DOCKET NUMBER
PROPOSED RULE PR 71
(65FR 44360)

(17)

Comments on Part 71 Rulemaking with Emphasis on the Unsupported Regulatory Burden Reduction for Uranium Hexafluoride (UF6) Packages due to a Lack of Information to Support Studies of the Risk and Associated Uncertainties, and a Transportation Safety Goal to Compare To

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1.0 Summary of Comments

The NRC should adopt regulations based on technical merit, with arguments including insights from operational experience, transportation history, and a study of the risks and uncertainties measured against a Safety Goal thereby giving meaning to terms such as safety margin and defense-in-depth. This risk-informed and performance-based approach to regulating can be used to focus attention on those areas of most importance to safety resulting in an appropriate level of conservatism in the regulations. Technically supported and publicly defensible justification may reduce the unnecessary regulatory burden on certificate holders while making the safety argument. Or the conservatism may be found to be inadequate, in which case appropriate levels of defense in depth must be enforced by the authority of Code through either design requirements or other means found to be appropriate for the level of risk. In the case of UF6 packages, we have operational experience and a transportation history, but the risks and associated uncertainties, and a Safety Goal have not been quantified.

The NRC should adopt a Transportation Safety Goal. A Transportation Safety Goal documents the acceptable risk for the transportation of radioactive material. The discussion of a Transportation Safety Goal is underway, but the road to the final product is long. A discussion of risk and uncertainty without the metric to compare to is an incomplete assessment of the level of safety that the package provides. In addition, the level of uncertainty is one of the factors that drives the amount of defense in depth required. Other factors include economic, political, and public confidence concerns. Without a Transportation Safety Goal, the conservatism of regulatory requirements may not be determined. The implementation of a Safety Goal may reveal that the regulations may be overly conservative, and burden reduction is justified when risk and uncertainties are compared. In other cases, the regulations may provide an appropriate measure of conservatism, and in still others, the conservatism may be inadequate. It is irresponsible to adopt less stringent regulations without a firm grasp of the elements of risk and the associated uncertainties which support a burden reduction argument.

A UF6 risk study of the scenarios leading to undesirable events, including containment breach and criticality is the rational way to examine what level of defense in depth is needed. The ACRS letter of May 25, 2000 contains a discussion on the use of defense in depth in risk-informing NMSS activities. Risk is determined both by the likelihood of an incident occurring, and the consequences should such an incident occur. Analyses of UF6 packages have been based on moderator exclusion. This means that the analysis was based on the absence of water from the package. There is no supporting analysis assuming moderator ingress which would lead to an inadvertent criticality incident. Therefore we cannot yet fully characterize the intertwined chemical and nuclear reactions that would occur with moderator ingress to this type of packaging.

Template = SECY-067

SECY-02

This means that justification for the burden reduction in Paragraph 677 of IAEA ST-1 has not been established. Though it may be viewed as a strengthening of regulations for the international community, it is a reduction of the American burden. Without a risk study, it is unclear whether the conservatism of current Part 71 regulations lies in the realm of adequate, inadequate, or unnecessarily conservative. Without a risk study, it is unclear whether the conservatism of ST-1 is adequate, or inadequate. Reduction of regulatory burden without justification leading to inadvertent criticality could lead to a loss of life, degradation of the environment, political and economic repercussions, and degradation of public confidence.

Primarily, technical safety must be justified. The defense in depth which provides a margin of safety may be adjusted due to economic and political factors, but unendangered life, property and the common defense and security must be assured at the very minimum.

This agency should have a technical safety basis to justify the adoption of Paragraph 677 of IAEA ST-1, 1996 edition into Part 71. The United States Nuclear Regulatory Commission rulemaking efforts include public involvement to arrive at a final rule. This is not the case internationally. All of the public, which includes industry, environmental groups, even NRC employees who have taken an oath to faithfully discharge the duties of office, have the opportunity to make their concerns known for issues affecting the regulation of the commercial uses of radioactive material. IAEA ST-1 will be adopted verbatim by some countries without this same opportunity. IAEA member states must adopt IAEA provisions for international compatibility. However, the United States Nuclear Regulatory Commission mandate is to protect the public health and safety. This is accomplished through adoption of, and regulation by technically justified requirements in the code, thereby ensuring that activities involving the peaceful uses of radioactive material are accomplished safely.

2.0 Background and Supporting Discussion

The function of every employee at the NRC ultimately is to assure protection of the public health and safety, the environment, and the common defense and security. Reasonable assurance that this mandate is accomplished during the transportation of radioactive materials is attained by ensuring that the contents of a package are not lost or dispersed, and that there will be no significant increase in the external surface radiation levels. The structural, thermal, shielding, criticality, containment, materials, and quality assurance aspects of a package are assessed for effectiveness in meeting our mandate. The regulations applying to the packaging and transportation of radioactive material are specified in Title 10 of the Code of Federal Regulations, Part 71 (10 CFR 71). The staff must have assurance that there will be no substantial reduction in the effectiveness of the packaging when constructed, and prepared for shipment as designed and approved, and transported under normal and hypothetical accident conditions. With reasonable assurance of package effectiveness, the staff can issue a Certificate of Compliance, and is in essence certifying to the public that the package can be transported and will not endanger life, property or the common defense and security.

2.1 Moderator Exclusion

Inherent in a transportation package review is the concept that inadvertent, uncontrolled criticality must be prevented under all conditions. Moderator exclusion packages rely on the

absence of a moderator to prevent uncontrolled criticality. Materials commonly thought of as moderators are water, hydrocarbons, and graphite. The containment boundary, which is the moderator exclusion boundary in the case of a moderator exclusion package, is the barrier to moderator ingress which would permit an inadvertent criticality. Therefore, regulations must be adequate to ensure that the integrity of this boundary will be maintained.

An example of a moderator exclusion package is the fissile uranium hexafluoride (UF6) package with contents enriched to greater than 1% U-235. Below this enrichment, a self-sustaining chain reaction cannot occur. In a package requiring moderator exclusion, the contents are not limited (i.e., the mass of the fissile U-235 is sufficient for criticality) and the geometry is not favorable for subcriticality under the assumption of moderator ingress. The UF6 must be shipped as a solid. The most common package shipment is 5020 pounds (2½-tons) of 5% enriched UF6 in a 30B cylinder surrounded by a protective steel and foam overpack. Less common are 10-ton rail shipments of 4.5% enriched UF6 in 48X cylinders. There is no 14-ton (48Y cylinder) package with a Certificate of Compliance.

2.2 Overpack

The US addition of an overpack to the cylinder occurred in the 1960's. At that time, research showed that a fire would cause hydraulic rupture and the release of all the contents of the smaller UF6 cylinders, but it was unclear what would happen if a cylinder with 2½-tons of contents should undergo this test. It was expected that the explosion may expel only part of the contents, leaving the rest of the fissile material available to a moderator, and the possibility of criticality. It was stated that at the time they didn't have enough land to test and release such a large amount of material, and rather than spend a great deal of money to investigate the various release and criticality scenarios, a decision was made to incorporate an overpack to provide thermal resistance for these 2½-ton cylinders to prevent hydraulic rupture during the fire test, and in doing so, provided structural resistance as a bonus. Since that time, the overpack and the cylinder together have provided a containment system for the fissile uranium hexafluoride. They are both necessary and perform different functions.

2.3 Current Requirements for fissile material packages - Authority under Part 71 of Title 10 of the US Code of Federal Regulations

Vendors seeking a Certificate of Compliance for their transportation package design must submit a Safety Analysis Report (SAR), commonly referred to as the SAR, and occasionally referred to as the application. The SAR is reviewed for compliance to 10 CFR Part 71. A technical reviewer examines the contents of the SAR to determine compliance with the regulations. A Request for Additional Information (RAI) is drafted when aspects of the submittal appear to be either inadequate, or unclear. These RAIs from each reviewer are forwarded to the Project Manager (PM) for that package. The PM reviews the questions for clarity, and in some cases discusses suggestions for changes, or clarification. The PM then assembles the RAIs from each technical review area into one document to be transmitted to the applicant for clarification or correction of the discrepancy of the materials presented in the SAR. A Certificate of Compliance can be issued when the aspects of the design, and associated procedures are in alignment with the code.

Section 71.4 Definitions: *"Fissile material* means plutonium-238, plutonium-239, plutonium-241, uranium-233, uranium-235, or any combination of these radionuclides. Unirradiated natural uranium and depleted uranium, and natural uranium or depleted uranium that has been irradiated in thermal reactors only are not included in this definition. Certain exclusions from fissile material controls are provided in Sec. 71.53,"

The definition of fissile material, as quoted from Section 71.4,suggests that when the contents of a UF6 package are enriched to greater than 1% U-235, then the requirements of Section 71.55 apply.

Section 71.55 contains the general requirements for fissile material packages. This Section is reproduced below. Italics and underlining have been added for emphasis to code of specific interest, 71.55(b) and (c).

2.3.1 Section 71.55 General requirements for fissile material packages

(a) A package used for the shipment of fissile material must be designed and constructed in accordance with Secs. 71.41 through 71.47. When required by the total amount of radioactive material, a package used for the shipment of fissile material must also be designed and constructed in accordance with Sec. 71.51.

(b) Except as provided in paragraph (c) of this section, a package used for the shipment of fissile material must be so designed and constructed and its contents so limited that it would be subcritical if water were to leak into the containment system, or liquid contents were to leak out of the containment system so that, under the following conditions, maximum reactivity of the fissile material would be attained:

(1) The most reactive credible configuration consistent with the chemical and physical form of the material;

(2) Moderation by water to the most reactive credible extent; and

(3) Close full reflection of the containment system by water on all sides, or such greater reflection of the containment system as may additionally be provided by the surrounding material of the packaging.

(c) The Commission may approve exceptions to the requirements of paragraph (b) of this section if the package incorporates <u>special design features</u> that ensure that no single packaging error would permit leakage, and if appropriate measures are taken before each shipment to
ensure that the containment system does not leak.

(d) A package used for the shipment of fissile material must be so designed and constructed and its contents so limited that under the tests specified in Sec. 71.71 (``Normal conditions of transport")–

(1) The contents would be subcritical;

(2) The geometric form of the package contents would not be substantially altered;

(3) There would be no leakage of water into the containment system unless, in the evaluation of undamaged packages under Sec. 71.59(a)(1), it has been assumed that moderation is present to such an extent as to cause maximum reactivity consistent with the chemical and physical form
of the material; and

(4) There will be no substantial reduction in the effectiveness of the packaging, including:

(i) No more than 5 percent reduction in the total effective volume of the packaging on which nuclear safety is assessed;

(ii) No more than 5 percent reduction in the effective spacing between the fissile contents and the outer surface of the packaging; and

(iii) No occurrence of an aperture in the outer surface of the packaging large enough to permit the entry of a 10 cm (4 in) cube.

(e) A package used for the shipment of fissile material must be so designed and constructed and its contents so limited that under the tests specified in Sec. 71.73 (``Hypothetical accident conditions"), the package would be subcritical. For this determination, it must be assumed that:

(1) The fissile material is in the most reactive credible configuration consistent with the damaged condition of the package and the chemical and physical form of the contents;

(2) Water moderation occurs to the most reactive credible extent consistent with the damaged condition of the package and the chemical and physical form of the contents; and

(3) There is full reflection by water on all sides, as close as is consistent with the damaged condition of the package.

The moderator exclusion UF6 packages are not subcritical if water were to leak into the containment system under the conditions of 71.55(b). Therefore, the requirements of 71.55(b) have not been met.

2.3.2 71.55(c)

An exception to the requirements of 71.55(b) is allowed provided the requirements of 71.55(c) are met, which states that, "The Commission may approve exceptions to the requirements of paragraph (b) of this section if the package incorporates special design features that ensure that no single packaging error would permit leakage, and if appropriate measures are taken before each shipment to ensure that the containment system does not leak.

2.3.3 Examination of Section 71.55(c)

Consider the function intended for the special design feature required by 71.55(c). It is a means of backup for providing protection from leakage in the case of a single packaging error that would lead to leakage and criticality. In order for a single packaging error to permit leakage, it would have to be one that would cause an opening or a breach in the containment/moderator exclusion boundary, which is the cylinder and the valve. A special design feature preventing leakage in the case of a cylinder or valve opening is inherently another layer of protection, which may have been referred to as "double containment." However, double containment may imply more than the regulation requires to maintain the boundary integrity. Double containment may imply the existence of a second fully enclosing containment boundary. But without a comprehensive study to identify the single packaging errors, or containment/moderator exclusion boundary weakness that would permit leakage leading to an inadvertent criticality, it cannot be determined what level of backup is necessary for defense-in-depth without being an over burdensome requirement. Further, without a comprehensive study, it cannot be determined if removing this backup as a requirement is in the interest of meeting our mandate.

Acceptable leak rates must be specified, such as leaktight (10-7ref cc/sec per ANSI N14.5) in the absence of a publically accepted watertight specification, and methods may be specified to assure the staff that appropriate measures have been taken to assure that the containment system does not leak.

2.4 IAEA ST-1 Requirements for fissile material packages being considered for adoption in to Part 71

The International Atomic Energy Agency (IAEA) first published a set of Regulations for the Safe Transport of Radioactive Material in 1961. These requirements are referred to as Safety Series 6 (SS-6). It was recommended to the IAEA Member States that those regulations be adopted as their own regulations for international compatibility. The United States has considered and adopted SS-6 revisions into Part 71 for international compatibility. There have been 5 subsequent revisions to the original IAEA SS-6 requirements. The latest revision is referred to as ST-1 and was approved by the IAEA Board of Governors in 1996. These regulations are being considered for adoption in the Part 71 rulemaking effort currently underway.

2.4.1 Paragraph 677 of IAEA ST-1

Paragraph 677 of ST-1 allows a single package to be assessed in the absence of water (moderator) even as a result of error if the design incorporates special features to prevent the leakage of water into or out of package void spaces. Paragraph 677 continues in defining *"special features" as multiple high standard water barriers*, each of which would remain water tight if the package were subjected to Normal and Accident Condition testing, and if there is a high degree of quality control in the manufacture, maintenance and repair of packages, and tests to demonstrate the closure of each package before each shipment. This is very much the same as our current Section 71.55(c).

However, ST-1 takes a step further in Paragraph 677 by defining "special features" for packages containing uranium hexafluoride only. It defines the special features as "no physical contact between the valve and any other component of the packaging other than its original point of attachment after the Normal and Accident Condition testing. And following the thermal testing, the valve**s** (seems to be plural for the sake of grammar) must remain leaktight; and there must be a high degree of quality control in the manufacture, maintenance, and repair of packagings coupled with tests to demonstrate closure of each package before each shipment."

The design feature requirement of multiple high standard water barriers has been removed for UF6 packages only.

The ST-1 requirement that the valve not contact any other component of the packaging seems imperative and obvious from the American perspective. This specification not only doesn't add anything to the safety argument, it detracts from it. This type of requirement is not explicitly stated in Part 71. But in assessing the structural effectiveness of the packaging under normal and accident conditions of transport, a bent valve would be unacceptable.

2.4.2 The Regulatory Burden Reduction

The requirement in Section 71.55(c) for a backup to prevent moderator ingress in the event of a single packaging error is required in addition to a structurally sound valve, which is not in danger of unseating, or causing leaks due to structural damage. Again, the design feature requirement has been removed for UF6 packages only, and if adopted would be an unsupported regulatory burden reduction.

2.4.3 Domestic Implications of Paragraph 677 of IAEA ST-1

Here in the US, we already require that the valve retain integrity under normal and accident conditions of transport. For us, the special design feature requirement may be in the realm of our design philosophy of defense-in-depth or it may be required as a minimum for technical safety. Without a study which determines the scenarios leading to a containment/moderator exclusion boundary breach, and the associated uncertainties and comparison to a Transportation Safety Goal, we do not have the justification for this burden reduction. The IAEA increased the regulatory burden by requiring the multiple high standard water barriers for moderator exclusion packages in Safety Series 6. We in the US have had the special design feature requirement for years. Serious consideration should be given to the removal of this requirement.

The valve is part of the containment/moderator exclusion boundary, and can be considered the weakest link in this barrier. It is important to note that in Paragraph 677 they have specified what special features are for a UF6 package. One conclusion that could be drawn from Paragraph 677 is that the overpack is not sufficient to meet the intent of a special feature to prevent the leakage of water into or out of the package if the valve leaks.

Another conclusion may be that the IAEA objective was to purge the intent the earlier requirements, i.e., the backup in case of error, just for UF6 packages requiring moderator exclusion. If this was the intent, it was done in an unexpected format, and with no supporting technical argument of why a UF6 moderator exclusion package was chosen and the integrity of its moderator exclusion barrier to be less of a risk than other moderator exclusion packages. This does not seem to be the intent of the revision, but it is a consequence. UF6 packages relying on moderator exclusion for the prevention of inadvertent criticality are not required to have the same level of defense-in-depth as fissile material packages which do not rely on moderator exclusion for criticality safety, or non-UF6 packages.

IAEA has specified and adopted this regulation which will be used to regulate foreign national and international transportation of enriched fissile material relying on moderator exclusion to prevent inadvertent, uncontrolled criticality. It is being considered for adoption into 10 CFR 71.

2.5 Safety Margin

The integrity of the containment/moderator exclusion boundary has been demonstrated by the applicant and current certificate holders through testing with the overpack in place under normal and accident conditions of transport. The cylinder has not been shown to perform its containment function under the hypothetical accident conditions without the overpack.

The "special feature" definition for UF6 packages only in ST-1 does not account for packaging errors, but for valve failure due to normal or accident conditions of transport. This definition of "special features" is a relaxation of requirements in American regulations and should be accompanied by technical support.

It does not make sense that a fissile moderator exclusion package, either Type A or Type B, should have less stringent requirements than packages without inadvertent criticality concerns, but with contamination concerns, such as a Type A package.

It does not make sense that a fissile moderator exclusion package, either Type A or Type B, should have less stringent requirements than packages without inadvertent criticality concern, but with release concerns, such a Type B packages.

The leakage that would occur from a failed valve in a UF6 package under transportation without moderator availability, or if breathing cycles could be terminated, would be HF gas, which if inhaled can have fatal consequences. This falls under the Hazardous Materials jurisdiction of DOT. Solid radioactive contents may indeed be held by the overpack, though it is not designed to retain any leakage, and there is no justification that the overpack would retain leakage if the valve were to fail.

To meet our mandate, material that is released that has uptake consequences should not be released under normal or accident conditions of transport. So a Type A fissile package must survive under accident conditions, and since the package contains a valve as part of the containment/moderator exclusion boundary, then it is valuable to require an enclosure not just to retain leakage from the valve in case of valve failure, but to prevent moderator intrusion in case of valve failure.

Explicitly, the criticality safety of Type A(F) packages is based on moderator exclusion and may rely on the presence of the valve enclosure to prevent inadvertent criticality under any condition, normal (in the event of error) or accident. The valve enclosure must prevent inleakage should the valve fail and moderator be present in an uncontrollable sufficient quantity. Should a sufficient quantity of moderator intrude through the valve under normal or accident conditions, the ensuing criticality creates fission products which could disperse greater than an A2 (U-235 A2 is unlimited, but fission products will have A2's that are not unlimited), of radioactive material, in which case the concern is radiation levels and release, and contamination, not to mention the public confidence, political, and economic consequences.

As such, the valve enclosure required to satisfy 71.43(e) must be a substantial one (not an overpack which has not been justified as a barrier), and could count as a special design feature of 71.55(c) to prevent the in leakage of moderator for packages relying on moderator exclusion to prevent inadvertent criticality and the release of radionuclides that don't have unlimited A2 values. The removal of this requirement through the burden reduction of Paragraph 677 of IAEA ST-1 has not been demonstrated to assure public health and safety.

In assessing the safety of a package, the package is measured against not only the regulations, but also by asking, "Is this package safe?" If the regulations have been written with moderator exclusion packages in mind, then the safety of these packages most likely can be determined solely on the basis of meeting the regulations. However if, when considering if the issues that impact safety for this package have been adequately addressed in the regulations (such as ST-1), the answer is no, or unknown as it is in this case, then the question, "Is this package safe?" must be investigated, and appropriate action taken. The staff must be assured that the shipment of these packages will not endanger life, property, or the common defense and security.

A study should be conducted which examines the scenarios leading to an undesirable event, including a failure of the containment/moderator exclusion boundary which could lead to criticality, the likelihood of such scenarios occurring, and the consequences of such scenarios. The chemical and nuclear reaction potentials must be fully understood. The resulting risks and uncertainties of such an investigation would be measured against a transportation safety goal.

The Safety Goal has been suggested in different forms - as a single number, and as a range. In either case, the resulting risks associated with the failure of the containment/moderator exclusion barrier must indicate that shipment of UF6 packages will not endanger life, property, or the common defense and security, that the risk falls within acceptable limits.

The Commission is moving toward risk-informed regulations. The Probabilistic Risk Assessment (PRA) Policy Statement (60 FR 42622, August 16,1995) states that, "The use of PRA technology should be increased in all regulatory matters to the extent supported by the state of the art in PRA methods and data, and in a matter that complements the NRC's deterministic approach and supports the NRC's traditional defense-in-depth philosophy." The Principles of Good Regulation require that regulatory activities be consistent with the degree of risk reduction they achieve. The risk associated with UF6 packages is uncertain.

2.6 No Immediate Safety Concern

There have been no UF6 criticality accidents since the DOT requirement for radioactive material incidents reports began in the early 70s. This history, coupled with the Type B testing of all uranium hexafluoride fissile packages, with the acceptance criteria of leaktight-ness afterward, provides a piece of the argument for the conclusion that there is no immediate safety concern. However, a complete safety argument for the adoption of Para. 677 has not been adequately supported.

2.7 Technical Support for Relaxed UF6 requirements in ST-1

Since the technical support for the IAEA ST-1 burden reduction seems to be without technical documentation, the adoption of IAEA ST-1 UF6 regulations first requires the assumption that the existing Part 71 regulations are over-burdensome, and the technical support for a burden reduction argument must be reviewed before adoption of those regulations into our own. Restated, the safety argument for the elimination of the "double containment" (recalling that does not necessarily mean full double containment) criteria and the adoption of the "valve" criterion (ST-1 Para. 677) must be reviewed. The valve criterion may be sufficient, but should be adopted based on technical merit. There is no risk study which sufficiently evaluates the criticality scenarios. The final discussion should certainly account for economic burden to the package providers and the nuclear industry, and consider how to ship safely without providing an unfair advantage to foreign commerce. But support for long-term continued shipment must include a technical safety argument to ship without endangering life or property (endangerment defined by risks below the established safety goal).

A report by Newvahner and Pryor, presented at the Second International Conference on Uranium Hexafluoride Handling, October 29-31, 1991, includes the estimate that a 2 ½ ton cylinder (30B) with 5% enriched UF6 would need 6 gallons of water for criticality when

analyzed with KENO calculations in a sphere geometry. The requirement is 57.5 gallons when modeled with slab geometry. UF6 is required to be shipped as a solid and fills the cylinder to 61% or 62% by volume to allow for the large increase in volume when the material changes phase to a liquid. An empty volume is available to be occupied by water that may enter the cylinder. The authors indicated that depending on the scenario, the cylinder may undergo "breathing" cycles. But if a breached cylinder were sprayed with an inch and a half firehose at a 100 gal/min flowrate over a 5 square foot area, the "safe-time" for emergency control could be relatively short, as little as 1 minute for a 10-ton or a 2 ½ ton cylinder. Certainly that is an extreme, and emergency procedures should preclude the use of moderators around moderator-controlled UF6 cylinders, or any moderator exclusion package. However, if the breach were to occur, and moderator were available in an uncontrollable manner, it is clear that a criticality incident could occur over some period of time.

I have not found a document that assesses the scenarios that may lead to criticality. The criticality assessments that I have seen seem to conflict - large volumes of water/small volumes of water required for criticality; UO2F2 is very soluble, or is a plug which will prevent the ingress of further moderator into a cylinder breach. The risk study that I have seen focuses on the release aspect without significant mention of the criticality aspect. A study which includes a literature review, and assesses the scenarios leading to a criticality incident among the undesirable events would be appropriate. The intertwined chemical and nuclear nature of UF6 packaged in 30B cylinders with overpacks must be investigated. The fact that these cylinders are used for processing, transportation and storage should be included in the investigation.

Without quantifying the risk and estimating the uncertainty and comparing to a safety goal, it is unclear how to best protect the public health and safety and the environment from a UF6 criticality incident, or to know how much of a concern it should be, and what the resulting defense-in-depth and design requirements should be for a moderator exclusion package. A technically unjustified regulatory burden reduction of criticality safety regulations should not be allowed. The consequences of such an action could be loss of life, environmental harm, and political and economic repercussions.