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DEVELOPING THE HISTORICAL TECHNICAL BASIS FOR THE MATERIAL AND PACKAGE CLASSIFICATION AND THE PACKAGE TEST REQUIREMENTS OF THE | INTERNATIONAL TRANSPORT SAFETY REGULATIONS

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ABSTRACT

In a companion PATRAM 2013 paper, C. Bajwa, et. al. provides an overview of international-level efforts that began in 2010 to develop a comprehensive and detailed technical basis document (TecBasDoc) to support the current IAEA Transport Regulations (SSR-6, 2012) and future revisions thereto. The draft TecBasDoc that has so far resulted from efforts by a large number of IAEA staff and international experts exceeds 300 pages in length using, to the greatest extent possible, historical documents dating as far back as the 1950s as reference material. The intent is to capture, for those Member States new to transport and for future generations, the scientific and technical heritage of the several decades of development that has occurred in transport safety, preserving this knowledge for future reference. The latest effort, in December 2012, involved consultants to the IAEA adapting the draft to reflect guidance from the IAEA's Transport Safety Standards Committee (TRANSSC) and delving into the IAEA's archives searching out many long-sought, older supporting documents. This paper will elaborate on Chapters 8, 9 and 10 of the TecBasDoc, dealing with, respectively:

- Classification of Materials,
- Classification of Packages, and
- Package Design and Testing.

Chapter 8 elaborates on the many decisions resulting in an initial nine material classifications, which focused more on the physical and not the radioactive characteristics of the materials; to the current, significantly different classifications that focus more on the material's radioactive properties. Chapters 9 and 10 combine to provide extensive, detailed elaboration on why decisions were made concerning the various package classifications and the associated design, testing and acceptance requirements associated with each package type. Chapter 10 cites two extensive supporting appendixes. These three chapters and two appendixes currently cite more than 200 historical documents. Efforts are underway to make this extensive document base more complete and to make as many documents as possible available electronically. In this paper each of these three drafted chapters and the two supportive appendixes will be overviewed, providing insight into key and typical findings that have been uncovered and incorporated into the draft

document. The many experts who have contributed to the current draft are appropriately acknowledged.

INTRODUCTION

The International Atomic Energy Agency (IAEA) began issuing Regulations for the Safe Transport of Radioactive Material in 1961 [1]. The latest edition of the Regulations was issued in 2012 [2]. Altogether, 15 different editions, revisions, amendments or supplements have been issued over a period of more than six decades, taking into account the world-wide experiences, new issues, new technologies, best practices, lessons-learned from their application, the demand for safer transport, and the need for harmonization. Problems, challenges and the demand for improvements drive the transport community to continuously review and revise the Regulations.

In the early part of the second decade of the Twenty-first Century, TRANSSC recognized that the scientific and technical heritage of these past several decades of development in transport safety needs to be assessed with a view to preserving the valuable knowledge involved in this extensive, long-term effort. In a companion paper presented at PATRAM 2013 [3], the scope of an effort undertaken by the IAEA with the assistance of a large group of experts from around the world is summarized, and the contents of part of the current draft Technical Basis Document (TecBasDoc) were summarized. In that paper, four of the TecBasDoc chapters were not discussed in detail.

This Paper provides an overview of three of the four chapters not addressed in Reference [3], namely

- Chapter 8 – Classification of Materials,
- Chapter 9 – Classification of Package, and
- Chapter 10 – Package Design and Testing;

and also provides an overview of two major appendixes that support Chapter 10, i.e.

- Appendix 3 – The technical basis for applying the graded approach, and
- Appendix 4 – Follow-on studies into the adequacy of the accident conditions of transport.

In another companion paper, Mennerdahl [4] provides a similar overview of Chapter 11, which deals with the technical basis for nuclear criticality safety.

Chapter 12, Approval and Statutory Requirements is not yet drafted.

As is noted in Reference [3], the international-level efforts in developing the TecBasDoc began in 2010 with a view to recording, for those Member States new to transport and for future generations, the scientific and technical heritage of several decades of development that has occurred in transport safety; and to capturing valuable knowledge so it can be preserved for future reference. This effort has involved consultants to the IAEA developing a very detailed draft technical basis document, while concurrently implementing guidance from the IAEA's Transport Safety Standards Committee (TRANSSC) by delving into the IAEA's archives and other sources of historical documents, searching out many long-sought, older supporting documents.

Furthermore, while "*the TecBasDoc has not been completed and the references have not yet been fully sorted and reviewed, a significant portion of the work on this document has been completed. During the remainder of the calendar year, plans are to finalize the document as far as possible and to then make it available to the members of TRANSSC for their review and comment. The document may never see formal publication, but may – instead – be updated periodically, as* *needed, and made available, in its most current form, to the transport community via the internet. In addition, ... to the extent possible the large array of documents that have been and continue to be captured will be made available electronically via the internet*." [3]

NOMENCLATURE

CS	Consultants Services
IAEA	International Atomic Energy Agency
IP	Industrial Package
LDRM	Low Dispersible Radioactive Material
LSA	Low Specific Activity
SCO	Surface Contaminated Object
TecBasDoc	Technical Basis Document
TRANSSC	Transport Safety Standards Committee
UF_6	Uranium Hexafluoride

BACKGROUND

As elaborated in Reference [3], the effort to develop the TecBasDoc began with two technical meetings convened in October 2010 and March 2011, where the focus was on identifying the underlying technical bases for some of the essential safety requirements for transport. Efforts were undertaken to collect historical documents, to correlate between those documents and the essential safety requirements, tracing the history in as much detail as possible with a view to clarifying the technical bases of each transport safety requirement.

A working draft of what will eventually become the TecBasDoc was prepared by a consultant services (CS) meeting in March 2012. A survey at this meeting showed that more than 300 years of personal involvement in the development and application of the Transport Regulations was represented by those in attendance. Following that meeting, extensive efforts by IAEA staff and by consultants to the IAEA were undertaken, which has resulted in further extensive development of the TecBasDoc. A draft of the document was provided to a working group at the TRANSSC 25 meeting in October 2012, which in turn provided guidance back to IAEA staff on the future development of the TecBasDoc.

A CS meeting was then held in December 2012, to incorporate the TRANSSC working group recommendations and to further edit and refine the draft of the TecBasDoc. Part of the December 2012 effort also involved searching the IAEA archives for supporting historical documentation. Documents pertaining to transport safety were reviewed, and copies of relevant documents were obtained, scanned, and are being incorporated into an electronic database of references for the TecBasDoc. Proceedings from relevant technical conferences and journals are also being reviewed and relevant papers are being incorporated as supplemental references for the TecBasDoc.

The following sections provide overviews of the three chapters and two appendixes that are the topic of this paper as noted in the introduction.

OVERVIEW OF CHAPTER 8 OF THE TECHNICAL BASIS DOCUMENT – CLASSIFICATION OF MATERIALS

The classification of materials has significantly changed and matured since the first edition of the Transport Regulations [1]. For example, in the early editions of the Regulations (i.e. the 1961, 1964 and 1967 editions) the individual radionuclides were classified into groups based on radioactivity as well as classifications based on physical properties. Between that time period and the issuing of the 2009 edition of the Regulations, the terms "classify" and "classification" were not used significantly in the Regulations, but the materials were still ordered according to radioactivity and physical properties. However, with the 2009 edition [5], and now with the 2012 edition of the Regulations [2], classification was imposed in detail according to specific physical characteristics of the radioactive material.

Chapter 8 provides a summary of how the concept of classification of materials evolved through the various editions of the transport regulations; it illustrates how these classifications changed, and provides some insight into why the changes were made.

Classification in the 1961 Edition of the Regulations

The first edition classified the materials in the following manner:

- Group I – very high radioactivity
- Group II – high radioactivity
- Group III – moderate radioactivity
- Large radioactive sources
- Non-friable massive solids that are non-soluble in water and non-reactive with air or water
- Pyrophoric radioactive material
- Explosive radioactive material
- Radioactive materials of low specific activity
- Fissile materials

From the radiological perspective, each radionuclide was assigned a group (i.e. Group I, II or III), where the quantity allowed in a package was limited except, if that quantity was exceeded, then it was to be treated as a "large radioactive source". These materials were required to be transported in Type B packages, the design of which was to be approved by the competent authority of the country in which the shipment originated.

From the physical characteristics perspective, for example:

- small quantities of the non-friable solids could be transported in Type A packages; however if a specified activity limit was exceeded, they were required to be transported in Type B packages;
- pyrophoric radioactive materials were required to be transported in Type B packages; and
- explosive radioactive materials were only permitted to be transported under special arrangements.

In addition, characteristics of materials with low specific activity were specified.

Classification in the 2009 and 2012 Editions of the Regulations

Chapter 8 of the TecBasDoc elaborates extensively on the classification of materials changes that occurred after the initial editions of the Regulations were issued. This includes the development in the 1985 edition of the Regulations of the detailed low specific activity (LSA) and surface contaminated object (SCO) classifications that led to applying a graded approach to these materials (LSA-I, LSA-II and LSA-III) and objects (SCO-I and SCO-II), and to the manner in which they are to be packaged (i.e. Industrial Packages IP-1, IP-2 and IP-3).

It also addresses the specific classification of uranium hexafluoride (UF_6) in the 1996 edition of the Regulations, requiring specific UF_6 packaging and package design approval requirements; and at the same time addresses the introduction of the low dispersible radioactive material (LDRM) concept that is tied to whether a Type B package can be used for air transport of some materials or whether those materials must be transported in Type C packages.

The changes in classification were extended and so denoted in the 2009 edition of the Regulations [5], where significant emphasis was placed on the classification of material. Specifically, the title of Section IV of the Regulations was changed from "ACTIVITY LIMITS AND MATERIAL RESTRICTIONS" to read "ACTIVITY LIMITS AND CLASSIFICATION". Paras 408 through 419 of the 2009 edition and paras 408 through 420 of the 2012 edition of the Regulations elaborate the requirements for (a) LSA material, (b) SCO, (c) special form radioactive material, (d) LDRM, (e) fissile material, and (f) UF6. The change, with the enhanced emphasis on classification, was introduced to clarify that materials (and also packages, as is discussed in Chapter 9 of the TecBasDoc) are classified according to the above for radiation protection purposes and clarity in application of the Regulations. As a result, this then led to the re-assignment of UN Numbers according to the classification of material and sometimes package used.

OVERVIEW OF CHAPTER 9 OF THE TECHNICAL BASIS DOCUMENT – CLASSIFICATION OF PACKAGES

Chapter 9 traces a similar trend in terms of the designation of package types used in the Regulations. Initially, in the first editions of the Regulations, five basic types of packages were specified. The specifications for the packages, which were graded according to the risk posed by the contents, were:

(a) Exempt and Empty Packages: packages that were exempt from requirements, containing small quantities of radioactive material and having a minimal set of package design requirements;

(b) Strong, leak-proof packages: packages for materials that were judged to be "inherently safe", e.g. low specific activity materials such as radioactive ores, where the regulations provided for their carriage in "bulk or in strong, leak-proof packages";

(c) Type A packages: containing larger, but limited, quantities of radioactive material while being designed to be resistant to normal conditions of transport;

(d) Type B packages: containing larger quantities of radioactive material while being resistant to both normal and accident conditions; and

(e) Large radioactive source packages: containing large radioactive sources, where the activity exceeded the limits for Type B packages, and where additional requirements were imposed on materials compatibility, containment system pressure and pressure relief systems, protection of valves, and proper design of attachments and tiedowns [1].

The chapter includes a table (presented here as Table 1) that depicts how the designation of package types varied by edition of the Regulations.

Table 1. Summary of number of package types by edition of the Transport Regulations

Package Type	Edition of the Transport Regulations					
	1961	1964	1967	1973	1985	1996 and beyond
Exempt Package / Empty Package	X	X	X	X		
Excepted Package / Empty Package					X	X
Strong, leak-proof package	X					
Strong industrial package		X	X	X		
Industrial Package Type 1 (IP-1)					X	X
Industrial Package Type 2 (IP-2)					X	X
Industrial Package Type 3 (IP-3)					X	X
Type A	X	X	X	X	X	X
Type B	X	X	X			
Large radioactive source packages	X	X	X			
Type B(U)				X	X	X
Type B(M)				X	X	X
Type C						X

* Note: This table does not include the specific package requirements that address unique characteristics of fissile material and/or uranium hexafluoride. The specific package requirements for fissile material result in designating the package aprovals as Type IF, Type AF, Type B(U)F, Type B(M)F, and Type CF. The requirements for these are discussed in Chapter 11 of the TecBasDoc. The specific package requirements for fissile uranium hexafluoride result in designating the package approvals as H(M) and H(U).

Table 1 illustrates that, in the 1985 edition of the Regulations, the number of package types had grown to seven (which included the transition from "strong, leak-proof package" in the first edition, to "strong industrial package" in the 1964 – 1973 editions, and to the elimination of "strong industrial package" in the 1985 edition; with that designation being replaced by Industrial Packages IP-1, IP-2 and IP-3.

Since the publication of the 1996 edition, there have been eight different package types classified in the Regulations, which came about with the addition in 1996 of the designation of the Type C package type.

Also, it is noteworthy, as can be seen in the footnote to Table 1, the classification by package type shown here does not include the specific package requirements that address fissile material and uranium hexafluoride. The types of approvals for fissile material are Type IF, Type AF, Type B(U)F, Type B(M)F, and Type CF. The requirements for these fissile material package are discussed in Chapter 11 of the TecBasDoc. Similarly, the types of approvals for uranium hexafluoride are H(M) and H(U); where the requirements for those approvals are elaborated in Chapter 10 of the TecBasDoc. Thus, the number of types of package approvals can exceed the number of package types.

The rationale for these changes in classification and approval has been partially researched and documented, but further efforts looking at the historical documents is still needed.

OVERVIEW OF CHAPTER 10 OF THE TECHNICAL BASIS DOCUMENT – PACKAGE DESIGN AND TESTING

Currently, the largest portion of the draft TecBasDoc consists of Chapter 10 combined with its two supportive appendixes. Chapter 11 is also quite large, but its supporting appendix has not yet been completed.

Chapter 10 provides insights into the technical bases for the package design and testing requirements that are embodied in the Regulations. A significant amount of supporting historical documentation has been identified, much of which has already been incorporated into Chapter 10 and Appendixes 3 and 4 on the technical bases for establishing the requirements and also for later justifying their continued use.

Chapter 10 specifically looks at and provides, where possible, the historical background, rationales, and insights into the development of each requirement ranging from the minimal set for routine conditions of transport that are applied to excepted packages, to the much more robust set of tests simulating normal and accident conditions of transport that are associated with Type B packages. It concludes by considering the historical basis for the even more demanding requirements that are imposed on Type C packages, some of which are also imposed on fissile material packages; and then looks at the bases for the design and test requirements imposed on UF_6 packages.

The chapter emphasizes that the package design and testing requirements follow the graded approach, which is discussed in detail in Appendix 3. It is currently structured as follows:

- 10.1. Technical basis for routine conditions of transport for packages
- 10.2. Technical basis for the target for mechanical testing of packages
- 10.3. Technical basis for normal conditions of transport package tests
- 10.4. Technical basis for accident conditions of transport package tests
- 10.5. Technical basis for industrial packages IP-1, IP-2 and IP-3
- 10.6. Technical basis for Type C package tests
- 10.7. Technical basis for uranium hexafluoride (UF_6) package tests

The insights that have been developed into the history behind each of the accident test requirements are significant and enlightening. Four examples of the findings and insight are summarized in the following.

Packages to be Recoverable after an Accident

One concept that was emphasized from the beginning, and is stressed in the development of the historical bases, deals with a Type B package that has been involved in an accident. For this situation, Fairbairn and George [6] noted the concept was (and, it is noted, still is) that:

> "*…Type B packaging must be capable of withstanding the accident to an extent that safe recovery of such packages was feasible within overall emergency plans and procedures. It was never conceived that after such recovery the packaging should be suitable for re-use; in other words, Type B packaging was never required to withstand a succession of so-called 'maximum credible accidents'."* [emphasis with underlining added]

Elimination of the Maximum Credible Accident Concept

It is noteworthy that the first edition of the Regulations imposed the requirement that Type B packages must adequately survive *"the most severe accident which is considered credible for the mode of transport involved"*.

This concept of specifying a *'maximum credible accident'* for Type B packages became a significant driver for modifying package design requirements in the second edition (i.e. the 1964 edition) of the Transport Regulations. Discussions on this issue are elaborated in Chapter 2 of the TecBasDoc, but are also critical to understanding all of the test principles addressed in Chapter 10. Specifically, Messenger and Fairbairn [7] noted that:

> *"The requirement for the packaging to be able to withstand the 'maximum credible accident' is novel in the transport field; it has not been applied as a mandatory requirement to the carriage of non-radioactive dangerous goods, some of which, for example, cyanides, may be far more hazardous than many radioactive materials".* [emphasis with underlining added]

At that time, Appleton and Servant [8] stated that:

> *"The conditions defined are somewhat vague and the concept of the maximum credible accident appeared particularly objectionable and so unpracticable that it was discarded. On the basis of experience and work done in the interim period in Member States a major effort was made during the recent revision of the Agency transport regulations to make such conditions more objective in terms of testing procedures".* [emphasis with underlining added]

Sequencing of Tests

Another concept that has withstood the test of time is the sequencing of accident-simulating tests. The deliberations leading to transitioning from the maximum credible accident requirement in the first edition of the Regulations to the series of test requirements in the 1964 Edition of the Regulations considered multiple inputs [e.g. 6, 7]. These deliberations looked at environments that could be expected in transport accident by land, sea and air. This "*led to the decision by the Packaging Panel to simulate the damaging effects of transport accidents by the combining of the mechanical and thermal tests as resulted in being specified in the 1964 Edition of the Regulations*". [emphasis with underlining added]

Thus, as early as 1964, the concept of sequencing of the mechanical tests followed by the thermal test was deliberated and agreed. For example, on page 28 of Ref. [9] it reads that "*it was emphasized that the introduction should make it quite clear that the sample package should be subjected consecutively to the mechanical and thermal test, and in that order*". [emphasis with underlining added]

Depth used for Water Immersion Test

Frequently, an apocryphal statement has been made that the depth of 15 m that specified in the water immersion test for Type B packages was determined based on the depth of the Bay of Naples; yet most people have then argued that the Bay of Naples was deeper than 15 m. The recent search through the IAEA archives resulted in finding the report of the second technical meeting [10] leading to the text in the 1964 edition of the Regulations. In that meeting report it was noted that Fairbairn had initially suggested a 50 m depth (as a holding point for further discussion). The report then noted the following:

> *"The U.K. has carried out the review and it was found that 15 m was a more appropriate figure for the depth of water at quays and wharves at which packages of radioactive materials could be dropped during loading or unloading. (It was subsequently learned that the 50 m was a figure in respect of an offshore loading anchorage in Naples Bay where a special radioactive material consignment was loaded). There was considerable discussion and it was thought that the type B tests were adequate to ensure that the containment vessel would withstand the 50 m depth without referring to that figure.*
>
> *"It was eventually agreed however to keep the requirement but to reduce the depth to 15 m."* [emphasis with underlining added]

Fairbairn and George [6] elaborated further on the test as follows:

> "*For practical purposes the depth of water in harbours, rivers and canals in which packages might be dropped is unlikely to exceed 50 ft; recovery up to such a depth is most probable.*" They then noted that "*As with Type A packaging, the Agency's revised regulations specify certain packaging design requirements not covered by test procedures, for example that the containment vessel must remain intact at a depth of 15 m in water*" (i.e. 50 ft of water). [emphasis with underlining added]

Thus, peripherally, the discussion concerning the depth for the water immersion test included consideration of the depth of Naples Bay, but the 15 m depth does not, in fact, represent the maximum depth of that bay.

OVERVIEW OF APPENDIX 3 OF THE TECHNICAL BASIS DOCUMENT – THE TECHNICAL BASIS OF THE SAFETY APPROACH

This appendix expands at great length on how the graded approach concept has been applied to

- packaging contents activity limits,
- types of package designs and the tests required of each type,
- package performance acceptance standards, and
- package design approval.

For example, the section in Appendix 3 dealing with the package test requirements and their associated acceptance parameters contains a table (presented here as Table 2) that depicts how these requirements and parameters are dealt with using the graded approach.

Associated with that table, the TecBasDoc provides historical insights from a significant number of individuals involved in the early development of the regulatory requirements, including Messrs Fairbairn, Aikens, Macdonald, Goldfinch, Swindell, Aspinall, Gibson, Morley, and

George; many of whom are no longer with us, but have left their legacy in the printed word that is being captured as part of the TecBasDoc effort.

Table A.2. The Graded Approach to Package Test Acceptance Parameters.

Package Type*	Test Requirements	Acceptance Parameter		Relevant SSR-6 paragraphs
		Containment	Shielding	
Excepted	None	None	None	622
Industrial Type IP-1	None	None	None	623
Industrial Type IP-2	Normal Condition free drop and stacking tests	No loss or dispersal of radioactive contents	No more than 20% increase in the maximum radiation level at any external surface of the package	623, 722, 723
Industrial Type IP-3	All Normal Condition tests			624, 648, 719-724
Type A				635, 648, 719-724
Type B(U) and Type B(M)	All Normal Condition tests	Restrict loss of contents to not more than 10^{-6} A_2/h	No more than 20% increase in the maximum radiation level at any external surface of the package	652, 659, 719-724
	All Accident Condition tests**	Restrict loss of contents to not more than A_2 in one week	Radiation level 1m from package surface does not exceed 10 mSv/h	659, 726-729
Type C	All Normal Condition tests	Restrict loss of contents to not more than 10^{-6} A_2/h	Not specified	669, 671(a), 719-724
	Enhanced Accident Condition Tests for Air Transport***	Restrict loss of contents to not more than A_2 in one week	Radiation level 1m from package surface does not exceed 10 mSv/h	669, 671(b), 734-737

* Packages containing UF_6 (which are not elaborated upon in this appendix) must satisfy specific requirements which pertain to the radioactive and fissile properties of the material, and generally must also withstand (a) without leakage or unacceptable stress, a hydraulic pressure test (para. 718 of SSR-6); (b) without loss or dispersal of the UF_6, the normal condition free drop test (para. 722 of SSR-6), and (c) without rupture, the accident condition thermal test (para. 728 of SSR-6).

** Further grading results within the accident condition tests. For example, if a package contains more than 10^5 A_2 of radioactive material, it is required to withstand, without rupture, exposure to an enhanced water immersion test (paras 660 and 730 of SSR-6).

*** The enhanced accident condition tests for air transport include (a) a burial test (para. 670 of SSR-1), (b) a puncture-tearing test (para. 735 of SSR-1), (c) an enhanced thermal test extending exposure from 30 to 60 minutes (para. 736 of SSR-1), and (d) an enhanced impact test with impact velocity of 90 m/s (para. 737 of SSR-1).

OVERVIEW OF APPENDIX 4 OF THE TECHNICAL BASIS DOCUMENT – FOLLOW-ON STUDIES INTO THE ADEQUACY OF THE ACCIDENT CONDITIONS OF TRANSPORT

Appendix 4 is quite extensive, and is growing rapidly as more reference sources are being identified and incorporated therein. The appendix, which considers documentation of studies from the mid-1970s onward, currently covers the following topics:

- Follow-on studies into the adequacy of the accident conditions of transport
- Follow-on studies into the adequacy of the 9 m drop accident test scenario
- Follow-on studies into the adequacy of the1 m puncture probe accident test scenario
- Follow-on studies into the adequacy of the dynamic crush accident test scenario
- Follow-on studies into the adequacy of the accident-simulating thermal test
- Follow-on studies into the adequacy of the enhanced 200 m water immersion test

Suffice it to say that the 40 references cited and discussed so far in this appendix lend a great deal of credence to the adequacy of the current test requirements; and there are yet many references to be cited and discussed.

HISTORICAL REFERENCES

As is discussed in the companion paper [3], the collecting of historical references has been one of the challenging aspects of the TecBasDoc effort. To enhance the collection of historical references, the IAEA archives have been accessed to find early documents that might shed some light on some of the decisions made in the early editions of the regulations. The search continues for documents related to the topics addressed in Chapters 8, 9, and 10; and the effort to properly incorporate them into the document also continues.

It is clear that some key documents are still missing. For example, documents relating specifically to the decisions on LSA materials, SCOs, Industrial Packages, and UF_6 test requirements are needed. Anyone having access to additional materials on these topics could assist the Agency in fleshing out those sections of the TecBasDoc by providing them to the IAEA Transport Safety Unit.

CONCLUSIONS

The TecBasDoc efforts in the areas of classification of materials, classification of packages, and package design and testing are well along, but much work has yet to be accomplished. These chapters will go a long way toward comprehensively defining why the provisions in the Regulations in these areas were established, and with the expected growth of Appendix 4, will further establish the adequacy of these provisions.

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