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Environmental, Health, and Safety Issues of Sodium-Sulfur Batteries for Electric and Hybrid Vehicles

Volume III: Transport of Sodium-Sulfur and Sodium-Metal-Chloride Batteries

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Preface

This report is the third of four volumes to identify and assess the hazards and risks involved in using sodium-sulfur (Na/S) battery technology as the energy source in electric and hybrid vehicles. These reports assess environmental, safety, and health issues affecting the commercialization of Na/S batteries and are intended to help the Electric and Hybrid Propulsion Division of the Office of Transportation Technologies in the U.S. Department of Energy (DOE/EHP) determine the direction of its research, development, and demonstration program for Na/S battery technology. Unlike the other three volumes, sodium-metal chloride batteries are included in this assessment. Although there are differences in these two sodium battery technologies, the basic configuration and operation are similar. In this assessment, batteries employing either technology are generically described as sodium-beta batteries, and, for purposes of transport, no distinction is drawn between them. Unless otherwise noted, this assessment specifically addresses sodium-beta batteries with respect to their use in electric or hybrid vehicles and is not concerned with stationary energy storage.

These reports were prepared by the Analytic Studies Division of the National Renewable Energy Laboratory and are one part of DOE/EHP's RD&D program to work with industry to commercialize Na/S batteries. For example, data and information obtained through these reports will assist the DOE/EHP implement recommendations made by participants at government-industry meetings on sodium-beta batteries sponsored by the DOE/EHP. The reports may also assist the DOE/EHP and the Ad Hoc Electric Vehicle Battery Readiness Working Group coordinate the RD&D needed to commercialize Na/S and sodium-metal chloride battery technologies.[1]

I am indebted to many people who helped me obtain information and reviewed drafts of this volume. I am especially indebted to E. Altemos, technical consultant from Winston and Strawn, who helped me understand some of the technical intricacies of the domestic and international regulatory processes for dangerous goods and who patiently reviewed several drafts of this volume. I would also like to thank R. Taenaka of Hughes Aircraft Company, C. Ke of the U.S. Department of Transportation, G. Henriksen from Argonne National Laboratory, and H. Haskins from Ford Motor Company for reviewing this volume for technical accuracy. Finally, I thank D. O'Hara of DOE/EHP for his leadership and support in directing and sponsoring the EH&S program and these assessments.

[1] The Ad Hoc Electric Vehicle Battery Readiness Working Group consists of leading scientists and program managers from government agencies, battery developers, automobile manufacturers, and the chemical processing industry.

Table of Contents

Page No.

Introduction 1

Regulations for Shipping Hazardous Materials 1

General 1

International Regulatory System 2

Domestic Regulatory Process and the Relationship to International Transport Requirements 3

Shipping Requirements for Sodium-Beta Batteries 5

Exemptions and Rule Makings 6

Current Status 7

Geneva Meeting 7

Next Steps 8

Committee of Experts Process 8

Regulatory Process 9

General Activites 10

Conclusions 11

References 12

Appendix A-1

List of Tables

Page No.

Table 1 - Hazardous Materials Table. 6

Introduction

This report examines the shipping regulations that govern the shipment of dangerous goods. Since the elemental sodium contained in both sodium-sulfur and sodium-metal-chloride batteries is classified as a dangerous good, and is listed on both the national and international hazardous materials listings, both national and international regulatory processes are considered in this report. The interrelationships as well as the differences between the two processes are highlighted.

It is important to note that the transport regulatory processes examined in this report are reviewed within the context of assessing the necessary steps needed to provide for the domestic and international transport of sodium-beta batteries. The need for such an assessment was determined by the Shipping Sub-Working Group (SSWG) of the EV Battery Readiness Working Group (Working Group), created in 1990. The Working Group was created to examine the regulatory issues pertaining to in-vehicle safety, shipping, and recycling of sodium-sulfur batteries, each of which is addressed by a sub-working group. The mission of the SSWG is to establish basic provisions that will ensure the safe and efficient transport of sodium-beta batteries. To support that end, a proposal to the UN Committee of Experts was prepared by the SSWG, with the goal of obtaining a proper shipping name and UN number for sodium-beta batteries and to establish the basic transport requirements for such batteries (see the appendix for the proposal as submitted). It is emphasized that because batteries are large articles containing elemental sodium and, in some cases, sulfur, there is no existing UN entry under which they can be classified and for which modal transport requirements, such as the use of packaging appropriate for such large articles, are provided for. It is for this reason that a specific UN entry for sodium-beta batteries is considered essential.

Thus, a key activity of the SSWG is to work to obtain a UN shipping number and to draft papers for the subsequent development of international regulations. These activities are described in a later section entitled Current Status. In addition to providing for international transport, the Department of Transportation (DOT) will also be petitioned to initiate rule making to provide for the transport of sodium batteries under domestic regulations.

Regulations for Shipping Hazardous Materials

General

Shipping regulations govern the safety aspects of transporting materials for the different modes of transportation—sea, land, and air. Shipping regulations also require that special procedures be followed for the transport of materials defined as hazardous. These procedures may require special packaging, handling, labeling, and other safety-related procedures. Although there is a definite interface between U.S. transport regulations and those promulgated on the international level, ultimately hazardous materials shipped domestically must comply with U.S. shipping regulations, and those shipped internationally must comply with international regulations. Since sodium-beta batteries contain materials defined as hazardous, the transport of these batteries (and other advanced batteries for electric vehicles that contain hazardous materials) must comply with shipping regulations for hazardous materials.

International Regulatory System

The UN Committee of Experts is the focal point of international activity regarding the transport of packaged hazardous materials (except radioactive materials). Over thirty years ago, the UN Economic and Social Council (ECOSOC) established a UN Committee of Experts on the Transport of Dangerous Goods. The purpose of the committee was to develop international recommendations for the transport of dangerous goods (i.e., "hazardous materials") applicable to all modes of transport, i.e., sea, land, and air. This effort was to promote global standardization and uniformity in hazardous materials transportation.

The primary role of the UN Committee of Experts is to update and publish the *Recommendations on the Transport of Dangerous Goods* (commonly referred to as "the UN Recommendations" or simply, the "Orange Book"). These recommendations address the multiple modes of hazardous materials transport requirements, such as hazard class definitions, classification tests, listing of hazardous materials, and the construction, marking,and labeling of packaging as well as shipping documentation requirements. With respect to hazard classes, for example, (a hazard class refers to the category of hazard assigned to a hazardous material), the UN system segregates hazardous materials into three distinct "packing groups" based on the relative danger of the materials. Packing Group I consists of very dangerous materials. Packing Group II consists of materials considered to present moderate danger. Packing Group III consists of materials considered to present minor danger. Thus, a UN 1A1 steel drum would have to survive a drop test of 1.8 meters if it were to carry a material in Packing Group I, 1.2 meters for Packing Group II materials, and 0.8 meters for Packing Group III materials. (This assumes the specific gravity of the material does not exceed 1.2— denser materials would have higher drop heights [1].) These broad, performance-oriented specifications allow packaging manufacturers to exercise design and production ingenuity to produce packagings that are both cost-effective, as determined by the marketplace, and safe, as determined by conformance to the performance standards.

Although the UN Recommendations are only recommendations with no regulatory force, they form the basis for a number of international modal agreements, which give these recommendations the force of regulation. Two primary international regulatory bodies are the International Maritime Organization (IMO) and the International Civil Aviation Organization (ICAO), each of which adds its own requirements applicable to the appropriate mode of transport to the UN "core" recommendations.

The IMO is a specialized agency of the UN concerned primarily with the promotion of safety in shipping and the prevention of marine pollution from ships. The IMO regulatory system for shipping hazardous materials is known as the *International Maritime Dangerous Goods Code* (or IMDG Code). The ICAO promulgates rules for the safe transportation of hazardous materials by air and has established its own set of regulations, the *ICAO Technical Instructions for the Safe Transport of Dangerous Goods by Air.* The ICAO shipping regulations and the IMDG code both contain hazardous materials tables, which list the shipping requirements for specific hazardous materials. Materials in these tables are identified by four digit UN shipping identification numbers (the numbers begin with the prefix "U.N.").

With respect to the UN Committee of Experts' membership, it is currently composed of 14 members. The voting membership consists of delegates nominated by Canada, China, France, Germany, India, Italy, Japan, the Netherlands, Norway, Poland, Sweden, the United Kingdom, the United States, and Russia.

Representatives of a number of other governments routinely participate in the work of the committee as nonvoting observers.

In addition, representatives of various intergovernmental and nongovernmental international organizations participate in the work of the committee in a nonvoting "observer" status. Examples of such intergovernment organizations include IMO, ICAO, the UN Environment Programme (UNEP), the International Labor Organization (ILO), and the European Economic Community (EEC). Nongovernmental international organizations participating in the committee's work include the European Council of Chemical Manufacturers' Federations (CEFIC), the Hazardous Materials Advisory Council (HMAC), the International Chamber of Shipping (ICS), and the International Air Transport Association (IATA). As is the case with "observer" governments, these international organizations are allowed to participate in all aspects of the committee's deliberations and activities except that they can not vote.

The Committee of Experts has one subcommittee. The composition of the subcommittee is the same as that of the committee. The committee meets once every two years in December. Between these biennial meetings of the committee, three meetings of the subcommittee are held, spaced at approximately six-month intervals. Most of the detailed discussion and deliberation regarding the development of new recommendations, or revisions to the existing recommendations, is accomplished at the subcommittee meetings. During the biennial committee meeting, the new and revised recommendations developed by the subcommittee during its previous three sessions are considered, revised as necessary, and adopted in the form of Amendments to the Orange Book.

Upon adoption by the committee, the new and amended recommendations are submitted directly to ECOSOC for approval. Upon approval by ECOSOC, the amendments to the Orange Book are incorporated into a revised edition and published by the UN. At the same time, they are transmitted by ECOSOC to the UN member governments with a request that the revised recommendations be incorporated into domestic and international transport regulations as soon as possible.

Domestic Regulatory Process and the Relationship to International Transport Requirements

The Research and Special Programs Administration (RSPA) is part of DOT. RSPA is responsible for developing a national regulatory program to protect against the risks to life and property inherent in the transportation of materials by all modes of transport [1]. In a 1985 reorganization of RSPA, the Office of Hazardous Materials Transportation (OHMT) assumed responsibility for regulating hazardous materials. The hazardous materials regulations govern the transport of hazardous materials in commerce in the United States and were issued pursuant to the Hazardous Materials Transportation Act of 1974. Requirements address the safety aspects of shipping, including requirements for the classification of materials, packaging, hazard communication, transportation and handling, and incident reporting.

With the publication of DOT's Docket No. HM-181 on December 21, 1990 (a final ruling published in the *Federal Register*) the hazardous materials regulations (HMR; 49 CFR Parts 171-180) were comprehensively revised to reflect the guidelines established by the UN Recommendations. DOT altered the hazardous materials regulations because the regulations were, at that time, difficult to use; they were long and complex, inflexible and outdated concerning nonbulk packaging technology, deficient in terms of safety with respect to the classification and packaging of certain categories of hazardous materials, and

generally not in alignment with international regulations based on the UN Recommendations. Domestic regulations that had remained fundamentally unchanged for the first half of this century were dramatically altered, resulting in UN decisions directly affecting not only international transport but transport in the United States as well.

The revised regulations included several benefits, including increased flexibility in packaging, enhanced safety through better classification and packaging, a reduced need for exemptions from the regulations, and facilitation of international trade. In addition, the revised regulations implemented packaging standards based on performance criteria rather than detailed design specifications. Thus, the packaging standards accommodate technical innovation and result in federal standards for modal transport that are consistent with safety requirements and international standards.

A brief description of the revised hazardous materials regulations (49 CFR Parts 171-180) follows.

Part 171 - Includes definitions, reporting requirements, a listing of matter incorporated by reference, and procedural requirements, including provisions that permit the use of other regulations, such as the ICAO Technical Instructions and the International Maritime Dangerous Goods (IMDG) Code.

Part 172 - Contains a listing of hazardous materials in the hazardous materials table (Part 172.101) and various communications requirements for marking and labeling of packages, placarding vehicles and bulk packagings, and communicating emergency responses. The table contains a list of all hazardous materials that may be shipped domestically.

Part 173 - Contains various hazard class definitions for classifying materials and lists the packagings authorized for specific materials.

Parts 174-177 - Contain requirements applicable to specific transport modes: Part 174 for transport by rail car, Part 175 for transport by aircraft, Part 176 for transport by vessel, and Part 177 for transport by motor vehicle.

Part 178 - This part is addressed primarily to packaging manufacturers and contains standards for a wide variety of packagings.

Part 179 - Addresses the specifications for tank cars.

Part 180 - Contains requirements for the continuing qualification and maintenance of packagings.

The hazard class definitions of the revised domestic hazardous materials regulations are aligned generally with the UN Recommendations and use the same nomenclature. In certain instances, however, shipping requirements unique to the U.S. transportation system are retained [2] . For example, DOT regulations require that nonbulk packagings be capable of withstanding a vibration test, in addition to other performance tests, to address rigors not taken into account by the UN tests [1]. U.S. requirements for conduct of performance tests, including design qualification tests and periodic retests, are included in 49 CFR Part 178 for all packagings manufactured to UN standards.

Likewise, although the provisions in subchapter C of the DOT regulations are generally based on the UN Recommendations and are consistent with the regulations of the ICAO and IMO, they are not identical in all respects, and compliance with U.S. regulations will not guarantee compliance with international regulations. The reverse situation also applies: compliance with the ICAO regulations or the IMDG code does not ensure compliance with DOT's regulations.

As noted above, the UN Recommendations are incorporated into various international transport regulations, such as the IMDG Code and the ICAO Technical Instructions. Historically, U.S. international shipping companies of hazardous materials have complied, practically speaking, with these international regulations as a condition of shipment. This compliance requirement has not stemmed so much from rules imposed by DOT as it has from the fact that foreign governments have mandated compliance as a condition for permitting shipments into their jurisdiction. As a result, some foreign carriers have simply refused to accept hazardous materials shipments made by U. S. shippers unless the shipment fully conformed to the relevant international requirements [7].

In recognition of the need for U. S. exporters to comply with the IMDG Code and the ICAO Technical Instructions to export hazardous materials, the DOT regulations have for a number of years incorporated these international standards by reference and allowed them, under certain conditions, to be used as an alternative to the DOT regulations. In certain cases, failure to comply with international requirements has resulted in a violation of the DOT regulations [7].

While the DOT "UN" rule making started years ago as an advance notice to replace existing DOT design packaging specifications with UN performance-oriented packaging, the scope of the action has been greatly expanded and, as a result, the HM-181 final rule has had the practical effect of virtually replacing the "old" DOT hazardous materials regulations with new regulations based on the UN Recommendations. Having implemented the UN Recommendations through the HM-181 final rule in order to, among other reasons, provide greater consistency between the international and domestic requirements, it is a forgone conclusion that DOT will follow future UN decisions by proposing "parallel" amendments to the DOT regulations. As a result, the decisions of the UN Committee of Experts have a direct impact on American industries who ship hazardous materials domestically as well as internationally, even though there may be several years between the time the UN committee adopts new or revised recommendations and when the effects of the UN action are felt in day-to-day transport operations [7].

Shipping Requirements for Sodium-Beta Batteries

Part 172 of 49 CFR contains a hazardous materials table, which lists materials that are considered hazardous to transport. For each listed material, the hazardous materials table lists an identification number, identifies the hazard class, and specifies that the material with transport requirements and/or restrictions. The table also gives the proper shipping name and specifies or references requirements pertaining to the labeling, packaging, and allowable quantity limits aboard aircraft. Sodium and sulfur are found in Table 1.

Sulfur is listed twice, once under an optional domestic shipping entry number and once under the corresponding international entry. Additional information is contained in the hazardous materials table

for materials in Table 1. This information concerns packaging authorizations, special provisions, and vessel stowage requirements. The regulations do not have provisions for shipping sodium-sulfur or sodium-metal-chloride *batteries*. Therefore, the actual shipping requirements for batteries, such as packaging methods and allowable shipping quantities, must be specified through the regulatory process. Up to the present time, Na/S batteries have been authorized for transport under the provisions of a DOT exemption.

Table 1. Hazardous Material Table

Hazardous Materials Description and Proper Shipping Name	Hazard Class or Division	Indentification Number	Packing Group	Labels Required
Sodium	4.3	UN1428	II	Dangerous when wet
Sodium sulfides	8	UN1849	II	Corrosive
Sulfur (international shipping)	4.1	UN1350	III	Flammable solid
Sulfur (domestic)	9	NA1350	III	Class 9

Exemptions and Rule Makings

An exemption is a document allowing for the transport of a material either not allowed in the hazardous materials regulations or under conditions different from those specified in the regulations. RSPA's authority to issue exemptions is established in Section 107 of the Hazardous Materials Transportation Act of 1974 (HMTA). This section authorizes exemptions from specific requirements of the regulations when hazardous materials are transported in a manner that achieves a level of safety at least equivalent to that provided by the regulations, or which is consistent with the policy of HMTA [1]. Exemptions are usually for two years and may be renewed when they expire. Exemptions apply only to the person (or company) filing the application, unless the exemption is nonconfidential, in which case other applicants may become "party" to that exemption [2]. To become "party" to an exemption, the director of OHMT must determine that the applicant is eligible and that the exemption to which the applicant seeks to become party concerns a "matter of a continuing nature and does not depend upon information entitled to confidential treatment" [2]. Exemptions for sodium-sulfur batteries have been successfully received in the past.

With respect to exemptions addressing transport of sodium batteries, an exemption may be limited in scope, applying to a very specific technology or design, or general in scope, applying to a range of designs that fall under a more general technology description [3]. An example of a limited exemption is an exemption for sodium-sulfur batteries covering a specific battery design for a single mode of travel (e.g., by road). Conversely, an example of a general exemption is an application for sodium-sulfur batteries written in a general manner to allow flexibility in the design and to cover shipment by all modes of transport —air, land, and sea.

A rule making is an adoption of a new regulation (known as a regulation of general applicability), and hence is not limited to a specific time period or company. Regulations of general applicability may be written in a generic manner to eliminate design or manufacturer-specific issues. Rule making petitions may require extensive safety-test data and backup data. Exemptions are often converted into regulations of general applicability [4].

General exemption applications and petitions for rule making applying to the shipment of batteries as cargo should be written to address the complete range of hazardous materials to be shipped in a single container, including quantities in individual cells and full- size sodium-beta batteries. Batteries shipped inside of vehicles would be subject to the same requirements [5].

OHMT develops and promulgates amendments to the hazardous materials regulations based on a variety of sources: petitions from the general public or other government agencies; rule- making proposals from the Federal Aviation Administration, Federal Highway Administration, Federal Railroad Administration, or the U.S. Coast Guard; and OHMT initiatives. Public participation is essential and encouraged through the solicitation of comments to Advanced Notices and Notices of Proposed rule making [4].

Petitions for rule makings (i.e., new rules) from the general public are often submitted by an organization that represents an industrial viewpoint (e.g., a trade association) and is seeking to establish an industry standard for shipping. Potential candidates for submitting a rule- making petition for sodium-beta batteries (or other batteries for electric vehicles) include the following organizations [6]:

- Motor Vehicle Manufacturer's Association (MVMA)
- National Electrical Manufacturer's Association (NEMA)
- Society of Automotive Engineers (SAE)
- Electric Vehicle Association of the Americas (EVAA)
- U.S. Advanced Battery Consortium

Current Status

Geneva Meeting

The UN Subcommittee of Experts on the Transport of Dangerous Goods held its sixth session in Geneva, Switzerland, from July 6 to 17, 1992. During the course of the meeting, the subcommittee considered a proposal submitted by the United States to incorporate into the UN Recommendations basic provisions for the shipment of sodium-beta batteries. The proposal was, for the most part, intended to provide for the large-scale, commercial transport of cold (nonactivated) sodium-beta batteries and cells. Although there are instances when hot (activated) batteries containing liquid elemental sodium must be transported, the transport conditions necessary to ensure the safe transport of these batteries are somewhat more elaborate. Therefore, the proposal made no attempt to establish conditions for the transport of hot sodium-beta batteries except under the approval of the competent authority. The competent authority is defined as the transport authority in the country in which the shipment originates.

The U.S. proposal on sodium batteries was presented in a document that was circulated to members of the SSWG prior to the UN meeting for their review and information. Before the meeting, direct

communications also took place with the subcommittee delegates to clarify any outstanding questions or issues.

During the UN meeting, the proposal was initially considered by an informal working group that was convened in order to review all of the proposals before the subcommittee relating to matters of listing and classification of dangerous goods. The proposal was accepted by the working group without modification, and the working group submitted a recommendation to the main subcommittee to adopt the amendments as proposed in the U.S. document.

Upon review of the recommendations submitted by the informal working group on listing and classification, the subcommittee unanimously adopted the amendments in the U.S. document exactly as proposed. During the course of discussion of the proposals, the representative from Germany, while fully supporting adoption of the United States proposals, noted the need to address the matter of shipping hot sodium-beta batteries, and suggested that this should be pursued by the subcommittee sometime during the committee's next biennium. The subcommittee agreed that such work should be undertaken at some point after the December committee meeting and upon receipt of appropriate written proposals.

Next Steps

The UN process is considered to be a three-to-five-year process, from the date of initial submittal to the UN Committee of Experts through the promulgation and adoption of regulations by the IMO and/or ICAO. The UN committee is considered to be a recommending body, but has no direct role in promulgating regulations. While the committee may recommend transport requirements, the review and actual implementation of these requirements is the responsibility of IMO and/or ICAO. Both IMO and ICAO are organizationally separate and distinct from the Committee of Experts even though all are within the UN system. UN Recommendations also provide the basis for many national transport regulations, such as those applied in the United States and Canada.

The dates referred to below represent the "best case scenario" for obtaining the necessary recommendations/approvals at each juncture in the process. The proposals considered by the Committee for finalization in December 1992 will, in general, become effective regulations on January 1, 1995 under the IMO and ICAO.

Committee of Experts Process

- Submittal of proposal to the UN Subcommittee of Experts—April 15, 1992
- Amendment recommended by the UN Subcommittee at Geneva meeting—July, 1992
- Amendment recommended by subcommittee finalized by the full UN Committee of Experts—December 1992.

Regulatory Process

- IMO and ICAO meetings held—October, 1992

  Based on the July 1992, Subcommittee of Experts recommendations, working papers are developed for discussion at the meetings. Since July when the UN Subcommittee accepted the U.S. sodium-beta battery proposal for recommendation, the SSWG has been in the process of developing proposals for submittal for both meetings. The IMO and ICAO submittals will take place through appropriate U.S. government representatives, in code format (e.g., International Maritime Dangerous Goods (IMDG) Code Amendment format) to ensure appropriate consideration of the working papers. The proposals represent the first draft of the regulations and will include not only the parameters for the shipment of cold batteries, as specified in the recommended amendment, but also a provision that authorizes the transport of batteries or cells with liquid elemental sodium on the basis of competent authority approval. Thus, even though the competent authority approval procedure is referenced in the regulations, neither the IMO nor the ICAO is charged with formulating the detailed transport requirements for such batteries because the responsibility for developing the applicable requirements is delegated to the competent authority. Guidelines developed by the competent authority stand alone, and as such, need only to be developed by January 1, 1995 when the code amendment recognizing such guidelines as a basis for international transport becomes effective. However, it is anticipated that the development of the competent authority guidelines will follow shortly after the issuance of DOT general exemption for the domestic shipment of sodium-beta batteries as cargo.[2] On the basis of an informal understanding between various competent authorities, it is further anticipated that the exemption might serve as a model for transport specifications for hot batteries, and as such, could also be used as the basis for the subsequent development of transport specifications by the various competent authorities having an interest in the transport of such batteries.

  Once established, the competent authority guidelines are reflected in a "competent authority approval" letter that is usually required to accompany the shipment along with other shipping papers. The benefit of the competent authority provision is that it establishes a procedure whereby, on the basis of one authority's approval, the movement of batteries or cells with liquid elemental sodium is recognized and accepted under international agreement by other nations. Thus, the need for exemptions in each country, a cumbersome process at best, is eliminated.

- IMO and ICAO hold final meetings in January 1993 and September 1993, respectively. In the case of IMO, this final meeting is an informal meeting of an editorial group, and no new proposals will be considered. They will only place in final form amendments adopted, either in full detail or in principle, by the October 1992 meeting of the full IMO Subcommittee.

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[2]At the date of publication, the general exemption application was being prepared for submittal. It is hoped that the exemption will be issued by DOT in early 1993.

The draft regulations are finalized at these meetings to become effective January 1, 1995. The time between the final meetings and the effective date is needed so that, among other things, the codes can be translated into four different languages and national legislation and regulations can be amended, where appropriate, to reflect the amendments to the international codes just adopted.

General Activities

The SSWG will complete three phases of work prior to January 1, 1995. The first, representing the efforts associated with the presentation to, and adoption of, the sodium-sulfur proposal by the Committee of Experts, is referred to as the UN phase, or the April through mid-July 1992 period. The UN phase was primarily composed of direct communication efforts with delegates from several countries to provide information on the proposal and to solicit their support for the U.S. application at the July UN meeting. The UN phase was essentially complete at the publication of this paper as the U.S. proposal was adopted in July 1992.

The latter two phases can be referred to as the IMO/ICAO phase, or the mid-July through October 1992 period, and the interim phase, or that time period between the final IMO/ICAO meetings (January 1993 and September 1993 respectively) and January 1, 1995, the effective date of the regulations. As mentioned previously, the IMO/ICAO phase will entail using the UN Recommendation as the basis for the development of international transport specifications and submitting working papers to the IMO/ICAO secretaries. In addition, much discussion with the IMO/ICAO representatives will take place to clarify any outstanding questions.

During the IMO/ICAO phase, transport regulatory activities on the domestic level will also take place. Considerable attention will be devoted to developing the criteria and conditions for a general exemption which will apply in a generic sense to sodium-beta batteries. Once experience in transporting batteries under the provisions of the exemption is obtained, DOT could then be petitioned for rule making to incorporate the new transport specifications into its regulations.

After the DOT exemption is issued, the activities of the interim phase will concentrate primarily on developing the competent authority provisions for hot battery transport. It is anticipated that battery developers possessing the most experience with sodium-beta batteries and cells will supply invaluable information regarding technical issues, appropriate transport controls and conditions, and shipping experience. A shipping data base being developed by the SSWG will also be useful as an information base. These hot battery transport specifications will regulate hot battery shipment until the the UN Subcommittee of Experts recommends the inclusion of hot batteries under the sodium-beta battery entry. Efforts will undoubtedly take place to introduce hot battery transport provisions in the next UN cycle, which will begin in 1994, and culminate with IMO/ICAO regulations in final form by as early as 1997.

In general, after IMO/ICAO regulations are finalized, some countries choose to allow the use of these regulations for shipment of particular materials prior to the internationally applicable effective date of the regulations. However, because the IMO/ICAO regulations, based on the UN decisions, will not be effective officially until January 1, 1995, the SSWG will continue efforts to facilitate interim measures making provision for the shipment of hot and cold sodium-beta batteries.

Conclusions

The regulatory process for the shipment of sodium-beta batteries is multifaceted and complex. Although separate processes are required at the international and domestic levels, a key first step in both is for the UN Committee of Experts to accept appropriate provisions for inclusion in the Orange Book. Since the adoption of such provisions will take place by the full UN Committee of Experts in December of 1992, the road will be paved for the domestic and international regulations to be developed and finalized.

As written, the sodium-beta battery proposal only provided for the transport of hot batteries through the competent authority approval provision and did not provide specific requirements for the transport of hot batteries. After consulting with regulatory authorities specializing in the transport of dangerous goods, it was concluded that additional experience was needed in hot battery shipment before detailed transport requirements could be adequately addressed before the UN Subcommittee.

To accumulate additional shipping experience with hot batteries, the SSWG is preparing an application for a general exemption for submittal to DOT, which will address specific conditions for hot battery transport. The hot battery transport specifications will not only guard against potential hazards associated with liquid elemental sodium, but will also consider the electrical hazards associated with hot batteries. It is likely that these conditions for hot battery shipment will provide the basis for not only the competent authority provisions but for the future UN proposal as well. Further support for the future proposal to the UN Subcommittee of Experts will be provided by a shipping data base operated at the National Renewable Energy Laboratory. The data base will record all international shipments of sodium-beta batteries and keep a detailed record of the collective shipping experience of sodium-beta batteries, both hot and cold.

Near term activities will focus on developing regulations on cold battery shipment through the IMO/ICAO processes. DOT will also be petitioned to incorporate similar regulations at the national level. In the near term, hot battery transport will be provided for at the domestic level through the DOT exemption and provided for at the international level through the competent authority provisions.

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Appendix

UNITED
NATIONS

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Secretariat

RESTRICTED

ST/SG/AC.10/C.3/R.294
8 April 1992

Original: ENGLISH

COMMITTEE OF EXPERTS ON THE TRANSPORT
OF DANGEROUS GOODS

Sub-Committee of Experts on the Transport
of Dangerous Goods
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LISTING AND CLASSIFICATION: NEW ENTRY FOR BATTERIES CONTAINING SODIUM

Transmitted by the expert from the United States of America

BACKGROUND

1. Batteries employing elemental sodium afford considerable advantages in certain applications (for example, powering of vehicles) when compared to the more common and conventional battery technologies.

2. Two basic sodium battery technologies have emerged thus far, the "sodium/sulphur" battery and the "sodium/metal chloride" battery. While there are differences in these two sodium battery technologies, the basic configuration and operation is similar and batteries employing both technologies are generically described as "sodium/beta" batteries. This proposal addresses both types of batteries and, for purposes of transport, draws no distinction between them.

3. An extensive testing and development programme for sodium/beta batteries has been largely completed, and plans are now being implemented for the commercial utilization of these batteries as an alternate energy source for propulsion of vehicles.

4. The purpose of this proposal is to establish basic provisions that will ensure the safe and efficient transport of sodium/beta batteries. In this connection, it is emphasized that because these

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batteries are large articles containing elemental sodium and, in some cases, sulphur, there is no existing UN entry under which they can be classified and for which, in modal transport requirements such as the IMDG Code, use of packaging appropriate to such large articles is provided for. It is for this reason that a specific UN entry for sodium/beta batteries is considered essential.

GENERAL DESCRIPTION OF SODIUM/BETA BATTERIES

5. Sodium/beta batteries for electrically powered vehicles are large, normally with a mass of several hundred kilograms but with the largest (to date) ranging up to a mass in excess of 800 kg. The batteries consist of a number of individual cells, electrically connected and mounted within a battery casing. Cells, which contain the sodium and any other reactants, consist of hermetically sealed metal casings. In the cells, sodium and other reactants are separated by a ceramic component which functions as the battery electrolyte.

6. When the battery is "cold" (i.e., the elemental sodium in the battery is in a solid state), the battery has no capability to produce electricity and is, therefore, electrically inert. Before a sodium/beta battery will operate to produce electricity, the cells must be heated to approximately 300 to 350 °C. Heating is accomplished by heating elements installed in the battery and requires an external power source. Once at operating temperature, the elemental sodium in the cells is in a liquid state and must be maintained in this state during battery operation. Because the battery is "hot" (i.e., the elemental sodium in the battery is in a liquid state) when operating, the battery casing consists of a double-walled, welded stainless steel vessel with the space between the inner and outer walls fitted with thermal insulation and usually evacuated of air.

7. Since elemental sodium is converted to various sodium compounds during the operation of the battery, the amount of elemental sodium present in a cell depends on the level of charge of the cell. However, the amount of sodium present is always relatively small in relation to the gross mass of the cell or battery. For example, for the largest sizes of sodium/beta batteries (i.e., with a gross mass of approximately 830 kg), the maximum total quantity of elemental sodium that would be present in the battery would be only approximately 60 kg. In addition, the individual cells further separate the sodium present into quantities of less than 75 g in each hermetically sealed cell.

SUMMARY OF THE PROPOSAL

8. The basic assumption in preparing this proposal is that the hazard presented by sodium/beta batteries, in the event of a release of dangerous goods contents in transport, is essentially that presented by elemental sodium, which is classified as a substance of Division 4.3. Although the sodium/sulphur type of battery also contains some quantity of sulphur, it has been assumed that the hazard associated with the sodium clearly takes precedence and, therefore, the primary hazard may be considered to be that represented by Division 4.3. Since a need also arises to transport individual cells for eventual installation in a battery, the proposal also provides for transporting cells without the benefit of the outer battery casing.

9. Establishing the crash-worthiness of the batteries and cells under motor vehicle accident conditions has necessitated testing of the batteries to performance levels far exceeding those provided for packagings in Chapter 9 of the UN Recommendations. As such, batteries and associated cells are designed to a level of structural integrity that affords an inherently high degree of safety in transport.

10. Given the high level of structural integrity, it is considered that appropriate safety will be provided in transport if cells are required to be transported in outer packagings that have been tested to Packing Group II performance levels. Similarly, based on the additional integrity afforded when these cells are installed within the double-walled, outer battery casing, it is proposed that the batteries be permitted to be transported either unpackaged or in protective enclosures such as crates that are not subject to packaging performance tests.

11. The proposal presented in this document is, for the most part, intended to provide for the large-scale, commercial transport of "cold" sodium/beta batteries and cells. While there are instances when "hot" batteries containing liquid elemental sodium must be transported, the transport conditions necessary to ensure the safe transport of these batteries are somewhat more elaborate. Therefore, this proposal makes no attempt to establish conditions for the transport of "hot" sodium/beta batteries, and provides that such batteries may only be transported with the approval of the competent authority. In the future it may also be necessary to elaborate the transport conditions for "hot" sodium/beta batteries.

TRANSPORT EXPERIENCE WITH SODIUM/BETA BATTERIES

12. Sodium/beta batteries are currently being manufactured in Germany and the United Kingdom and demonstration programmes employing these batteries for vehicle propulsion are underway in those countries and in other countries, including Canada and the United States. Under specific approvals, considerable transport experience has accrued. While many consignments of both batteries and cells have been transported and, although some incidents have occurred, none resulted in a release of dangerous goods. This experience has demonstrated that sodium/beta batteries can be safely transported.

PROPOSAL

13. The expert from the United States proposes the following amendments to the Recommendations:

(1) Insert the following new entry in the LIST OF DANGEROUS GOODS MOST COMMONLY CARRIED in Chapter 2:

(a1)	(a2)	(b1)	(b2)	(b3)	(c1)
"32AB	BATTERIES, CONTAINING SODIUM, or CELLS, CONTAINING SODIUM "	4.3	-	XYZ	II

(2) Add the following new Special Provision to Chapter 3:

"XYZ Batteries or cells transported under this entry may contain no other dangerous goods with the exception of sulphur. Batteries or cells may not be offered for transport at a temperature at which any liquid elemental sodium is present in the battery or cell unless approved, and under the conditions of transport established by the competent authority.

Cells should consist of hermetically sealed, metal casings which fully enclose the dangerous goods and which are so constructed and closed as to prevent the release of the dangerous goods under normal conditions of transport. Cells should be placed in suitable outer packagings with sufficient cushioning material to prevent contact between cells and between cells and the internal surfaces of the outer packaging, and to ensure that no dangerous movement of the cells within the outer

packaging occurs in transport. Packagings should be tested and marked according to the provisions applicable to Packing Group II solids.

Batteries should consist of cells secured within, and fully enclosed by a metal casing so constructed and closed as to prevent the release of the dangerous goods under normal conditions of transport. Batteries may be offered for transport, and transported unpacked or in protective enclosures (e.g., in fully enclosed or wooden slatted crates) that are not subject to the packaging testing provisions of these Recommendations."

(3) Add the following entries to the Index:

"BATTERIES, CONTAINING SODIUM.....4.3 32AB

CELLS, CONTAINING SODIUM.....4.3 32AB"