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MINUTES OF THE ACNW WORKING GROUP MEETING
ON THE IMPACTS OF CARBON-14 RELEASES
ON HLW REPOSITORY PERFORMANCE ASSESSMENT
October 26, 1990, Bethesda, Maryland

On October 26, 1990, the ACNW Working Group on the Impacts of Carbon-14 Releases on the HLW Repository Performance Assessment met. Dr. Martin J. Steindler was Chairman of the Working Group. Other members in attendance included Dr. Dade W. Moeller, Dr. William J. Hinze, and Dr. Paul W. Pomeroy. Dr. David K. Okrent, Dr. Donald Orth, Dr. Joseph Donoghue and Mr. Eugene Voiland, ACNW Consultants were also present. Speakers included representatives of the Environmental Protection Agency, Lawrence Livermore National Laboratory, University of California-Berkeley, and Science Applications International Corporation. Representatives of the NRC Staff and Department of Energy also made statements. A list of attendees is attached.

Dr. Steindler in his opening remarks, noted that Carbon-14 can be found in the crud, in the fuel cladding, in the hardware and inside the cladding as well as in the fuel itself. He noted that the speciation of C-14 is important. A comparison was made to cosmic ray production with the observation being that perhaps C-14 could be considered a trivial issue. However, it was pointed out that there are scenarios postulated for the high-level waste repository that result in releases greater than allowed by the regulations.



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[Mr. Howard J. Larson was the Designated Federal Officer for the meeting.]

Dr. Steindler noted that the meeting was being conducted in accordance with the provisions of the Federal Advisory Committee Act and the Government in the Sunshine Act, Public Laws 92-463 and 94-409, respectively. He also noted that a transcript of the meeting was being made, and would be available in the NRC Public Document Room at the Gelman Building, 2120 L Street, N.W. Washington, D.C.

Priscilla Bunton, EPA, the initial presenter, discussed the A. D. Little September 1990 report entitled "Exposure Assessments of Carbon-14 Releases from Disposal of Spent Nuclear Fuel in an Underground Repository in Tuff."

She noted that in a previous report (A. D. Little, 1990), it was stated that the 40 CFR Part 191 limit for C-14 would be exceeded by a factor of 10. Similarly, this most recent report states C-14 would exceed the limit, assuming all waste in the repository was spent fuel. A release rate of $10^{-3}$ of the initial inventory/year was postulated by A. D. Little, with the C-14 primarily in the gaseous carbon dioxide form. Transport time to the surface was estimated to be 100 years. However, utilizing a retardation factor

of 30, travel time would then be ~3000 years with most of the inventory released over the first 2-3000 years. Insofar as individual dose, with conservative assumptions, an individual living on the surface of the repository and growing all his own food where he lived, would receive 7.2 mrem/year. Ms. Bunton noted that, in 1985, when the standards were first issued, EPA looked only at doses received by a person drinking 2 liters of water/day, with no dose from airborne radioactivity. EPA is currently reviewing whether Table I of 40 CFR 191 should be modified.

The next agenda topic "Application of EPA and NRC Regulations to the Release of C-14 from Spent Reactor Fuel After Disposal in a Geologic Repository" was to be presented by Dr. L. Ramspott, Lawrence Livermore National Laboratory (LLNL). Due to illness he was unable to attend. Dr. Van Konynenburg, LLNL, appeared instead.

Dr. Van Konynenburg noted that although under current regulations "C-14 will mandate extreme containment measures at Yucca Mountain," the release of even the total inventory would be comparable to releases currently allowed from other nuclear fuel cycle facilities. He briefly related the history of repository regulatory development, the possibility of fuel reprocessing, DOE's non-consideration before 1982 of an unsaturated site and the discovery in 1984 of the release of C-14 dioxide from heated fuel.

One needs to understand this background in order to put the release of C-14 in proper perspective vis-a-vis the regulations.

Further research into the origin and sources of C-14 has yielded the following:

1) As much as 2% of the entire spent fuel inventory of C-14 is on the fuel cladding surface.
2) ~1/2% of the C-14 inventory of unclad spent fuel in water is released in a year.

Dr. Van Konynenburg noted that if C-14 reaches its release limit of 0.1 Ci/MTU, the EPA standard permits no release of any other radionuclide. A release to the accessible environment of only 9% of the currently estimated inventory would result in attainment of that limit.

The need for a numerical interpretation of "substantially complete containment" was stressed. R. Weller, HLWM-NMSS, who was in attendance, stated that the NRC staff is attempting to determine whether it can develop such a numerical interpretation.

It was noted that 40 CFR Part 191's Table 1 limits apply to the accessible environment (for C-14, the surface of the ground) while 10 CFR Part 60's release rate limits (for Yucca Mountain) apply at

the borehole wall (the border of the engineered barrier system). With these differences it is possible to meet the NRC limit and the repository still exceed the EPA limit by 60%. Factors affecting the 60% number are: C-14 inventory and the mix of spent fuel and only defense waste (the latter does not contain C-14).

Since 2% of the C-14 inventory is on the cladding surface, spike releases are more likely than for other radionuclides. Furthermore, if 2% of the inventory is readily released, it has been calculated that, under these conditions, only one container in 30,000 could breach in any year in the first thousand years and 15 containers in any year between year 1,000 and 10,000.

Specific concerns insofar as the regulations and potential C-14 releases at Yucca Mountain:

- For gaseous transport to the ground surface, only C-14 has a sufficient half-life to potentially violate current release limits.

- Violation of the current regulations only for C-14 would add very little population risk or individual dose hazard.

- A minor issue like C-14 could potentially block use of a site with otherwise outstanding characteristics.

Due to the rapid dispersion of the slowly emitted C-14 dioxide into the atmosphere, followed by mixing and dilution worldwide, the people located at the repository are not at a significantly greater risk than anyone else in the world.

A comparison of C-14 release limits between nuclear power plants and the repository indicates that the limits on the latter are very strict. Nuclear power plants currently release 1/4 to 1/3 of their gaseous C-14 inventory over roughly 40 years without exceeding any limits while only a 9% release of the initial repository inventory over 10,000 years would violate the EPA limit. That 9% equates to only 0.0023% of the natural production by cosmic radiation. If all the C-14 in the repository were released instantaneously, the current atmospheric inventory would increase by <2%. However, the natural variation in atmospheric C-14 has been measured to be more than 10% over 1000 year time frames. This variation is caused by changes in the solar cycle, sun spot activity, changes in the earth's magnetic field and the like.

This concluded Dr. Ramspott's presentation. Dr. Van Konynenburg then proceeded with his "Review of Carbon-14 Release from a High-Level Nuclear Waste Repository."

After reviewing (and concurring with) Dr. Ramspott's conclusions Dr. Van Konynenburg stated his opinion that a change in the regulations to allow higher Carbon-14 releases would be the most reasonable solution.

Some C-14 facts and nuclear physics characteristics:

- $T_{1/2}$ -5730 years
- Decays by beta emission with maximum energy - 0.1555 Mev
- Main natural cosmic production is n-p with nitrogen-14 (because of the isotopic abundance of nitrogen and its cross-section)
- Entire annual atmospheric production rate - 28,000 Ci

The mixing process with the oceans (both surface and deep) and with organic material on land was discussed and a history of C-14 levels in the atmosphere was presented. The impact of the industrial revolution and the atmospheric nuclear weapons testing program were graphically displayed. The current C-14 global inventory is ~230 million curies, mostly bicarbonate in the oceans. (Current atmospheric inventory is ~3.8 million curies, comprised mostly of $CO_2$ with some methane and CO). It was noted that the C-14 concentration in humans is generally in equilibrium with the atmosphere and, furthermore, the vast majority (~100X) of the C-14 dose is from ingestion (as compared to inhalation.)

C-14 production in power reactors (light and heavy water and graphite) was discussed as was a description of research done/in process on nitrogen inventories in reactor fuels, cladding and structural materials. Based on extensive analyses, the current best average C-14 inventory value (in 33000 Mwd/MTU burnup PWR spent fuel) is ~1.0Ci/MTU. Insofar as the chemical form of the carbon in the materials, while there is evidence that at least some in the $UO_2$ is in the elemental carbon state, it is believed the rest exists either as a carbide or an oxycarbide. A more quantitative breakdown as to the form is not possible.

Dr. Van Konynenburg retraced the history leading to the unexpected discovery in 1983 of C-14 being present in the fuel. This discovery led to the subsequent concerns and studies. He also discussed the postulated release mechanism from the zircalloy clad.

Dr. Steindler questioned the belief that the carbon form in the $UO_2$ was elemental. Dr. Van Konynenburg described the reasoning behind that belief but also noted there are still unknowns that require further analyses in order to better understand the mechanisms.

It was stated that no release of C-14 dioxide can occur unless the waste packages are breached. Although there is currently an effort in process to analyze the distribution over time to cladding

failure it is an extremely difficult task with several recognized modes of degradation. These can be affected by such things as the determination of the number, size and time distribution of perforations. Although more costly containers may apparently be able to comply with the current regulations, it is doubtful that one could provide "reasonable assurance" this could be obtained since even the dominant failure modes are not known.

Dr. Van Konynenburg next presented his logic as to why it appeared possible to exceed 40 CFR Part 191. The travel time to the surface will be comparable to, or less than, one half-life. Consequently, little credit can be taken for decay during transport. Based upon experimental release data, the 10,000 year time frame, the uncertainties in container performance and the transport time, it is difficult to give assurance that less than 9% of the C-14 inventory would not reach the accessible environment in 10,000 years - and thus lead to a violation of the EPA limit.

Some further C-14 comparison data:

- Global inventory - 230,000,000 Ci
- Repository - 71,000 Ci
- Only three years of cosmic production = repository inventory
- Nuclear weapons testing released 9,600,000 Ci into the atmosphere

- Instantaneous release of entire repository inventory would result in a 2% increase in the atmospheric inventory
- C-14 dose currently received from the atmosphere (including bomb tests) = 1 mrem/year (out of 300 mrem/yr effective dose to the average individual from natural sources)
- Resultant dose to an individual if the entire repository inventory released - 20 microrem/yr

The maximally exposed individual was assumed to live directly on top of Yucca Mountain but his food is grown elsewhere (different assumption than in EPA's A.D. Little report). 1000 Ci of C-14 is released at the surface in one year over the repository area (1500 acres). Using actual wind data from Yucca Mountain, and with the person standing outside all the time, 0.5 mrem/year would be received (compared to A.D. Little's reported value of 7.2 mrem). In response to a question from Dr. Steindler, it was noted that this exposure assumes only inhalation, not ingestion. Summarizing,

Dr. Van Konynenburg noted that the calculation of collective effective dose equivalent commitment (CEDEC), from a total repository C-14 inventory release, for an assumed world population of 10 billion, over 100,000 years, gives a resultant which is a factor of 10 million lower than natural background.

Dr. Steindler asked whether a CEDEC value of 470 person-rem/curie was consistent with EPA's 1,000 deaths in 10,000 years. Dr. Van Konynenburg noted that the EPA CEDEC value was 399 person-rem/curie. He then described, in general, the calculation of the EPA number.

Dr. Moeller noted the difference between the timespans for releases from reactors (40 to 60 years) and the repository release period (10,000 years) and noted this possibly impacted upon the validity of Dr. Van Konynenburg's perspectives. In response, it was noted that while the observation on timespans is correct, it is important to recognize that 1/4 to 1/3 of the total C-14 inventory in its fuel is released from the reactor during its operational lifetime.

Dr. Moeller asked about the impact on C-14 releases if the spent fuel were reprocessed. It was noted by Dr. van Konynenburg that he believed that currently there is no regulatory limit on C-14 releases from such facilities. Noted, parenthetically, was the fact that defense facility releases do not currently have regulatory controls.

Dr. Moeller then elaborated on his belief that if the dose rates due to C-14 releases were on the order of 20 microrems/year, per the NCRP recommendations which state individual doses <1 mrem/year should be discarded, exposures from C-14 should be discarded.

Dr. Okrent questioned what was meant by a "much more costly storage container." In reply it was noted that current container designs are estimated to cost ~$50,000 each. A total for the repository system would therefore be $1-2B. While an exact number for a new container system was not available it was felt that a safe estimate would be $1-2 billion more.

Dr. Steindler asked what the impact would be if the C-14 speciation assumptions were all wrong and that all C-14 in the fuel was as methane. After much discussion it was stated that while methane would percolate through Yucca Mountain more rapidly, the resulting atmospheric impact would not be significant. In addition to not being photosynthesized by plants, the C-14 would probably go directly to the stratosphere.

A discussion ensued on possible reasons behind designing an alternate container. It was pointed out that in addition to C-14, the long-lived technetium, iodine and cesium isotopes were also considerations. However, in the event the container was breached (but still remained dry), only the C-14 would be an issue because of its gaseous release. In response to Dr. Donoghue's question, it was indicated by Dr. Van Konynenburg that, to his knowledge, thought had not been given to moving the site to a different geologic formation, rather than spending additional billions on new container designs.

Mr. Voiland asked about the impact BWR hydrogen injection had on the C-14 issue and was told that GE had reported no observable change. Some discussion followed on the origin of the C-14 on the outside of the fuel and how crud is dealt with. Although fuel vendors have provided some information, there is a need for additional data.

Dr. W. W.-L. Lee, University of California, Berkeley, next addressed the Committee, basing his presentation on the paper "Release and Transport of Gaseous C-14 from a Nuclear Waste Repository in an Unsaturated Medium."

Dr. Lee noted that the role of his theoretical modeling group is to develop mathematical models which will be tested against applicable data. In his presentation, two principal topics were intended to be covered: 1) how to estimate the release rate of C-14 from a hole in the canister, and 2) how C-14 is dispersed at Yucca Mountain.

Once the initial hole size is determined the flows can be determined using various accepted flow models. In most all cases the flow will be viscous but, even if molecular, the flow would be so small as to be negligible. Based upon the calculational model (derived in the referenced paper) the release rate is $2 \times 10^{-5}$ moles/year (in contrast to the A.D. Little assumed value of $10^{-3}$.)

In response to Dr. Steindler's question regarding hole sizes, Dr. Lee stated that it was necessary to start with an assumed hole size. In his model, five and ten micrometer holes were used initially but then a spectrum of hole sizes was modeled. In response to a question, Dr. Lee confirmed the assumption that the flow rates for five two micrometer holes would be the same as one ten-micrometer hole.

Dr. Lee next discussed his far-field analyses in which a discreet fracture is analyzed for liquid/gas equilibrium and then a porous media model applied. A transport equation involving only the concentration of $CO_2$ in the gaseous phase can be written once the liquid phase is eliminated. Since the Peclet number is significantly less than one, elimination of the liquid phase was relatively easy.

Based on the assumption that each waste package contains 3.1 Ci, and other mathematical assumptions for repository area, fracture aperture and gas-phase diffusion coefficient, the inhalation dose at the ground surface of Yucca Mountain was calculated as $2 \times 10^{-3}$ mrem/yr. A sensitivity analysis varied this value from 0.1 mrem/year to $10^{-4}$ mrem/year.

Dr. Lee noted that depending upon the gas value assumed for the Darcy velocity, the C-14 inventory would be released over a period of from several hundred years to tens of thousands of years.

In concluding his presentation, Dr. Lee noted that if all the cans instantaneously release 10% of their inventory and the gas Darcy velocity is 10x calculated, the resultant dose is $<10^{-2}$ mrem/yr., 0.01% background. Two caveats to the analyses were noted: 1) the container material is unknown and therefore the likely failure mode is unknown (the study assumes a cylindrical hole) and 2) if the actual site evaluation shows fracture zones that provide for a direct pathway, then a different model would be required.

Dr. Okrent asked about buoyancy effect. This was not considered. Dr. Lee also noted that the calculations were to be extended to less convenient geometries such as a crack.

Chris Pflum, Science Applications International Corporation (SAIC), presented the highlights of his co-authored paper "Requirements for Controlling a Repository's Releases of Carbon-14 Dioxide; The High Costs and Negligible Benefits."

After stating that Dr. Van Konynenburg's C-14 inventory numbers were essentially correct, Mr. Pflum proceeded to address the Rapid

Release Fraction (RRF) of that total inventory which can be rapidly released as $CO_2$. Initially 1% was assumed, but recent data suggests perhaps 5% is a more realistic number. Unpublished German data suggests the RRF could be as high as 10%.

For example, if a reprocessing plant were to be built on Yucca Mountain, then 500-1000 Ci/yr of C-14 could be released. Should a nuclear power plant be built there, then 10-15 Ci/yr could be released. However, 40 CFR Part 191 limits the release from a repository to 0.7 Ci/yr while utilizing the 10 CFR Part 60 formula yields a 1 Ci/yr limit. The measurement boundaries, however, are different, as earlier noted by Dr. Van Konynenburg. It was noted that the limits in Parts 61, 20 and 50 were all greater than 1 mrem/yr.

Equating the repository C-14 limit to breaching of the containers, and assuming a 10% RRF, not more than three out of 30,000 waste packages could fail each year for 10,000 years. Under this condition, SAIC calculates that the limits would just be met.

Mr. Pflum stated he had three main points to make, as follows:

1, If EPA and NRC release limits are met (≤1Ci/yr), the annual dose to the maximally exposed individual would be $5x10^{-5}$ mrem.

2. The increased costs to produce a high-integrity package is estimated as being 2-3x cost of current package (resulting in an incremental $2-3B). The benefits, however, of designing a package only to contain C-14 are perceived as being negligible.

3. 40 CFR Part 61 should apply to a repository, thus permitting a 10 mrem maximum dose for all released gases.

Dr. Steindler pointed out that one major difference with releases from a repository is that while an operating facility can be "turned off" and emissions stopped, a repository cannot readily cease emissions. Mr. Pflum stated that stringent regulations should be tolerated as long as they protect the public from hazardous radioactive emissions. However, based upon his studies, he believes that the quantity of C-14, as a radioactive emission, is not hazardous as viewed today.

Mr. C. Interante, NRC asked whether if in the course of developing a "substantially complete containment" package, the C-14 issue may very well be taken care of without a directly associated cost.

Mr. Pflum agreed, but pointed out that in his opinion too much time has already been spent on C-14 and, while it is a problem which

must be addressed because it is in the regulations, it deserves much less attention.

With the conclusion of the formal presentations, the Working Group held a roundtable discussion, opening the meeting to both the speakers and the audience.

Dr. Van Konynenburg noted that the A. D. Little report suggested that perhaps some carbon containing material could be added in the vicinity of the package to retard C-14 egress to the surface. A concern was noted that organic colloids could thus be formed which would take away the protection believed to be present insofar as the solubility of actinides (by perhaps making them more transportable.)

Mr. F. Galpin, EPA, stated that 40 CFR 61 does not apply to anything covered by 40 CFR 191. While there may be a period during the experimental phase at the repository when Part 61 would apply, there is prescriptive language that states that when subpart (b) applies, Part 61 does not apply. EPA does not want two regulations applying to the same release at the same time. He also cautioned that before one proposes either different interpretations or changes to the current regulations, one should wait until the new Clean Air Act (CAA) recently passed by Congress "hits the

streets." He pointed out that what he has seen has led him to believe the new CAA would be more prescriptive and less flexible.

Dr. Moeller discussed the court ordered remand of 40 CFR Part 191 asking Mr. Galpin if the EPA review and changes shouldn't be broader than just responding to the well injection criteria question. Mr. Galpin replied that while well injection appeared to present a case of dual jurisdiction, issues such as fuel reprocessing and the CAA do not. As one simplistic example of Congressional inconsistencies, he noted that in administration of the CAA, the Atomic Energy Act and the Superfund, all "look at costs in an entirely different way."

Mr. Galpin noted that: 1) EPA is taking the C-14 issue very seriously, viewing it as both a technical as well as a policy issue, 2) EPA recognizes that the standards issued in 1985 did not consider gaseous releases and 3) EPA would appreciate more detailed remarks from the ACNW on C-14, the HLW standards stringency issue and topics such as collective dose truncation. [He noted that while EPA management understands that the Committee feels Part 191 is too stringent, they are unable to define in sufficient detail precisely what that means and how the Committee believes that stringency should be corrected.]

Mr. Galpin also noted that repository releases realistically will not be a constant over a number of years but rather the releases will be concentrated over a shorter timeframe. Committee advice as to how to handle such would be appreciated.

Dr. Okrent questioned whether it would be better to place a limit of so many millrem/year on the maximally affected person. Mr. Galpin noted that EPA does have such a limit for undisturbed performance.

R. Weller, NRC, noted Part 61(13) provides for an annualized limit. The Chairman pointed out that the discussion was beginning to wander from its C-14 topic and that the topic of dose calculations, assumptions, etc. was "for another day."

Dr. Moeller brought into the discussion the NCRP philosophy of negligible individual risk limit (NIRL). Mr. Galpin observed that, by definition, it is negligible risk, not one that doesn't exist.

After further discussion on radiation protection risks as provided for in IAEA, NCRP, ICRP and BEIR V documents, it was stated by Mr. Galpin that EPA has, as a policy, "on the books, an absolute belief in linearity to zero."

Dr. Okrent asked about truncation consistency within EPA, using chemicals as an example. Mr. Galpin noted that for chemicals EPA truncates by distance but admitted that the Agency is not consistent overall.

R. Weller, NRC, noted that Part 61 has enough flexibility in it to permit proposing alternative containment periods or release rates or groundwater travel times. Dr. Van Konynenburg agreed but stated that is very difficult, from a practical standpoint, for one agency to ask another agency for an exception. He also noted that timing is important as DOE is less likely to risk requesting an exception than they would be in "buying" assurance that their final application would be accepted.

E. Regnier, DOE, noted, in passing, the differences presented at the meeting insofar as doses to someone on top of the repository - 7.2 mrem to $5 \times 10^{-5}$ mrem. There was no quantifiable answer provided to his question as to whether ingestion of food grown on Yucca Mountain would result in the same numbers as A. D. Little's report due to the variables involved such as the different dose conversion factor. His final comment was that while the EPA HLW standard may not be "massively changed," the people he works with at EPA are reasonable and are attempting to work out problems.

U. Sun Park, SAIC (and co-author with Mr. Pflum of the referenced paper) discussed not only the gaseous release of C-14 but also the impact of its release to groundwater. He stated that not only is the fast-release gaseous fraction a concern but all C-14 is as it will all be swept to the surface in a cumulative manner.

He stated that comparing the release of C-14 as being equivalent to the risks from 70,000 tons of unmined uranium is simply not true. The EPA report on risks from uranium ore bodies, 520/3-080-009 was discussed, noting that two mines are compared in the report. One is an actual mine with an associated risk level between 100,000 and 1,000,000 deaths while the other was a hypothetical mine with an assumed risk level equivalent to only 10 deaths. EPA picked a value in between - 1000 deaths. Mr. Park's penultimate point was "there is no basis for the 1,000 health effects" since the value picked had no substantive basis.

Mr. Park then presented an argument that if nuclear energy supplied the whole world and the current capacity was increased 10X, then the total C-14 generation would be equivalent to the generation of C-14 in nature. This would therefore make C-14 a global problem. He argued that one then cannot absolutely argue that C-14 does not have to be regulated. However, current regulations are inconsistent and unbalanced between themselves (for example: the 1000 health effects comparison is not well-grounded). Table 1 in

40 CFR Part 191 must be examined to determine whether it has a good scientific basis. He also discussed genetic effects noting that typically 200 health effects/million man-rem is used, portioned out with 60% causing cancer and the remaining 40% resulting in genetic defects. He also pointed out the difference (several orders of magnitude) in conversion rates between A. D. Little, NCRP, UNSCEAR, etc. SAIC performed a very conservative analysis similar to A. D. Little's. The calculations assumed that people lived all year on top of the repository, drank only water from the area and ate only vegetables grown inside the enclosure. The entire 1000 curies released in one year was assumed trapped in the area. The resultant calculated individual dose was 2 mrem/year.

J. Bradbury, NRC, noted that the assumption that equilibrium exists between a liquid and gaseous phase is most non-conservative.

Mr. Voiland suggested that the members reread ICRP 46 "Radiation Protection Principles for the Disposal of Solid Radioactive Wastes," as it was an excellent guide for producing regulations for this kind of issue.

With no further comments by the Chairman or questions received from members, consultants, speakers, or the floor, the meeting was adjourned.

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NOTE; A transcript of the meeting is available at the NRC Public Document Room, Gelman Bldg. 2120 "L" Street, N.W., Washington, D.C. Telephone: (202) 634-3383 or can be purchased from Ann Riley & Associates, LTD., 1612 K St., N.W. Suite 300, Washington, D.C. 20006, (202) 293-3950.

H. LARSON

ADVISORY COMMITTEE ON NUCLEAR WASTE — WORKING GROUP ON CARBON-14

LOCATION P-110, Bethesda, Md.

DATE October 26, 1990

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| Geraldine Gruhe | NRC/NMSS |
| Paula Austin | SAIC |
| Steve Oston | TRW |
| Bob Andrews | NMSNRC |
| U-Sun Park | SAIC/YMPO |
| Ron Green | CNWRA |
| Ricardo Palabrica | WESTON/UE&C |
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ADVISORY COMMITTEE ON NUCLEAR WASTE — WORKING GROUP ON CARBON — H. LARSON

LOCATION: P-110, Bethesda, Md.

DATE: October 26, 1990

## ATTENDANCE LIST

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