operational period. EPA concluded, however, that it is inadvisable for DOE to wait until the year 2023 (the sixth recertification period) to begin to contact potential repositories, since EPA's cursory investigation suggested that there may be problems associated with securing records in some of those repositories.

43.C.1 REQUIREMENT

(a) "Any compliance application shall include detailed descriptions of the measures that will be employed to preserve knowledge about the location, design, and contents of the disposal system. Such measures shall include:

(3) Other passive institutional controls practicable to indicate the dangers of the waste and its location."

43.C.2 ABSTRACT

DOE must submit descriptions of any PICs that it plans to implement other than those specified in Sections 194.43(a)(1) and (2). The CCA and supplemental information sent by DOE contain descriptions of the following additional PICs: government control of the WIPP site; land use restrictions; and agreements with certain professional societies, publishers, map makers, and private companies to distribute information about the WIPP's location and the hazards posed by its contents. EPA reviewed the information provided by DOE to determine that the proposed PICs are practicable and would preserve knowledge about the site and its hazards.

43.C.3 COMPLIANCE REVIEW CRITERIA

The category of "other" PICs incorporates government ownership, regulations regarding land or resource use, and any other methods of preserving knowledge about the WIPP site, as defined in 40 CFR Part 191. EPA expected to see a description of any such controls and the manner in which they preserve knowledge of the site, and an explanation of why they are practicable (including DOE's plans to implement them).

43.C.4 DOE METHODOLOGY AND CONCLUSIONS

The information supporting DOE's compliance with this requirement is found in Chapter 7.3.3.3 and Section XVI of Appendix PIC. Also, DOE submitted supplemental information relevant to Section 194.43 with the 2/7/97 supplement. This supplement clarifies statements in the CCA concerning implementation of other PICs, as discussed under "EPA Compliance Review" below.

Section XVI of Appendix PIC states that the additional PICs that DOE intends to employ are:

- ♦ U.S. Government ownership of the WIPP site.
- ♦ Federal restrictions on land use at the WIPP site.
- ♦ Dissemination of informational material about the WIPP to publishing houses, resource information companies, and professional organizations.
- ♦ Changes to maps and other media.
- ♦ Internet resources.

<u>Government Control and Land Use Restrictions</u>

Section XVI of Appendix PIC states that continuous ownership of the WIPP site by the U.S. Federal Government functions as a PIC because anyone seeking leases to exploit resources would learn from records that the Federal Government owns the site and prohibits commercial resource exploration. The hypothetical investigator would likely seek additional information concerning the site and would learn of the existence of the WIPP. DOE assumed that government control of the WIPP site will continue as long as the U.S. Government exists.

The WIPP Land Withdrawal Act (LWA) withdrew the WIPP site "from all forms of entry, appropriation, and disposal under public land laws, material sale laws. . . and mining laws" and granted DOE jurisdiction regarding land use within the withdrawal area. Land use controls are a PIC because DOE (under authority of the LWA) prohibits mining or drilling in the withdrawal area, with the exception of two existing leases at the extreme southwestern corner of the land withdrawal area. Anyone attempting to procure a lease to explore resources near the WIPP site would be likely to learn of DOE's prohibition.

Distribution of Information

Section XVI of Appendix PIC states that DOE will send information about the WIPP (in the form of maps showing the location of the WIPP and describing its hazards) to the following organizations: U.S. and international professional societies of cartographers and geographers; companies providing energy and resource data to commercial enterprises active in the Delaware Basin; and mapping agencies at the Federal and State of New Mexico levels. DOE also intends to arrange the incorporation of WIPP information in maps and road atlases, encyclopedias, high school and college textbooks, dictionaries, and the Internet.

DOE Conclusions

Chapter 7.3 (p. 7-64), states that the program described in Appendix PIC will fulfill the requirements of Section 194.43(a)(3).

43.C.5 EPA Compliance Review

EPA reviewed DOE's description of additional PICs to determine how these additional controls preserve knowledge of the site, why these controls are practicable, and how DOE plans to implement them. This CARD discusses endurance and comprehensibility of additional PICs under Section 194.43(b) below.

Government Control and Land Use Restrictions

Government ownership of a disposal site and regulations regarding land or resource use are identified in the definition of PICs at 40 CFR Part 191. Based on the description of these PICs in Section XVI of Appendix PIC (pp. 98-99), EPA determined that DOE understands the purpose and effect of government control and land use restrictions. The LWA transferred ownership of the site to DOE and prohibited resource development there. A change in ownership or restrictions on resource development would require an act of Congress.

Distribution of Information

The purpose of PICs is to preserve knowledge of the existence of the WIPP and its hazards for as long as possible. EPA concurred with DOE's conclusion that widespread dissemination of WIPP information via maps, textbooks, references, and other media will further that purpose. Because the WIPP would be a site of national and international significance, it is likely that interest in the site among professional organizations, companies, mapmakers, and educators would be self-perpetuating and would not require ongoing oversight by DOE.

This proposed PIC appears to be practicable because it involves little more than sending WIPP information to various organizations, but there is little indication in the CCA of the extent to which DOE attempted to confirm this aspect. In regard to professional organizations, Appendix PIC states, "The actual distribution of the information will depend on agreements worked out between the DOE and these organizations and societies" (p. 97). Appendix PIC also states, "Location and hazard information *should* be submitted to various Federal and State of New Mexico mapping agencies. . . " (p. 97) (emphasis added). DOE provided examples of various organizations, companies, and agencies that may serve as preservers and distributors of WIPP information but did not indicate that specific arrangements had been made with any of them or that any had been contacted to gauge their potential as a recipient.

EPA asked DOE in a letter dated December 19, 1996, to provide "evidence that DOE, in proposing the design as practicable, gave serious consideration to the amount of time, human effort, and money likely to be required to implement the major aspects of the design." DOE's supplemental information, dated February 7, 1997, showed that DOE contacted a variety of potential recipients and that these recipients would welcome the information (see pp. 9 to 12). While DOE would not necessarily be able to control how a recipient uses WIPP information, it appears that DOE would be able to reach a sufficient number of diverse organizations that its purpose of disseminating the information would be served.

The 2/7/97 supplement also makes a specific commitment that DOE will complete its arrangements during the operational period (2023-2033) and will inform EPA of the arrangements as they are made (p. 5).

43.D.1 REQUIREMENT

(b) "Any compliance application shall include the period of time passive institutional controls are expected to endure and be understood."

43.D.2 ABSTRACT

DOE must estimate the amount of time that the proposed PICs will endure and be understood by potential intruders. This requirement asks DOE to state the basis for concluding that any proposed PICs are as permanent as practicable. Estimates and any assumptions made to support those estimates should be reasonable and based on available facts. There is no specific period of time that any given institutional control must endure or be understood.

DOE took several steps in response to the requirement. First, DOE identified possible events and processes that could be expected to act against the effectiveness of PICs and then took steps to account for those events and processes in the design of PICs. Second, DOE

identified analogs for PICs from around the world and discussed their relevance to the proposed design. The timespan the analogs have endured provided the basis for DOE's estimate of the proposed design's endurance. Finally, DOE developed a set of assumptions regarding human behavior and language to estimate the period of time PICs will be understood. EPA reviewed Revision 1 of Appendix EPIC to determine whether the estimates provided were based on reasonable assumptions and were supported by available evidence.

43.D.3 Compliance Review Criteria

PICs are intended to identify the WIPP site for as long a period as possible. To increase confidence that any proposed PICs would serve effectively in this capacity, EPA required DOE to estimate the length of time that PICs would endure and that the information they carry would be understood by potential intruders into the site. EPA expected that DOE would also present a reasonable argument why PICs may be expected to endure and be understood for the period of time proposed (CAG, p. 59). EPA's understanding of what constitutes a reasonable argument is described below.

No established scientific methodology exists to enable DOE to determine precisely the length of time that a PIC will endure, much less be understood. Any such prediction is inherently speculative. EPA expected that, especially where the endurance of PICs is concerned, DOE would seek to employ facts where facts are available to support their estimates. For example, information is available about the age and condition of site markers around the world that have survived to the present. EPA recognized in the preamble to the Proposal for 40 CFR Part 194 that it cannot determine how many such markers did not survive (60 FR 5779). Nonetheless, it should be possible for DOE to draw reasonable conclusions about its own design, based on the extent to which it is comparable with known analogues, in terms of size, material, local weather, and other such factors (CAG, p. 60).

The exact processes involved in transmitting and receiving information, including how messages are understood by the human mind, are in greater dispute than the physical processes that lead, for example, to the breakdown of stone in different environments. EPA expected that DOE, in order to propose the period of time that messages will be understood by potential intruders, would have to develop assumptions, supported as much as possible by objective evidence and scholarly research, that would guide its analysis (CAG, p. 60). The reasonableness of DOE's conclusions would depend heavily on the validity of their assumptions.

DOE must demonstrate reasonably that the PICs are as permanent as practicable. There is no specific period of time that any given institutional control must endure or be understood. DOE was not required to demonstrate that the proposed PICs would last 10,000 years.

43.D.4 DOE Methodology and Conclusions

The information supporting DOE's compliance with this requirement is located in Appendix EPIC. On January 21, 1997, DOE sent EPA a revision of Appendix EPIC (Revision 1), dated November 14, 1996, and an addendum to Appendix EPIC, dated December 6, 1996 (Docket A-93-02, Item II-G-16). All future references to Appendix EPIC in this CARD pertain to Revision 1. Appendix EPIC represents the findings of the PIC Task Force (PTF), which DOE

created primarily to estimate the effectiveness of PICs in deterring inadvertent human intrusion. As part of its mission, the PTF estimated the amount of time that the proposed PICs would endure and be understood. The PTF also identified likely causes of failure and explained how the proposed PICs account for such scenarios.

DOE's estimate for how long each PIC will endure and the basis for the estimate are summarized below.

Berm

Appendices EPIC.5.2.1 (p. 5-8) and EPIC.6.2 (p. 6-11) state that the proposed berm will endure for at least 5,000 years. DOE based its estimate on two earthworks: the concentric banks at Stonehenge and the Serpent Mound in Ohio. The banks at Stonehenge have existed approximately 4,700 years, while the Serpent Mound is perhaps half as old. The proposed berm is larger than the earthworks at Stonehenge and has the benefit of a layered design to minimize erosion. Appendix EPIC states, "both the Stonehenge and Serpent Mound earthworks are ancient structures built of on-site or near-site materials in climates more severe with respect to erosion of earthen structures than the climate currently found in southeastern New Mexico. The current remains of the banks and the mound do not contain any design features explicitly intended for the long-term preservation of the structures," yet they have survived to the present. The potential failure mechanisms and associated design solutions for the berm are:

- Erosion. Berm materials will be selected and layered for the purpose of minimizing erosion. The outer layer of soil and riprap will support stabilizing vegetation. The next layer, consisting of riprap, will drain water away from the berm and protect against wind and water erosion of the compacted caliche layer. A compacted caliche layer will minimize the infiltration of water into the salt core. This design employs layers that are similar in function to the current minimum technology standard for final covers constructed on hazardous waste landfills in arid and semi-arid climates.

- Burial by migrating dunes. The proposed berm will be higher than existing dunes in the area. In addition, the large areal extent of the berm will help to prevent total coverage by dunes.

- Dismantling and/or removal. The dimensions of the berm will be so large that it would take a major effort to obliterate the marker. Even if materials such as salt from the salt core or the magnets and radar reflectors were recovered, it is likely that large amounts of material would remain at the site.

Monuments

Appendices EPIC.5.2.2 (pp. 5-12 to 5-13) and EPIC.6.1.1.1 (p. 6-3) estimate that the proposed granite monuments will endure for at least 4,000 years. DOE based its estimate on two analogues: the monoliths at Stonehenge and the Rock of Behistun (a bas-relief carved into the

side of a mountain in Iran). Of the original ring of 30 monoliths with lintels (horizontal beams) that were constructed over 4,000 years ago at Stonehenge, 18 monoliths and 5 lintels still exist. The monoliths have not lost the characteristics that define the original configuration, and engravings may still be seen on one of the upright stones. Regarding the Rock of Behistun, DOE stated that large-scale engravings made on the rock's sheer face more than 2,500 years ago may still be read today; thus the Rock of Behistun is an example of exposed engravings that have endured for thousands of years.

DOE stated that the base material of the proposed monuments (i.e., granite) is superior to the rock types used at Stonehenge in terms of its ability to withstand erosion, weathering, and defacement. Also, less water erosion and weathering are expected at the WIPP site than at Stonehenge because of the drier climate. The potential failure mechanisms and associated design solutions for the monuments are:

- Weathering (chemical alteration). Granite is one of the most durable rocks currently used for building construction. The surface of the granite will be polished to remove loose material and indentations where water could collect.

- Erosion. Again, granite is one of the most durable rocks currently used for building construction. Messages will be inscribed near the top of monuments to minimize wind erosion, which is greatest near the ground surface. Monuments at the repository footprint perimeter will be situated close to the interior of the berm to block wind and thus minimize erosion.

- Burial by migrating dunes. The monument height will be higher than existing dunes in the area. The use of multiple monuments over a wide area will increase the likelihood that some monuments will not be buried. The berm, which will be higher than the monuments, will reduce the amount of sand that could be carried by wind into the repository footprint area.

- Removal. The use of multiple, redundant monuments will minimize the likelihood that all monuments would be removed from the site. The size and weight of the monuments will make them difficult to move. Removal of some monuments for certain purposes, such as exhibition in a museum, could promote knowledge of the site. In addition, granite is of relatively low value as a recycled material.

- Vandalism (such as target practice, toppling, and graffiti). Granite is one of the most durable rocks currently used for building construction. The use of multiple, redundant monuments will minimize the likelihood that all monuments would be damaged so that their message is not conveyed. Engraved messages will be detectable under paint. The monuments will have large flat surfaces that are difficult to deface entirely. Messages will be inscribed well above normal human height.

Buried Storage Rooms and Information Center

Appendices EPIC.5.2.4 (pp. 5-20 to 5-21) and EPIC.6.1.1.3 (p. 6-5) estimate that the buried storage rooms will endure for at least 4,500 years or perhaps half as long if they are dug up and exposed to the elements. DOE based its estimate on two analogues: Newgrange (a passage grave in Ireland) and the Great Pyramids of Egypt. In the grave at Newgrange, the engravings on the internal walls of the buried stone structure are still distinct and show no signs of weathering after more than 5,000 years. DOE stated that the example of the Egyptian Pyramids, which were constructed approximately 4,500 years ago, demonstrates the ability of stone structures to function as monuments for thousands of years. In addition, engravings on the walls of burial chambers inside the pyramids are still legible.

DOE stated that the base material of the proposed buried rooms (i.e., granite) is superior to the rock types used at the Pyramids in terms of its ability to withstand erosion and defacement and that the durability of the rooms would be the same as that of the Information Center in the event they are excavated.

Appendices EPIC.5.2.3 (p. 5-18) and EPIC.6.1.1.2 (p. 6-3) estimate that the proposed information center will endure for at least 2,400 years. DOE based its estimate on two analogues: Australian Rock Art and the Acropolis in Greece. The ancient paintings, engravings, and peckings located on protected surfaces (but not enclosed rooms) that represent Australian rock art have lasted approximately 25,000 years and possibly up to 35,000 years. At the Acropolis, a large number of monuments, statues, and structures have endured for at least 2,400 years.

DOE stated that the base material for the proposed information center (i.e., granite) is superior to the limestone and marble used in the Acropolis structures in terms of its ability to withstand erosion, weathering, and defacement. In addition, the dry climate and remote location at the WIPP site is expected to reduce the effects on the marker of erosion, weathering, and deterioration due to weather, pollution, and acid rain.

The potential failure mechanisms and associated design solutions for the information center and buried rooms are:

- Weathering (chemical alteration). Granite is one of the most durable rocks currently used for building construction. The surface of the granite will be polished to remove loose material and indentations where water could collect.

- Erosion. Again, granite is one of the most durable rocks currently used for building construction. Messages will be inscribed on the inside walls of the information center to reduce the effects of blowing sand. The information center will be shielded from wind erosion to some extent by the berm. In addition to being buried, the interior granite slabs of the storage rooms will be protected from erosion by the walls, floor, and ceiling.

- Burial by migrating dunes. The information center will be protected from migrating dunes by the berm.

- Removal. The size, weight, and placement of the information center and buried storage rooms will make them difficult to remove. Removal of some or all of any of the rooms for certain purposes, such as exhibition in a museum, could promote knowledge of the site. The information center will acknowledge the existence of only one buried room, which will increase the likelihood that at least one room will endure at the site.

- Vandalism (such as target practice, toppling, and graffiti). Granite is one of the most durable rocks currently used for building construction. The use of multiple, redundant rooms will minimize the likelihood that all rooms would be damaged. Engraved messages will be detectable under paint. The large, flat walls of the rooms will be difficult to deface entirely. In addition, DOE proposed to engrave a duplicate granite veneer for each engraved wall in the buried storage rooms.

Small Buried Markers

Appendices EPIC.5.2.5 (pp. 5-24 to 5-25) and EPIC.6.1.1.4 (p. 6-5) estimate that the small buried markers will survive for at least 3,700 to 5,000 years. DOE based its estimate on two analogues: the Code of Hammurabi (inscribed on a stone slab found in Iraq) and inscribed Mesopotamian clay tablets. The detailed text of the Code of Hammurabi is still legible, despite being both buried and exposed during the course of approximately 3,700 years. Fired clay tablets with inscriptions that are up to 5,000 years old have been found in Mesopotamian tells (mounds composed of the remains of successive settlements).

The potential failure mechanisms and associated design solutions for the small buried markers are:

- Weathering (chemical alteration). Markers will be made of granite, fired clay, and aluminum oxide, which are durable materials. The surfaces will be polished to remove loose material and indentations where water could collect.

- Removal. The existence of thousands of markers will increase the likelihood that some will remain on the site. Random distribution of the markers relative to the surface and each other will discourage systematic recovery. Removal of some monuments for certain purposes, such as exhibition in a museum, could actually encourage distribution of information about the site. Even if some markers are removed, it is unlikely that any operation at the site involving soil removal would fail to reveal other markers. The proposed materials are of relatively low value.

Archives and Record Centers

Appendices EPIC.5.3 (pp. 5-29 to 5-30), EPIC.5.4 (5-33), EPIC.6.1.3 (pp. 6-7 to 6-8), and EPIC.6.1.4 (p. 6-9) estimate that WIPP records will survive in at least some of the proposed repositories for at least 4,000 years. EPIC.5.3.3 states that WIPP information is expected to endure at least as long as the original paper can survive (i.e., thousands of years). DOE based its estimates of the endurance of archives and paper on three analogues: the Vatican Archives, the German Archives, and ancient documents. The Vatican Archives retained records for 1,100 years without modern temperature and humidity control or papers and inks. Ancient documents made of papyrus have endured for over 4,000 years. DOE concluded that the German Archives, which were protected from destruction during World War II, illustrate the importance of widespread distribution, multiple copies, and general recognition of the social (not necessarily monetary) value of documents.

The potential failure mechanisms and associated design solutions for the archives and record centers are:

- Decay of Paper. Records will be made of archival quality paper and carbon black ink. The indoor environment of archives will be strictly controlled.

- Theft. There is no inherent value to documents. Multiple, reproducible copies will be located at different locations.

- Misfiling. Records will be indexed and distinctively bound.

- Catastrophe. Multiple, reproducible copies will be located at different locations.

- Recycling or disposal by archivist. Covers and summary document will state the importance of the records.

- Records Lost or Deliberately Destroyed. Multiple, reproducible copies will be located at different locations.

Land Use Restrictions and Government Control

Appendices EPIC.5.5 (p 5-34 to 5-36) and EPIC.6.1.5 (p. 6-10) indicate that land use restrictions and government control will serve as a PIC by preventing exploration in the land withdrawal area. DOE did not provide a specific estimate for the length of time land use restrictions and government control are expected to endure, although DOE stated that land use restrictions should be effective as long as the paper recording those restrictions lasts. Appendix EPIC.5.5.2 discusses three analogues: Boston Commons, Santa Fe Plaza, and Yellowstone National Park. DOE identified one potential failure mechanism for this PIC—a decision by the Federal Government to open the withdrawal area to resource exploration and exploitation.

Other Passive Institutional Controls

Appendices EPIC.5.6 (pp. 5-36 to 5-38) and EPIC.6.2 (p. 6-10) discuss the following additional PICs: incorporation of the WIPP's location on maps and road atlases; incorporation of WIPP information in encyclopedias, common references, and high school and college textbooks; and the development of a home page on the Internet. DOE did not estimate the time that these other PICs are expected to endure, other than to remark that written records have endured and been reproduced and translated for thousands of years. In addition, DOE referred to several examples whereby government-owned or regulated areas are identified on maps: the Nuclear Test Site and Nellis Air Force Base in Nevada, White Sands Missile Range in New Mexico, and Chocolate Mountain Gunnery Range in California.

Assumptions For Estimating the Length of Time the PICs are Expected to be Understood

Appendix EPIC.3.2 describes the assumptions on which DOE based its estimate of the length of time that each PIC will be understood by potential intruders. The categories of assumptions that pertain to the estimates are Basic Human Attributes (EPIC.3.2.1), Language (EPIC.3.2.3), and Estimating PICs Effectiveness (EPIC.3.2.5). DOE alternately referred to assumptions as regulatory assumptions, PTF assumptions, PTF conclusions, and common denominators, depending on whether DOE attributed them to the PTF or to EPA's CAG for 40 CFR Part 194.

The relevant assumptions under Basic Human Attributes (p. 3-5) are:

- Common Denominator 1: Humans will continue to be curious. Resource industries will have an economic interest in being curious, i.e., seeking as much information as possible about a site and its owner before investing time, effort, and capital.

- Common Denominator 2: The use of the written word to transmit information and concepts will continue. Written records have been and continue to be widely used to transmit information about property ownership, regulations, natural resources, etc.

- Common Denominator 3: Storytelling or the generational passing down of history will continue. Resource industries will have an economic interest in preserving knowledge of past successes and failures.

- Common Denominator 4: The ability of pictures to convey meaning will continue. Maps and other images will be valuable resources for resource industries.

The relevant assumptions under Language (p. 3-7) are:

- PTF Assumption 4: Current English will continue to increase in the size of its vocabulary and areas of use, but the basic vocabulary and structure will resist change. English is the international language of science, technology, commerce, and diplomacy. The number of people who speak English worldwide ranges from 800 million to 1.5 billion, and English has official status in more than 60 countries.

- PTF Assumption 5: Current English will remain decipherable by future generations of English readers for at least 1,000 years after disposal. High school students can read the works of Shakespeare (modern English), which are approximately 350 years old. College students can read the works of Chaucer (i.e., Middle English), which are approximately 600 years old. Scholars can read the epic poem Beowulf (i.e., Old English), which is approximately 1,000 years old.

- PTF Assumption 6: Current English will continue to be read by the natural resources exploration and exploitation industries. These industries use specialized language that is resistant to change. Current terminology is expected to be retained in a manner similar to Latin, which has become a “second” language for certain professions.

The relevant assumptions under Estimating PICs Effectiveness (p. 3-11) are:

- PTF Conclusion 1: Communicating with future societies using words, pictographs, symbols, and diagrams through a variety of media will be possible. Derived from Common Denominators 2, 3, and 4.

- PTF Assumption 9: Historical analogues of structures, media, and messages that have withstood the test of time represent design characteristics that will allow DOE to design for success. DOE must attempt to reproduce the features of analogues that appear to be responsible for their survival.

On the basis of these assumptions, DOE estimated that messages written or engraved in English on granite markers, records, and other documents, will be understood by potential intruders for at least 1,000 years after disposal.

43.D.5 EPA COMPLIANCE REVIEW

EPA reviewed Revision 1 of Appendix EPIC to verify that (1) estimates were provided of the period of time the PICs are expected to endure and be understood by potential intruders, (2) estimates of endurance were reasonably supported by available evidence, and (3) assumptions used to estimate comprehensibility of messages over time were reasonable and were supported by available evidence.

EPA found that DOE had provided estimates of potential endurance for all proposed PICs with the exception of Government Control, Land Use Restrictions, and those involving distribution of WIPP information. Particularly in the case of markers, DOE expressed confidence that the PICs have a high probability of enduring for the entire regulatory period. DOE's argument, however, was constructed to provide minimum estimates of endurance, which are listed below.

- Berm—at least 5,000 years.

- Monuments—at least 4,000 years.

- Information Center—at least 2,400 years.

- Buried Rooms—at least 4,500 years, or at least 2,400 years if unearthed.

- Small Buried Markers—at least 3,700 years.

- Archives and Record Centers—at least 1,000 years.

EPA considered it appropriate that DOE did not offer estimates of the potential endurance of Government Control, Land Use Restrictions, and the additional PICs. In contrast with the other proposed PICs, there is no reasonable historical analogy on which DOE could base estimates of how long the U.S. Government or the Department of Energy will function in

their intended capacity as PICs. Similarly, the historical precedent for drawing an estimate for the additional PICs is either absent, as in the case of the Internet, or too broad to lead to any meaningful conclusion, as in the case of placing the WIPP on maps. The capacity of these measures to endure does not appear to be something that DOE could either control or predict.

As noted in DOE Methodology and Conclusions above, DOE assumed that current English will remain decipherable by future generations of English readers for at least 1,000 years after disposal (PTF Assumption 5). At several points in Appendix EPIC.6.1, DOE states that messages inscribed on markers "are virtually certain to be understood by individuals within the natural resource industries for thousands of years after disposal" (p. 6-3). Appendix EPIC.6.1.4 states that "For the potential intruder or the site investigator who visits an archive, the warnings within the WIPP records are almost certain to be readily understood for more than 1,000 years after disposal because of the specialized vocabulary based on current English associated with natural-resource and land use" (p. 6-9). EPA concluded from these statements that DOE considers 1,000 years to be the minimum amount of time that messages, whether on markers or in archived documents, will be understandable to potential future intruders.

Estimates of the Amount of Time PICs Will Endure

EPA evaluated DOE's estimates of the amount of time PICs will endure by determining the correctness of facts presented, the appropriateness of analogues, and whether PICs were designed to compensate reasonably for forces that could act against their endurance (i.e., failure scenarios).

EPA found that the analogs used by DOE to support its estimates were appropriate, and that the factual descriptions of those analogs were accurate. EPA noted that it is likely that markers will be subjected to environmental degradation, vandalism, and removal, and that records left in repositories may to some degree be lost, destroyed, or otherwise made inaccessible. The design solutions presented by DOE, such as placing redundant markers, repeating messages, and sending documents to multiple archives and other repositories, compensate reasonably for the likely types of failure.

In drawing conclusions from its comparison of the PICs conceptual design with analogues, DOE assumed that "[t]oday's scientific and engineering communities have the capability to create PICs that will perform at least as effectively as historical analogues" (PTF Assumption 10. See Appendix EPIC.3.2.5). Appendix EPIC notes that the technologies used to undertake the cited analogues were primitive by today's standards, and that DOE has attempted to exceed in its own design the characteristics of the analogues that contributed to their survival. EPA considered this assumption reasonable.

DOE assumed that the oldest analog represents the minimum amount of time that a similar, contemporary effort may be expected to endure, given the marked difference in technological capabilities between then and now. EPA is less inclined to draw such a precise parallel between an analogue and a proposed PIC, since each analogue is unique and survived under unique circumstances. However, DOE pointed to differences between analogues and proposed PICs that strengthen the conclusion that the PICs design is more likely to endure. For example, DOE observed that granite is a hardier construction material than the stones used in

some analogues. While the degree of similarity between analog and proposed PIC may vary, the approach employed by DOE is sufficient to support its approximations.

Assumptions For Estimating the Amount of Time PICs Will Be Understood

EPA reviewed DOE's assumptions to determine whether they were reasonable and supported by available data. EPA found that the information provided by DOE in support of its assumptions generally was not elaborate but was sufficient to demonstrate that the assumptions were reasonable.

In some cases the justification of the assumption contained questionable statements, but the assumption itself appeared valid. One example is the explanation of PTF Assumption 4 (English usage will increase but the basic language will resist change), which states, "People have invested so much time and effort in learning English that they will not accept wholesale changes except over extremely long time frames." More persuasive support for PTF Assumption 4 may be found under PTF Assumption 5 (current English will be understandable for 1,000 years), where DOE refers to evidence that English at various stages of its development is still recognizable to contemporary scholars. In another example, DOE used the analogy of Latin to support its assumption that "industry-specific" language (i.e., specialized and technical terminology) would remain recognizable to the resource exploration industries (PTF assumption 6), but did not provide examples to illustrate the analogy.

It is important to note that DOE regards the natural resource industries as the primary audience for the messages conveyed by PICs. This approach is consistent with the purpose of PICs (to caution against intrusion) and the requirement that DOE specifically consider drilling and mining as human intrusion events in its modeling of future processes. However, DOE did not demonstrate that a worker in a resource industry a thousand years hence will understand current English any better than a comparable worker today can understand Old English.[3] DOE attempted to address this problem by assuming that workers would recognize technical jargon in the messages. EPA noted it is more likely that a worker who encounters a PIC and does not immediately comprehend its warning will notify managers, who in turn will seek out an expert who can interpret it. Several of DOE's assumptions envision such a scenario (current English will remain decipherable, humans will continue to be curious, etc.). However, the scenario is by no means a certainty.

43.E.1 REQUIREMENT

(c) "The Administrator may allow the Department to assume passive institutional control credit, in the form of reduced likelihood of human intrusion, if the Department demonstrates in the compliance application that such credit is justified because the passive institutional controls are expected to endure and be understood by potential intruders for the time period approved by

[3] For example, the famous text *Beowolf,* which was written approximately 1,000 years ago in Old English, is virtually unreadable in its untranslated form except by linguistic scholars. DOE itself cites an example of Middle English (circa 14th century) whose meaning is not readily apparent: "The stele of a stif staf the sturne hit bi gripte. . ." (Appendix PIC, p. 27)

the Administrator. Such credit, or a smaller credit as determined by the Administrator, cannot be used for more than several hundred years and may decrease over time. In no case, however, shall passive institutional controls be assumed to eliminate the likelihood of human intrusion entirely."

43.E.2 ABSTRACT

The compliance criteria allow—but do not require—DOE to propose a credit for PICs in the form of a reduced likelihood of human intrusion in performance assessments (PAs). PICs credit may not constitute a 100 percent reduction in human intrusion and may not extend more than approximately 700 years from the time of disposal. DOE compared the proposed PICs to analogues around the world and concluded that they were virtually certain to endure and be understood by potential drillers for 700 years. DOE then attempted to calculate known failures of land use control whereby a well is mistakenly drilled outside the approved lease. This analysis led DOE to conclude that there was at most a 0.00001 chance that PICs could fail, which DOE raised to 0.01 (99 percent) for the sake of conservatism.

EPA considered whether DOE employed expert judgment to derive the credit, as the Compliance Criteria indicate is appropriate. EPA also reviewed the proposed credit to determine whether DOE had followed the CAG by, among other actions, identifying and explaining guiding assumptions and accounting for uncertainty.

43.E.3 COMPLIANCE REVIEW CRITERIA

DOE was not required to assume a PIC credit in the CCA. Construing credit as integral to the WIPP's compliance would contradict EPA's intent for institutional controls, as stated in the preamble to the 40 CFR Part 191 disposal regulations:

> The Agency's overall objective has been to protect public health and the environment from disposal of radioactive wastes without relying upon institutional controls for extended periods of time—because such controls do not appear to be reliable enough over the very long periods that these wastes remain dangerous. Instead, the Agency has pursued standards that call for isolation of the wastes through the physical characteristics of disposal siting and design, rather than through continuing maintenance and surveillance (50 FR 38080).

While EPA concluded in 40 CFR Part 191 that PAs should not rely on institutional controls, the Agency also recognized that "a limited role for passive institutional controls would be appropriate when projecting the long-term performance of mined geologic repositories. . . ." (50 FR 38080). This limited role takes the form of a reduction in the likelihood of inadvertent, intermittent human intrusion. Thus, the Compliance Criteria for the WIPP permit DOE to propose a reduction in human intrusion in the CCA.

If DOE chose to assume a credit, the Compliance Criteria place the following restrictions on it: 1) the credit cannot be used in the PA for more than approximately 700 years, and 2) PICs cannot be assumed to be 100 percent effective at preventing human intrusion. The former condition was imposed on the basis of public comments and recommendations from the National

Advisory Committee on Policy and Technology's Subcommittee on the WIPP. The latter condition was imposed because "there will always be a chance that some individuals will overlook or misunderstand the markers and records" (50 FR 38080).

EPA did not attempt to prescribe a rigorous methodology for deriving credit in the disposal regulations or Compliance Criteria. Doing so would have been arbitrary, since no proven quantitative methodology for predicting the future has been shown to exist. The Compliance Criteria clearly indicate, however, that the best available approach for predicting the future effectiveness of PICs would be to solicit the judgment of those best qualified to make predictions, i.e., experts in related fields (e.g., linguistics, archaeology, resource exploration). EPA specifically stated:

> [T]he degree to which PICs might reduce the future drilling rate can be reliably determined only through informed judgment. The Agency agrees with the NACEPT Committee that no rigorous and non-speculative method is available to determine the appropriate amount of credit for PICs. Thus, DOE's proposed reduction in the likelihood of human intrusion due to PICs would probably be conducted through an expert judgment process that considers the specific PICs to be implemented at the WIPP by DOE (61 FR 5232).[4]

As discussed in the CAG (pp. 60-61), EPA expected that DOE's argument in support of any proposed PIC credit would account persuasively for uncertainties inherent in making predictions about longevity and message comprehension. It would include a related discussion of scenarios in which elements of the PIC design could potentially fail at their purpose. It would have as a framework assumptions that represented reasonable extrapolations of what is known or accepted about human behavior and other factors that could affect the performance of PICs. It would make use of available facts and a wide range of expertise. Finally, the argument would have to be consistent with the estimates for endurance and comprehensibility of PICs that DOE provided to show compliance with Section 194.43(b).

DOE was not permitted to assume that all present-day societal and demographic factors would remain constant.

[4] This usage of expert judgment is consistent with guidance in NUREG/CR5424, "Eliciting and Analyzing Expert Judgment," which states, "In general, when good actuarial data are unavailable, predicting future events or actions requires use of expert judgment. . . in order to adjust, sometimes radically, from the status quo or past patterns in making predictions." [NRC 1990, p. 4]

43.E.4 DOE METHODOLOGY AND CONCLUSIONS

Evolution of the Document

The rationale for assuming credit based on the effectiveness of PICs is described in Chapter 7 and Revision 1 of Appendix EPIC. These parts of the CCA rely heavily on the PIC conceptual design contained in Appendix PIC.

A draft of Appendix EPIC and related materials were submitted by DOE to a peer review panel beginning in May 1996. Revision 0 of Appendix EPIC and the PIC peer review panel's July report were included in the CCA received by EPA on October 29, 1996. In December 1996, DOE reopened the PIC peer review to resolve issues raised by the panel. The panel received Revision 1 of Appendix EPIC (dated November 14, 1996) to review. The panel subsequently issued a second report. The second report incorporated issues raised by the panel and DOE's responses to those issues, the latter of which were made an addendum to Appendix EPIC on December 6, 1996 (Docket A-93-02, Item II-G-15 and 16).

Appendix EPIC underwent substantial revision between Revisions 0 and 1. The revisions consisted of clarifications and additional information that DOE intended to resolve concerns raised by the peer review panel. EPA noted that the following entirely new sections, at a minimum, were added to Revision 1 of Appendix EPIC: 1.6, 2.11, 3.1, 3.1.2, 3.2, 3.3, 3.4, 4.1, 4.4, 5.1, and 6.4.1-3, as well as the December 1996 addendum. Because the Appendix was altered so extensively, EPA did not consider Revision 0 in its review of the credit proposal, except as it was necessary to understand the initial findings of the peer review panel. The discussion below, unless otherwise specified, relates to Revision 1 of Appendix EPIC.

The Credit Rationale

DOE's rationale for assuming credit for PICs is complex. To meet the purpose of this CARD, a condensation of the credit argument, derived from the Executive Summary of Appendix EPIC (pp. ix-xiii), is provided in this section.

The rationale for credit was developed by the PTF. The purpose of the PTF was to estimate how long the PICs would endure and the amount of time messages would be understood by potential intruders, and on the basis of these estimates propose a level of credit for use in PAs. As mentioned above, credit takes the form of a reduced likelihood of inadvertent human intrusion. The PTF did not attempt to account for the actions of individuals who understand a message but do not heed its warning, since such actions would constitute intentional (as opposed to inadvertent) intrusions and would therefore fall outside the scope of PAs.

Appendix EPIC describes a five-step process used by the PTF.

- The PTF generated a list of assumptions (alternately referred to as premises, assumptions, and conclusions) concerning basic human attributes, government, language, natural resources exploration, and an additional category labeled Estimating PICs Effectiveness. Assumptions are discussed in Appendix EPIC.3 (pp. 3-1 to 3-12). The PTF relied in particular upon a requirement at Section 194.33(c)(1) that "future drilling practices and technology will remain consistent with practices in the Delaware Basin at the time the compliance application is prepared."

  The framework of assumptions established by the PTF is that government and regulatory agencies will continue to exist for at least 700 years after closure, some form of procedure for permitting and record-keeping of natural-resources exploration and exploitation will continue, and English will continue to be understood by the natural resources industry for 700 years. Exploratory and developmental drilling will continue throughout the Delaware Basin at such a high yearly rate that record centers will remain active and no time intervals will occur during which the procedures will be forgotten.

- The PTF considered historical analogues in terms of specific design characteristics they shared with the PICs conceptual design. In some cases, historical analogues were considered only for their durability, while in other cases they were considered for both durability and their communicative function. The relationship between an analogue(s) and a PIC was stated as one-to-one (i.e., if the analog survived for 4,500 years, the related PIC is predicted to last at least that long).

- The PTF identified potential failure mechanisms for each PIC and described how both the overall design and the individual PICs accounted for those potential failures. The PTF states that the conceptual design, by virtue of its redundancy and other features, eliminated virtually any possibility that individual PICs, much less the overall system, could ultimately fail to communicate their purpose. The PTF also states that each PIC is virtually certain to survive for the entire 700 years of concern to PICs effectiveness.

- Drilling in the wrong location on the correct lease was identified by the PTF as the only plausible failure scenario. The PTF examined drilling records and conducted personal interviews with individuals familiar with drilling in the Delaware Basin, and found no instances in which wells were drilled in the wrong location in the Delaware Basin. When the survey was extended to the Permian Basin in New Mexico and Texas, five instances of wells out of 429,000 were found to have been drilled in the wrong location (i.e., failure of 0.00001). The PTF also considered similar errors in other areas of the U.S. and Canada. The failure rate of 0.00001

was derived from the single PIC component of government control of land use. Given the PTF's guiding framework of assumptions, other PICs were assumed to be at least as effective as the government control of land use.

- The PTF bounded the failure rate for the sake of conservatism and recommended that PICs be assumed to be 99 percent effective in reducing the likelihood of human intrusion in PAs from 100 to 700 years after closure of the WIPP. The rationale assumed that the active institutional controls will be completely effective in deterring inadvertent intrusions for the first 100 years. Because the premises under which the PTF worked applied to mining as well as drilling, the PTF recommended that the failure estimate developed for inadvertent drilling also be used for potential mining intrusions.

DOE Conclusions

DOE concluded in Chapter 7 that "for performance assessment calculations, the passive institutional controls are considered to be 0.99 (that is, 1 to 0.01) effective in deterring inadvertent human intrusion over the entire withdrawal area" (p. 7-89). Also, "the effectiveness of passive institutional controls for use in performance assessment is focused on the time period from year 100 to year 700 after disposal" (p. 7-87). In other words, there is only a one percent likelihood that PICs would not deter an inadvertent intrusion for 600 years after the conclusion of the 100-year period of active institutional controls. (DOE assumed that active institutional controls will be 100 percent effective at deterring human intrusion for 100 years after the WIPP ceases operation. For more information, see **CARD 41—Active Institutional Controls**).

43.E.5 EPA Compliance Review

EPA's consideration of DOE's proposed PIC credit first focused on the answers to three questions:

- Did DOE rely on informed judgment, in particular an expert judgment process?
- Is the period of time PICs are assumed to be effective reasonable (i.e., no more than approximately 700 years?
- Were PICs assumed to eliminate the likelihood of human intrusion entirely?

Expert Judgment

DOE did not conduct an expert judgment process, in the manner prescribed by Section 194.26 (Expert Judgment), to derive the PICs credit. Instead, DOE prepared a credit proposal and submitted it to a peer review panel.

EPA did not consider the peer review conducted by DOE to be equivalent to an expert judgment elicitation. In Section 194.26, the Agency established explicit requirements for the conduct and documentation of expert judgment. DOE's documentation of the PIC peer review does not comport with these requirements (see Section 194.26(b)(7) in particular). For instance, the PIC peer review panel was composed of three members, whereas EPA's expert judgment requirements call for at least five members on a panel (Section 194.26(b)(7)(i)).

As discussed in the DOE Methodology and Conclusions for Section 194.43(a)(1) above, DOE undertook two expert judgment exercises related to PICs prior to the promulgation of the final compliance criteria. In one exercise, DOE asked groups of experts to predict the likelihood of various intrusion scenarios in the future. In another, DOE asked an expert panel to identify the elements of a marker system and to estimate the probability that such system would deter inadvertent intrusion. In neither case did DOE present the panel with the conceptual design for PICs that is in the CCA and ask the panel to derive a credit proposal based on that design. EPA therefore noted that the results of either exercise may not be viewed as directly relevant to DOE's credit proposal, and DOE has not requested that EPA consider them in this way.

Reasonable Time Span for Credit

DOE proposed a PIC credit effective over a six hundred year period that begins 100 years after closure of the WIPP (Chapter 7, p. 7-87). This period falls within EPA's limitation that PIC credit could apply no more than approximately 700 years past the time of disposal (closure). Also, the proposal is consistent with DOE's estimates for the amount of time PICs are expected to endure and be understood, which extend well past 700 years (see Section 194.43(b) above).

PICs Assumed to Eliminate the Likelihood of Human Intrusion Entirely

DOE's core argument in support of the proposed credit (see Appendix EPIC.6.4, pp. 6-12 to 6-16) is:

- Most PICs, markers, archives, etc., are virtually certain to endure and be understood for 700 years, based on DOE's assumptions and use of analogues for PICs.

- There is no scenario that could result in the failure of all proposed PICs.

- There is only one PIC with the potential to fail in 700 years, namely, control of land use. Specifically, the failure scenario involves the issuance of a correct lease to a driller, who then inadvertently drills in the wrong location.

- DOE estimated that there have been at most 5 instances of drilling outside a lease out of 429,000 wells, resulting in a failure rate of 0.00001. Such failures occurred in areas where no PICs (such as markers) were present.

- To account for any additional uncertainty, DOE increased the failure rate of PICs to 0.01 (99 percent).

Based on the information discussed under Section 194.43(b) above, EPA observed that it is highly likely that the proposed PICs, in particular site markers, will endure for at least 700 years. In addition, it is likely that someone, though perhaps not drillers directly, will be able to interpret messages on markers 700 years hence. However, EPA determined that the bounding value of 0.01 over the proposed period did not reasonably account for uncertainties inherent in DOE's approach.

EPA recognized in the CAG that DOE, in order to quantify something as speculative as the effectiveness of PICs over time, would have to make assumptions to circumscribe the future. Such assumptions should be based on common denominators (i.e., patterns of human behavior observable throughout history and around the world). EPA considered the assumptions that DOE made (see Section 194.43(b) above) to be sufficient for the purpose of supporting DOE's approximations of the period of time PICs are expected to endure and be understood.

However, EPA did not intend for its guidance on assumptions to be used to justify the elimination of uncertainty from DOE's analysis. While individual assumptions may appear more or less grounded in fact, they should not be confused with fact. They are at best informed predictions. DOE did not explicitly discuss whether there is uncertainty associated with any of its assumptions, or with all assumptions together. Instead, DOE used its assumptions to eliminate potential failure scenarios.

For instance, DOE concluded that messages and records are virtually certain to be understood by drillers 700 years from now simply because DOE assumed that would be the case: "Current English will continue to be read by the natural resources exploration and exploitation industries" (PTF Assumption 6, Appendix EPIC, p. 3-8). Similarly, DOE concluded that warnings in WIPP records "are almost certain to be readily understood" by potential intruders "for more than 1,000 years" (Appendix EPIC, p. 6-9) because DOE assumed that current English will be understood for at least 1,000 years. DOE also stated that all PICs are virtually certain to endure for 700 years, and that drillers will unavoidably encounter either offsite records or onsite messages that they are virtually certain to understand.

Such statements occur repeatedly throughout Appendix EPIC.6.1 (pp. 6-2 to 6-10). There is no practical distinction between virtual certainty that PICs will be effective and the assumption that PICs will eliminate the likelihood of human intrusion entirely.

EPA agrees that human error in the process of granting a permit or locating a drilling operation is the most probable scenario whereby the proposed PICs could fail to deter an inadvertent intrusion.[5] However, the uncertainty associated with this failure scenario is probably greater than is reflected in the approach used by DOE to quantify it.

[5] DOE's actual statement is that an error in permitting is the "only" way PICs could fail to communicate with a potential intruder (Appendix EPIC, p. 6-12). EPA is less confident of this conclusion.

DOE identified drilling outside an approved lease as the only plausible failure involving human error. Appendix EPIC.6.4.2 (pp. 6-13 to 6-15) describes DOE's attempts to identify the number of times that wells were drilled at a location outside the approved lease. DOE found no such instances in the Delaware Basin and found perhaps five in the larger Permian Basin. DOE stated, "occurrences of resource trespass are so rare that none of the agencies contacted have kept records. As a result, the PTF relied on anecdotal information from knowledgeable individuals" (p. 6-14).

DOE failed to consider (at a minimum) another plausible failure scenario involving land use controls, i.e., one in which a regulatory agent errs in recording or issuing permits. The Environmental Evaluation Group (EEG) has documented instances where important DOE documents either dealt with inconsistently or overlooked two active leases and a gas well within the WIPP land withdrawal (Silva, 1992. See also Docket A-93-02, Item II-D-114). EEG also evaluated DOE's and the Bureau of Land Management's (BLM) performance under the terms of a Memorandum of Understanding between the two agencies. During the period 1990-1992, this Memorandum of Understanding called for BLM to notify DOE of applications to develop resources within one mile of the land withdrawal boundary and wait to issue a permit until DOE had commented. EEG found numerous instances in which BLM or DOE did not follow the established procedure (Silva, 1994).

In addition, EEG noted that in 1996 a vertical well was drilled on a lease near the withdrawal area, even though DOE had already purchased the lease in 1978 to prevent private resource development (Environmental Evaluation Group, 1997). These examples of institutional lapses raised by EEG suggest that government control over the WIPP site can involve error or oversight and should not be assumed to be "virtually certain to be completely effective" as a deterrent, as DOE stated in Appendix EPIC.6.1.5 (p. 6-10).

DOE asserted that rounding up from 99.99 percent to 99 percent more than adequately compensates for the uncertainty associated with land use controls plus any additional sources of uncertainty (see Appendix EPIC.6.4.3, p. 6-15). Given the examples discussed above, EPA does not agree that this approach is conservative, particularly for purposes of PA calculations.

43.F REFERENCES

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