The IAEA Transport Regulations: A Review of Their Development and Coverage

by A. Fairbairn

The twentieth century has seen an increasing use of products of the nuclear industry in medical and engineering fields, scientific research and for the generation of electricity. Such uses require effective transport arrangements for the varied radioactive and fissile materials involved.

Throughout its development the nuclear industry has recognized that transport arrangements must be such as to ensure safety of persons, property and the environment. Accordingly, controls have been developed by organizations involved in the various modes of transport. Prior to 1959, the various national and international controls were, in the main, based on the United States Interstate Commerce Commission regulations which essentially aimed to facilitate the movement of radioactive ores and concentrates and packages containing relatively small amounts of radionuclides for medical and industrial use. The rapid expansion of the nuclear industry then foreseen required that these early regulations be further developed so as to facilitate the safe movement of all kinds and quantities of radioactive materials.

DEVELOPMENT OF THE IAEA REGULATIONS

In July 1959, the United Nations Economic and Social Council expressed the desire "that the Agency be entrusted with the drafting of recommendations on the transport of radioactive substances". The IAEA Regulations for the Safe Transport of Radioactive Materials were first published in 1961 Ref.[1]. In approving these regulations, the Board of Governors of the Agency authorized the Director General to promulgate them as a component of the Agency's Safety Standards and to recommend to Member States and appropriate organizations that they may be used as a basis for national and international regulations.

In order to be acceptable for world-wide application in all modes of transport, the Agency recognized that for any radioactive and fissile material, its regulations must reduce the hazards to transport workers and the general public to an acceptably low level, i.e. be "safe". The following basic requirements must be met to achieve safety:

- effective control of radiation emitted from the material;
- effective containment of the material;
- adequate dissipation of any heat generated when radiation from the material is absorbed;

and, for any fissile material,

- a critical condition, i.e. "criticality" must not develop

Prior to his retirement, Mr Fairbairn was a staff member in the Safety and Reliability Directorate, UK Atomic Energy Authority, Risley, Warrington, UK.

The IAEA regulations, although applying to the Agency's own operations, are, for administrative purposes, "model regulations" recommended to Member States and appropriate international organizations. This means that to facilitate their conversion into the format and "language" used by the various modes of transport, the Agency's regulations must be practical concerning what the various parties involved, especially consigners and carriers, are required to do. Also, as is the practice for the transport of other dangerous goods, the regulations must be clear and concise, stating "what" has to be achieved rather than "why", and with examples of methods of compliance, i.e. "how", being given in any supporting document rather than in the regulatory document itself.

The procedure used by the Agency for the preparation of its regulations Ref.[2] is largely responsible for their extensive national and international application and has, in effect, removed from the area of debate whether a convention was necessary. The difficulty of keeping a convention up to date in the rapidly developing nuclear field was appreciated during the preparation of the 1961 regulations. While it was expected that the basic principles underlying the regulations would be acceptable, it was decided that a "feed-back" of experience in application should be facilitated by revision after some five years. This led to the first complete revision published in 1967 Ref.[3], a partial revision having been published in 1965 Ref.[4], and the second complete revision in 1973. These current regulations were recently published in 1979 as "1973 Revised Edition as Amended" Ref.[2]. For each of the 1961, 1967 and 1973 stages of regulatory development, the Agency's procedure essentially involved the convening of a panel, whose members represented not only an extensive coverage of Member States and international organizations concerned, but also experience of the various administrative and technical problems requiring solution. On the basis of proposals co-ordinated by the Secretariat, this panel prepared draft regulations for comment by all Member States and all international organizations concerned. Then, following panel consideration of such comments, a final draft was prepared for approval by the Agency's Board of Governors. While the 1961 and 1967 issues of the regulations represented the work of two or more independent panels, each covering specified areas, only one panel which met in February 1970 and October 1971, was responsible for the whole of the 1973 regulations. All panels benefitted from the work of consultants, especially regarding provisions for criticality control of fissile materials.

The current issue of the Agency's regulations Ref.[2] prescribes "what" must be achieved, some supplementary information giving guidance concerning "why" and "how" being given in a companion document Ref.[5]. Similar guidance relevant to the 1961 and 1967 regulations is to be found in Ref.[6] and in Refs.[7, 8] respectively.

BASIC CONCEPT/PRINCIPLES ADOPTED DURING THE DEVELOPMENT OF THE REGULATIONS

The two panels responsible for the 1961 regulations established certain basic principles which have been maintained during the two complete revisions leading to the 1973 regulations. These concern:

- regulations to prescribe "what" not "how";
- radioactivity threshold for application of the regulations;
- hazardous characteristics other than radioactivity;

- contributions by consigner (shipper) and carrier to safety;
- packaging/package prescriptions;
- competent authority approval;
- special arrangements.

Some comments on these may be helpful; more details are to be found in Ref.[9].

In prescribing "what" has to be achieved rather than "how", the regulations encourage packaging/package design effort, especially regarding the use of new materials and improved constructional techniques. Also the fact that the transport of any specific radioactive material is not prohibited results largely from this basic principle.

Many substances, including living tissue, contain minute amounts of naturally occurring radionuclides. The figure 0.002 μCi/g* used in various radiological protection controls is specified in the Agency's regulations as the level up to which any material is not regarded as radioactive for purposes of transport.

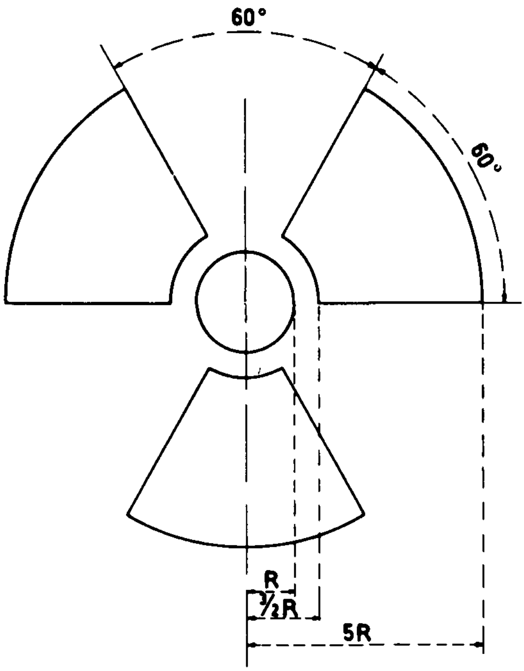

Figure 1.
The trefoil, symbol of ionizing radiation.

The trefoil symbol (Figure 1) alone is used on transport labels/placards to denote radioactive material. Should the material also be chemically explosive, this characteristic would considerably increase its potential radioactive hazard and is consequently taken into account in the Agency's regulations. Any other hazardous characteristic, e.g. flammability, is not taken into account as it is considered that it will be nullified by compliance with the relevant prescriptions in the regulations for carriage of other dangerous goods.

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* μCi = microcurie or millionth of a curie The curie is a measure of radioactivity and is defined as 3.7×10^{10} nuclear disintegrations per second.

Whatever the radioactive material, the regulations maximize the consigner's (shipper's) contribution to safety. This minimizes the carrier's contribution to that of following a few simple rules based on information on the package labels, e.g. for storage and segregation from persons and undeveloped photographic film. This major contribution by the consigner is achieved by compliance with packaging, package and full load prescriptions appropriate to the nature and quantity of radioactive material carried.

The concept of "certification of approval by competent authority" for movements within the higher range of potential hazard to transport workers and the general public requires scrutiny by legally appointed persons entirely independent of the consigner, carrier or consignee to ensure compliance with appropriate packaging/package/shipment prescriptions prior to transport. These prescriptions are divided into those which permit shipment following approval by the competent authority of the country of origin, i.e. unilateral approval, and others which require the prior approval of all competent authorities of the countries involved, i.e. multilateral approval. The latter includes any shipment made under "special arrangement". For such a shipment, approval is subject to compliance with precautions and controls specified to offset any deficiencies in compliance with the relevant regulatory prescriptions.

CONTROL OF RADIATION EMITTED FROM RADIOACTIVE MATERIAL

The safe transport of radioactive materials requires compliance with radiological protection procedures comprising those that require containment, being designed to prevent or limit human intake with consequent "internal" irradiation and those designed to control any radiation emerging from the consignment which has not been absorbed or shielded by the packaging. The current regulations Ref.[2] for control of emergent radiation will be discussed first; an account of their development is to be found in Ref.[9].

The aim of the external radiation control limits is to protect persons and undeveloped photographic film during transport. In so doing, protection is also afforded to livestock and inanimate goods. The limits are prescribed with respect to external surfaces of a package and to specified distances from these surfaces and relate both to packages in transport with other goods and to "full-load" transport, e.g. a vehicle or freight container carrying only the radioactive material. They include 0.5 mrem/hr, 50 mrem/hr, 200 mrem/hr and 1000 mrem/hr limits at surfaces and 10 mrem/hr at 1 metre or 2 metres from surfaces, each limit being specifically prescribed in relation to the content of the package or full load and its mode of transport. Effect is given to the limits by labels which carry the trefoil symbol. Labels are assigned according to categories I, II and III; Category I is white while Categories II and III are yellow. The category number I, II or III is printed in red.

When the external radiation emerging from the surface of the package, or in the case of a full load, from the vehicle or freight container, does not exceed 0.5 mrem/hr at the surface the potential hazard is very low indeed and is denoted by a Category I white label. This signifies to the carrier that separate storage from other goods is not required. When surface radiation levels exceed 0.5 mrem/hr a yellow label is required; the upper limits of surface radiation for Categories II and III are 50 mrem/hr and 200 mrem/hr. Such packages require segregation from other goods based on a "transport index" figure entered by the consigner on the label. A transport index of 1 indicates a radiation level of 1 mrem/hr at one metre from the surface of the package and is based on the "radiation unit" of carrier regulations. In addition to the surface radiation limits, packages carrying Category II or III yellow labels are limited to a transport index of 1 and 10 respectively. The transport index of a Category I white label package is nil. To facilitate the safe stowage of radioactive packages carried in passenger and goods vehicles, the carrier is required to add up the transport index figures entered on the package labels and to stow the package assembly in accordance with distances specified in segregation tables provided by the transport authority appropriate to the mode of transport. Such tables are not given in the current issue of the Agency's regulations as they must be derived to take account not only of the external radiation control limits but of factors related to the specific mode of transport Refs.[10, 11].

The Category I, II and III label system also provides effective control for full-load carriage, whether by vehicle or freight container. Subject to conditions specified in the regulations, the surface radiation and transport index limits for a Category III yellow full-load consignement are increased from 200 to 1000 mrem/hr and from 10 to 50 respectively.

Developments in the nuclear industry made it necessary for the Agency's regulations to cover the safe transport of relatively large quantities of radioactive ores and concentrates, process residues and wastes, all of which present a relatively low potential hazard. The "low specific activity" (LSA) and "low level solid" (LLS) containment concepts discussed later meet these requirements. The regulatory prescriptions dealing with external radiation control for such materials take account of the substantial self-shielding (i.e. absorption of radiation) by the material itself. This is essentially achieved by a definition of transport index specific to such materials when carried by full load.

It is most important that the regulations provide means whereby packages containing manufactured articles, e.g. watches carrying a small amount of radioactive material, which present a very low potential hazard, may be carried by all modes of transport, including by post. For purposes of external radiation control this is essentially achieved by imposition of the 0.5 mrem/hr limit at the surface of the package.

While control of potential hazard arising from radioactive packages involved in accidents is achieved essentially by containment prescriptions relating to package/packaging design, the requirements for testing these packages impose quantitative limitations on the increase in external radiation dose rate at the surface of the package. In addition, in order to help provide information in the event of mishap, the consigner is required to enter the nature of the radioactive content and its activity in curies on the white or yellow label.

CONTAINMENT OF RADIOACTIVE MATERIAL

The basic principle of maximizing the consigner's contribution to safety results in regulations concerning packaging standards and design, package contents, and as necessary, load and shipping movement controls. Compliance with these prescriptions prevents or severely limits the escape of radioactive material to the environment during transport, so reducing the radiotoxicity risk. Only a broad outline of these prescriptions will be given; more information can be found in Ref.[9].

The range of potential hazard of radioactive material requiring transport is very wide indeed and raises the problem of whether regulations should prescribe packaging design requirements linked with defined limits for package contents, or package design requirements, for example heat dissipation, whose implementation will restrict the contents. When the regulations were first developed, it was decided to use both approaches; this resulted in the Type A and B package concepts.

Prescriptions for the design of a Type A package relate both to package design and to quantitative contents limits. The packaging is required to provide both adequate shielding and containment under normal conditions of transport (including rough handling and exposure to adverse weather conditions). The contents limits are prescribed so that in the event of total release in a severe accident the consequent hazard will not be unacceptable. In addition, for fissile material, the contents are limited to comply with criticality control provisions.

While the Type B package design prescriptions include those relating to the packaging, no contents limits are directly specified. The actual content of any Type B package is "indirectly" controlled by compliance with prescriptions concerning radiation emission from the package, heat dissipation, control of internal pressure, and, for fissile material, criticality control. In addition to compliance with all Type A packaging design requirements, Type B packaging is required to be designed to retain adequate shielding and containment and maintain its criticality control features in very severe accidents. Besides satisfying special design requirements, both Types A and B packaging must be capable of passing a series of prescribed tests intended to produce the damage that would be expected under rough handling cum adverse weather, and rough handling cum adverse weather followed by severe accident conditions respectively.

The current regulations prescribe two upper limits for activity content, A_1 and A_2, for individual radionuclides when carried in a Type A package. A_2 is the activity limit for material in a potentially dispersible form, e.g. gas, liquid or powder; A_1 is the activity limit for what is termed "special form", that is, in a state which, by virtue of inherent properties (e.g. massive non-friable solid, insoluble in water and non-combustible in air or material encapsulated to prescribed standards) would be virtually non-dispersible after its release from a package. For most radionuclides, given compliance with prescriptions for encapsulation, the A_1 limit exceeds that for A_2. The A_1/A_2 concept is a further development of the Radiotoxicity Group concept used in the Agency's earlier regulations Refs.[1, 3]. In addition to the outline of its development given in Ref.[9], more detailed information is to be found in Refs.[12] and [13].

As it is required to cover a worldwide environment and transport by all modes, it is not surprising that the specification of the Types A and B packaging designs and their test requirements has presented a formidable task to the Agency's panels. As an illustration of the basic principle of stating "what" must be achieved rather than "how", the current design and test requirements use the concept of "containment system" rather than the "containment vessel" of earlier regulations. Regarding compliance with test specifications, the prescriptions include the important requirement "so as to suffer minimum damage". As the A_2 contents limits apply to gases and liquids as well as dispersible solids, additional packaging tests are prescribed for the design of Type A packaging for gases and liquids.

The design of Type B packaging is required to withstand accident conditions comprising a severe crash followed by an intense fire. In deriving the mechanical and thermal tests prescribed in the regulations, account was taken of accidents and associated investigations in various countries Ref.[14]; this work has recently included more detailed investigations of accident conditions Ref.[15] and results of tests involving actual vehicle collisions.

Regarding "indirect" limitation of contents, two kinds of Type B package design are provided for, B[U] and B[M]. Since Type B[U] must satisfy additional design criteria for containment, it requires the approval only of the competent authority of the country of origin of the design. A Type B[M] package is not required to meet all the additional design criteria for containment specified for a Type B[U] package, but it must satisfy certain additional containment requirements specified for a Type B[M] package. A failure to meet any of these additional containment criteria must be offset by control conditions specified by the consigner. Consequently, a Type B[M] package design is subject to approval by all competent authorities involved in the shipment. The Type B[M] and B[U] package design concepts result from the Large Radioactive Source LRS[U] and LRS[M] concepts of the Agency's earlier regulations Ref.[4] and associated transport experience, together with the development of the A_1/A_2 system and the development of regulatory provisions to ensure adequate heat dissipation from packages during transport.

While the Types A and B package design prescriptions provide for the safe transport of many nuclear materials whose potential hazard is in the medium and high part of the range, it is important that provision be made for the transport of materials of low potential hazard. For purposes of the regulations, such materials are classed either as "Low Specific Activity" (LSA), "Low Level Solid" (LLS) or "Items exempt from specific prescriptions" by virtue of their small radioactive content. Containment standards less stringent than those set for a Type A package and closer to the standards for industrial or commercial packaging used for certain chemicals is justified for such materials provided that the material in the package or load is "inherently safe". This requirement means that it must be inconceivable under any circumstances arising during transport for a person to suffer an intake of sufficient material to give rise to a significant radiation hazard Refs.[9, 12, 13]. For such materials, the regulations specify quantitative limits for radioactivity contents as fractions, e.g. 1/10 000, of the A_2 (non-special form) limits for radionuclides Refs. [5, 9, 12, 13].

Although the emphasis of the regulations is to ensure standards of containment appropriate to the nature of the material being carried in a package, the possibility of slight radioactive contamination on the external surface of certain packages, e.g. a container carrying irradiated reactor fuel, cannot be completely ruled out, especially if the outer packaging has been exposed to such contamination in areas where radioactive material is handled or stored. Consequently the regulations specify a surface contamination test and prescribe radioactivity limits which require compliance prior to transport Refs.[5, 9].

SAFE DISSIPATION OF HEAT

The relevant prescriptions in the current regulations Ref.[2] have two objectives: first, to maintain the integrity of the radioactive shielding components, the containment system (and for fissile materials, criticality control features) of a transport package; and second, to avoid injury to people and damage to other goods during transport as a result of high temperatures on any accessible surface of the package. Their development is outlined in Ref.[9] and takes due account of the facts that:

(a) the heat generated by a radioactive source is a product of its radioactive strength expressed in curies and of the energy released by each nuclear disintegration (expressed in electron-volts (eV)). Because the decay energies of the roughly 200 known radionuclides vary widely (from thousands to millions of electron-volts) the strength of a radioactive source in curies is not a good guide to its properties as a heat source.

(b) heat is generated when radiation is actually absorbed. For alpha and beta emitters this takes place mainly in the radioactive material itself, i.e. well inside the package. For gamma emitters, absorption is within the shielding, e.g. lead or steel; such material is usually in the outermost part of the package.

(c) the actual dissipation of heat from the surface of a package is dependent on ambient temperature and insolation conditions; these vary widely in various parts of the world.

The responsibility for formal heat assessment of a package rests with the consigner; for the great majority of Type A packages this is essentially solved by the control provided by the A_1/A_2 contents limits. To be acceptable for transport with other goods, the contents of a Type B[U] package can in fact be limited by the need for compliance with an "in the shade" accessible surface limit of 50°C when assessed against an ambient temperature of 38°C and 12 hours/day insolation, this data being specified in the regulations for form and location of package surfaces. Failure to comply with the 50°C limit would require the Type B[U] package to be carried as a full load, in which case it would be necessary to show that the "in the shade" temperature of any readily accessible surface would not exceed 82°C. Failure to comply with this requirement would mean that the package would become subject to Type B[M] requirements thereby involving the prior approval, by all competent authorities concerned, of the operational controls specified to avoid injury to persons and damage to other goods during transport.

The current regulations impose a stowage limit of 15 W/m^2 (watts per square metre) as the average heat flux for any package to be carried amongst packaged general cargo other than in sacks or bags. The experimental work underlying this limit is described in Ref.[16]. The procedure for safe stowage of any package exceeding the 15 W/m^2 limit must be subject to the outcome of assessment by a heat transfer specialist and requires competent authority approval prior to transport. For such work, guidance is given on the application of a higher limit, 90 W/m^2, above which full-load conditions should apply. This guidance is found in the companion advisory document to the regulations Ref.[5].

PREVENTION OF CRITICALITY

All fissile materials are radioactive, hence their transport is subject to the radiation control, containment and heat dissipation prescriptions of the regulations. However, very few radionuclides are fissile, the predominant ones being uranium-235 and plutonium-239. Consequently, for purposes of transport, the regulations define fissile material, make specific prescriptions for the transport of Fissile Class packages and list exemption conditions as "Fissile Exempt" from such prescriptions. The development of this important part of the regulations is described in Ref.[9].

Transport of fissile material is exempted from the Fissile Class package prescriptions provided that the material satisfies any one of seven requirements listed in the regulations. These result from the work of criticality specialists in various countries and essentially facilitate the safe transport of materials containing very small quantities or concentrations of fissile radionuclides, as defined in the regulations. Further development of such prescriptions on the basis of the outcome of criticality assessments is to be expected.

The prescriptions for the transport of packages termed Fissile Class I, II or III aim to achieve criticality safety to a very high and equal degree. The method of achieving this varies according to the contribution by the consigner in the design of the package and the contribution of the carrier through controls applied during transport, using the transport index procedure.

To justify its transport as Fissile Class I, a package must be shown by criticality assessment to be a net absorber of neutrons before and after being subject to the Type B packaging thermal and mechanical test conditions. Fissile Class II packages are not required to be net absorbers of neutrons and hence are subject to a limit termed "allowable numbers" which restrict the number of packages that may be carried together. Similarly, Fissile Class III packages may be transported only in accordance with controls specially imposed. It is important to note that for purposes of radiological control, a Fissile Class package is not required to be Type B unless its contents exceeds the A_1 or A_2 limit, as appropriate for the radionuclide carried. However, for practical purposes, to achieve the "net absorber of neutrons" requirement after being subject to the accident test conditions, the packaging of most Fissile Class I packages is up to Type B standard. Also, the packaging of Fissile Class II or III packages carrying relatively large amounts of fissile material is likely to be Type B. While requiring that Type A and B packaging test results be used in the assessment of a package by a criticality specialist, ability to satisfy the tests is not required. However the greater the degree of failure, the greater will be the restriction of contents and allowable numbers imposed by the specialist.

During the first complete regulatory revision, the previous "radiation unit" was developed into the present "transport index" to provide a means through which a carrier can have control of the number of fissile class packages that may be safely carried together. This facilitates the effective use of Fissile Class II and III packages. While the transport index of a Fissile Class I package is solely determined by external radiation control, i.e. number of mrem/hour at one metre from the external surface of the package, that for Fissile Class II and III packages is the larger of two numbers: (1) the maximum radiation level in mrem/hour at one metre or (2) the number obtained when 50 is divided by the "allowable number" derived by the criticality specialist for the package design. (Fifty is the regulatory limit imposed for maximum number of transport indices to be carried together except under full-load conditions.)

ADMINISTRATION REQUIREMENTS FOR CARRIAGE AND STORAGE

The last section of the regulations Ref.[2] is very important in that it is devoted to certification of approval by competent authority, consigner's responsibilities and quality control in the manufacture and maintenance of packaging that forms part of an approved package design. The content of this important section results from the experience gained in the application of the Agency's earlier regulations.

Designs listed that do not require certification of competent authority approval include Type A packaging unless this is used for a Type A package containing fissile material not complying with one of the seven conditions for "fissile exempt". Requirements are listed as to information necessary for competent authority approval of "special form" which then merits the use of A_1 limits when such material is transported in a Type A package. Similarly, the information required for approval of Types B[U], B[M], and Fissile Class I, II and III package designs is listed. Prescriptions then follow concerning prior approval of shipment and transport by special arrangement.

Having defined circumstances requiring some form of competent authority approval and the information to be supplied by the consigner requesting this approval, prescriptions then follow as to the identification marks used in the relevant approval certificate.

The regulations make the consigner (or his agent) fully responsible for compliance with the labelling and marking prescriptions prior to a consignment being handed over to the carrier. As documents are involved in this handing over, requirements are listed regarding the consigner's certification to the carrier that the consignment complies with the relevant regulatory prescriptions, together with supporting information. To facilitate the provision of emergency arrangements, prescriptions are then given as to when prior notification to competent authorities concerned is required before shipment of packages containing activities exceeding specified values.

To help ensure quality control in the manufacture and maintenance of packaging to an approved design, the regulations make the manufacturer, consigner and user responsible for providing evidence of compliance as and when required by a competent authority concerned.

FURTHER DEVELOPMENT

The current IAEA Regulations for the Safe Transport of Radioactive Materials provide a sound basis for national and international transport of radioactive and fissile materials by all modes of transport for the decade from the mid-1970s. While there is a real need for a period of stability in their structure and content, regulatory experience in the overall field of transporting dangerous goods/restricted articles indicates the need for review at suitable intervals. In continuing to implement the Economic and Social Council's decision, the Agency now proposes to make further reviews at 10-year intervals, preparations for the "1983" review are now in hand.

In addition, a procedure has been authorized by the Board of Governors under which changes of detail necessary to keep the regulations up to date may be introduced at any time provided that written notice is given to Member States 90 days in advance and due account is taken of any comments submitted by them. The minor amedments introduced in the 1979 version of the 1973 regulations Ref.[2], result from application of this "90 day rule" procedure.

To help a user comprehend "what" is required, any regulation must be clear and concise. This is especially important in the case of the Agency's transport regulations as besides being translated into various languages, they need to be converted by transport organizations into the form of the regulations used for dangerous goods as a whole. However aside from the need for a clear and concise regulatory document stating "what" is required, it is important that guidance be available as to "how" certain regulatory requirements may be met, such guidance being given as *a* way, not *the* way. Also, in order to promote understanding of the technical basis of any regulatory prescription and to help those concerned with further reviews, comprehensive information of a "why" nature is required. For the

1973 regulations, certain information both of a "how" and "why" nature is to be found in the companion advisory document Ref.[5].

Besides greatly assisting all concerned with the application of the Agency's future regulations, public acceptance will also be promoted if the work of future review panels is represented by a trilogy of documents, viz

(a) the regulatory document, prescribring "what" is to be achieved;
(b) an advisory document providing examples as to "how" certain regulatory requirements can be met;
(c) an explanatory document giving the basis (i.e. "why") of certain regulatory requirements.

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