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**PROCEEDINGS OF THE OECD WORKSHOP ON THE EFFECTIVE COLLECTION  
AND RECYCLING OF NICKEL-CADMIUM BATTERIES**

Lyon, France, 23-25 September 1997

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**OECD Environmental Health and Safety Publications**

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NICKEL-CADMIUM BATTERIES**

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**IOMC**

**INTER-ORGANIZATION PROGRAMME FOR THE  
SOUND MANAGEMENT OF CHEMICALS**

**A cooperative agreement among  
UNEP, ILO, FAO, WHO, UNIDO, UNITAR and OECD**

**Environment Directorate  
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT  
Paris 1999**

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The Organisation for Economic Co-operation and Development (OECD) is an intergovernmental organisation in which representatives of 29 industrialised countries in North America, Europe and the Pacific, as well as the European Commission, meet to co-ordinate and harmonize policies, discuss issues of mutual concern, and work together to respond to international problems. Most of the OECD's work is carried out by more than 200 specialised Committees and subsidiary groups made up of Member country delegates. Observers from several countries with special status at the OECD, and from interested international organisations, attend many of the OECD's Workshops and other meetings. Committees and subsidiary groups are served by the OECD Secretariat, located in Paris, France, which is organised into Directorates and Divisions.

The work of the OECD related to risk management is carried out by the Working Party on Risk Management, with Secretariat support from the Environmental Health and Safety Division of the Environment Directorate. As part of its work on risk management, the OECD has issued "status report" monographs on five substances that were, or continue to be, the subject of review: **lead, cadmium, mercury, selected brominated flame retardants and methylene chloride**. It has also published two volumes of the **proceedings of the OECD Cadmium Workshop** held in Saltsjöbaden, Sweden, in 1995 and a **survey report on methylene chloride**, supplementing the information presented in the monograph on methylene chloride (see list of publications on page 4). In 1996, OECD Environment Ministers endorsed a **Declaration on Risk Reduction for Lead** to advance national and co-operative efforts to reduce the risks from lead exposure.

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*This publication was produced within the framework of the Inter-Organization Programme for the Sound Management of Chemicals (IOMC).*

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**The Inter-Organization Programme for the Sound Management of Chemicals (IOMC) was established in 1995 by UNEP, ILO, FAO, WHO, UNIDO, UNITAR and the OECD (the Participating Organizations), following recommendations made by the 1992 UN Conference on Environment and Development to strengthen co-operation and increase international co-ordination in the field of chemical safety. The purpose of the IOMC is to promote co-ordination of the policies and activities pursued by the Participating Organizations, jointly or separately, to achieve the sound management of chemicals in relation to human health and the environment.**

## **FOREWORD**

These Proceedings contain the presentations made at the OECD Workshop on the Effective Collection and Recycling of Nickel-Cadmium Batteries held in Lyon, France, on 23-25 September 1997. There is also a report of the Workshop, including participants' findings and recommendations. A description is provided of the OECD's Risk Management Programme, under which the Workshop was held; the development of methodologies to support Member countries' efforts to manage risks posed by chemical substances; and the role of this Workshop in supporting such activities.



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## EXECUTIVE SUMMARY

The OECD Workshop on the Effective Collection and Recycling of Nickel-Cadmium Batteries was held in Lyon, France, on 23-25 September 1997. It was sponsored by the Governments of Australia, Canada, Japan, Mexico and the United States, in co-operation with the International Cadmium Association. The scope of the workshop included portable, industrial and electric vehicle batteries and production wastes.

This workshop provided the opportunity for 53 representatives from 15 OECD countries and the European Commission to share their experiences with collection and recycling programmes, and to identify elements that are most likely to be found in successful programmes. The main focus was on improving collection and recycling rates, rather than on risks associated with cadmium or the substitution of Ni-Cd batteries with alternatives.

John Atherton (International Cadmium Association) and Joe Carra (US Environmental Protection Agency) co-chaired the workshop. The rapporteurs were Hugh Morrow (International Cadmium Association) and Steven Algrove (UK Department of Trade and Industry).

The background to this workshop was a discussion during a 1995 OECD workshop, hosted by Sweden, on sources of cadmium input to the environment. At that workshop considerable attention was focused on Ni-Cd batteries, as they constitute approximately 65% of the total cadmium market in the western world. Furthermore, the portable Ni-Cd market is estimated to be growing at a rate of 5% per year.

The OECD's Cadmium Working Group of Policy Experts, which met following the Swedish Workshop, agreed that it was desirable to increase the collection and recycling of Ni-Cd batteries. It encouraged industry to participate with governments and other interested stakeholders at local, national and international levels, in order to facilitate increased collection and recycling in an efficient and cost-effective way. The Joint Meeting of the OECD's Chemicals Group and Management Committee also recommended that this workshop be held, to discuss strategies and techniques that could improve collection and recycling rates in Member countries (currently estimated at 10-30% for consumer batteries, but up to 85% for industrial batteries).

The Lyon workshop was organised to provide formal presentations and discussions touching on a range of issues, including both current and prospective collection and recycling programmes. Following the presentations (included in these Proceedings), participants divided into two Working Groups which discussed the goals of collection and recycling programmes; barriers to the development of successful programmes; drivers; critical steps for success; "what's gone wrong"; how to measure success; benefits and costs; and suggestions for establishing programmes. At the conclusion of the workshop, participants made a series of recommendations (see the Summary of Workshop Activities). These recommendations were considered by the Joint Meeting in February 1998.



## **Introduction**

The OECD Workshop on the Effective Collection and Recycling of Nickel-Cadmium Batteries was held in Lyon, France, on 23-25 September 1997. The Workshop was sponsored by the Governments of Australia, Canada, Japan, Mexico and the United States in co-operation with the International Cadmium Association. The scope of the Workshop included portable, industrial and electric vehicle batteries and production wastes.

The Workshop provided the opportunity for 53 representatives from 15 OECD countries and the European Commission to share experiences with regard to collection and recycling programmes, and to identify those elements which are most likely to be found in successful programmes. The main focus was on improving collection and recycling rates, rather than on the risks associated with cadmium or the substitution of Ni-Cd batteries with alternatives.

The Workshop Chairs were John Atherton (International Cadmium Association) and Joe Carra (US Environmental Protection Agency). The Rapporteurs were Hugh Morrow (International Cadmium Association) and Steven Algrove (UK Department of Trade and Industry).

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### ***Workshop Objective***

The main objective of this Workshop was to provide an opportunity for governments and industry to share experiences with collection and recycling programmes, and to identify those elements that are most likely to be found in successful programmes. The main focus was on improving collection and recycling rates, not on the risks associated with cadmium or on the substitution of Ni-Cd batteries with alternatives.

### ***Challenges to the Workshop***

The Workshop was structured in a way that provided for both presentations and discussion on a range of issues, including a description of both current and prospective programmes.

In introducing the discussion of these topics, the Workshop Chairs identified the following challenges or sub-objectives for the Workshop:

- to increase awareness of the range of activities which are ongoing in the context of Ni-Cd battery collection and recycling;
- to identify the benefits and costs of the various approaches;
- to identify the factors that contribute to or inhibit their success;
- to identify ways to enhance collection and recycling.

In order to meet these sub-objectives within the discussion, the participants were invited to be mindful of the following questions:

- What are the primary goals of a programme?
- What are the drivers and barriers for a successful non-regulatory programme?
- What are the critical steps in initiating and maintaining a successful programme –
  - for individual countries?
  - for regions or world-wide initiatives?
- Where have existing programmes gone wrong and why? There is a need to study not only successes, but also failures, as more is often learned from the latter.
- Which criteria should be used to measure a programme's success?
- What are the benefits and costs of programmes?
- What suggestions could be made for the OECD, individual Member countries, industry/companies or NGOs interested in establishing programmes?
- How can the OECD help?

## Summary of Workshop Activities

### *Elements of a Successful Programme*

The Workshop identified the following elements which were regarded as necessary for a successful collection and recycling programme:

- 1) A programme must be easy for a motivated consumer to understand and use.
- 2) Public information programmes should:
  - motivate more consumers to recycle;
  - instruct motivated consumers on how to recycle.
- 3) Environmental regulatory requirements may need to be revised to facilitate collection, transport, storage and recovery of valuable resources from batteries, taking into account appropriate management practices related to the potential hazards posed by the materials.
- 4) It is desirable for designers, manufacturers and distributors to have to deal with only one global labelling system.
- 5) It should be possible for recyclers to easily, efficiently and safely identify and sort different kinds of batteries.
- 6) The system, including public information programmes, should be financed using a pre-payment built into the cost of the product.
- 7) There should be robust methods for measuring the success of the recycling programme.

### *Formal Presentations*

An overview paper was prepared for the Workshop by Hugh Morrow of the International Cadmium Association and John Keating of Natural Resources Canada. This background document, presented by Mr. Morrow, described the global market for Ni-Cd batteries, the stages in their life cycle, and typical approaches to their collection and recycling.

The issue papers presented at the Workshop addressed industry, government or NGO experience with collecting and recycling Ni-Cd batteries. The issues identified relate to each stage in the life cycle of these batteries: that is, their manufacture; the manufacture of products which use them; consumer product repackaging, distribution and retailing; management of collection programmes; spent battery collection; management of recycling facilities; and the role of government. Identification of these issues facilitated the Workshop discussions. In particular, they assisted in identifying factors which contribute to successful programmes, as well as possible future government, industry and OECD activities which could enhance their success.

### *Findings of the Working Groups*

Following the formal presentations, the Workshop divided into two Working Groups in order to address the objectives identified above. The findings of the Working Groups have been combined and are presented below. They are also presented individually in Annex I.

At the start of the Working Groups' discussions, it was agreed that successful collection and recycling programmes are technically feasible. The main thrust of the discussions therefore focused on ways to encourage and enhance collection and recovery of Ni-Cd batteries from all **end-users**. In this connection it was noted that end-users could include a range of groups, from consumers to businesses to public entities such as hospitals, police, electric utilities, etc.

#### *Goals of a Collection and Recycling Programme*

The Working Groups first discussed the goals of collection and recycling programmes.

As regards the scope of a programme, the question was first raised as to whether a programme should target the collection of all batteries, or whether there should be selective collection programmes for specific rechargeable battery types - and Ni-Cd batteries in particular. Also, is it better to start collecting one type and then expand to others, or the reverse? If a programme focuses on only one battery type, how is it possible to educate the consumer to distinguish it from others?

A number of participants suggested that a programme designed to collect all battery types could increase the collection of Ni-Cd batteries.

The question was raised as to the environmental benefits of recycling the various chemistry types, vis-à-vis the value of the recycled materials, their utility in creating new products, and the energy used for the recycling process.

It was noted that, depending on the country's policy preference, either a voluntary industry-based approach could be taken towards establishing a programme or there could be a government-sponsored programme. In either case it would be important to set realistic rates. For example, it would be impossible to reach a level of 100% collection and recycling - in fact, it is likely to take many years to achieve a high target. It would also be important, in choosing between industry or government-sponsored schemes, to choose the more cost-effective management option. Any funds generated should be dedicated solely to collection and recycling.

It was also recognised that a programme should identify a simple message to the consumer, including the easy recognition of recycling or collection symbols.

Finally, it is important to return the maximum of the recycled materials to the battery industry or for other uses.

#### *Barriers*

The following barriers to the development of successful collection and recycling programmes were identified:

- Consumers choose products, not battery types based on their chemistry, which can limit the effectiveness of single-chemistry collection programmes.
- Limitations related to transportation, collection or storage regulations may inhibit the development of a programme.

- Since there is no collection programme in some OECD countries, producers may not be in a position to use recycle symbols as the national authorities may consider such labels misleading.
- Collectors with used batteries, who have not anticipated the cost of recycling, may place the batteries in landfill sites since that is a cheaper option.
- Collection and recycling programmes need to take antitrust laws into account.
- Multiple symbols are confusing to the consumer, difficult to put on the battery because of limited space, and may lead to programmes that are incompatible between countries.
- The transportation of vented industrial cells filled with electrolyte is heavily regulated, but the best management of the electrolyte may be at the recycling facility. Current policy encourages collectors to first drain electrolyte in order to reduce the regulatory burden.

#### *Drivers*

The following drivers, or factors which promote the success of collection and recycling schemes, were identified:

- The increased environmental awareness of end-users, governments and industry is promoting higher collection and recycling rates.
- A desire to improve the public image of companies (OEMs, battery manufacturers) is an additional factor.

#### *Critical Steps for Success*

The following steps were identified as critical for the success of collection and recycling programmes:

- In order to educate and motivate the consumer, it is necessary to provide clear information concerning what to do with batteries and where they should be returned.
- It is important to classify and target market user segments and the associated educational efforts. For example, emergency lighting is managed by professionals, whereas consumers handle common OEM equipment, so that the educational strategies will be different.
- Corporate level management involvement is necessary in order to motivate retail employees to ensure collection success.
- An efficient programme design should include market certainty, with a stable flow of materials, a return on investment, and an end-product market for recovered materials.
- The programme design should include efficient financing:
  - Pre-payment should be built into the cost of the product, and the payment should go to the collection and recycling programme;
  - Anticipate a slow start to collection, and meanwhile concentrate on education;
  - Any charge to the consumer must be at the point of purchase, while the product still has value to the consumer.

- The programme design should consider whether the charge to the final consumer should be transparent.
- The programme design should be tailored to specific countries with respect to local regulations, policies and culture.
- Co-operative approaches among all stakeholders (especially between industry and government) are essential.
- It is important to identify and take advantage of every possible take-back route.
- A key part of the education aspect is to clearly label packaging and/or product user manuals, stating that the consumer has already paid a fee for recycling the battery(ies), in order to encourage a high level of return.

#### *What's Gone Wrong?*

The following problems with existing recycling and collection programmes were identified:

- Batteries get mixed into selective collection programmes, raising questions about their future management.
- Most programmes were only recently initiated, so more time may be needed to analyse the problems.
- Failure to plan for the full cycle of collection and recycling can lead to lengthy storage times for those batteries for which no recycling option is yet available.

#### *How to Measure Success*

The following were identified as measures of success:

- The actual collection rate is one measure, but the utility of this measure is debatable.
- If the collection rate for a particular type of battery is comparable to its market share, the collection programme is likely to be a success.
- Comparing sales volume to amount recycled is inappropriate. It is necessary to develop or use an existing formula that takes into account the life of batteries, application, and other factors.
- If the number of batteries in household waste is measured and compared from one year to the next, the improvement rate can be determined.
- Sales measures are units/dollars, collection measures are weights, and the comparison is hard.
- Knowledge of the extent to which consumers understand and participate in a given programme is one measure.
- Final recycling rate compared to collection rate is another measure.
- Joint efforts to improve measures of success are desirable.

*Benefits and Costs*

The following benefits and costs of collection and recycling programmes were identified:

- Collection and recycling remove **hazardous** materials from the waste stream.
- The high cost of collecting **all** batteries (in order to keep the consumer message simple) may be necessary at the initial stage of a programme.
- The costs are shared by all, including consumers.
- Collecting all batteries may improve the management of primary batteries, even if they are not recycled.
- If the use of cadmium in batteries is banned, what will happen to the recovered cadmium?

*Suggestions for Establishing Programmes*

The following suggestions were made in regard to establishing new recycling and collection programmes:

- Review the lessons learned from existing programmes before creating new ones.
- The European Portable Battery Association and other international industry/government organisations should co-ordinate their efforts in reviewing various measures of success, in order to identify opportunities for voluntary harmonization.
- Encourage the use of internationally accepted symbols to mark batteries, recognising the limited space available on the batteries.
- The issues of interest to OECD countries are more on the consumer role and service/distribution side; in general, industrial vented cells are currently well managed and are subject to high collection and recycling rates.
- A finance system should be designed to minimise costs.
- Most collection and recycling programmes are at early stages of development. It is too early, therefore, to attempt harmonization.
- In the long term, it is important to consider how to help non-OECD countries as Ni-Cd battery use increases - for example, with technology transfer and with assistance in developing collection facilities.

*Workshop Recommendations*

- 1) The OECD should convene a meeting of interested groups, including the International Organization for Standardization (ISO), the International Electrotechnical Commission (IEC), national battery recycling organisations, the European Commission, national governments, as well as manufacturers of batteries and battery-powered products, to seek harmonization of requirements for marking systems to serve the purposes of:
  - end-user identification of batteries that are to be separately collected;
  - efficient (and, where possible, automatic) sorting for recycling or proper disposal.

- 2) The OECD should convene a meeting of experts from government and industry (including manufacturers and those involved in collection and recycling, as well as waste industries) to compare different measures that may be used to determine the effectiveness of battery collection and recycling programmes, with a view towards developing common measures to allow comparisons of the effectiveness of such programmes across countries and types of programmes.
- 3) A document on financing arrangements for Ni-Cd battery recycling programmes should be created and disseminated. This document would include descriptions and characteristics of various financing arrangements (e.g. "payback" systems for the return of used batteries) as well as the experience of OECD countries in implementing them. This document would be shared with Member and non-member countries that may be interested in developing their own programmes.
- 4) Guidelines should be developed on how to establish a successful Ni-Cd battery recycling programme. These would consist of general guidance, based largely on the Workshop report, as well as chapters based on individual case studies of currently operating and newly developing recycling programmes. The purpose of this document would be to share experiences among OECD countries and beyond.

In addition, the sense of the meeting was that:

- Ni-Cd batteries are products that have been increasingly used by consumers around the world. They contain valuable raw materials which are potentially hazardous, so it is important that environmentally responsible collection and recycling systems be established.
- Significant private investment is being made, and will continue to be made, to establish such systems. For the continuation of private investment, it is important that there be a stable market, a high collection and recycling rate, an adequate return on investment, and end-product markets for the recovered materials.
- A recent proposal of the European Commission (for a directive on batteries and accumulators) may have some bearing on maintaining the above conditions. The Workshop agreed that it should share the report of this meeting with appropriate officials within the European Commission, for their consideration, as they finalise the proposed directive.

## **PAPERS PRESENTED AT THE WORKSHOP**



# Overview Paper on Effective Recycling of Ni-Cd Batteries

**Hugh Morrow, International Cadmium Association**

**John Keating, Natural Resources Canada**

## **The Ni-Cd Battery**

The nickel-cadmium (Ni-Cd) battery is a rechargeable battery system based on the reversible electrochemical reactions of cadmium and nickel in an alkaline potassium hydroxide electrolyte. The chemical compositions of Ni-Cd batteries can vary widely depending on the type and its specific application. While the industry generally assumes an average cadmium content of 15% and an average nickel content of 30% in Ni-Cd batteries, the specific values in various Ni-Cd battery types can vary by as much as 10% from these averages. In addition, most Ni-Cd batteries contain significant amounts of iron, plastics and electrolytes and small amounts of metals such as cobalt, copper, chromium and zinc.

Ni-Cd batteries are generally viewed as high performance battery chemistries with good energy density and power density, especially suitable for high drain rate applications. Included in their best performance characteristics are their high cycle life and thus long service life and dependability, wide temperature operating range, resistance to electrical/mechanical abuse and rapid charge/discharge characteristics. They may readily be formulated into many different types, shapes and sizes of batteries designed to meet the specific requirements of many different applications. They range in size from 10-gram AAA-sized cells to multi-cell modules weighing hundreds of pounds for electric vehicle use. The average sized consumer Ni-Cd battery is assumed to weigh approximately 30 grams.

## **Applications and Markets**

Since the early to mid 1980s, the Ni-Cd battery market has grown significantly with the result that in 1996 this sector accounted for approximately 70% of world-wide cadmium consumption, and is predicted to account for an even higher proportion by the year 2000. The Ni-Cd battery market, at least from the cadmium usage point of view, is further divided into two sectors - the large industrial batteries and the small consumer cells. The industrial Ni-Cd batteries currently account for slightly more than 23% of the cadmium consumed by the Ni-Cd battery industry with the remaining 77% going to the portable consumer applications. In the past decade, it has been the rapid growth in the small consumer cells which has led to the strong growth of the overall Ni-Cd battery market. The relative proportions of cadmium consumed in the industrial and consumer Ni-Cd battery markets are summarized in Table I for 1983 through 2003.

Specific applications for industrial and consumer Ni-Cd batteries cover a very wide range of products and uses. In the industrial Ni-Cd battery sector, most batteries are utilized for either aircraft or railway/transit system applications. Aircraft uses include main engine and auxiliary power unit (APU) starting power and emergency power for numerous on-board electrical systems necessary for aircraft operation, instrumentation, navigation and data processing. Railway and transit system applications include engine starting, signalling, switching, and emergency power. Recently, nickel-cadmium batteries have been adapted to power the first generation of electric vehicles (EVs), and are currently utilized in the

full-scale production of four French EVs - Peugeot 106 Electrique, Citroen AX, Renault Clio, and Renault Express. The present Ni-Cd industrial battery market is divided roughly equally between the aircraft and railway applications, and has been growing recently at an annual rate of 2% to 4%.

The small portable consumer Ni-Cd batteries are utilized for an even wider variety of products and applications, but are usually categorized into seven general categories - home appliances, communications, power tools, office equipment, security and emergency lighting, hobbies and toys, and other applications such as measuring equipment, metal detectors, uninterrupted power supplies and remote area energy storage.

The nickel-cadmium consumer battery market has been analyzed in several different ways, in some cases according to geography, in others according to millions of cells sold, and yet in others in terms of the total sales value. These figures can often be quite different, and it is important to recognize these differences and why they occur. In general, it is believed that the best measure of world-wide Ni-Cd battery use is the total number of cells manufactured throughout the world even though the Japanese battery manufacturers Sanyo and Matsushita/Panasonic produce the lion's share of Ni-Cd cells. Summarized in Tables II and III below are the breakdowns of the Ni-Cd consumer cell market by application according to the Battery Association of Japan and the Santa Clara Consulting Group respectively.

Nickel-cadmium batteries are expected to continue to enjoy widespread use in power tools, cellular telephones, lighting and security applications, and toys and other uses. The power tool and cellular telephone markets, in particular, are forecast to grow strongly and Ni-Cd batteries will continue to be the dominant battery chemistry used in those applications. Various analyses of the Ni-Cd consumer battery market have placed its overall growth rate between 4% and 8% per annum.

### **The Life Cycle for Recycling of Nickel-Cadmium Batteries**

In recent years, there has been a concerted effort to consider the human health and environmental effects of products such as Ni-Cd batteries over their entire life cycle to ascertain their total impact rather than the impact during only one particular phase, for example, battery manufacture or battery disposal. In order to do so, a complete life cycle analysis (LCA) must be performed. Although no complete LCA has been performed on Ni-Cd batteries to date, some partial analyses do exist and the general steps in the life cycle of a Ni-Cd battery have been established. The stages for the recycling of Ni-Cd batteries are represented schematically in Figure 1 below.

The main stages for the recycling of a rechargeable nickel-cadmium battery are:

1. Production of Battery Raw Materials
2. Production of Ni-Cd Batteries and/or Battery Packs
3. Incorporation into Battery-Powered Devices and Applications
4. Distribution/Transportation to End Users
5. Use, Recharging and Maintenance by End Users
6. Recycling (Collection, Processing and Recovery)

**Table I. Western World Nickel-Cadmium Battery Markets****Percent of Ni-Cd Battery Cadmium Consumption**

<u>Year</u>	<u>Industrial</u>	<u>Consumer</u>
1983	46	54
1988	34	66
1993	26	74
1998	23	77
2003	20	80

**Table II. Japanese Ni-Cd Consumer Battery Market in 1996\***

<u>Application</u>	<u>Market Share(%)</u>
Home Appliances	28
Power Tools	22
Communications	19
Security & Lighting	11
Toys & Others	7
Office Equipment	7
Round Cells	6

\*Kinya Fujimoto, "Latest Activities of Small Rechargeable Batteries Recycling in Japan," *3rd International Battery Recycling Congress, Noordwijk Aan Zee, The Netherlands, July 1997.*

**Table III. World Ni-Cd Consumer Battery Markets for 1995 and 2000\*****Shares of "4Cs" Ni-Cd Market**

<u>Application</u>	<u>1995</u>	<u>2000</u>
Cellular Telephones	44.6	45.7
Cordless Power Tools	38.1	40.9
Camcorders	15.3	13.2
Computers	2.0	0.2

\*Joel Tax, "Nickel-Cadmium Batteries in the 4C's Markets: 1995-2000," *Nickel-Cadmium Battery Update '96, Sitges-Barcelona, Spain, September 30-October 1, 1996.*

## NiCd Battery Recycling Inventory Analysis

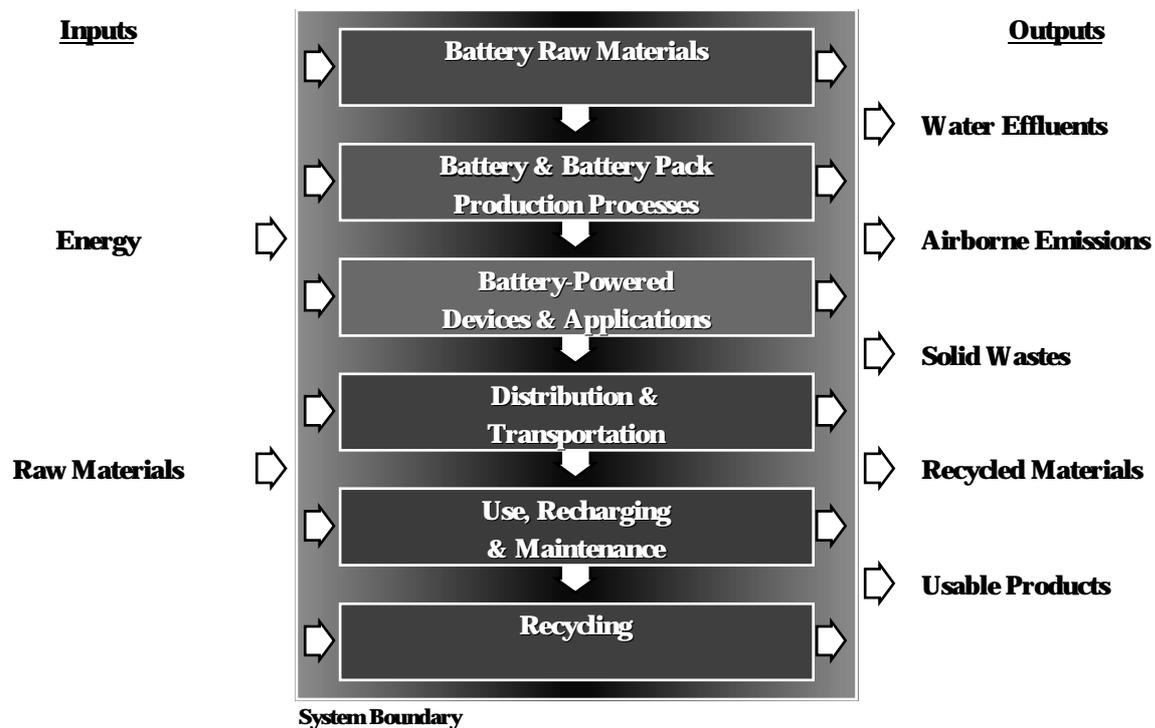


Figure 1. Schematic Representation of Life Cycle Analysis Scope and Inventory Analysis for Recycling of Ni-Cd Batteries

*Production of Battery Raw Materials* - For the most part, the product's major materials of construction are the ones which will most affect its life cycle analysis. In the case of the nickel-cadmium battery, those materials will be nickel, cadmium, iron and the potassium hydroxide electrolyte. The forms of nickel and cadmium utilized in Ni-Cd batteries are generally the oxides or hydroxides of these metals with a closely controlled particle size, particle size distribution and overall chemistry. These products are supplied by only a limited number of suppliers throughout the world. Similarly the steel strip which serves as the electrode substrate and the potassium hydroxide electrolyte are closely controlled to ensure battery quality and are generally supplied from a limited number of sources. In a number of cases, the Ni-Cd battery manufacturers may produce their own raw material to ensure quality and protect proprietary formulations.

It is, however, well established that the cadmium oxide raw materials suppliers in many cases have arrangements with their Ni-Cd battery manufacturing customers to take back and receive credit for cadmium-rich manufacturing wastes. Opportunities may also exist between the raw material supplier and the Ni-Cd battery manufacturer for the return of other materials as well. Thus, the first point in the life cycle of a Ni-Cd battery where recycling opportunities exist is between the raw material supplier and the Ni-Cd battery manufacturer. As will subsequently be shown and discussed during this workshop, some primary cadmium producers, notably Mitsui Mining & Smelting Co., Ltd. and Toho Zinc Company in Japan, have already successfully integrated Ni-Cd battery recycling into their primary cadmium production.

Battery and Battery Pack Production - The vast majority of nickel-cadmium batteries are produced by only a limited number of battery manufacturers which, however, may have manufacturing and battery assembly plants all over the world. The major manufacturers are:

Sanyo Electric Company, Ltd.  
 Matsushita/Panasonic  
 SAFT S.A./SAFT America  
 Energizer Power Systems Division of Eveready Battery Company  
 GPI International Limited  
 Varta Batteries AG  
 Marathon Power Technologies  
 Hoppecke Batterie Systeme GmbH  
 Acme Electric Corporation  
 Tudor Group  
 Mine Safety Appliance Company

For the most part, Sanyo, Panasonic, SAFT, Energizer and GPI (Gold Peak International) are the major producers of the consumer Ni-Cd batteries, while SAFT, Varta, Marathon and Hoppecke are the major producers of industrial Ni-Cd batteries. The major consumer battery manufacturers, in particular, have assembly plants located in those areas such as North America, Europe and Japan to serve their major end-use markets. However, they will often produce a critical component such as the positive nickel electrode and negative cadmium electrodes in bulk form at their main plant, and then ship to regional assembly plants where individual electrodes are slit for assembly into individual batteries. Manufacturing plants for industrial Ni-Cd batteries are located in North America and Europe and generally serve end-use markets in those respective areas.

Individual batteries, most commonly “C”, “sub-C” and “4/3 C”, are also very often assembled into battery packs for usage in Ni-Cd battery powered appliances. Assembly may be performed by the Ni-Cd battery manufacturer or an independent company devoted exclusively to battery pack production. Battery packs vary greatly in size and shape and are generally designed to fit the form and function of the tool or appliance which they power. Recently, companies such as Black & Decker, amongst others, have designed their Ni-Cd battery powered tools so that battery packs may be easily removed and interchanged as the power sources for several different tools. Such a design not only improves the versatility of their Ni-Cd powered tools, but also facilitates the removal of spent batteries for collection and battery materials recovery.

Most of the nickel-cadmium battery manufacturers have maintained battery take-back programs for some years, and developed specific arrangements with certain recovery facilities to process those batteries. One company, SAFT NIFE AB (formerly Nife-Jungner AB) in Sweden, actually built its own Ni-Cd battery metals recovery plant in the late 1970s to process Ni-Cd battery manufacturing wastes, and continues to process Ni-Cd batteries today at its industrial battery production plant in Oskarshamn, Sweden.

*Battery Powered Devices and Applications* - Whereas the production of industrial and consumer Ni-Cd batteries or battery packs is concentrated in a relatively small number of sources, these batteries find their way into the products of hundreds of battery powered devices and end-use applications. For example, while there may be only half a dozen major manufacturers of industrial Ni-Cd batteries, there are probably hundreds of railroads, transit authorities, airlines and aircraft manufacturers who utilize those batteries. The distribution of Ni-Cd batteries into consumer end-use applications is even more widespread with at least a dozen major product manufacturers in each one of the seven major end-use applications. In addition, most of these product manufacturers are international in scope and normally have plants in several different areas of the world to serve the markets in those regions. The end result is that Ni-Cd batteries become widely distributed in the process of being incorporated into battery powered devices and end-use applications.

However, a distinction in the degree of distribution between industrial and consumer Ni-Cd batteries must be made. In general, the industrial Ni-Cd batteries are produced in plants in North America or Europe and shipped directly to the end users, such as railroads, transit authorities or aircraft manufacturers in those regions. The number of batteries produced is far less than the number produced for the consumer market, and the industrial batteries are generally concentrated in fewer applications. Consumer Ni-Cd batteries, on the other hand, are utilized in far greater numbers in a much greater variety of sizes, shapes and applications by a far greater number of end-product manufacturers. Thus, the degree of distribution of the consumer Ni-Cd batteries is much greater than that of the industrial Ni-Cd batteries.

Nonetheless, many manufacturers of Ni-Cd powered consumer products, such as Motorola, have had take-back programs in place in the past, and do participate in the battery association voluntary programs in place today. In addition, the industrial Ni-Cd battery users generally have arrangements with their suppliers to return spent Ni-Cd batteries for recycling. It is relatively easy to collect, process and recover materials from the industrial Ni-Cd batteries because of the limited number of end-users and the size and geometry of the batteries in the latter case, but has proved more difficult to collect most of the smaller, sealed consumer cells from the large number of widely distributed end-users in the former case.

*Distribution and Transportation of Ni-Cd Powered Products* - Once incorporated into Ni-Cd battery powered consumer products or industrial applications, the products are transported and distributed to the ultimate end-user through retail outlets in the case of consumer batteries and to the major industrial users in the case of industrial Ni-Cds. Once again, these retail outlets and major industrial end-users do provide opportunities or points in the Ni-Cd life cycle where effective collection of spent batteries could be realized, and, in fact, these points already do constitute major paths through which established Ni-Cd battery recycling presently operates.

For example, in the PRBA/RBRC program in the United States, retail outlets such as Radio Shack, Sears and Wal-Mart are an established part of the network which collects spent consumer Ni-Cd batteries and returns them to INMETCO for recycling. Such a wide network of retail outlets is necessary to recover a substantial portion of the widely dispersed consumer Ni-Cd batteries. In the case of the industrial end-users, spent batteries may be collected in a more centralized manner. For example, a railroad or transit authority could collect all of the spent industrial Ni-Cds from their operations and return them to their industrial battery supplier for credit and recycling.

*Use, Recharging and Maintenance* - During the use, recharging and maintenance phases of a Ni-Cd battery's life cycle, cells would only be collected and returned if defective. Ordinarily, a defective Ni-Cd battery or battery powered product would be returned to the battery manufacturer or to the battery powered product manufacturer, who could be part of the recycling network as described above.

A consideration here is the average life expectancy of the various types of Ni-Cd batteries. In general, industrial Ni-Cds last much longer than consumer Ni-Cds, but the range may be considerable depending on the application and battery design. For example, the most often reported figure for the life of a small consumer Ni-Cd battery is five years, but in some applications, the lives may be as short as one year or as long as ten years. Industrial Ni-Cd batteries are attributed with an average life of ten years, but again the actual life may be five years to twenty-five years depending upon the specific battery design and its application.

### **Recycling (Collection, Processing and Recovery)**

Recycling of Ni-Cd batteries generally involves three distinct stages - collection, processing and materials recovery. The challenge of recycling nickel-cadmium batteries, particularly the small consumer cells which constitute more than 75% of the present Ni-Cd battery market, is largely a collection and not a processing or recovery issue. There are at present three forms of Ni-Cd battery wastes which are recycled:

- Industrial Ni-Cd batteries
- Consumer Ni-Cd batteries
- Ni-Cd battery manufacturing wastes

By and large the industrial Ni-Cd batteries and the Ni-Cd battery manufacturing wastes are concentrated in only a few sources, are generally relatively easy to collect and thus make up the bulk of the Ni-Cd battery wastes which are recycled today. The industrial Ni-Cd batteries are generally reported to be recycled at rates as high as 80%. The challenge for industry and governments is to devise systems which will ensure the recycling of the more widely scattered small consumer Ni-Cd cells.

*Collection Programs* - Ni-Cd battery collection programs are either voluntary or mandated, and have arisen mainly in the Western World areas of high Ni-Cd battery use such as North America, Europe and Japan. The voluntary programs depend upon Ni-Cd battery consumer participation and have been organized by the major portable battery associations throughout the world such as the Portable Rechargeable Battery Association (PRBA) in the United States, the Canadian Household Battery Association (CHBA) in Canada, the Battery Association of Japan (BAJ) in Japan, and the European Portable Battery Association (EPBA) in Europe with the aid of battery associations in specific countries. European collection programs include BEBAT in Belgium, ARGE BAT in Germany, COBAT in Italy, REBAT in the United Kingdom and ECOVOLT in France. The BAJ program, the oldest voluntary collection program, has enjoyed steady growth from the early 1980s. It has shown especially marked increases in recent years, as shown in Figure 2 below.

The mandated programs have arisen within the European Community. Austria ("Batterien"), Denmark, Netherlands (STIBAT), Sweden and Switzerland (BESO) all have government-sponsored programs some of which require the collection of all battery chemistries for recycling. In some cases, the program is run strictly by the government, while in others, a government-sponsored organization has been set up to administer the program or the program is carried out by an outside organization in co-operation with the government. These programs are all financed by fees or taxes on the batteries.

*Processing Considerations* - Ni-Cd batteries collected under the various collection programs may be shipped directly to a recovery facility or may first be processed at a consolidation point or battery processor, often referred to as a "battery breaker." Kinsbursky Brothers, Inc. in the United States is one example of a battery breaker. It is generally the responsibility of the battery breaker or consolidation point to separate batteries of different chemistries and to direct them to their proper metal recovery facilities.

Battery breakers may also serve the purpose of actually performing a limited amount of processing to facilitate metals recovery during the final metals recovery steps. For example, SAFT will process their industrial Ni-Cd batteries to remove the potassium hydroxide electrolyte, separate the positive nickel and negative cadmium electrodes, and then process the negative electrodes at their facility in Sweden to recover cadmium.

*Recovery Technology* - While collection of small consumer Ni-Cd batteries is a challenge, recovery of cadmium, nickel, iron and all of the other battery materials is relatively easy because of the low free energies of formation of the battery metal oxides in this system, which allows a virtually complete (>99%) recovery of all of the materials in a Ni-Cd battery. At present, there are four principal types of Ni-Cd battery materials recovery operations in the world, and these technologies will be discussed in more detail during the course of this workshop. These four types are:

- Dedicated Ni-Cd battery recovery facilities
- Primary zinc refineries
- Stainless steel recovery facilities
- Hydrometallurgical

A comprehensive listing of most of the world's major Ni-Cd battery metal recovery plants is summarized in Table IV below along with their location, type and estimated processing capacity.

Under the Battery Association of Japan (BAJ) collection program, industrial and consumer Ni-Cd batteries as well as Ni-Cd battery manufacturing wastes have been collected since the early 1980s and processed at the Japan Recycle Center, Kansai Catalyst, Mitsui Mining & Smelting and Toho Zinc Company. The amounts recycled under the BAJ program in recent years are summarized in Figure 2 below, showing a breakdown of the relative amounts of industrial cells, consumer cells and manufacturing wastes recycled.

In Europe, both SAFT in Sweden and SNAM in France have been processing and recovering metals from the Ni-Cd batteries collected under various programs for many years. SNAM currently processes the largest amounts of Ni-Cd batteries in the world, while the SAFT operation is directed mainly towards the recovery of metals from its own Ni-Cd batteries. The volumes of Ni-Cd batteries processed at SNAM in recent years are summarized in Figure 3 below.

Finally, the major stainless steel recovery facility in the USA, INMETCO, processes Ni-Cd and NiFe batteries to recover nickel and iron for the stainless steel industry, and has recently added a cadmium unit to recover cadmium from spent Ni-Cd batteries for reuse in the battery industry. INMETCO is the designated Ni-Cd battery metal recovery facility for the PRBA/RBRC collection program in the United States and the CHBA collection program in Canada, and is the only Ni-Cd battery recycler in the world which recovers both nickel and cadmium on site. A summary of the Ni-Cd battery tonnages processed by INMETCO in recent years is shown in Figure 4 below.

**Table IV. World's Major Ni-Cd Battery Metals Recovery Plants**

<u>Company</u>	<u>Location</u>	<u>Type</u>	<u>Capacity (mt)</u>
INMETCO	USA	Stainless Steel	3,000
Japan Recycle Center	Japan/Korea	Dedicated Ni-Cd Facility	3,000
Mitsui Mining & Smelting	Japan	Zinc Refinery	1,750
Toho Zinc Co., Ltd.	Japan	Zinc Refinery	1,700
Kansai Catalyst	Japan	Zinc Refinery	500
Hydrometal S.A.	Belgium	Hydrometallurgical	1,300
SAFT NIFE	Sweden	Dedicated Ni-Cd Facility	1,500
SNAM	France	Dedicated Ni-Cd Facility	5,400
TNO/Esdex/Leto	Netherlands	Hydrometallurgical	200
Uniquel, S.A.	Spain	Hydrometallurgical	2,400*

\* *Planned Capacity*

## JAPAN

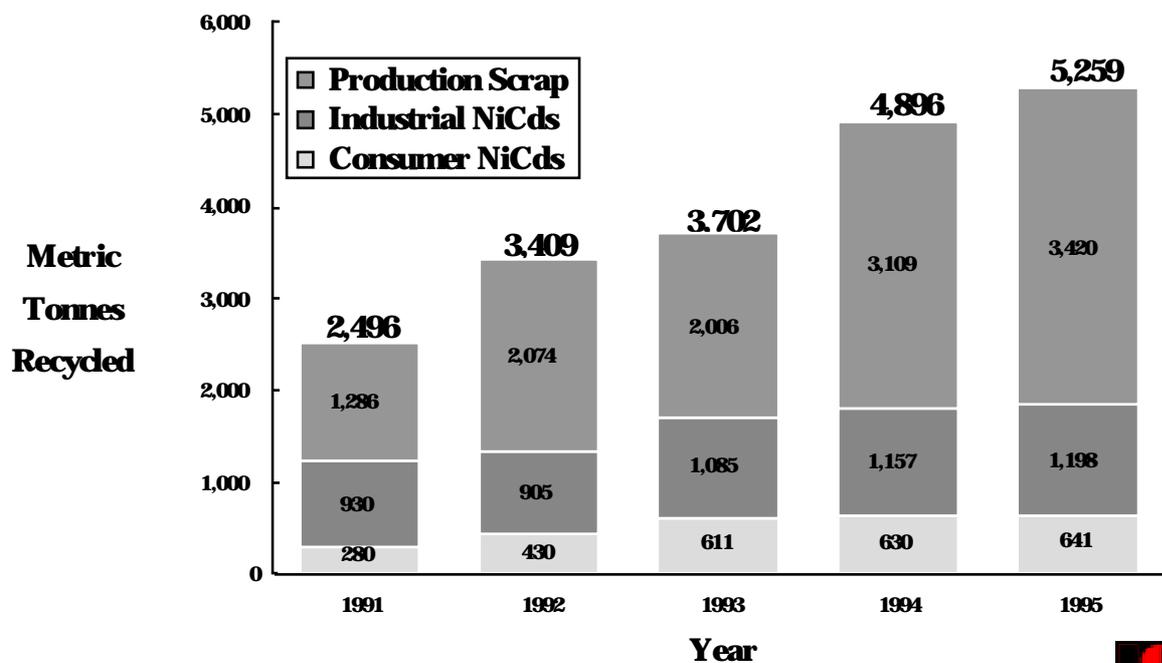


Figure 2. Battery Association of Japan Ni-Cd Battery Recycling Program

## S.N.A.M. - FRANCE

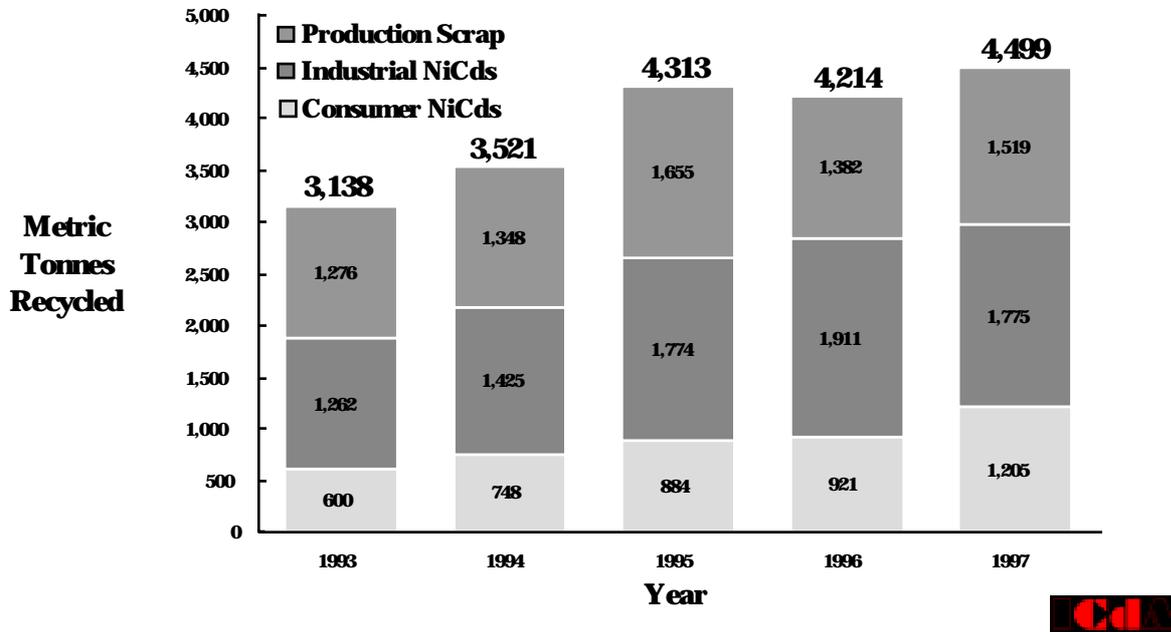


Figure 3. SNAM (France) Ni-Cd Battery Recycling Program

## INMETCO - USA

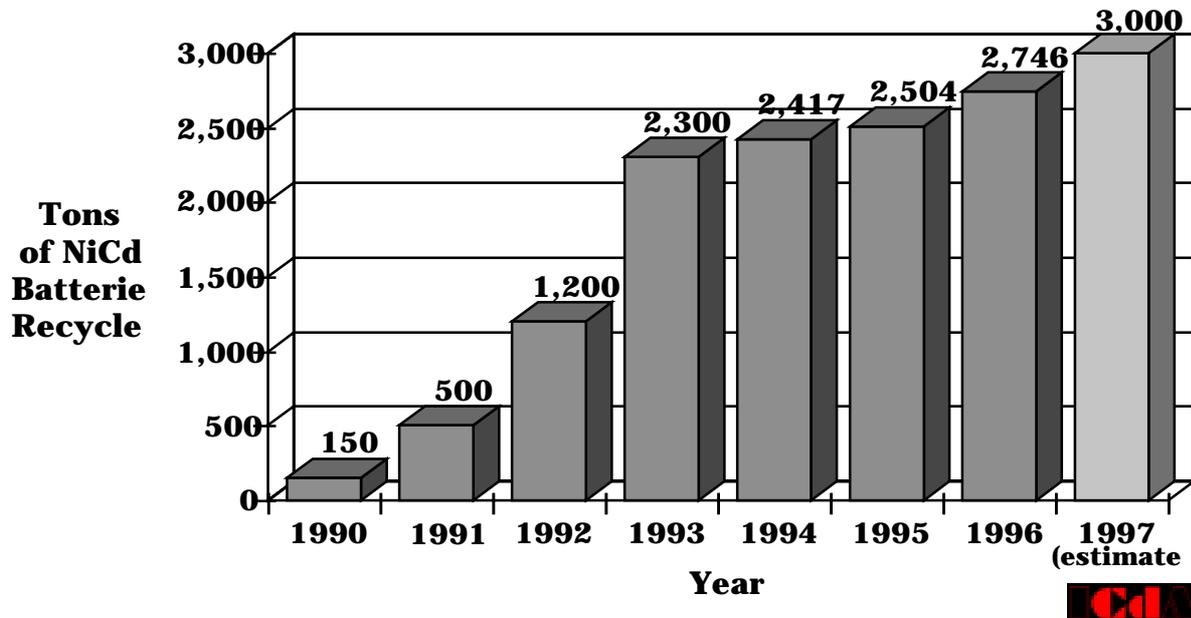


Figure 4. INMETCO (USA) Ni-Cd Battery Recycling Program

It is readily evident from the data shown in Figures 2 through 4 that the majority of the Ni-Cd battery wastes recycled in the world today are either large industrial batteries or manufacturing wastes. In fact, it has been estimated that the recycling rate for industrial Ni-Cd batteries is between 80% and 85% but only somewhere between 10% and 30% for the small consumer cells depending on specific country or area.

*Recycling Program Considerations* - Economic issues of importance in Ni-Cd battery recycling include both economic incentives and barriers. For example, large Ni-Cd battery metal recovery operations such as those at SNAM and INMETCO tend to be more cost-effective than smaller facilities such as the hydrometallurgical plants simply due to lower unit costs of materials processed or economies of scale. Similarly, collection programs which are national or international in their scope may be more cost-effective than those which are confined to smaller regions. The larger the volumes of materials processed, the more cost-effective the recycling operation. In this respect, any prohibitions or product bans on Ni-Cd batteries would have severe negative effects on the economics of Ni-Cd battery recycling and would certainly discourage establishment of new recycling programs. Secondly, large industrial Ni-Cd batteries and manufacturing wastes will probably be less expensive to collect since they originate from fewer sources. The small consumer Ni-Cd batteries arise from a far wider variety of sources, are more difficult to collect, require more processing, and therefore would be more costly to recycle.

Another factor is the nature of the recovery process itself. In general, pyrometallurgical recovery processes appear to involve fewer steps and to be more economical than hydrometallurgical processes. Recovery processes involving very high temperatures or electrowinning processing steps are likely to be more energy intensive and thus more expensive per unit of material recycled than those conducted at lower temperatures or without electrowinning processes. In general, the more complex a process is and the more steps which are involved the costlier that operation becomes. Unless this cost is more than balanced by recovery of a greater number of metals or metals of higher value, the process may not be economically justified.

The success of metal recycling is also dependent upon current metal prices, or if the program is not supported by the monies recovered from the metals recycled, then on the financial system which is utilized to support the recycling system. Thus, the funding mechanism for some programs is very important. In some cases, the Ni-Cd battery industry is paying for the collection, processing and recovery program, while in others governments, both local and national, may be paying for the program. In either case, these costs ultimately will be shifted back to the battery user, either through increased product costs, deposits, taxes or other economic instruments.

It is expected that an effective collection system will require receiving batteries back through as many channels as possible to ensure as full a recycling rate as possible. Some of the many approaches which have been and might be used for the collection of small consumer Ni-Cd batteries include the following:

- Reverse Original Equipment Manufacturers (OEMs)
- Retail outlets
- Institutional generators
- Municipal collection programs
- Battery manufacturers
- Government users

The reverse OEM program includes collection systems such as those devised by Black & Decker and Motorola to take back spent Ni-Cd batteries from their battery-powered appliances such as power tools and cellular telephones. Retail outlets include organizations such as Wal-Mart in the United States which sells individual Ni-Cd cells and collects spent Ni-Cd batteries, and Radio Shack which may offer Ni-Cd batteries as part of battery-powered equipment or as replacement cells. The institutional generators include hospitals, police departments, fire departments and other organizations which may utilize either small consumer or larger industrial Ni-Cd batteries as part of the performance of their daily functions. The municipal collection programs include community or curbside systems through which individual consumers may return their spent Ni-Cd batteries for recycling. All of the major Ni-Cd battery manufacturers - Sanyo, Panasonic, SAFT and Energizer - also have take-back systems of their own, whereby spent Ni-Cd batteries may be returned directly to the manufacturer for recycling. Finally, many governments, through either their armed services or government agencies, are large users of Ni-Cd batteries, and operate successful programs for the collection and recycling of Ni-Cd batteries.

### **Conclusions**

Nickel-cadmium battery markets continue to grow. The degree of Ni-Cd battery collection and recycling continues to increase, and many opportunities exist within the life cycle of a Ni-Cd battery to improve collection and recycling rates. Industrial Ni-Cd batteries are currently recycled at fairly high rates, variously estimated to be between 50% and 80%. Although consumer Ni-Cd battery collection and recycling rates are much lower, typically 10% to 30%, many new collection programs have recently been put in place and the amounts of consumer Ni-Cd batteries collected are increasing. The recovery of materials from Ni-Cd batteries is relatively easy and is very high, approaching 100%.

The successes, failures, incentives and barriers for all of the approaches for improving Ni-Cd battery recycling rates need to be explored in order to identify opportunities to further enhance the recycling rates for nickel-cadmium batteries around the world.

# **Collection and Recycling from the Perspective of a Waste Handler**

**Paul Daynes, Loddon Holdings Ltd, United Kingdom**

## **Introduction**

It was towards the end of 1991 that Loddon, as a supplier of transport and storage services to Motorola at Basingstoke, in the United Kingdom, was asked to become involved in setting up a scheme for the collection and disposal by recycling of spent Ni-Cd battery packs, arising mainly from the land mobile products sector (Radio Communications).

The initiative was born of concern by Motorola for the environment and a determination that, from 1991 onwards, all Motorola batteries retrieved would be recycled and the cadmium and nickel recovered, leaving only the plastic cases to be granulated and landfilled.

Given the brief by the Energy Resources Division of Motorola, Loddon set about obtaining the requisite licences both for the transport of all rechargeable batteries, including those batteries designated as special waste, and for storage and consolidation of these products. In short, we became a Waste Transfer Station.

In February 1992, we received and shipped to SNAM our first quantity of batteries, collected from all over the United Kingdom and amounting to 2.3 tonnes, at a total cost of around £1100 per tonne. At this point in time Motorola was very much a pioneer, leading the way in the collection and recycling of Ni-Cd battery packs. This situation continued throughout the whole of 1992 and 1993, with costs to Motorola staying at around £1100 per tonne. During this period we shipped a total of 22.1 tonnes, almost all from the Radio Communications sector. During 1992 we came into contact with the International Cadmium Association and its then director, Murray Cooke, who saw a need, as a matter of some urgency, to develop interest among major battery producers and some large users in a voluntary scheme to implement EEC directive 91/157. In 1993, The Battery Recycling Group was formed with Motorola still the only organisation with a formal, structured collection programme.

## **The Battery Recycling Group**

The Battery Recycling Group, a loose association of companies, came together during 1993 under the auspices of the International Cadmium Association, representing battery manufacturers, large users, transport and logistics, all with a common interest and main objective of finding viable solutions to the collection and recycling of batteries, within a voluntary framework, which would satisfy the requirements of EEC directive 91/157. By mid 1994 the association had in excess of 25 member companies, some of whom embraced the Motorola philosophy, adding collections from their own facilities and users through Loddon and enabling consolidation and bulking up for shipments to France, a situation which is still very much with us today, with such organisations as Black & Decker, Makita, Bosch,

Simoco (formerly Philips), One 2 One, Alexander Batteries, Energizer Batteries, Euro Energy, Varta and SAFT as main participants, together with Motorola.

### **The Collection Programme**

The Motorola collection programme, which became the model for other participating companies, was designed to make the collection of spent battery packs as trouble free as possible for the waste producer (the customer). The land mobile sector was chosen first of all because the customers, and therefore the waste producers, are in the main large users of battery packs and secondly because the people involved in this sector, radio workshop managers and engineers, are technically aware of the make-up of a battery pack and the need to dispose of spent cells with care. This, coupled with the fact that many of the organisations involved, such as police forces, fire and ambulance services and oil companies, had their own environmental policies in place, made this sector ideal as a starting point, as opposed to the more difficult task of collecting from members of the general public.

The scheme was and still is basically quite simple. Motorola, through their Radio Parts and Service Group, offered customers the opportunity of disposing of their spent Motorola batteries by sending them to, or having them collected by, Loddon at their expense. Thereafter, all costs were to be borne by Motorola, which, you will recall from the introduction, were not inconsiderable. This scheme was immediately successful, particularly as it was pre-Special Waste regulations and collections were treated as controlled waste. The incentive to Motorola, of course, is the ongoing sales of batteries and, to the customer, the trouble free cost savings at the end-of-life.

Other companies, among them Makita Power Tools, have given cash discounts on new batteries for old, of their own make, with free collection and recycling of any make of battery against a Makita battery purchase. Incentives of this kind have a limited success, as they rely very heavily on the co-operation of the retailer, who does not generally perceive battery collection as a potential profit centre.

As more companies joined in the general scheme of things, the types of Ni-Cd battery became more varied. We were now being asked to collect end-of-life power packs from the power tools sector, Black & Decker, Bosh and Makita, single cells in plastic tubes from the emergency lighting sector, large electrical contractors, and wet cells from emergency power locations on behalf of Saft Nife, which embraces three sectors, namely power tools, emergency lighting and heavy industrial.

This departure from fairly standard power packs brought its own problems of sorting and grading, a labour intensive operation. Collections, with the exception of wet cells and some waste regulation authorities, were still relatively easy as the controlled waste regulations required only a waste transfer note, which meant that the logistics of nation-wide collections were mainly the logging of requests and route planning, with all the advantages of economy that are associated with that kind of operation.

### **Collections Post September 1996**

The introduction of the Special Waste regulations in September 1996 impacted on our logistical arrangements, and therefore the economics of collection, to the extent that all rechargeable batteries became designated Special Waste and therefore required pre-notification to the Environment Agency, with a three working day delay before collections could be made and the added cost to the waste producer of 15 pounds sterling for the consignment note. From a nation-wide collection point of view, the new

regulations have made the planning of collection journeys rather more difficult and certainly more expensive, due mainly to the time constraints imposed under them.

There are many examples of the regulations impeding collection schemes. A typical example would be where, having sent a vehicle to collect in a remote part of the UK, and being unable to delay any longer due to time expiring on the pre-notification, a request is received to collect in the same area. Under the regulations as they are, we would be unable to collect until the statutory three working days had expired, resulting in the difference between a viable and less than viable journey.

Another example of how the Special Waste regulations can make life difficult concerns the so-called carrier's rounds. This is where pre-notification on one consignment note can be made, accompanied by a carrier's schedule of several addresses for collections. If the total to be collected does not exceed 400 kg, a week is allowed for collection and a small non-achograph vehicle can be used. However, where the quantity to be collected exceeds 400 kg, collections must be completed and the waste must be at its designated destination within 24 hours. This means, of course, that carrier's rounds for large quantities from long-distance locations are ruled out on time, which means added costs to what is already quite a costly exercise compared to landfill, with which we are too often competing.

The collection strategy is changing, with more and more organisations looking at exactly what is being sent for waste. For instance, are all the batteries returned to dealers or communications workshops really spent? Batteries which appear to be in good order may not be spent at all. Until they are pronounced scrap or totally spent, they are not designated as waste. Therefore, they do not fall within the Special Waste regulations and can be collected and taken to a central point for test and evaluation without the need to treat them as anything other than an ordinary consignment.

Loddon is already involved in such a scheme, and it may well be that waste transfer stations such as ours could be used for this type of operation in the future, with all kinds of possibilities presenting themselves for recycling in the true sense, re-using what already exists.

For this scheme, our customer has reorganised the way its product is marketed to the extent that sales are channelled through just a few strategically located main dealers supplying many satellite sub-dealers. This same network is used to collect the batteries returned as spent or warranty, with the result that all returns are monitored more easily and collected rather more economically. More recently, we have participated in a pilot scheme where collections are being made from the general public, in other words the consumer sector via retail outlets, a sector from which hitherto the industry has generally shied away. It is perhaps a little early to quantify the success of this scheme, although the logistical experience gained is invaluable and will form the basis for a refined programme in the future.

This scheme operated and funded by Manufacturers Alcatel, Ericsson, Motorola, Nokia, Panasonic and Philips with British Telecom, under the auspices of ECTEL (European telecommunications and professional electronics industries), has now expanded to include all airtime providers BT Cellnet, One-2-One, Orange and Vodafone, and as of May 12, 1999 became a fully operational and established scheme, to take back end of life cellular phones, batteries and accessories from the general public for recycling.

The funding is being shared equally by all partners and Loddon Holdings have been appointed managers of what is truly an industry led solution to take back and recycling from the consumer sector.

In spite of the effects of the new regulations mentioned, we believe that regulation has had an effect for good, although it is clear that changes to the regulations need to be made. In our experience the

biggest single barrier to a truly efficient, all-embracing nation-wide collection and recycling scheme is quite simply cost, and who pays.

### **Cost of Collecting and Recycling**

When looking at battery collection schemes and the associated costs, it has to be remembered that industry requires a total service, a service which will relieve the waste producer from much if not all the responsibility of arranging the safe and environmentally acceptable disposal of their arisings, which means that we have to consider four elements of cost. Collection within the united Kingdom, including Northern Ireland and Gibraltar, should reflect the cost of sorting, consolidation and storage, delivery to the recycling facility, in our case SNAM based near Lyon, recycling, and the cost of an Environmental Agency consignment note.

The first two elements can benefit from economies of scale, as collections within the UK mainland can be as high as 35 pence and as low as 10 pence per kg, while deliveries to SNAM are as high as 35 pence and as low as 15 pence per kg. Recycling charges are not under our control, but can add about 35 pence per kg to the total cost. Here again economies of scale come into play, as well as the market prices for cadmium and nickel. A point could be reached where prices for cadmium and nickel, together with greater tonnages, would produce a break even or positive situation. From the beginning of our involvement in 1992, the cost of most collections and all recycling has been borne by the companies participating in the collection programme with no external funding at all. For most participants, this has not been a problem, as most of the batteries collected were originally supplied by them and the decision to bear the cost of collection and recycling was commercially based. However, looking at wider schemes where arisings emanating from the consumer sector include mobile phones, camcorders and IT, the problem of imports from the Far East either as imported spurious batteries or as part of imported equipment is very real, prompting the seemingly endless debate on who pays.

Over the years we have found large quantities of look-alike batteries without name or identification, even on the cells within the battery packs. We have found battery packs purporting to be Ni-MH which, on close examination, proved to be Ni-Cd. It is estimated that more than 20% of all Ni-Cd batteries in the marketplace cannot be identified, so it comes as no surprise that there is a reluctance in the various industry sectors to sponsor any collection scheme where costs cannot be fairly apportioned. Members of the German ARGE BAT scheme are facing this problem now with, it would seem, no ready solution.

### **Battery Disposal**

When the batteries arrive at our facility at Alton in Hampshire, they are inspected to ensure that we are receiving what is listed and defined on the special waste consignment note, and to make sure that the transport companies delivering (if not our own transport) are registered carriers authorised to transport waste. At this stage we complete the consignment note.

The next stage is to weigh and record the receipt. The batteries are then put into the sorting area of the warehouse, where sorting and repackaging takes place. It is part of our agreement with SNAM that we sort into battery types, removing any contaminants such as mercury, lithium, lead-acid and primary cells.

Once sorted, the batteries are decanted into special plastic crates and stored to await a sufficient quantity to constitute a viable load, generally about 24 metric tonnes, at which time a transfrontier movement of waste form is completed together with a packing list bearing the names of contributing companies, essential for auditing purposes, and shipment to SNAM is arranged.

On arrival at SNAM the Loddon shipment is unloaded, weighed and stored to await processing. When the shipment is eventually processed, and in any event within 180 days, SNAM must provide Loddon with a certificate of disposal which is held on file with copies available on request.

SNAM, with two processing plants in France, one at Viviez and one close to Lyon, altogether has a current processing capacity of over 4000 tonnes with authorisation for around 5500 tonnes. There are other plants in Europe also with capacity, which argues against the development of further capacity in Great Britain, a subject which appears to be under almost permanent review.

## Summary

Looking at the effects of collection schemes with which Loddon has been involved, and considering that they have been purely voluntary, they have been successful to the extent that in the five years since the first scheme began Loddon has collected and delivered for recycling about 311 metric tonnes, 180 tonnes of which was collected in the 18 months ending in June 1997. Measured against Germany, with 1700 tonnes per annum, and France with about 1200 tonnes, we have a long way yet to go, even allowing for the difference in size and population.

If we are to continue with a voluntary approach, industry, that is to say the battery producer and large sellers, must be prepared to make resources available to heighten awareness among all sectors of our community. At Loddon, we are made constantly aware of how little is known about what happens and, more importantly, about what should happen to rechargeable batteries at end-of-life. To the person with a camcorder, torch, mobile phone or other device using a rechargeable, a battery is a battery. Companies, organisations, local authorities and even some departments of the Environment Agency using mobile phones and other devices appear to be either unaware of any legislation regarding the safe disposal of Ni-Cd batteries or, if they are aware, they do not know what to do with them. Large organisations, occupying very large facilities, often find that after a change of emergency lighting batteries there are discarded batteries in their basements, left there by electrical contractors who either did not know or did not want to know what to do with them. The exception to this is the heavy industrial battery for back-up power. In this case, the suppliers seem to know exactly what is required of them when they supply replacement cells.

Looking to the future, we believe that to be successful in collecting Ni-Cd and other rechargeables we cannot be selective. We have to provide a service where we collect all batteries, involving local authorities and their waste contractors, as well as battery wholesalers and retailers willing to accept batteries onto their premises for collection. We have to be prepared to sort and segregate and to educate and inform all segments of our community via the media, as happens in Japan and elsewhere.

Equally, we believe that the Department of the Environment must be prepared to allow some flexibility for those organisations able to demonstrate that they are competent and responsible, and dedicated to collecting and disposing of batteries in an environmentally acceptable way. For instance, it may be those organisations such as Loddon which can show that Ni-Cd and other rechargeables are collected for recovery should be exempt from the Special Waste regulations of September 1996. Finally, we believe that there should be some financial assistance from the European Community to assist with the funding of suitable equipment now available for sorting the batteries into their various groups. To date, a

ENV/JM/MONO(99)17

great many people from organisations both large and small have put a great deal of effort into trying to implement EEC directive 91/157 for little or no gain. It is no accident that the large waste contractors have shown little interest, it is financial.

## **Waste Battery Management – A Perspective on Collection, Treatment and Recycling**

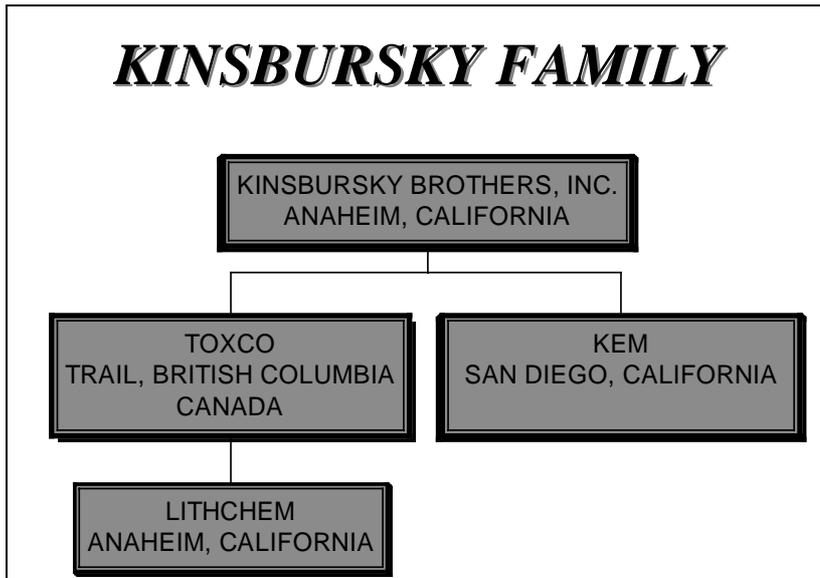
**Todd R. Coy, Kinsbursky Brothers Inc., United States**

### ***Introduction to KBI***

- In operation since 1955
- Battery management since 1977
- Fully permitted TSDF since 1989
- Located in Anaheim, California
- Manages all types of batteries

### ***Introduction to KBI***

- KBI is a secondary battery recycler, processing more than 2 million pounds of batteries per month
- KBI's permit allows for battery storage, separating battery components, and treatment of electrolytes
- KBI is going through a permit renewal process which will allow for the expansion of battery processing and storage capacity

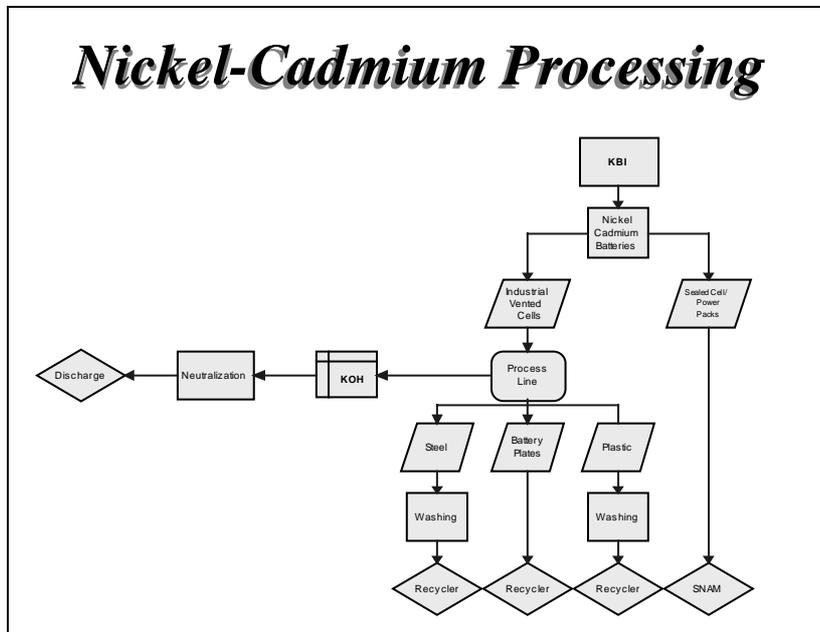


## ***Battery Collection***

- KBI is the largest collector and processor of nickel-cadmium batteries in the western United States
- Collection efforts focus on environmental companies and batteries generated in industrial and commercial applications
- Batteries are delivered directly to KBI from generators throughout the U.S.
- Collection rate of 300 tons of nickel-cadmium batteries per year

## ***Battery Management***

- Batteries are stored in secondary containment
- Battery plates and components are supplied to secondary recovery facilities (smelters, plastic recyclers, etc.)



## *Regulations*

- Universal Waste Rule (Part 273) eased transportation and storage restrictions for Nicads
- Mercury Containing and Rechargeable Battery Management Act (P.L.104) allows for portions of Part 273 to be implemented in the U.S.

### ***RBRC Collection***

- KBI began working with RBRC in April 1996
- KBI serves as the west coast consolidation point for RBRC's national battery collection program
- To date, the RBRC has collected 15% of the available small sealed cell batteries within the U.S.
- KBI has collected 50 tons of batteries

### ***Summary***

- Collection efforts are focused on specific targets
- Permitted company
- Good working relationship with state regulators
- Reputation in the industry



# **Incentives for Automated Spent Batteries Sorting**

**Chrystèle Ganivet and Jean-Pol Wiaux, EURO BAT TRI, France**

## **Part 1. Spent Battery Sorting**

### **Technical Description and Cost Considerations**

EURO BAT TRI was established as a company in January 1996. It is a joint venture between TITALYSE and SNAM. The company's activities are concentrated on the conception, the assembly and the turn-key delivery of spent battery sorting units. The basic technology has been developed by the founders of the company and is protected by four patents granted on an international basis.

The objective of the company is to satisfy the growing needs in spent battery sorting operations on an international basis. After collection by the local councils and professional organisations and before applying any recycling process, spent batteries need to be sorted according to their chemical composition. This aim has already been achieved by firms which decided to invest in sorting units.

Two machines are currently in operation:

- a first one at GMA in Germany, operating at a capacity of 1.0 metric tonne per hour of spent batteries;
- a second one at our SNAM Head Office, located in Lyon, whose initial capacity is 400 kg per hour. The machine is modular in order to allow a future increase of the sorting capacity.

This machine allows SNAM to sort batteries from French collection on a service basis. Sorted batteries are delivered to the appropriate recycling plants and Ni-Cd processed at SNAM. This service amounts to a maximum of 1.5 French francs per kg.

In addition, EURO BAT TRI has delivered sorting sensors for the EPBA sorting line which will soon be in operation at AVR in Rotterdam.

### **Background**

For economic and environmental reasons, the collection and recycling of spent batteries has become a reality in many European countries as well as in Japan and the United States.

The collection of spent batteries has been undertaken in order to:

- support the recovery of valuable metals contained in batteries;
- avoid the spreading of toxic/hazardous materials in our environment.

Many attempts have been made to organise and carry out the selective collection of used batteries. This has been successfully achieved in the industrial spent battery market. Lead-acid batteries are selectively collected in tonnage ranges of several hundred thousand tonnes per year in certain countries. Similarly, Ni-Cd professional batteries reach recycling volumes of 8000 tonnes per year in Europe. For spent batteries used by the general public, however, such selective collection schemes have failed and mixed lots of batteries have always been obtained as the result of these schemes.

An efficient collection, sorting and recycling scheme is based on the shipment of all types of spent batteries to a centralised plant for the preparation of selective lots of spent batteries sorted by type and chemical composition. These will be further processed in specialised recycling plants to recover metals.

**Table 1: Type of batteries recovered by the EURO BAT TRI sorting unit**

Battery type after sorting	Recycled materials
Zinc-carbon	Zinc, iron and manganese oxide
Alkaline-manganese	Zinc, iron and manganese oxide
Nickel-cadmium	Cadmium, nickel and iron
Mercury	Mercury and other metals
Lead-acid	Lead, sodium sulphate and PP
Lithium	Lithium salt and other metals
Button cells	Silver, mercury and other metals

The advantage of sorting spent batteries by type is that the recycling plant is in a position to select the most appropriate composition for the process input stream. This will influence the process parameters and enhance the quality of the final product.

Using the automatic sorting unit of EURO BAT TRI has several impacts on the management of spent batteries. It leads to:

- selective recycling routes for metals;
- efficient recycling rates;
- higher level of purity of recovered metals;
- safer storage conditions for hazardous materials;
- higher recycling ratios for toxic materials like mercury, lead and cadmium;
- reduced processing complexity.

## Process Basis

The principles of automatic sorting are based on the necessity to select and identify a mixture of spent batteries according to four basic physical criteria: geometry, magnetic properties, weight, and ferro-magnetic nature. The combination of these criteria will give a reliable sorting process.

Due to the large uncertainty about the composition of the collected lots of batteries, the EURO BAT TRI sorting machines are designed in the most flexible way. Parts of the machines can be adapted to the specific needs of clients in terms of types of batteries to be sorted, the nominal sorting capacity, and the efficiency of the recovered lots of batteries to be achieved.

**Table 2: Average composition of unsorted spent batteries processed in the EURO BAT TRI sorting unit**

Battery types	% Weight	Units/tonne	Remarks
Big blocks	0-5	0-5	Unit weight: 2-20 kg
Multicells	0-5	0-50	Pack of unit batteries, between 0.2-2 kg
Buttons	0-0.5	0-1500	Individual button cells
Cylindrical (OD < 17 mm)	30-40	15 000-25 000	Individual cylindrical cells
Cylindrical (OD > 17 mm)	30-40	4 000-5 000	Individual cylindrical cells
Prismatic (9V, 2R12, 3R12)	30-40	2 500-3 000	Individual prismatic cells

The sorting scheme involves four basic stages:

- removal of large batteries and button cells by screening;
- separation of magnetic from the non-magnetic cells;
- sorting of cells according to their size and geometry by screening;
- identification of each individual cylindrical cell with magnetic properties using a sensor device developed by TITALYSE. The sensor allows identification of the following battery types: nickel-cadmium, zinc-alkaline, zinc-carbon, mercury and lithium.

## **Performance**

Several factors are important in performance evaluation: capacity, efficiency and time. General information on the performance achieved by the EURO BAT TRI sorting unit is given below.

### ***Capacity***

The sorting machines have capacities ranging from 300 kg to more than two tonnes per hour (with the average composition mentioned in Table 2).

The overall performance of the system is always influenced by the composition of the incoming lots of spent batteries. Experience shows that they are irregular by nature. Consequently, the EURO BAT TRI system is designed to cope with such variations in the composition of spent battery lots. Buffer capacities are installed at three key locations in the sorting unit, in order to obtain a regular flow of batteries to the final sensors.

### ***Efficiency***

A warranty is given on the recovery and purity rates of batteries sorted by the unit.

Recovery rate: percentage of batteries correctly sorted, compared with the batteries of the same composition present in the initial batch;

Purity rate: percentage of batteries found in a final sorted batch, compared with the amount of other batteries present in the same batch.

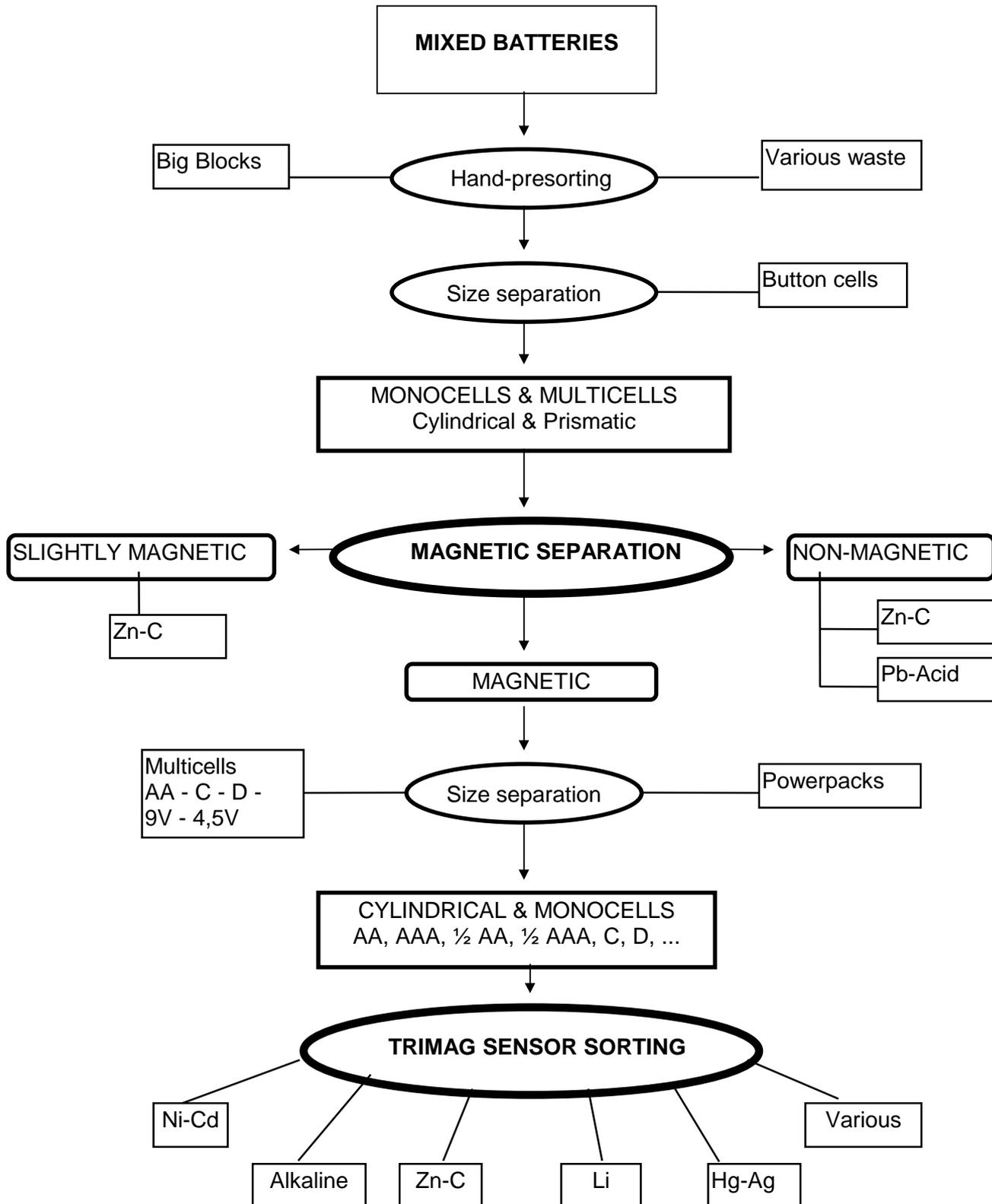
For a basic sorting design, EURO BAT TRI guarantees 96% recovery and 96% purity in the sorted lots of batteries.

## **Cost Considerations**

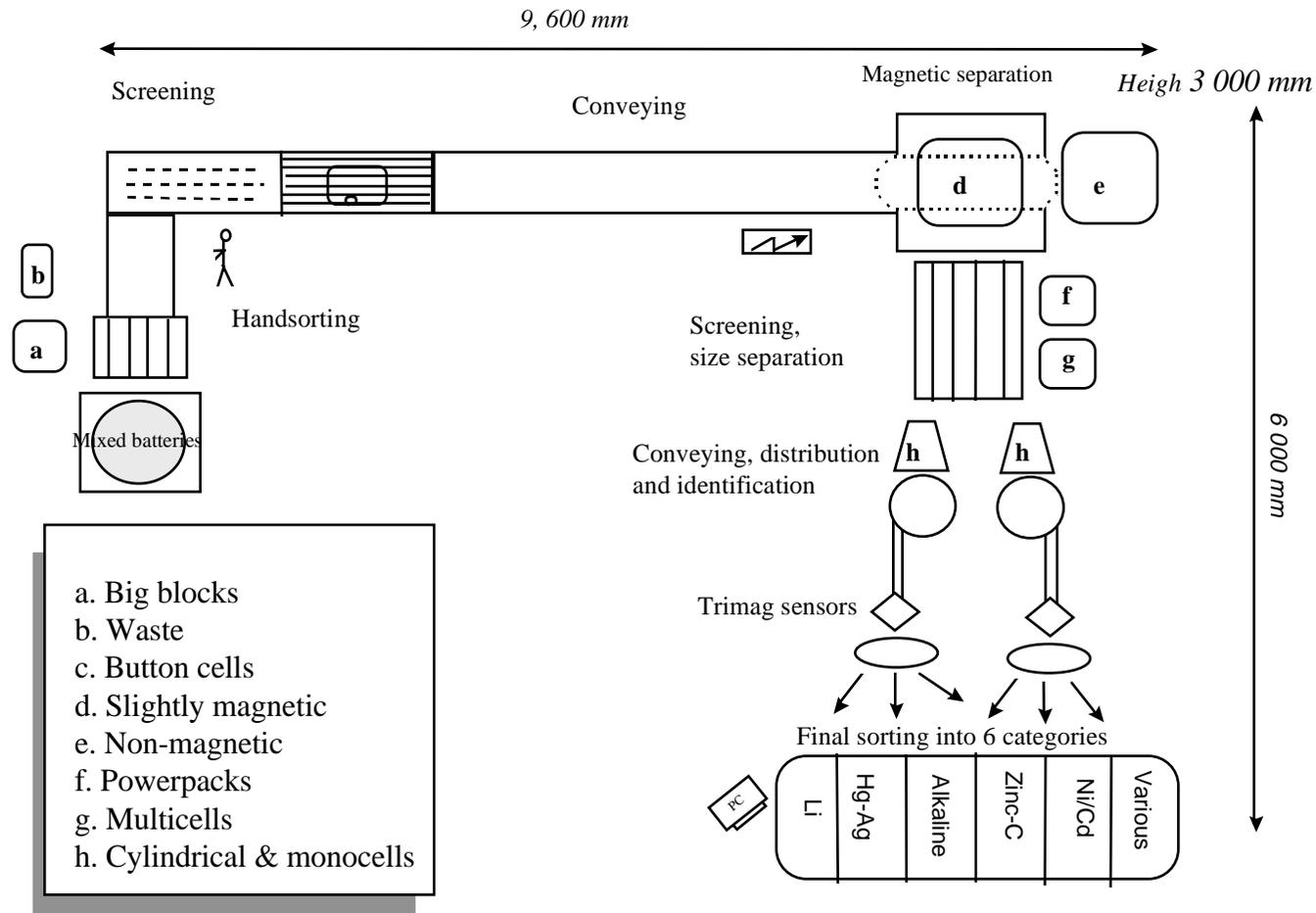
Costs of investment and operation have been evaluated for two machines with a capacity of 400 kg and 800 kg per hour. We consider that the units operate 5 days a week, 8 hours a day. The investment depreciation has been considered within 5 years at an interest rate of 6%. The operating costs are calculated on a yearly basis and are represented in Graphs III and IV. Infrastructure costs are not included in our estimate.

<u>Investment</u> :	Capacity 400 kg:	1 350 000 FRF
	Capacity 800 kg:	1 900 000 FRF

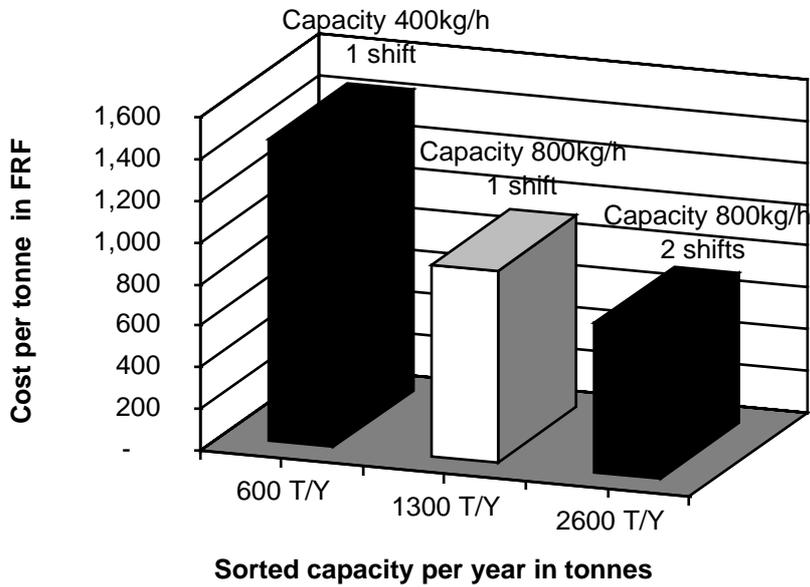
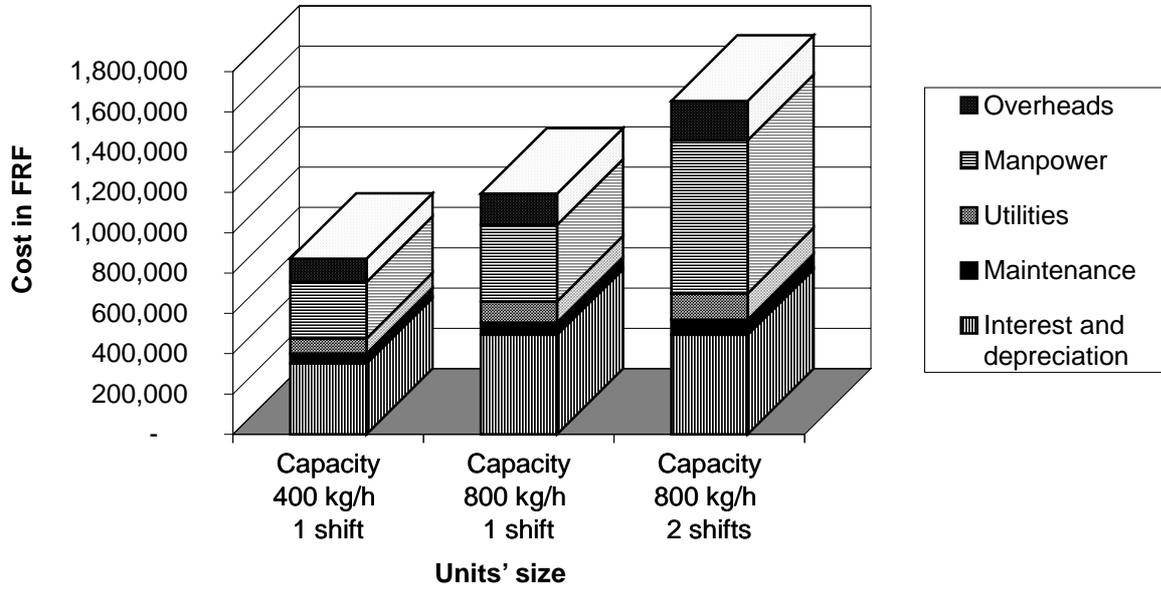
Graph I: Flow chart showing spent battery sorting process



**Graph II: Schematic layout - EURO BAT TRI sorting unit with capacity of 400 kg/h**



**Graph III: Operating costs on a yearly basis in FRF**



**Graph IV: Sorting costs per tonne in FRF**

While utility and maintenance costs are relatively unaffected by the size of the unit, factors related to investment become significantly lower with larger machines. Sorting units with a capacity of 400 kg require 1 person full time and another part time, while units with a 800 kg capacity require 2 operators.

## **New Developments**

In order to satisfy market requirements, we have focused our research and development programmes on the complementary technologies needed to achieve an efficient sorting of packs. We are currently developing a process that will recognise the different rechargeable packs after they have been pre-sorted by the existing machine. In the future, this operation should be easier if an appropriate marking is applied inside the power packs. It is one of EURO BAT TRI's objectives to bring a solution to this approach. A production design should be available by the end of 1997, and a machine should be in operation at SNAM in early 1998. The aims of power pack sorting are:

- to separate packs according to their chemical composition;
- to determine the pack's trademark.

Consequently it should be possible to share costs of collection, sorting and recycling among the OEMs and according to their production rates.

## **Part 2. Spent Battery Sorting**

### **Economic Incentives**

#### *Introduction*

The enforcement in individual Member States of the EEC directives on spent batteries is causing an increase in spent batteries collection rates in most European countries. Beyond the effort spent on the organisation of efficient collection schemes, the debate is still open on the best technical solution and the most economical route for recycling spent consumer batteries. The pioneering but expensive experience of Switzerland, which has acquired five years of practice in the spent consumer batteries recycling field, leads to the conclusion that a unique process for the treatment of spent batteries has a high cost which is supported by the Swiss consumer but which cannot be justified either for economic or technical reasons.

The most economical recycling option appears to be the implementation of selective recycling routes, where the chemical nature of the various components of the batteries is controlled. As shown in Figure I (not reproduced in this report) recycling processes can be applied selectively for secondary/rechargeable batteries like Ni-Cd, Ni-MH and lead-acid. In the case of primary batteries, the separation of mercury-containing from mercury-free batteries offers the possibility to use existing recycling technologies and, consequently, the most economical approach to this problem.

Materials with the highest added value are found inside rechargeable batteries, where metals like nickel, cobalt and metal hydrides are contributing to the higher added value of the secondary cells market.

In order first to enhance recycling rates, secondly to support the most efficient selective recycling process, and finally to optimise the economics of spent battery recycling, the battery industry (See Literature 1-5) has agreed that the sorting out of spent batteries according to their chemical composition is a necessary preliminary operation in an overall scheme which includes the four steps: collection, sorting, processing and recycling of secondary products.

***Sorting spent batteries: technical features***

The development of an automatic process for sorting spent batteries will take into account the various technical characteristics of used spent battery lots:

- the wide range of sizes and shapes;
- the state of deterioration of the external envelope;
- the large weight distribution and the related numbers of cells per unit weight;
- the wide variety of labelling.

Consequently, an automatic sorting system has to be based on the following technical features:

- the identification of the chemical nature of the spent battery;
- the analysis of bulk properties;
- the recognition of individual physical properties;
- the possibility to overcome the overlapping of certain physical properties.

Such a system has been studied by TITALYSE (1) during five years and is currently under commercial development by EURO BAT TRI, a joint venture between TITALYSE and SNAM, a world leader in Ni-Cd battery recycling and in cadmium re-use in the rechargeable batteries industry.

The main objectives of the process commercialised by EURO BAT TRI are:

- the recovery of zinc at LME prices, this metal being the major valuable constituent of spent primary consumer batteries;
- the possibility to recover the value of manganese (or  $MnO_2$ ), which is the second most important chemical element present in primary batteries;
- the optimum recovery and recycling of individual metals like mercury, cadmium and lead found in primary and secondary batteries;
- the re-use of nickel in ferro-alloys;

- the recovery of other valuable materials like cobalt and lithium salts, as well as metal hydrides which are found in minor quantities in spent batteries.

An efficient sorting process will have an impact on three major parameters in the recycling scheme of spent batteries:

- the economic optimisation of direct processing costs;
- the increased value of recovered secondary metals and chemicals;
- the higher recycling rate of metals like cadmium, mercury and lead.

### **Standard composition of a lot of collected spent batteries**

In Table 3 (not reproduced in this report) a standard spent batteries composition mix is presented. It has been obtained from experiences in the field of collected post-consumer batteries within EURO BAT TRI (See Literature 6). In this study variations are introduced, mainly concerning the composition of Ni-Cd batteries, in order to demonstrate the economic incentives of the preliminary sorting step.

### **The case of mercury-containing batteries**

An important factor is the mercury content of spent primary batteries. In Europe, alkaline-manganese and zinc-carbon general purpose batteries have not contained mercury since 1 January 1994. Imported alkaline-manganese dioxide batteries still contain mercury. The situation is similar with the zinc-carbon batteries.

It is necessary to distinguish between the following categories:

#### ***Leclanché and saline batteries***

The zinc-carbon batteries manufactured in Europe are mercury free; they have been labelled as green batteries. Those manufactured without the previous label have a mercury content averaging 20-200 ppm. The zinc-carbon batteries manufactured in Far Eastern countries and reaching the European market which are found in toys and other OEMs have mercury levels well above 200 ppm.

#### ***Alkaline batteries***

Alkaline batteries with 200-500 ppm mercury.

Alkaline batteries that are mercury free. Those batteries have been progressively introduced on the market from 1994.

As it is not possible today to separate the mercury-free from the mercury-containing alkaline batteries, we are considering that all alkaline batteries have to be treated first with a de-mercurisation process.

### ***Mercuric oxide batteries***

Mercuric oxide batteries, which have a mercury content of 30% by weight, are collected mainly as button cells and small cylindrical cells. After sorting, the mercuric oxide button cells and small cylindrical cells will be processed with a mercury recovery process using, for example, the MRT technology.

This study has taken into account, in a simplified version, all these types of zinc batteries. It has been assumed that mercury-free batteries and batteries with less than 20 ppm mercury will be processed in a WAELZ furnace or using an equivalent technology as recommended by EPBA. Those technologies are in operation on an industrial scale, which makes them cost-effective when compared to a dedicated SUMITOMO/BATREC technology.

The mercury-containing zinc batteries will be processed with a de-mercurisation process like the RECYMET process which, in 1996, was operated at 2000 tonnes per year recycling capacity and demonstrated its industrial and cost efficiencies. In Table 4 (not reproduced) we have summarised the average metallic composition of the battery systems considered in this study.

In Table 5 (not reproduced) data are given on the current market prices of primary and secondary metals according to their purity grade. Those numbers have been used in this economic case study.

Finally, recycling costs have been fixed at values given by various actors in the field: EPBA target prices, Swiss BESO, SNAM, MRT and AFE Metals. These recycling costs are indicated in Table 6 (not reproduced).

### **The economic impact of sorting spent batteries on direct processing costs**

A case study has been performed on the economic incentive to sort batteries before recycling. The parameters used in the evaluation are those presented in Tables 3-6 (not reproduced). The economics of the recycling operation and the impact of sorting spent batteries are represented in Figure II (not reproduced).

Because Ni-Cd and mercury-free batteries can be processed at a much lower cost than mercury-containing batteries, a significant saving is obtained by sorting spent batteries before recycling.

From this case study it is concluded that savings of 20-30% on recycling costs can be achieved by an appropriate preliminary sorting process. It is clear that the maximum impact of sorting and the largest savings are obtained when the most expensive recycling process is considered.

### **The economic impact on secondary products value**

The wide range of market prices of metals is described in Table 5 (not reproduced), where the various elements are reported according to their composition ratios in spent batteries. For the economic evaluation of the recovered materials, the assumption is made that in the case of unsorted batteries (e.g. in a case where the Ni-Cd fraction is not recovered) the cadmium fraction is diluted in the zinc.

Consequently, the counter-value of cadmium is not credited in the case of processing unsorted batteries. In addition, the value of the recovered zinc is lowered in a significant manner. Indeed, zinc can

be sold at LME prices as long as its grade is maintained higher than 99.95 (SHG), but the contamination of zinc by 0.02% cadmium leads to a depreciation higher than 30% on the LME price of the metal.

In the case of nickel and cobalt present in Ni-Cd batteries, their dilution in steel does not lead to a full recovery of their value. A correction factor of 50% has been applied for their depreciation in the case of recovery without sorting.

In Table 5 (not reproduced) such factors have been taken into consideration. When this type of calculation is applied to various Ni-Cd percentages in zinc batteries, one can evaluate the impact of sorting undesirable elements from a main stream according to the required final purity of the recovered secondary products.

It can be observed from the analysis of Figure III (not reproduced) that the impact of sorting spent batteries on the recovered value from secondary metals is increased by 20-30%.

The impact of sorting on direct processing cost savings and on the recovered metals value increase leads to a saving per tonne of spent batteries higher than US\$ 250/MT.

### **The economic impact of minor metals**

As can be concluded from the table, metals like cobalt or metal hydrides which are minor constituents of spent battery lots (<1.0% range) have a significant economic impact on the overall sorting balance due to their high commercial value. The best example is obviously the case of cobalt present in spent lithium-ion batteries.

### **The technical and economic limits of an automatic sorting process**

This case study has allowed the following conclusions to be drawn:

1. An automatic sorting process should not cost more than US\$ 200-250 per tonne of spent batteries. This cost range will allow the sorting operator to have a positive economic balance, versus the savings achieved as a consequence of the sorting step.
2. Sorting efficiency is influenced by the average composition of the batteries mix. Within the limits of the standard composition presented in this study, it has been possible to determine the sorting efficiency required for the two major actors: zinc and Ni-Cd batteries. For an average mix of 5% of Ni-Cd batteries in a 90% zinc batteries matrix, a sorting efficiency of 96% is required.
3. If one considers the case of cadmium contamination by zinc metal, the purity of the sorted batches of Ni-Cd must be higher than 99%. Zinc batteries must be totally removed from the sorted Ni-Cd batteries.

### **Conclusions**

With the diversification of the chemical composition of portable electrical energy sources, the sorting of spent batteries before recycling is a necessary step for economic reasons. This will be further

justified by the rapid market volume increases of the high added value rechargeable power packs used in the 3C (cordless appliances, communication and computer) applications.

Organisations like EPBA, JBA and RBCA, involved directly or indirectly in the collection of spent primary and/or secondary batteries, have acknowledged the fact that sorting is a necessary preliminary step before recycling spent batteries. Spent battery recyclers like the lead battery and the Ni-Cd recycling industries have traditionally collected selective lots of spent SLI and vented Ni-Cd cells. The nascent primary zinc battery recycling industry is following the same approach.

When quantities of collected batteries remain discrete, hand sorting is the preferred way to carry out this operation. Inevitably, when significant volumes (> 500 T/y) of collected batteries are obtained, automatic sorting is needed, both for technical efficiency and cost reasons. It is the objective of TITALYSE SA and EURO BAT TRI to serve such a market for the development of sorting units, because they support spent battery recycling and are achieving a better recovery of valuable materials.

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# **The Collection and Processing of Spent Ni-Cd Batteries in North America and INMETCO's Role**

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**International Metals Reclamation Company, United States**

## **Abstract**

INMETCO will describe the collection of spent Ni-Cd batteries in North America. Several very different collection methods have been developed to meet the needs of battery manufacturers, users of products such as power tools and cellular phones, computer manufacturers, hospitals, emergency groups, fire departments, police, municipalities, etc. In addition, collection has been expanded to Canada as well as South America and other continents.

INMETCO, located near Pittsburgh, Pennsylvania, is a wholly owned subsidiary of Inco Ltd. of Canada. Inco is a leading supplier of nickel world-wide including its specialty nickel powders and nickel foam products to the battery industry.

A brief review of the unique INMETCO capabilities of processing cadmium and nickel components will also be given.

## **Ni-Cd Battery Facility**

INMETCO began operation of its \$5 million state-of-the-art cadmium recovery facility on December 29, 1995, and is currently capable of processing more than 3,000 tonnes of spent Ni-Cd batteries per year. The facility can be expanded to process up to 10,000 tonnes annually when the North American collection programmes are more fully developed. Currently, the facility has four cadmium furnaces in operation with provisions for expansion up to 16 units.

Several collection programmes are in place for the collection of nickel-bearing batteries. One programme is operated by the Rechargeable Battery Recycling Corporation (RBRC), which is associated with the battery manufacturers. They consolidate batteries and forward them to INMETCO for recycling. The RBRC pays all costs involved with reclamation of the batteries. It encourages the collection and recycling of consumer type Ni-Cd batteries to preserve natural resources and to prevent heavy metals from entering the waste stream, incinerators or landfills. Also, as a matter of US law, non-household users of Ni-Cd batteries are prohibited from discarding used Ni-Cds into the municipal solid waste stream. INMETCO offers companies and organisations a legal, cost-effective and environmentally sound manner in which to deal with spent Ni-Cd batteries. The facility has been fully permitted by the Pennsylvania Department of Environmental Protection.

INMETCO developed programmes to meet the needs of cellular phone companies, hospitals, police, libraries, municipalities and the local community. We even developed an exchange programme

with lead smelters who occasionally get spent industrial Ni-Cds in error and can now ship them to INMETCO for recycle.

### **Consumer-sealed Dry Cell Ni-Cd Batteries**

Batteries are collected by INMETCO with the following programmes:

1. INMETCO Mail-Back Programme - Used by companies who want to provide their individual customers a programme to recycle their Ni-Cd batteries without using a consolidation location. The company sends its customers an envelope for the return of the spent battery and pays the postage and recycling fee. There is no direct cost to the customer.
2. INMETCO Prepaid Container Programme - The generators of consumer Ni-Cd batteries order containers from INMETCO. The containers hold approximately 14 kg of spent batteries. INMETCO charges for the containers, including the recycling charge and prepaid United Parcel Service (UPS) transportation. A very favourable UPS rate makes this a low-cost and customer-friendly approach.
3. The Rechargeable Battery Recycling Corporation (RBRC) Programme - Provides a consumer Ni-Cd recycling programme for the United States and, beginning in September 1997, Canada. The RBRC sells a customised recycling seal to manufacturers, marketers and branders of Ni-Cd batteries to put on their products. These monies pay for the recycling costs of the batteries. Retailers and municipalities recycle Ni-Cds at no cost for either the recycling process or transportation. Containers are provided free of charge to the retailers. Businesses and institutions are provided a free recycling process programme but are responsible for paying the transportation to INMETCO.

All of these types of generators sign up to participate in the programme.

4. INMETCO's Small Package Programme - Small businesses who are not part of the RBRC programme can send Ni-Cds to INMETCO by agreeing to normal terms and conditions. Transportation is the responsibility of the generators.
5. Milk Runs - Where possible, INMETCO helps organise milk runs to efficiently save the generators transportation costs. INMETCO can arrange transportation for the generator. This is especially important to generators who have long distances to ship to INMETCO.

### **Industrial Wet Ni-Cd Batteries**

1. INMETCO's Collection Programme - Generators of industrial Ni-Cds qualify to send their batteries to INMETCO by issuing a purchase order and then arranging their own transportation. INMETCO can arrange transportation at an additional cost.
2. Environmental Companies Collection Programmes - Many environmental companies collect Ni-Cds as part of their comprehensive recycling and disposal programmes. Many of their customers want one source to handle all types of their hazardous waste. The environmental firms then ship in large quantities to INMETCO.

Some environmental or broker companies specialise in providing sorting of different battery types, packaging on pallets and scheduled pickup of batteries from railroads. Railroads require a pickup schedule every 90 days to satisfy hazardous waste laws. The batteries are then delivered to INMETCO.

### **Environmental Protection Agency**

On November 22, 1989, the US Environmental Protection Agency (EPA) requested public comments on their plans to grant a "Capacity to Variance" which would have allowed Ni-Cd batteries to be landfilled until sufficient high-temperature processing capability existed in the United States. INMETCO commented on January 8, 1990, concerning these proposed regulations that we could process those spent Ni-Cds through our facility.

As a direct result of INMETCO's comments, the EPA decided *not* to allow landfilling of those Ni-Cds and further indicated that they must be treated by high-temperature metals recovery (HTMR), for which INMETCO was already fully permitted and recognised by the EPA. In fact, we were the *only* company in the US with the ability to process spent Ni-Cd batteries by HTMR.

INMETCO immediately began advising potential users and manufacturers of Ni-Cd batteries of our recycling capabilities.

In the early 1990s a group was formed by the Ni-Cd battery manufacturers and end-users called the Portable Rechargeable Battery Association (PRBA) to unify a large number of major US companies towards the goal of collecting and recycling Ni-Cd batteries. Eventually a separate non-profit corporation was formed, called the Rechargeable Battery Recycling Corporation (RBRC), with the purpose of developing a national collection programme. In addition, the RBRC signed a long-term Ni-Cd recycling agreement with INMETCO in 1994. INMETCO produced the first 99.99% pure cadmium metal in 1995.

### **Collection Programme Development**

Since 1990, when about 250 tonnes of spent Ni-Cds was collected, INMETCO has almost doubled its collection programme each year. We collected over 3000 tonnes in 1996. As the collection programmes of the RBRC and INMETCO mature, we fully expect to recycle about 9000 tonnes by about the year 2000.

INMETCO has been receiving spent Ni-Cds from Canada for several years. The expansion of the RBRC Collection Programme to Canada in 1997 will have further enhanced the ability of Canadians to easily recycle their Ni-Cds.

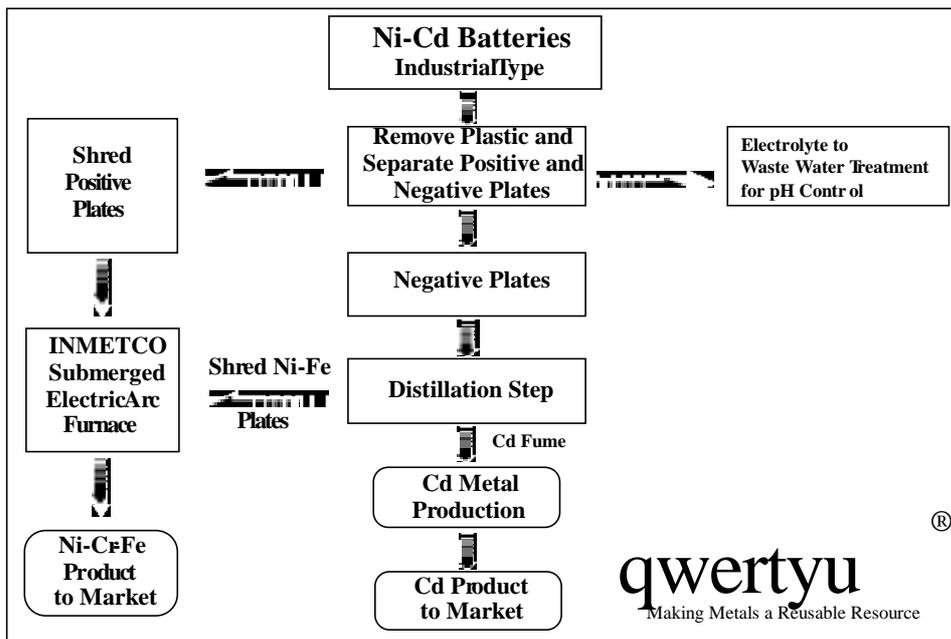
INMETCO has received spent Ni-Cds from South America as well as Europe. In addition, Ni-Cd production scraps have been sent to INMETCO from several Ni-Cd producers in the USA. as well as elsewhere in the world.

### **Processing of Industrial Ni-Cd Batteries**

Flow Sheet 1 shows the steps involved in the reclamation of industrial type batteries. These batteries are large units used by railroads, mass transit authorities, etc. as backup of emergency power devices. The strongly basic sodium hydroxide electrolyte contained in the battery is drained and pumped to INMETCO's waste water treatment plant for use as a pH control reagent. The cells are dismantled

using a large band saw to cut the tops off the batteries, allowing the nickel and cadmium plates to be separated.

The positive plates are shredded and fed into the rotary hearth furnace and subsequently to the electric arc furnace for nickel and iron recovery. The negative plates are charged in a cadmium recovery furnace, along with a small amount of carbon as a reductant. The charge is heated and the cadmium is distilled, then collected in a water bath, forming a shotted product that is 95% +3 centimetres. The final product is drummed, weighed, assayed and shipped to the customer. The residue from the cadmium furnace, which is mostly iron, is shredded and fed into the rotary hearth furnace as an iron addition.

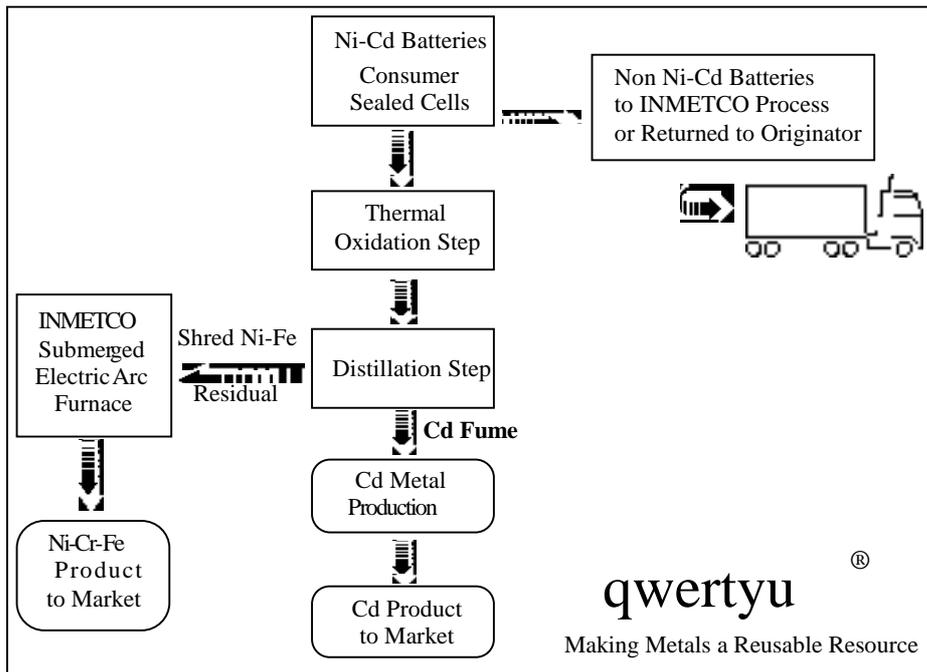


**Flow Sheet 1: Processing of Industrial Ni-Cd Batteries**

**Processing of Consumer Ni-Cd Batteries**

Flow Sheet 2 shows the steps involved in the reclamation of consumer cell batteries, also known as dry cells. These are smaller cells familiar to most consumers as rechargeable power packs for cordless drills, cellular phones, computers, camcorders, etc. Most of these packs are contained in plastic which must be removed prior to extraction of the cadmium. The plastic is removed from these packs in INMETCO’s natural gas fired thermal oxidiser, which is vented into the rotary hearth furnace. The gases from the thermal oxidiser are completely consumed for heat value. Stack measurements show that no dioxins are released.

After the plastic has been removed, the batteries are charged into a cadmium furnace and the cadmium distilled and collected as detailed above. The residue from the furnace is high in nickel and iron and is charged back into INMETCO’s main plant for the production of stainless steel.



**Flow Sheet 2: Processing of Consumer Ni-Cd Batteries**

**Recent Operating Results**

Specifications for INMETCO’s cadmium product CADMET™ are shown in Table I. Basically, two types of cadmium shot are sold by the facility. Type A metal is a low lead material suitable for critical applications. Type B metal contains a higher residual amount of lead, but is still of adequate purity to be used for the production of batteries. Lead is the most common contaminate in cadmium metal used in the manufacture of Ni-Cd batteries.

**Table I: INMETCO CADMET™ Chemistry Specification**

<u>Parameter</u>	<u>Type A Metal</u>	<u>Type B Metal</u>
Cadmium	99.99% Minimum	99.95% Minimum
Lead	0.010% Maximum	0.020% Maximum
Copper	0.002% Maximum	0.002% Maximum
Arsenic	0.001% Maximum	0.001% Maximum

Table II shows INMETCO's recent CADMET™ chemistry. Since refining the operating parameters in 1996, excellent purity of cadmium metal has been achieved. This has been accomplished through several refinements.

**Table II: INMETCO CADMET™ Average Analysis**

<u>Parameter</u>	<u>1996</u>	<u>1/97</u>	<u>2/97</u>	<u>3/97</u>	<u>4/97</u>	<u>5/97</u>	<u>6/97</u>
% Cadmium	99.97	99.99	99.99	99.99	99.99	99.99	99.99
% Lead	.024	.008	.009	.009	0.010	0.010	.008
% Zinc	.002	.001	.001	.001	.001	.001	.001
% Nickel	.003	.004	.004	.002	.002	.002	.002
% Iron	.001	<.001	<.001	<.001	<.001	<.001	<.001
% Copper	<.001	<.001	<.001	<.001	<.001	<.001	<.001
% Arsenic	<.001	<.001	<.001	<.001	<.001	<.001	<.001
% Thallium	an	an	an	<.0005			

First, training has been performed with both operators and customers, teaching them how to distinguish Ni-Cd batteries from rechargeable lead-acid and other types. Batteries the operators are unsure of are set aside until laboratory analysis is performed to verify the type of battery involved. The surest method of preventing lead contamination is to prevent lead from entering the furnace with the cadmium plates and consumer cells.

Second, proprietary processing improvements have resulted in preventing lead carryover into the final product. This has been an ongoing learning experience for production operators and the engineering department which has resulted in optimising the process and, more importantly, the cadmium quality to fully meet the needs of the Ni-Cd battery manufacturers.

A complete plant flow sheet is attached [not included in this report].

**Additional Facts about INMETCO**

INMETCO is a high-temperature metals recovery (HTMR) facility located in Ellwood City, Pennsylvania. It takes secondary materials generated mainly by the stainless steel industry in North America and recycles them for productive reuse in commerce. Specifically it recovers nickel, chromium, and iron for further industrial use. In addition, an inert co-product is produced which is used for roadbed and other construction purposes. Operating in strict compliance with Federal and State regulations under a Part-B Hazardous Waste Storage, Processing, and Treatment Permit issued by the Pennsylvania

Department of Environmental Protection, INMETCO serves Western Pennsylvania and the country as a whole by conserving natural resources and protecting the environment in a number of important ways:

- It is the only company that uses HTMR technology to recover nickel, chromium and iron from the specialty steel industry of the United States, of which six companies are located in Pennsylvania, four in other states and one in Canada. HTMR is recognised as BDAT (Best Demonstrated Available Technology) by the US EPA for the types of metal-bearing wastes generated by the specialty steel industry.
- Its HTMR technology was recognised as BDAT for Ni-Cd battery wastes by the Environmental Protection Agency in 1990. In 1996, over 3000 tonnes of batteries was received from municipal authorities and industry for recycle.
- INMETCO operates the only commercial cadmium recovery operation in North America producing 99.95% plus pure cadmium from spent Ni-Cd batteries, which is reused to produce new batteries.
- It directly recovers about 40,000 tonnes of materials annually that would otherwise be disposed of in landfills. INMETCO returns these materials to the commercial mainstream as products and co-products.
- It conserves non-renewable resources by limiting the need to mine and process virgin materials. In addition, INMETCO's HTMR process is 50% more energy efficient than metal production from virgin ore, resulting in reduced energy demands and avoiding the generation of about 34,000 tonnes of carbon dioxide, 300 tonnes of sulphur dioxide, and 125 tonnes of nitrogen oxide.
- It employs about 124 area residents and brings substantial financial benefits to the community.
- It meets EPA's Clean Air and Clean Water standards. Its own by-products are collected and sent elsewhere for recycling.

### **The INMETCO Process**

The original INMETCO process consists of three basic steps: 1) feed preparation, blending and palletising; 2) reduction; and 3) smelting and casting.

The equipment used is relatively well known in the primary metal producing industry. The feed preparation equipment is specifically suited to the feed material, utilising a rod mill for mill scale and a table feeder and rotary breaker for the swarf. For blending, mass flow bins with electronic speed controls are employed to move the finely prepared material, via a screw feeder, to the covered conveyor and into screw conveyors. The screw conveyor discharge is carried by conveyor to a palletising disc 4.3 metres in diameter where water is added and the pellets (approximately 1.2 cm in diameter) are formed. The first reduction step is carried out in a 16.7 m diameter rotary hearth furnace (RHF). Smelting and final reduction are accomplished in a 10 million volt amps (MVA), 6.4 m diameter submerged electric arc furnace (SEAF). Casting is performed by pouring the hot metal from a 12 metric tonne ladle into a twin strand pig caster. Pig weight is about 14 kg.

The first step in the process involves receiving the various wastes and pretreating them, where necessary, to insure a uniform size material. These pretreated wastes are stored in separate silos, from which they are fed at a carefully controlled rate. The wastes are blended with coke or coal and water in a screw conveyor. The mixture proceeds to a disc Pulitizer which produces green pellets strong enough to resist disintegration in the subsequent thermal operations. Since the pellets are not going to be tumbled in the reduction process, the strength requirement is minimal.

The second major step in the process is the partial reduction of the metal oxides in a rotary hearth furnace. In this furnace, some of the carbon in the pellets reacts with oxygen in the waste to produce reduced metal. A portion of the zinc, lead and halogens contained in the flue dust is exhausted into the off-gas treatment system. Hot, metallic, sintered pellets are transferred in sealed containers to the electric arc smelting furnace, where the third major operation is performed. At this stage the pellet is melted and chromium oxides are reduced by the residual carbon in the pellet. Lime, silica, alumina and magnesia separate to form a liquid slag which assists in cleansing the metal bath. Metal and slag are tapped periodically from the furnace. The metal is cast from a refractory lined ladle into pigs, which are sold to steel mills as a charge to steel making furnaces. The slag is treated in a special area in order to obtain a sized material that can be used locally as road aggregate. INMETCO's slag is non-hazardous, does not leach above applicable standards, and is recognised as a co-product by the Pennsylvania Department of Environmental Protection (PADEP). The process water is treated and yields a filter cake that is recycled in a separate processing plant to recover the zinc and lead values.

**Table III: INMETCO® Remelt Alloy Specification and Typical Analysis**

<u>Element</u>	<u>Range</u>	<u>Typical</u>
Ni	8.0-16.0	12.5
Cr	9.0-19.0	13.0
Mn	0.5-4.0	1.5
Mo	1.5 Max	1.1
Cu	1.0 Max	0.8
P	0.055 Max	0.049
Co	0.8 Max	0.4
Si	1.2 Max	0.1
C	4.5 Max	3.5
S	0.5 Max	0.2
Fe	Balance	66.9

® INMETCO is a registered trademark

### **Waste Feed Materials Recycled in the Main Plant**

Furnace baghouse dust or flue dust is generated during the melting and refining steps in the manufacture of stainless steel. Flue dust is the most metallurgically complex and contaminated waste. These dusts are usually collected in baghouses and consequently are dry. The principal constituents are the major components of steel and slag. A typical flue dust composition is shown in Table IV. Flue dust particles are extremely fine, typically one micron particle diameter, and flow readily. Stainless steel flue

dusts are considered hazardous by the Environmental Protection Agency because they are strongly alkaline and contain high levels of Cr<sup>+6</sup> and lead. While flue dust is the most metallurgically complex and contaminated waste, it is one of the easiest materials for our system to handle. Since it is dry, it can be collected in pneumatic truck tankers and transported to the INMETCO facility.

### Mill Scale

Mill scale results from oxidation of the stainless steel surface during operations such as soaking or preheating the steel, forging and hot rolling. This waste has a flaky appearance and is quite variable in particle size. A typical mill scale chemistry is shown in Table IV.

Mill scale is quite variable in size, and thus must be ground to 0.03 mm before it is fed into the palletising circuit. Since the mill scale is very hard and abrasive, all wear parts in the grinding circuit must be made of Ni-hard cast iron.

**Table IV: Range of Variation of Major Elements Contained in INMETCO Plant Feed Material (Composition % by Weight)**

<u>Constituent</u>	<u>Flue Dust</u>	<u>Mill Scale</u>	<u>Grinding Swarf</u>
Nickel	0.95-5.35	1.25-4.09	4.79-20.10
Chromium	2.15-19.10*	7.80-13.10	13.40 -20.00
Molybdenum	0.07-1.04	0.12-0.41	0.27-1.55
Copper	0.19-1.65	0.01-1.35	0.23-1.42
Zinc	1.0-8.0	0.01-0.02	0.01-0.03
Lime	4.30-48.40	0.25-0.50	0.30-0.50
Oil & Water	-	6-12	25-32

\* A portion of the chromium is in the hexavalent form and is thus considered hazardous along with leachable lead and cadmium.

### Grinding Swarf

Swarf or oily grindings, as identified here, is a product of the belt grinding of stainless steel sheets, bars and tubes. This material presents special handling problems.

Grinding swarf is metallic and not oxidised, thus no reduction or oxygen removal is required. The swarf contains oil which is used as a source of fuel for our furnace. Thus, swarf is much desired as a feed material for INMETCO. The fine, oily strands that make up the swarf tend to form into wads or clumps. These wads are too large for the pellet feed circuit and must be broken up into smaller pieces. INMETCO has developed a "swarf breaker" which promotes breakdown of the swarf by a tumbling action similar to autogenous grinding of mineral ores. The result is a 0.25 mm material that can be stored and transferred to pellet making without excessive reagglomeration. See Table IV for a typical analysis.

### **Chrome Refractories**

Spent chromium-bearing refractories, such as chrome-magnesite bricks, are recycled to recover the chromium, iron and nickel while using the magnesia as a slag additive. Most spent chromium refractories are hazardous due to the leaching of hexavalent chromium. The INMETCO process consumes this hazardous waste and avoids landfilling of yet another non-renewable valuable resource.

### **Waste Acid Pickling Solutions**

INMETCO has the ability to consume selected spent acid pickling solutions, which present a significant disposal problem for most stainless steel producers. We have taken these solutions and used them as a wetting agent during production of our normal pellet. These pellets are reduced in our furnaces, and the metallic values are recovered while safely disposing of the acid.

### **Pickling Filter Cakes from Spent Pickling Solution**

The majority of specialty steel mills in North America lime neutralise their spent pickling acids to precipitate the metals and then filter the material, ending up with a cake containing 60-70% solids. Some people dry the material and ship it to INMETCO pneumatically, while others ship it as a wet filter cake.

### **Spent Carbon Brick from Pickling Tanks**

Carbon brick from pickling tanks can be reprocessed and used as a reductant in the INMETCO process. No longer does this refractory brick need to be treated and landfilled. This carbon product, which replaces a purchased operating supply, is then used in the electric furnace to aid in chromium oxide reduction and, most importantly, avoids landfilling.

### **Baghouse Bags from Electric Furnace Dust Collection Systems**

Baghouse bags from electric furnace dust collection systems containing hazardous metals can be recycled through the INMETCO process to recover valuable metals while avoiding landfilling of this hazardous waste.

### **Super Alloy Wastes**

Super Alloy Wastes from either standard melting or rolling mill operations, along with electrochemical machining (ECM) operations, can be recovered/recycled in the INMETCO process. Once again, the nickel, chromium and iron will be recovered instead of being landfilled.

### **Spent Catalysts**

Many nickel and chrome-containing catalysts are used in the chemical, petroleum refining and food processing industries. Once the useful life of these catalysts is gone, they need to be disposed or recycled. INMETCO can process these spent catalysts by a variety of methods. Dry rings and beads of

nickel catalysts can be directly fed to our electric furnace, where the nickel, chromium and other valuable metallics will be recovered. Liquid-containing catalysts, such as those containing activated nickel, will be consumed in our blending circuit and roasted in the rotary hearth furnace prior to smelting. Again, the valuable metallics are recovered and recycled back to industry.

### **Nickel-metal Hydride Batteries**

These spent batteries are easily handled at INMETCO. We receive them separately from Ni-Cds and directly charge them into our RHF. The nickel, iron, and cobalt are reclaimed into our remelt alloy and the rare earths or titanium are collected in our co-product slag.

### **Conclusion**

INMETCO operates a world-class recycling facility that has successfully added Ni-Cd to the long list of materials it processes.

Each year, over 50 environmental audits are performed to meet our customers' demands for a suitable recycling company to manage their wastes in a manner that will avoid potential liability. We have continued to satisfy over 500 customers' expectations on this environmental issue.



# **The SAFT Recycling Process with Respect to Industrial Nickel-Cadmium Batteries**

**Lars Erik Johansson, SAFT AB, Sweden**

## **Summary**

Thermal recycling of Ni-Cd batteries is based upon very simple technical principles - concern for the environment is the deciding factor of the process design.

The SAFT recycling plant at Oskarshamn, Sweden, is integrated into the production of industrial batteries and the process is adapted to the new concept of sustainable consumption of natural resources - raw materials, energy and water. Cadmium recovered from industrial as well as sealed Ni-Cds is used for the production of new industrial Ni-Cd cells.

Cadmium emissions from battery production corresponding to 350 tonnes of cadmium, and the recycling of 800 tonnes of industrial Ni-Cds and 400 tonnes of sealed cells, are approximately 8 kg and 2 kg respectively per year.

Batteries are supplied world-wide and battery scrap is received from all parts of the world. More than 96-97% of the industrial Ni-Cds disposed of in Sweden are treated in the SAFT recycling plant at Oskarshamn.

## **Introduction**

### ***The aim of recycling***

Recycling of batteries and battery scrap has existed since at least the beginning of this century. However, the incentives have varied through the years. At first, recycling *or* material recovery offered a possibility to secure a supply of critical raw materials at reasonable costs even in periods of material shortage. Today the main reason for most recycling - or final treatment - is to protect the environment from the impact of landfilling and incineration. Recycling is a way to reduce the need for waste material disposal.

However, expressions such as “sustainable development” occur more and more frequently, indicating that we are all becoming aware of the fact that global natural resources are limited. Recycling is a way to economise on natural resources.

### *Metals in batteries*

The electrochemical reactions of batteries are based upon metals that are more or less hazardous to the environment. A few of these metals - mercury, cadmium and lead - are defined in, for example, the EC battery directive as “environmentally hazardous”. Ni-Cd and lead-acid batteries are the two traditional and predominant industrial batteries, and for many years both types have been recycled.

The first industrial Ni-Cd batteries were based upon the pocket plate concept. This type has now been used for 90 years in train lighting and stand-by applications such as uninterrupted power supply systems for hospitals, airports and off-shore installations. The active materials - nickel hydroxide in the positive and cadmium hydroxide in the negative electrode - are enclosed between perforated steel strips, which are folded into “pockets”.

Today we have industrial Ni-Cds in which the active substances are supported by a nickel metal structure (sinter and fibre electrodes) or a polymer matrix on nickel-plated steel (plastic bonded electrodes).

The sealed Ni-Cds (portable cells, consumer accumulators) are based upon similar electrode concepts.

## **Recycling Ni-Cd Batteries**

### *Nickel*

The nickel content of a used Ni-Cd battery can be recovered through, for example, a leaching process in acid solution. However, the most effective way to bring the nickel content back in use is to re-use it for steel production, especially if iron is present and the nickel/iron separation would otherwise require a lot of effort.

### *Cadmium*

Already during the 1910s, i.e. 30-40 years before cadmium was regarded as hazardous, cadmium from industrial Ni-Cd batteries and related production scrap were recovered using simple processes. Cadmium plates were charged together with some coke into a tube closed at one end. The tube was heated in a horizontal position in a brick furnace to 900° C. The cadmium vapour formed was condensed in water and the recovered metal was used for the production of new batteries.

The present processes for cadmium recovery of Ni-Cd batteries at SAFT in Sweden, SNAM in France, ACCUREC in Germany and INMETCO in the United States are based upon the same fundamental pyrometallurgical principle. Concern for the environment, the working environment as well as the external one, has however influenced the process designs. Today recovering cadmium is far more than a heating and cooling process.

Hydrometallurgical processes for spent Ni-Cds have been described recently, but these processes tend to be too complicated for industrial use.

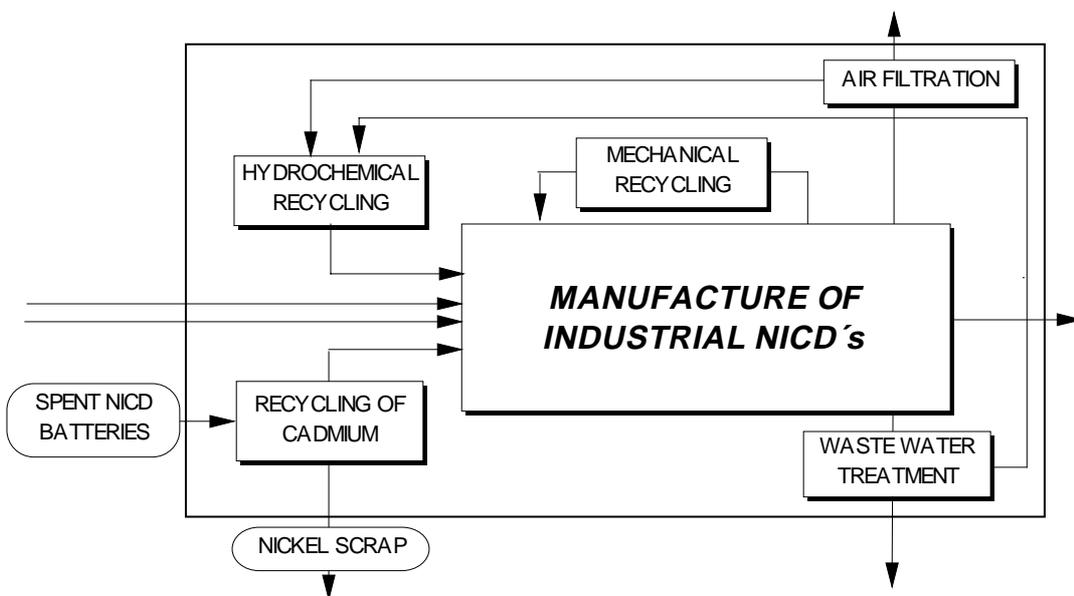
## Recycling activities at SAFT in Sweden

### *Recycling as part of the loop*

Recycling of industrial Ni-Cd batteries and related materials has taken place at periods since 1917 at the SAFT plant for Saft Nife industrial Ni-Cd batteries at Oskarshamn, Sweden.

The existing SAFT process for Ni-Cd batteries was developed from 1978 onward, initially to become an essential part of a company vision of the 1970s: a “closed loop” factory where the only flow out of the battery factory would be battery products, treated air, treated water, and cadmium-free metallic scrap to be used by the steel industry (Figure 1). Finally, after a long life in service, the battery products would be returned to the factory for safe final treatment.

The cadmium process reached industrial scale in 1986. A minor modification had made it possible to also handle sealed Ni-Cds, but with somewhat lower efficiency.



**Figure 1: The Closed Loop Factory**

### *Main principles*

The industrial cells (open, prismatic cells) are dismantled manually (Figure 2). The negative plates with 10-25% cadmium are washed and dried, charged into a crucible and heated with coke to 900° C in an electric furnace for 24 hours. The cadmium is distilled off and the fluid metal is dripped into water, where it forms small metallic pellets.

The sealed Ni-Cd batteries are subjected to a pyrolysis step prior to distillation, in which the polymer compounds are pyrolysed at 400° C and the gas is completely combusted, washed and filtered before being emitted to the atmosphere.

The recovered cadmium (purity grade >99.95%) is transferred to the production of new industrial batteries and can be used without any limitations. Provided that no cadmium has been added to the nickel electrodes, these plates are disposed of to the steel industry together with the distillation residue. The process water is treated in the factory waste water treatment plant. All exhaust air passes through effective filters. Other battery components of dismantled cells - cell containers, cell tops and separators - are washed free of nickel and cadmium.

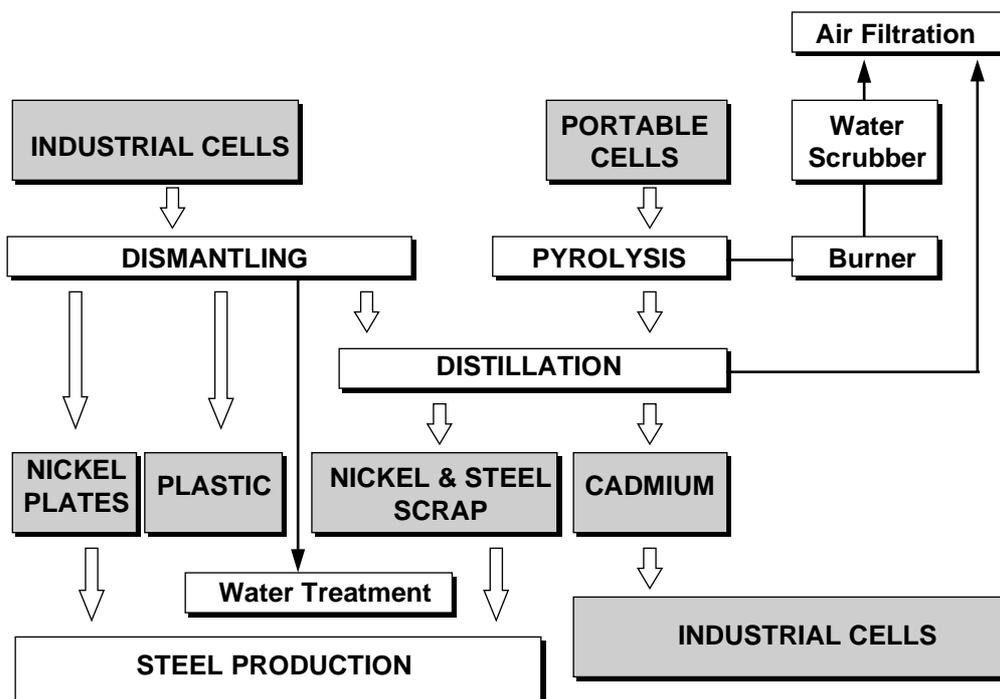


Figure 2: SAFT Recycling of Ni-Cd Batteries

### Changing demands

The present recycling process was initially designed for industrial batteries only, but consumer cells have indeed been treated at the Oskarshamn plant since 1986. During the last ten years, the market for sealed Ni-Cds has grown dramatically. In addition, the collection rate with respect to sealed Ni-Cds has improved in, for example, Sweden. Consequently, the ratio of sealed batteries to industrial batteries for recycling in Oskarshamn has increased and will increase further.

Therefore, in 1996 a new separate pyrolysis furnace was installed to improve the efficiency of the processing of sealed cells. A crucible containing sealed cells and battery packs is treated in the

separate pyrolysis furnace and then transferred to one of the two distillation furnaces. A new improved equipment design reduced the pyrolysis time from approximately 72 hours to 18-24 hours.

The changes in the equipment and the material flow reflect the actual environmental trends of industrial production in general and, especially, the trends of recycling activities.

The requirements with respect to emitted process air and water have been tightened up. To economise on energy and water is a necessity. Dumping of waste, independent of whether the waste material is regarded as hazardous or not, must be avoided. Possibilities to co-ordinate the "waste streams" - materials and water as well as energy - of adjacent plant units mean advantages.

### **The SAFT recycling plant of 1997**

#### *Capacity*

The installation of a separate pyrolysis furnace increased the capacity of the plant from approximately 800 tonnes of a representative mixture of waste batteries to 1200 tonnes. If only industrial cells are treated, i.e. only the negative electrodes are subjected to distillation, the capacity is 1500 tonnes of batteries/year.

The operation is closely integrated into the production of industrial pocket plate batteries, corresponding to approximately 500 tonnes of nickel and 350 tonnes of cadmium. The recycling plant produces approximately one-third of the cadmium needed for production of industrial batteries at the Oskarshamn factory.

#### *Emission of cadmium to the water recipient*

The process water is treated in the company treatment plant to a cadmium content of 0.03-0.04 mg/litre, i.e. final treatment of 1500 tonnes/year of industrial batteries corresponds to an emission of 0.2 kg of cadmium to the recipient, the Oskarshamn harbour.

Efforts to economise on water have been successful. For instance, cooling water from the distillation furnaces is today used to wash battery components and containers. The present consumption of water, 6000 m<sup>3</sup> per 1500 tonnes of industrial batteries, corresponds to approximately 50% of consumption in 1986.

#### *Emission of cadmium to the air*

The first plant in 1986 was equipped with an air filter consisting of an electrostatic filter plus a cassette filter. The emission of cadmium was 4-5 kg/year.

The present plant is equipped with a double cassette filter. The emission of cadmium is now less than 1 kg/year.

### ***Distillation residues***

The cadmium content of the steel residue after distillation of cadmium plates is 0.01%. This cadmium content is collected during further processing by the steel works, when the cadmium content of the positive electrodes is also collected (0.2-0.4%).

### ***Pyrolysis gases treatment***

The increased amount of polymer compounds in cells and battery packs requires an improved combustion furnace for post-treatment of the pyrolysis gases. To assure that no dioxins, etc. are emitted to the atmosphere, the pyrolysis gases pass a burning chamber at a minimum temperature of 1200°C at excess of oxygen (> 6%). Retention time is a minimum of three seconds.

Possible corrosive gases and hydrochloric and fluoric acids are removed in a scrubber operated with alkaline water.

In spite of the very careful sorting of the collected batteries to disclose all primary batteries, a mercury filter has been found necessary for safety reasons.

### ***Energy recovery***

The energy content of the cooling air is used for drying of wet plates and pre-heating of crucibles to be processed. After distillation, the hot crucible is placed in a temperature equaliser, where its energy content is transferred to the incoming crucible. By this simple arrangement, the energy consumption of the distillation process is reduced by 8%.

The energy content of the pyrolysis gases is via a heat exchanger utilised for drying nickel hydroxide in an adjacent plant for positive active material. Decomposition of plastic material generates 139 kWh per 100 kg of sealed batteries. As the distillation process requires 113 kWh, the treatment of 100 kg of sealed batteries generates 26 kWh. The former process, without energy recovery, required 350 kWh per 100 kg of batteries.

### ***Energy from plastic containers***

In 1986 the plastic containers of industrial cells could be disposed of as secondary raw material, but the demand for unqualified polypropylene was falling off. Today the concern for the environment has generated new processes and the demand is again increasing. However, in a life cycle assessment perspective, the impact of transportation of this rather bulky material is obvious.

Irrespective of whether the plastic containers are disposed of as raw material or are brought to an external incineration plant, careful washing to eliminate every trace of cadmium is required. The new pyrolysis unit makes it possible to burn the plastic containers within the existing environmental protection system. Only a coarse wash is needed - less consumption of water - and the generated energy may be utilised in adjacent processes without transportation losses.

### *Cadmium balance*

From 800 tonnes of industrial batteries, and 400 tonnes of sealed cells or packs, 100 tonnes of cadmium is recovered. Approximately 99.1% of the cadmium content is used for battery production, 0.9% is collected and recycled by the steel industry, and 0.001% (approximately 2 kg of cadmium) is emitted to the environment.

### **Collection of industrial batteries**

#### *Strategy*

As the recycling activity is an essential part of an environmental strategy of the Oskarshamn plant for industrial Ni-Cds, an effective system for collection of used batteries is as essential as an environmentally safe process. Customers and users of industrial Ni-Cds all over the world are encouraged to return their used batteries, and they can do so free of charge. All industrial Ni-Cds are accepted for delivery at Oskarshamn independently of the brand name. No actions in return have been required.

#### *Collection rate*

The main part of the industrial cells are used in systems for uninterrupted power supply. The number of users are few. The cells are relatively large, and each installation is equipped with a number of cells. The batteries are normally handled by trained professionals. The life of a battery depends on the application, but 10-25 years is normal, which is why it is difficult to establish a convincing base of collection rate calculation. As the SAFT plant in Oskarshamn has been the main supplier of industrial Ni-Cds to the Swedish market for many years, however, this market can serve as an example.

Except for a period during the early 1980s, the supply of industrial batteries to the Swedish market has been rather stable, corresponding to 9-11 tonnes of cadmium per year. During the period 1989-1996, a few years after the start-up of the new recycling plant, industrial batteries corresponding to an average 10.6 tonnes of cadmium per year were returned from the Swedish market for treatment. The additional batteries delivered in the late 1970s and early 1980s were installed in stand-by power systems and are still in use.

A review of 1993 sales shows that 91% of the industrial batteries were delivered to six large users with established routines for returning the used batteries - the railway, the metro, the coast guard system, etc. The same group of organisations were also the main end-users of batteries supplied to OEMs (4%).

The remaining 5% of the batteries were delivered to approximately 70 customers. This group of customers are also known to return the batteries after use, but it is more difficult to report the collection rate for that category of users.

Many of the exported batteries are returned to Sweden. Others are treated at recycling facilities in France, Japan and the US.

## **Conclusions**

The recycling process for Ni-Cd batteries at SAFT in Oskarshamn is an example of the new environmental concept:

- The metal content of the Ni-Cds is brought back into use with a very low impact on the environment. Cadmium emissions from battery production corresponding to 350 tonnes of cadmium and the recycling of 1000 tonnes of Ni-Cds are approximately 8 kg and 2 kg respectively per year.
- No waste materials remain after treatment.
- A favourable energy situation is obtained when used together with other processes.

Batteries are supplied to and received from the whole world. With respect to the Swedish market, 93-95% of the Oskarshamn products is used by customers with known battery collection systems. The remainder, i.e. 5-7%, is supplied to users that return their batteries directly to the Oskarshamn plant or via a scrap dealer.

# Recycling America's Rechargeable Batteries

## C. Norman England (President, CEO) Portable Rechargeable Battery Association, United States

The rechargeable power industry has gone through dramatic change in the last ten years. The beginning of this period is marked by the US Environmental Protection Agency changing the test that defines a waste as hazardous or non-hazardous. Suddenly used, small, sealed dry cell Ni-Cd batteries went from a non-hazardous to a hazardous classification. The end of this ten-year period was marked by the enactment last year of the **Mercury-Containing and Rechargeable Battery Management Act**, most commonly referred to as the Battery Recycling Act. This bill, among, other things, changed the classification of the batteries to a Universal Waste.

Previously, rechargeable batteries and rechargeable consumer products were regulated under a complex system of state, federal and international laws. These laws were designed to promote safety and the environmentally sound recycling or proper disposal of rechargeable batteries and battery-powered products.

The enactment of the Mercury-Containing and Rechargeable Battery Management Act initiates a new federal approach to the recycling of a ubiquitous consumer product - Ni-Cd batteries. The act does not impose a collection obligation on industry or establish rates and dates that must be met. Instead, it facilitates a largely private-sector collection programme, supported by a substantial industry-funded public awareness campaign to encourage consumers to recycle.

The programme is administered by the Rechargeable Battery Recycling Corporation (RBRC), a non-profit organisation whose sole mission is to promote and implement the separate collection of Ni-Cd batteries, removing these heavy-metal products from the municipal waste stream.

The recycling programme proposed by the Ni-Cd battery industry as early as 1993 and which today is being implemented by RBRC, with the assistance of Portable Rechargeable Battery Association (PRBA), is known as the **Charge Up to Recycle!** programme and contains several key elements which are specified in the US EPA regulation, various United States state laws governing Ni-Cd battery recycling, and the Mercury-Containing and Rechargeable Battery Management Act.

These include the following provisions:

- uniform battery labelling requirements;
- removability of batteries from products;
- national network of collection systems;
- regulatory relief to facilitate Ni-Cd battery collection for recycling;
- widespread publicity to encourage public participation;
- development of a funding mechanism for the programme.

The Charge Up to Recycle! programme offers various Ni-Cd battery recycling plans for retailers, communities, businesses and public agencies. These include the Retail Recycling Plan (20,000 plus participants), the Community Recycling Plan (300 enlisted), and the Business and Public Agency Recycling Plan (1000 enrolled). These activities ensure that the maximum return of the small consumer Ni-Cd batteries will be accomplished.

RBRC utilises third party vendors who can orchestrate the logistics involved in operating the collection programmes. The contractors inventory and distribute collection kits and instruction manuals, receive returns, make sure that batteries collected are properly sorted, and then arrange for shipments. RBRC has contracted with independent operators to provide geographically appropriate consolidation points to receive used batteries.

In the Charge Up to Recycle! programme in the United States, Kinsbursky Brothers in Anaheim, California, and the International Metals Reclamation Company (INMETCO) in Ellwood City, Pennsylvania, are the two consolidation points used for Ni-Cd batteries. INMETCO is also the Ni-Cd battery recycler.

RBRC is conducting public education programmes to inform consumers, retailers and manufacturers about battery recycling efforts under the Charge Up to Recycle! programme. Educating Ni-Cd battery users on the importance of battery recycling and the existence of a collection system is critical to the success of the programme. It is also important that those who operate the battery collection infrastructure, such as retailers and county and municipal co-ordinators, have a thorough understanding of how the programme works.

The cornerstone of the public education campaign is RBRC's information system, which includes an interactive web site ([www.rbr.org](http://www.rbr.org)), a fax-back system, and a toll-free helpline, 1-800-8-BATTERY.

The web site and helpline refer consumers to the Ni-Cd collection point nearest them and provide additional information on RBRC activities. For example, callers with household batteries will be asked to enter their zip code or surrounding zip code areas. The system will then refer the caller to an RBRC designated battery collection site, such as a municipal household hazardous waste programme or retail store.

Retailers or public agencies interested in joining the programme can utilise the web site or the fax-back system to obtain information on specific RBRC activities. To access the fax-back system, they call from the handset of their fax machine and choose from a menu of information. Retailers, for example, can register to participate in the Retail Recycling Plan or request additional collection containers. Businesses or municipalities can also have pertinent information sent via fax, including applicable regulations, pilot programme approvals in their state, and RBRC's insurance policies.

The programme provides for the establishment of various recycling plans for collecting used Ni-Cd batteries from many sources, including consumers, retailers, distributors, generators, county recycling facilities, county household hazardous waste collection sites, consolidation points and manufacturer-designated battery collection facilities.

The plans under the programme are briefly described below:

- **Retail Recycling Plan:** In conjunction with the United Parcel Service (UPS), RBRC has developed a simple, convenient recycling plan for retailers who sell Ni-Cd batteries and battery-powered products. Participation is free of charge. RBRC provides containers for retailers to collect and ship used Ni-Cd batteries, as well as pre-addressed, pre-paid shipping labels for the containers, shipping instructions, safety instructions, point-of-sale notices, and information about the programme. RBRC pays the cost of recycling the batteries; all the retailer must do is sign up.
- **Community Recycling Plan:** RBRC provides counties and municipalities with information on how to set up and operate a household battery collection programme. RBRC pays the cost of shipping the Ni-Cd batteries under the terms of the programme and the cost of recycling them. Counties will be asked to consolidate batteries at one consolidation point and ensure that they are properly segregated.
- **Business & Public Agency Recycling Plan:** RBRC provides business and government agencies with information on how to set up and operate a battery collection programme. It offers a streamlined and blanket rate for Ni-Cd batteries shipped to its recycling facility under the terms of the programme. Shippers pay only transportation costs. RBRC pays the recycling costs.

The Ni-Cd batteries collected under the Charge Up to Recycle! programme are recycled at the International Metals Reclamation Company (INMETCO) in western Pennsylvania. A subsidiary of INCO, one of the world's largest mining and metals companies, INMETCO is a leading recycling facility of metal-bearing wastes in North America.

INMETCO uses a state-of-the-art, high-temperature metal recovery process to recover the nickel, iron and cadmium content of the batteries. The process is recognised by the US EPA to be the "best demonstrated available technology" for recycling Ni-Cd batteries. As Mr. James Matthews, Deputy Assistant of the US EPA, stated, "None of the by-products of this facility are sent to landfills."

The recycled nickel and iron are returned to the steel industry to make stainless steel. The recovered cadmium is used in new Ni-Cd batteries. The plastic cases, which are removed from the cells prior to processing, are used as fuel in a submerged electric arc furnace.

The rechargeable power industry funds the Charge Up to Recycle! programme through the licensing of RBRC's battery recycling seal. License fees paid by rechargeable battery and battery-powered product manufacturers allow them to place the seal on their rechargeable products. Presently, the most world-renowned companies in the industry have entered into a License Agreement with RBRC, committing themselves to display the RBRC seal on the Ni-Cd batteries and packaging they market in the United States. Consumers can support these pro-environment companies by shopping for RBRC's battery recycling seal.

The display of the RBRC seal clearly distinguishes those manufacturers which are participating in the programme and those which are not. For batteries exported from the United States, rebates will be issued. The programme also provides an incentive for Ni-Cd battery users (licensees) to utilise their own distribution infrastructure to collect batteries and recycle them in a manner similar to that of commercial/institutional generators. Licensees can receive a rebate of up to 75% of their original licensing fee, based on the weight of batteries collected for recycling.

To get the word out about the Charge Up to Recycle! programme, RBRC is conducting a public education campaign which includes the promotion of Charge Up to Recycle! international spokesperson Richard Karn, who plays power tool expert "Al" on TV's *Home Improvement*. Mr. Karn promotes RBRC's Ni-Cd battery recycling programme through a variety of media events, including three filmed public service announcements (PSAs), recruitment messages for RBRC target audiences, and an educational video for RBRC's school curriculum plan, which is in development for the 1998 school year.

RBRC's Charge Up to Recycle! PSAs - distributed in May through October 1996 - ranked among the most successful PSA campaigns ever monitored by A.C. Neilson, Inc., with 100 stations across the country airing the PSAs a total of 6300 times. RBRC distributed a holiday PSA encouraging consumers to Shop for the Seal during the holidays, which was broadcast nearly 2000 times in a one-month period.

National media such as *Entertainment Tonight* and *Live with Regis & Kathie Lee* featured Richard Karn promoting the programme. RBRC also ran two full-page advertisements in *USA Today* to educate consumers about Ni-Cd battery recycling and to recognise the RBRC Licensee companies for supporting the environment through their funding of the Charge Up to Recycle! programme.

As RBRC continues to push for national awareness of Ni-Cd battery recycling through the Charge Up to Recycle! programme, Richard Karn will be a key factor in helping RBRC get its message to the public.

RBRC marketing activities include the distribution of RBRC's *Charge Up to Recycle!* quarterly newsletter. The newsletter proves a useful vehicle to disseminate information to participants in the programme. With features including Spotlight on a Licensee, Message from the President, the Latest from Canada and a Public Relations Update, newsletter recipients are kept-to-date with RBRC news.

The RBRC national Ni-Cd battery recycling programme - Charge Up to Recycle! - represents a comprehensive, cost-effective approach to recycling used Ni-Cd batteries and preventing them from entering the solid waste stream. RBRC is serving the nation's communities by recycling used Ni-Cd batteries from consumers, retailers, municipalities, businesses and public agencies.

Successful operation of the Charge Up to Recycle! programme will help conserve valuable resources by diverting batteries from the waste stream to the recycle stream, where the materials are reclaimed and returned to commerce.

# **The Black & Decker Corporation's Environmental Plan for Ni-Cd Batteries**

**Linda Biagoni, Black & Decker, United States**

The Black & Decker Corporation is a \$5 billion global manufacturer and marketer of quality products used in and around the home and for commercial applications. Our products are marketed in more than 100 countries, and we have manufacturing operations in 14 countries. Our strong brand names enjoy global recognition, and our product lines hold leading market share positions in their respective industries.

The Black & Decker Power Tool Division, plus the Household Products Division, account for approximately 65% of annual sales for the global corporation. These global divisions manufacture and market diverse lines of cordless rechargeable products powered by Ni-Cd batteries. Black & Decker's cordless rechargeable product offerings include power tools and outdoor products for consumers and for commercial applications, marketed under the Black & Decker VersaPak brand globally, the DeWalt brand globally and the ELU brand in Europe, and household products like the Dustbuster vacuums, SpotLiter rechargeable light, Scumbuster cordless tub and tile scrubber, and kitchen appliances marketed under the Black & Decker brand name.

Ni-Cd batteries are very important to the viability of Black & Decker's cordless rechargeable product lines for the following reasons:

- 1) Ni-Cds are the only battery technology that can provide the power necessary to make our products perform acceptably for our customers, particularly commercial power tools and heavy duty drills and cutting tools for consumers.
- 2) Ni-Cds can be recharged hundreds of times, which extends the useful life of the battery up to three to ten years (commercial product to consumer product).
- 3) Ni-Cds are economical and provide low-cost portable power to our customers.
- 4) Ni-Cds are recyclable, and therefore the metals can be removed from the batteries and returned to the stream of commerce without ever entering or causing a threat to the environment.

Globally, the number of rechargeable battery-powered products has been expanding at a rapid rate over the last decade and is predicted to expand even more rapidly in the next few years. Indeed, more and more products are now being developed than can use rechargeable Ni-Cd batteries, such as telephones, laptop computers, medical devices, advanced power tools, outdoor and household products, and more products are being invented every day. Market research has shown, and actual sales have proven, that the consumer likes the freedom that cordless products provide, and also the fact that the batteries can be charged over and over again for years of use instead of being discarded after one discharge.

In the global power tool industry the future design direction of products is well established. The direction is that power tool users, both consumer and commercial, want portable cordless rechargeable products that are free from the restrictions of the electric cord and have sufficient power to do the job. At present, Black & Decker's cordless power tool business segment is approaching 50% of the division's total annual sales. This percentage is expected to continue to increase rapidly over the next few years to meet the demand of our customers.

Cordless rechargeable power tools are very important to our customers around the world and are definitely important to Black & Decker and the rest of the power tool industry, which are developing new cordless products every day that are powered by rechargeable Ni-Cd batteries. We are aware that other battery chemistries exist and are currently in development, but it is still undetermined whether such chemistries will ever be able to provide the sustained power necessary for power tool usage.

Black & Decker has a corporate commitment to the protection of the environment and has demonstrated this commitment in North America by being very proactive in establishing and implementing programmes that remove Ni-Cd batteries from the waste stream. Some of these actions are:

- 1) Black & Decker's participation as a founding member of the Portable Rechargeable Battery Association (PRBA) in the US. This group was instrumental in the development of a battery collection and recycling programme managed by the Rechargeable Battery Recycling Corporation (RBRC) in the US, which has just also been extended to Canada.
- 2) Black & Decker instituted an internal Ni-Cd battery collection programme in our service centres that took back used batteries and products from our customers and sent them for recycling. During the years 1992 through 1995, 430,960 pounds of Ni-Cd batteries were collected and sent for recycling by Black & Decker in the US and Canada.
- 3) In the US, Black & Decker has 99 company-owned service centres and 38 retail outlet stores. Starting in early 1996, all of these centres and stores became members of the RBRC's Charge Up to Recycle! programme and they are now collecting and sending used batteries for recycling. In addition, Black & Decker has approximately 800 authorised service centres in the US. All of these centres have been informed of the RBRC programme and encouraged to join.
- 4) In Canada, Black & Decker has 11 company-owned service centres which will be participating in the RBRC programme starting in late 1997. Also, there are 367 authorised service centres which will be encouraged to join the RBRC programme.
- 5) Black & Decker made design changes to all existing cordless products to incorporate a more easily removable battery pack and to facilitate battery recycling. More recently, it designed and marketed new lines of cordless products that have very easily removable batteries and interchangeable battery packs. These new products make it very easy for the consumer to return the used batteries for recycling.

Black & Decker has joined the European Portable Battery Association (EPBA) and is being very proactive in developing a Ni-Cd battery collection and recycling programme for Europe.

We have already had some success in battery collection and recycling in the United Kingdom, where Black & Decker has been collecting used batteries since 1994 through our service centres. In 1996, 13 tonnes of used batteries were collected and sent to SNAM for recycling. In Germany, in conjunction

with the product “take-back” requirement, used Ni-Cd batteries are being collected at 2500 collection locations and being recycled. Based on our experience in the UK, Germany and North America, Black & Decker firmly believes that a pan-European collection and recycling programme for Ni-Cd batteries can be established and implemented to resolve the environmental concerns about these batteries and still ensure that consumers continue to enjoy the benefits of cordless rechargeable products.

As a global manufacturer and marketer, Black & Decker wants to be able to service its markets as efficiently as possible. Therefore we are concerned about the potential for conflicting or varying labelling requirements being required for our products. We need to be able to manufacture products that can be distributed anywhere in our market, without having to segregate product for country- or market-specific labelling. Also, as a global company Black & Decker wants to be able to satisfy the collection and recycling requirements of many countries as simply and efficiently as possible. Therefore, we would like to see a labelling, collection and recycling programme that is simple and standardised, which will make it desirable for all companies, countries and consumers to participate in order to achieve the common goal of battery recycling.

In addition, a successful collection programme needs the support and participation of retailers and local governments. The programme should be designed to make it easy and convenient for consumers, retailers, and local governments to comply with and participate in the programme.

In conclusion, Black & Decker has a commitment to protecting the environment in its manufacturing activities as well as in the products it sells to its customers. Black & Decker also has a commitment to provide its customers with the products that are high in consumer demand. Ni-Cd batteries provide the power necessary for our products to perform in a way that is satisfactory to the consumer. Additionally, we believe that Ni-Cd batteries are environmentally preferable because they are rechargeable and will last for many years. When the battery is finally no longer able to hold a charge, the metals can be recycled and returned to productive use. Ni-Cd collection and recycling preserves the benefits that Ni-Cd batteries can provide to the consumer, while keeping the batteries out of the environment. Black & Decker has experienced collection and recycling programmes in the United States, Canada, Germany and the United Kingdom, and we firmly believe that with the co-operation of all parties - battery manufacturers, battery users, recyclers, and regulators - we can continue to produce products that satisfy our customers without an impact on the environment.



# The Cell and Battery Collection Project in the UK

## Robin Cloke, GP Batteries (UK) Ltd, United Kingdom

The collection project started in early 1993 at the request of the British Department of Trade and Industry (DTI). By this time the DTI had taken action to bring into force the requirements of EEC directive 91/157 so that marking with the crossed out dustbin sign and easy removal of batteries from appliances, etc. was mandated.

Prior to this time, there were some recycling initiatives by individual original equipment manufacturers (OEMs), mainly in the communication and power tool sectors. Collection took place at the point of sale of new battery purchase, and the spent battery was returned to a third party consolidation point via the OEMs distribution network. This process is termed "collection via reverse distribution".

In most instances the collection of the spent product was voluntary, but some companies used the opportunity to promote their product by offering discounts on purchases and one cell supplier offered a discount voucher against the next purchase of Ni-Cd batteries.

The collection scheme was created to enable the British Government to satisfy the requirements of directive 91/157. It decided to implement the directive only to the extent that was required to satisfy the EU. The support of industry was requested, and the International Cadmium Association (ICdA) acted as secretariat.

The prime aim was not to create an organisation to collect and recycle, but to form an enabling structure to:

- 1) develop a collection strategy for used Ni-Cd batteries,
- 2) collectively address any practical difficulties which may be encountered,
- 3) monitor subsequent progress and report results, and
- 4) work collectively to minimise costs of collection and recycling initiatives.

Membership of the group required the payment of a nominal sum to cover the cost of meeting and administration, etc. and an agreement to:

- 1) ensure a clean waste stream of spent product, and
- 2) provide information on the amounts of batteries sent for recycling. It was also recognised that, as no other data existed, a benchmark as to how much product was being put into the market was needed and therefore a tabulation was agreed which can be amended year on year.

The table for 1994 is shown below.

**Ni-Cd Market Characteristics in the UK (1994)**

Battery Type by Application	Sales Estimate (Million)	Sales (% of Total)	Growth Rate	Average Battery Life(in Years)
Emergency Lighting	8	11	+	4
Power Tools/DIY/Cleaning	15	21	++	3
Mobile Communications	13	18	++	1.5
Cordless Appliances	8	11	n/a	5
Camcorders	7	10	+	5
Consumer Single Cells	8	11	-	7-10
Portable Computers	2	3	+	2
Others Toys Flashlights, Portable Instruments etc.	10	14	-	5

Growth rate: ++ = 20 to 30%; + = 5 to 20%; - = 0 to -5%

The table clearly shows that attacking three main sectors to increase battery recycling would have significant effects on the amount of batteries collected. The BBMA therefore addressed the product sectors of emergency lighting, power tools and mobile communications to gain acceptance of the need to collect and recycle batteries by holding meetings in early 1997 with the market leaders in the individual sectors.

A pilot scheme to encourage the recycling of mobile phones was launched in early 1997 by the Association of European Telecommunications and Professional Electronics Industry (ECTEL) in conjunction with British Telecommunications (BT). The scheme is based on the idea of "take back", by which manufacturers offer to take back and recycle items once consumers have finished with them. The group is firmly of the view that the ultimate objective of any battery collection scheme should be conservation of valuable raw materials through recycling and the recovery of marketable products. The group does not see any purpose to collection of used batteries for separate disposal, since there is no evidence that current disposal patterns/practices constitute an unmanageable environmental risk.

Membership included all the main Ni-Cd cell suppliers, major OEMs and cell consolidators, recyclers and trade associations, but a significant number of users of Ni-Cd batteries also joined the group.

The group is concerned that regulatory requirements governing the collection, storage and transport of waste may unnecessarily hinder the development of collection schemes. Several examples have been reported and in some cases have led to the cessation of collection initiatives. This affects activities within the UK and the export of batteries for recycling. These difficulties are often caused by the differential approach taken by local waste regulation authorities to the classification of used Ni-Cd batteries and the licensing of sites participating in their collection. The group has succeeded in securing exemption from certain requirements for licensing of sites storing up to 2.5 tonnes of Ni-Cd batteries.

To form an identity so that the organisation can evolve, it was decided to create the name Rebat. It was also decided to widen the scope of the organisation to include all non-lead acid rechargeable portable batteries, so that advice could be given on nickel-metal hydride and rechargeable lithium batteries in particular.

Most returned products was sent to SNAM in France for recycling.

Inhibitions that existed in 1996 on the collection and recycling of batteries were a combination of cost and (in September 1996) the UK Government's change to the classification of spent Ni-Cds from controlled waste to special waste, increasing the cost and complexity of spent battery collection.

To overcome the problems of the cost of recycling, it was decided in June 1997 to re-form the group into a non-profit limited company to collect a pre-payment fee, thereby acting as a pool to finance the recycling of spent batteries. Similar pool companies were looked at in the USA, Germany, Holland and Switzerland to ensure that in creating such a company the wheel was not re-invented.

Early investigations showed that problems encountered elsewhere such as anti-trust and corporation tax are not a problem for such a company operating in the UK. It was also decided at an early date not to create a requirement for an extra battery mark, but to control collections of money by licensing the Rebat logo, which the company would register and therefore control its copyright.

The principal of fee collection would be for all portable rechargeable batteries (except lead acid) to have a fee paid at the point of supply, which would be held by Rebat to both recycle spent product and fund promotional programmes for the recycling of portable batteries. It is recognised that confidentiality is required with the reporting of fees paid, as this may provide information on an individual company's market share.

Current expectations are for the scheme to be agreed in September 1997 and for the company to begin operations in January 1998. The expectations are for 75%+ of product returned to be received through the reverse distribution network, but it will also be necessary to create a retail-based network, subject to amendments to the Special Waste regulations and the co-operation of UK retailers.

At the time of preparation of this paper, ongoing work consisted of:

- 1) production of Articles of Association for the company,
- 2) production of a Business Plan,
- 3) collection of data to set the pre-payment fee,
- 4) collaboration between steering groups and cell suppliers,
- 5) registration of the Rebat symbol,
- 6) obtaining consensus of the whole Rebat group,
- 7) lobbying to amend Special Waste Regulations.

Ongoing from September 1997 will be:

- 1) company registration,
- 2) appointment of Board of Directors,
- 3) selection of consolidation company,
- 4) recruitment of staff,
- 5) recruitment of members,
- 6) creation of an awareness campaign.

Our expectations are that when the Rebat company is in full operation, several increases in the magnitude of the collection of Ni-Cd batteries will occur, as the inhibitions about the collection will have been removed.

## **Effective Collection and Recycling of Nickel-Cadmium Batteries: The Swiss Concept**

**Eduard Back, Agency for the Environment, Forests and Landscape,  
Switzerland**

### **Legal situation in Switzerland**

- ◆ **Current legislation on batteries is under revision** (Ordinance on Substances, Annex 4.10 Batteries)
- ◆ **A government proposal for revised legislation has been sent out to interested parties for consultation**
- ◆ **The formal consultation procedure on the proposal is ending on September 30, 1997**

### **Environmental policy goals**

- ◆ **Ban or minimize cadmium containing products on the market**  
(already prohibited: Cd-containing plastics; Cd-plated articles)
- ◆ **Replace Ni-Cd batteries by less environmentally harmful batteries**

## **Aim of the proposal**

- ◆ **Increase the returning rate of spent batteries from today's 60% to at least 80%**
- ◆ **Increase the returning rate of spent Ni-Cd batteries to 90%**
- ◆ **Recycle spent batteries into raw materials/ reusable residues**
- ◆ **Ban pollutant batteries that are permanently fixed to products**

## **Proposed measures**

- ◆ **Obligation to return and to take spent batteries**
- ◆ **Introduction of a mandatory prepaid disposal fee on all batteries**
- ◆ **Introduction of a deposit on Ni-Cd batteries**
- ◆ **Prohibition of products containing pollutant batteries if they are permanently fixed to them**

**Returning and taking back spent batteries:**

- ◆ **Obligation for the consumer to return spent batteries**
- ◆ **Obligation for the manufacturers and traders to take back spent batteries**
- ◆ **Obligation for the manufacturers and traders to provide at places of sale for collecting facilities and appropriate information**

**Deposit on Ni-Cd batteries:**

**Scope**

- ◆ **Small, sealed Ni-Cd batteries up to 5 kg in weight**
- ◆ **Exemptions:**
  - Ni-Cd batteries permanently fixed to products
  - Ni-Cd batteries for use by the army or civil defence

**Deposit on Ni-Cd batteries:**

**Level of deposit**

< 50 g	3 CHF (~ 2 US\$)
50 - 100 g	5 CHF (~ 3,5 US\$)
100 - 250 g	10 CHF (~ 7 US\$)
250 - 500 g	20 CHF (~ 14 US\$)
500 - 1000 g	40 CHF (~ 28 US\$)
1000 -5000 g	70 CHF (~ 50 US\$)

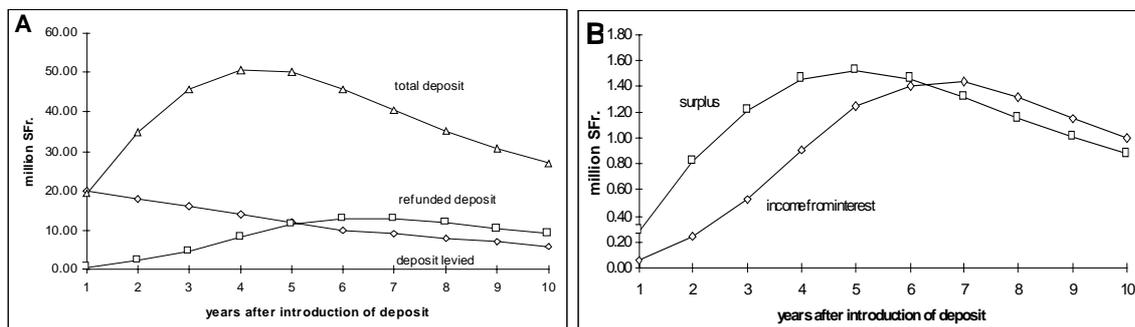
**Deposit on Ni-Cd batteries:**

**Implementing organization**

- ◆ **Private organization acting on a mandate by the government**

## Deposit on Ni-Cd batteries: Costs

- ◆ **Self-financing on deposit that is not reclaimed and on interest**
- ◆ **Estimated cash flow after introduction of deposit:**



### Prepaid disposal fee:

#### Scope

- ◆ **All batteries**
- ◆ **Exemptions:**
  - Batteries permanently fixed to products
  - Accumulators > 5 kg in weight
  - Batteries for use by the army or civil defence

**Prepaid disposal fee:**

**Level of fees**

- ◆ set out by the government
- ◆ based on the actual recycling costs
- ◆ 1997: about 5000 CHF (3500 US\$) per ton or 0.20 CHF (0.14 US\$) per standard unit (type AA/LR6)

**Prepaid disposal fee:**

**Use of fees**

- ◆ recycling of spent batteries into raw materials/reusable residues
- ◆ collection of spent batteries
- ◆ transportation to recycling plants (BATREC AG, RECYMET SA)
- ◆ promoting awareness raising actions and information campaigns
- ◆ operation costs of implementing organization (items 2 to 4 limited to 20% of total fees)

**Prepaid disposal fee:**

**Implementing organization**

- ◆ private organization acting on a mandate by the government

# **European Portable Battery Association Policy on Collection and Recycling**

**Patrick Houzé, Chairman, Rechargeable Working Group of EPBA, France**

## **Introduction of RWG**

RWG is part of the working group/committee of the European Portable Battery Association (EPBA). Its mission is to cover all European issues related to the field of portable rechargeable batteries.

RWG's main objectives could be summarised as follows:

- address environmental and legislative issues,
- provide a European forum for exchange and dissemination of ideas,
- give guidance to the national battery associations,
- represent members' interest in dealing with other associations and organisations.

RWG has 20 members and associate members. They meet at least every quarter, in Brussels.

## **Collection Sub Group**

During the course of 1996 it appeared necessary, in order to improve RWG's efficiency in dealing with collection issues, to create a specific sub group: the Collection Sub Group (CSG).

The members of the CSG are representatives of key rechargeable battery companies, as well as two major OEMs in the field of telecoms and cordless tools. They have had several meetings in 1996 and 1997, and I am now able to present a summary of their recommendations

First of all, the main concerns of the CSG are related to possible phase out (or ban) of Ni-Cd, and/or to heavy taxes or deposits imposed on Ni-Cd, these representing a major threat to the overall cordless product business in Europe as stressed by the OEMs' representatives in this group.

Their six key recommended actions are:

- implementation of common collection systems through:
  - ◇ reverse distribution through appliance manufacturers and OEMs
  - ◇ public agencies and institutions
  - ◇ municipal collection scheme
  - ◇ retail collection scheme
  - ◇ "industrial distributors"

- common and voluntary marking and colour coding of each of the currently existing rechargeable batteries, based on a choice of colours already used by members of the Japanese Battery Association,
- facilitation of the creation/development of recycling facilities *in Europe* for all rechargeable battery technologies including Li-ion,
- implementation, in countries where the system doesn't exist, of a fee added to the cell price to cover expenses related to collection,
- development of communication and training, in order to develop public awareness on collection,
- making sure the transportation of used batteries is no problem between (and inside) the various European countries and the countries where the recycling facilities are located.

In order to speed up these actions and their implementation in Europe, the RWG has proposed to the board of EPBA to hire a person specially in charge of this subject.

# Collection and Recycling Activity for Small Rechargeable Batteries in Japan

**Kinya Fujimoto (Sanyo Electric Co. Ltd), Battery Association of Japan**

## Introduction

In June 1993, sealed Ni-Cd batteries and products powered by these batteries were designated by the "Law for Promotion of Utilization of Recyclable Resources". The Ni-Cd battery was specified as a "second category product" the same as PET bottles and steel or aluminium cans.

Products powered by Ni-Cd batteries were specified as "first category products". This category includes 16 products such as power tools, cordless telephones, shavers, vacuum cleaners, etc.

In compliance with the relevant laws, the Battery Association of Japan (formerly JSBA, BAJ hereafter), consisting of 26 members, has actively started to promote the collection and recycling of used Ni-Cd batteries.

## Production and sales of Ni-Cd batteries in Japan

### *Sales (quantity)*

Table 1 shows the sales of Ni-Cd, Ni-MH and Li-ion batteries between 1992 and 1996.

**Table 1: Sales by Japanese manufacturers (millions of cells)**

Year	Ni-Cd	Ni-MH	Li-ion	Total
1992	773 (99%)	-	-	773 (99%)
1993	811 (105%)	70	-	881 (114%)
1994	880 (109%)	199 (285%)	-	1,079 (122%)
1995	867 (99%)	305 (153%)	30	1,202 (111%)
1996	703 (81%)	358 (117%)	114 (384%)	1,175 (98%)

(% increase on previous year)

\* In 1993, Ni-MH batteries were launched on the market and demand increased rapidly in 1994. Li-ion batteries were launched in 1995.

\* The sales ratio (quantity) for Ni-Cd, NI-MH and Li-ion batteries in 1996 was 60:30:10.

*Sales (in yen)*

Table 2 shows the amount of sales of Ni-Cd, Ni-MH and Li-ion batteries in the past five years.

**Table 2: Sales by Japanese manufacturers (billion yen)**

Year	Ni-Cd	Ni-MH	Li-ion	Total
1992	154 (105%)	-	-	154 (105%)
1993	138 (90%)	31	-	169 (110%)
1994	136 (99%)	75 (244%)	-	211 (125%)
1995	128 (94%)	95 (127%)	38	261 (124%)
1996	101 (79%)	90 (95%)	138 (367%)	329 (126%)

\* In 1993-1994, sales of Ni-Cd batteries decreased compared with the previous year. As shown in Table 1, although the quantity increased, the cost decreased. That is to say, cost performance was better.

\* Sales ratio (amount) of Ni-Cd, Ni-MH and Li-ion batteries in 1996 was 31:27:42.

*Domestic Japanese sales by application*

Table 3 shows sales of Ni-Cd, Ni-MH and Li-ion batteries by application on the domestic market in 1996.

**Table 3: Sales by application (millions of cells)**

Application	Ni-Cd	Ni-MH	Li-ion	Total
*Emergency lights	25 (11%)	-	-	25 (7%)
*Home appliance	64 (28%)	5 (8%)	13 (20%)	82 (23%)
*Office equipment	15 (7%)	21 (34%)	25 (38%)	61 (17%)
*Communication	43 (19%)	32 (52%)	28 (42%)	103 (29%)
*Power tool	51 (22%)	-	-	51 (14%)
*Round cells	14 (6%)	-	-	14 (4%)
*Others	16 (7%)	3	-	16 (5%)
TOTAL	228 (100%)	61 (100%)	66 (100%)	355 (100%)

(% ratio by application)

For Ni-Cd batteries, home appliances such as VCRs and shavers represented the largest field (28%). Next was power tools and toys (22%). For Ni-MH batteries, communication field (52%) and office equipment (34%) were the largest.

***Sales ratio of the three types of batteries by application***

The sales ratio (quantity) by battery chemistries in 1996 was as follows:

- In the emergency, power tool and round cell (charger) fields, Ni-Cd was 100% in 1996.
- In the office equipment field, Ni-Cd was 26%, Ni-MH was 34% and Li-ion was 16%.
- In the home appliance field, Ni-Cd was 78%, Ni-MH was 6% and Li-ion was 16%.

***BAJ's forecast concerning the portable rechargeable battery market***

- In 1995, Li-ion batteries were launched on the same market.
- The market for portable rechargeable batteries will continue to grow rapidly.
- The reason for this rapid growth is that the communications and personal computer fields continue to grow rapidly and need these rechargeable batteries.
- For technical reasons, at present the power tool, radio, radio-controlled car and emergency lighting fields continue to use Ni-Cd batteries.
- If new technology for Ni-MH and Li-ion batteries is developed, even the power tool, radio-controlled car and emergency lighting fields will sooner or later use these batteries.

**Activities of BAJ*****Collection and recycling of used Ni-Cd batteries***

The collection weight target is more than 2,400 tonnes (40%) by the year 2000 for sealed Ni-Cd batteries. In order to achieve this target, BAJ has developed a Ni-Cd battery collection program.

The summary is as follows:

- 1) Collection results for used Ni-Cd batteries and scrap. Table 4 shows the collection results for the past five years.

**Table 4: Weight of collected batteries and scrap (tons)**

Year	Ni-Cd (sealed)	Ni-Cd (vented)	Scrap	Total
1991	280	930	1,286	2,496
1992	430	905	2,074	3,409
1993	611	1,085	2,006	3,702
1994	630	1,157	3,109	4,896
1995	383*	1,198	3,420	5,001

\* These figures do not include used batteries from outside markets. In 1994, the recycled weight of used Ni-Cd batteries and scrap was 4,896 tonnes. The weight included sealed Ni-Cd batteries, vented Ni-Cd batteries and scrap. 100% of scrap from factories is collected and sent to recyclers. Vented Ni-Cd batteries are collected via professional routes and sent to recyclers. As these batteries are for non-consumer uses, the collection rate is almost 100%.

Sealed Ni-Cd batteries before 1994 included used batteries not only from the domestic market, but also from outside markets and factories. Therefore, in 1995 BAJ decided to focus in this program on only used Ni-Cd batteries from the domestic market. The weight collected was 383 tonnes.

2) Definition of "collection rate"

It is difficult to define the collection rate for used Ni-Cd batteries. In order to finalise the definition, BAJ is studying the matter:

- to determine service life by application
- to determine average weight
- to determine the quantity of indirect export

a) *Service life*

BAJ visited recyclers and investigated lot numbers by application. In order to finalise the service life, BAJ has investigated them twice up to now.

b) *Average weight*

Cell size is different according to application. Generally speaking, smaller sized cells are used more than larger sized ones in all fields. Therefore, the average weight becomes lower. BAJ considers cell weight to be a very important factor in calculating the collection rate.

c) *Export with appliances by each application*

Although BAJ can ascertain the quantity its members export, it cannot determine the quantity their OEM customers export with appliances. However, BAJ is making an effort to obtain better information.

3) Analysis of collected used Ni-Cd batteries sent to recyclers

a) *Analysis by application*

**Table 5: Weight of collected used Ni-Cd batteries by application**

Application	Weight (%)	
	1994	1995
*Emergency	17.1	13.3
*Home appliance	18.7	27.7
*Office equipment	7.5	6.8
*Communication	36.3	23.1
*Power tool, toy	6.7	6.1
*Others	14.6	23.2

\* The largest quantity was in communication in 1994 (36.3%) and in home appliance in 1995 (27.7%).

\* There was still a quantity in power tool, toy, etc.

b) *Analysis by route*

**Table 6: Weight of collected used Ni-Cd batteries by route**

Collection route	Weight (%)	
	1994	1995
*OEM reverse channel	71.67	76.9
*Waste collector	26.56	16.5
*Municipality	0.56	0.2
*Retailer	0.35	2.4
*Others	0.86	4.2

- \* Based on this analysis, the main route was OEM reverse distribution. The weight ratio was 72% in 1994 and 77% in 1995. The next route was waste collector route. The weight ratio was 27% in 1994 and 17% in 1995.
- \* The retailer route improved, with 2.4% in 1995.

4) Target weight of collection

At the present time, as BAJ has not defined the collection rate, it has decided on a collection rate target. This target is 2,400 tonnes by 2000. BAJ also decides the target for each year and promotes the achievement of this target.

5) Scheme of the Ni-Cd batteries collection program in Japan

BAJ has established a nation-wide collection program. At the present time, there are four recyclers in Japan. Total capacity for recycling is about 7,000 tonnes. Because the recycling capacity is adequate, it is most important to develop a system to collect Ni-Cd batteries.

6) Expenses for the collection of Ni-Cd batteries

BAJ members bear the expenses according to their share in Ni-Cd batteries production. BAJ is still considering how the cost of collecting other portable rechargeable batteries such as Ni-MH, Li-ion and sealed small lead-acid batteries will be borne.

7) PR/education activities

BAJ established a PR/education committee for Ni-Cd batteries collection. The committee has developed plans based on the Ni-Cd batteries collection program.

8) How to achieve the target

BAJ discussed which is the better collection approach, by application or by route. It ultimately decided on the latter. The following are the main points concerning how we use this approach.

*a) OEM reverse distribution routes*

- \* select the main companies by application
- \* decide the share according to BAJ members
- \* provide information on BAJ's collection system to OEMs through salesmen of BAJ members and connect OEM customers with recyclers

*b) Waste collection routes*

- \* investigate the present situation of waste collectors who return used Ni-Cd batteries to recyclers
- \* connect other waste collectors with recyclers if they do not know BAJ's collection system
- \* as a first step, visit waste disposal associations (there are more than 30 in Japan) and inform them about the waste collection system

*c) Retailer routes*

- \* over 60,000 collection tools (boxes, stickers and manuals) already delivered to consumer electric shops by BSA
- \* collection boxes to be placed in big shops (for example, supermarkets, discount stores)

*d) Municipality routes*

- \* 8,000 tonnes of primary cells collected voluntarily by over 1,900 municipalities in 1994
- \* primary cells could include Ni-Cd batteries
- \* present situations to be investigated
- \* municipalities under obligation to educate residents "to co-operate in collecting used Ni-Cd batteries"
- \* if possible, BAJ to ask to collect used Ni-Cd batteries on municipality routes

## **Collection and recycling of all rechargeable batteries in Japan**

1) Background and history:

At present, it is globally promoted to conserve natural resources. Recycling of used batteries is a subject of great concern among general consumers. In Japan the so-called Recycling Act was established in 1993. Since that time, the Battery Association of Japan has aggressively promoted the collection and recycling of used Ni-Cd batteries from the viewpoint of the conservation of valuable natural resources.

Recently, however, some countries in Europe are collecting all types of batteries in addition to Ni-Cd. And EPBA has been discussing collection/recycling of all rechargeable batteries.

2) The basic policy of BAJ is as follows:

- a) *We collect all rechargeable batteries, which means Ni-Cd, sealed lead-acid, Ni-MH and Li-ion.*
- b) *We promote collection/recycling of such used batteries in close co-operation with related industries and request the strong support of the government and municipalities*

3) The reason for our decision:

We decided on collection/recycling of all rechargeable batteries for the following reasons:

- a) *They contain various valuable natural resources*
  - \* adapt design to easily recognize Ni-Cd battery
  - \* make policy such that consumers can understand and co-operate
  - \* get much more co-operation from OEM customers (this means introducing simple design, only black color)
- b) *Basic design*

From the long-term point of view, BAJ considered not only Ni-Cd batteries but also other rechargeable batteries such as Ni-MH and Li-ion.

  - \* to easily recognize different types of rechargeable batteries collected to recyclers
  - \* to present the image of "recyclable batteries" to consumers, including different rechargeable batteries as well as Ni-Cds
- c) *Design concept*

It is important to consider the following items:

  - \* design which can make "recyclable batteries" easily recognizable
  - \* design which can easily distinguish and identify the battery chemistry
- d) *Actual design*

The actual design shows belt zone and symbol color.

  - \* belt zone: "recyclable battery" can be recognized all around
  - \* symbol colour: can identify the battery chemistry
    - ◇ Ni-Cd: greenish yellow (pantone 389C)
    - ◇ Ni-MH: orange (pantone 1375C)
    - ◇ Li-ion: blue (pantone 312C)
    - ◇ Lead acid: grey (pantone 877C)

- e) *Basic design to promote the co-operation of consumers*
  - \* To educate consumers both visually and by words
- f) *Extension of the basic design to promote co-operation of consumer*
  - \* It is possible to apply the basic design to various types of batteries and recycling tools (box, sticker, leaflet, etc.)
  - \* They can be used to educate consumers in colour coding without being confusing
- g) *Consideration for getting co-operation from OEM customers*
  - \* It is ideal to use the basic design for all rechargeable batteries
  - \* From the cost point of view, if OEM customers do not like to use the basic design, BAJ recommends simple design
- h) *Reason for using the basic design for pack type batteries*
  - \* BAJ recommended use of the basic design when consumers can remove or replace the pack type battery by themselves

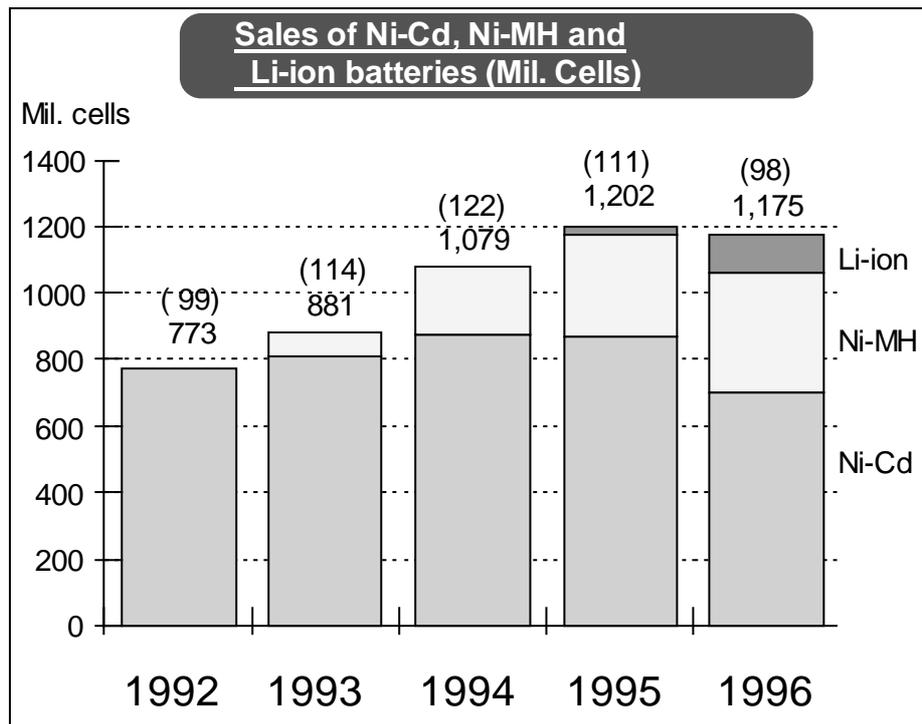


Figure in parentheses indicates % increase compared with previous year (see Table 1).

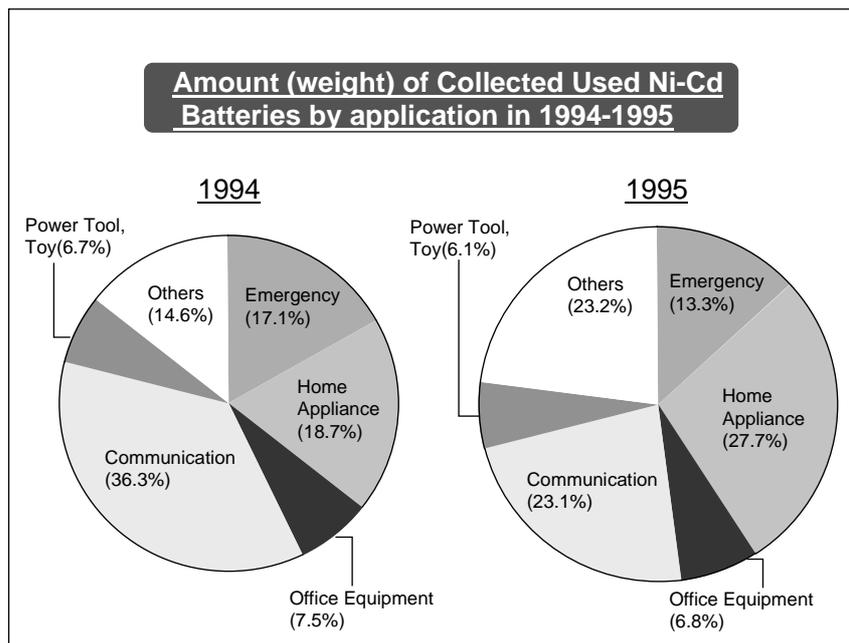
### Application Powered by Ni-Cd and Ni-MH Batteries

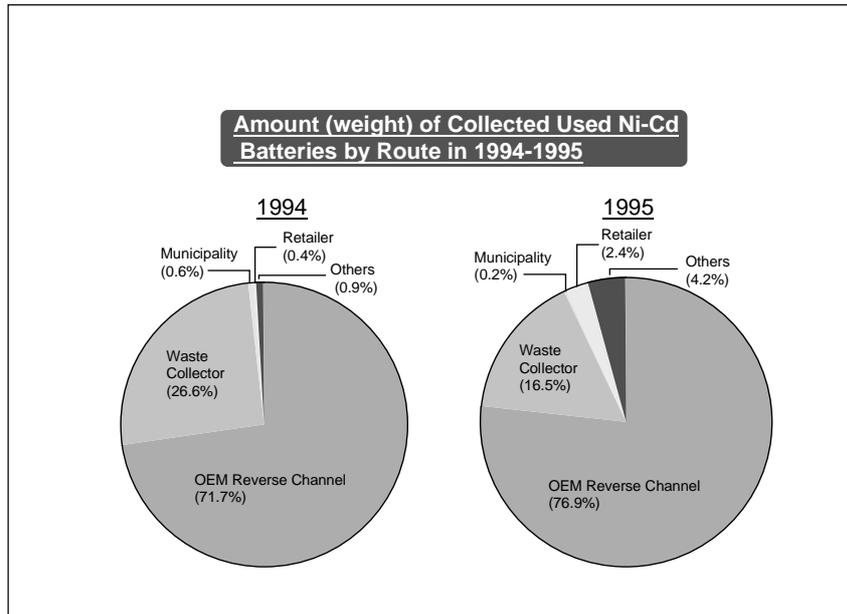
Application	Name of Appliance
Emergency	Light, Alarm System
Home Appliance	Video Camera, CD Player Headphone Stereo, Cleaner, Shaver Toothbrush, Liquid Crystal TV etc.
Office Equipment	Personal Computer, Word Processor Handy Copy, Printer etc.
Communication	Cordless Telephone, Cellular Phone Transceiver etc
Power Tool, Toy	Power Tool-Drill, Driver, Toy Radio-Control Car
Resale	Single Cell
Others	Medical Measurement, etc.

<b>Sales Ratio (%) of Ni-Cd, Ni-MH and Li-ion by Application in 1996 (Mil. Cells)</b>				
<b>Application</b>	<b>Ni-Cd</b>	<b>Ni-MH</b>	<b>Li-ion</b>	<b>Total</b>
*Emergency	25 (100)	-	-	25 (100)
*Home Appliance	64 (78)	5 (6)	13 (16)	82 (100)
*Office Equipment	15 (25)	21 (34)	25 (41)	61 (100)
*Communication	43 (42)	32 (31)	28 (27)	103 (100)
*Power Tool	51 (100)	-	-	51 (100)
*Resale	14 (100)	-	-	14 (100)
*Others	16 (84)	3 (16)	-	19 (100)
	228 (65)	61 (17)	66 (18)	355 (100)

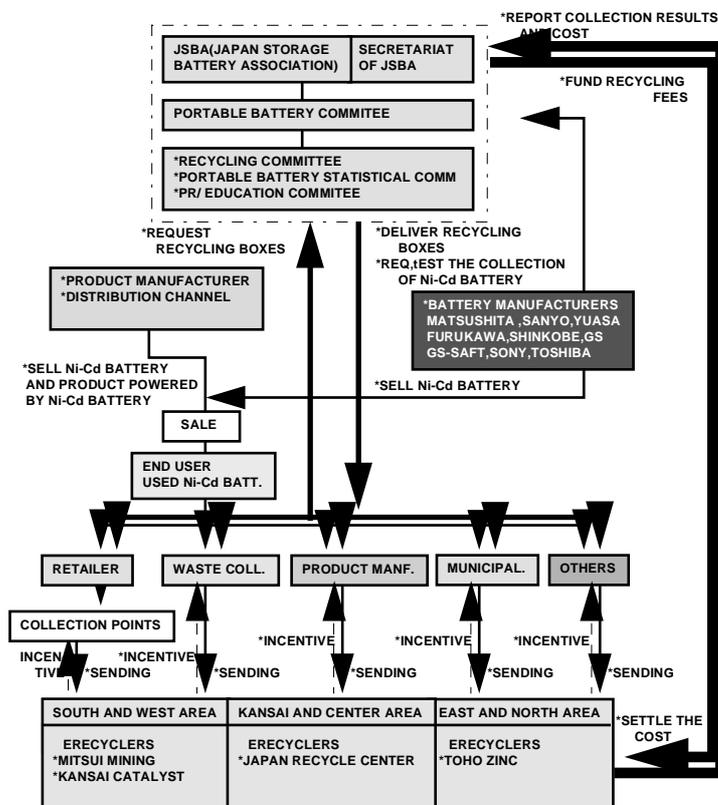
Also see Table 3.

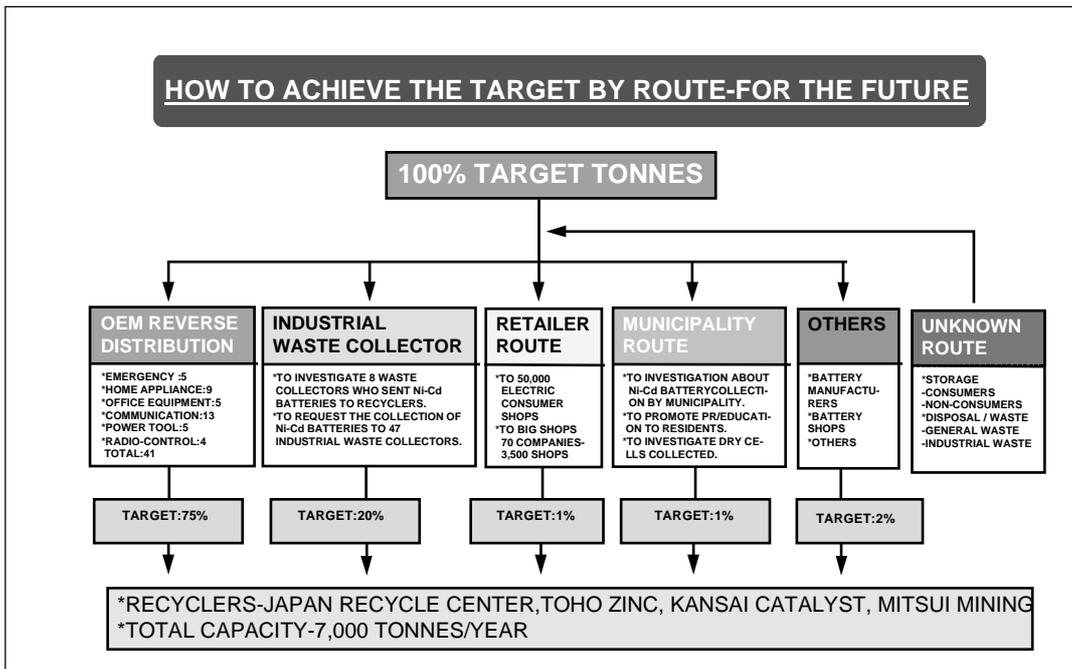
<b>Collected Weight of Used Ni-Cd Batteries and Scrap in Japanese Domestic Market</b>				
(unit:tonnes)				
years	Ni-Cd (sealed)	Ni-Cd (vented)	Scrap	Total
1991	280	930	1,286	2,496
1992	430	905	2,074	3,409
1993	611	1,085	2,006	3,702
1994	630	1,157	3,109	4,896
1995	641	1,198	3,420	5,259





## Ni-Cd BATTERIES COLLECTION PROGRAM IN JAPAN





## Collection and Recycling of All Small Rechargeable Batteries

### What is background?

- (1) It is globally promoted to conserve resources.
- (2) BAJ promotes collection/recycling of Ni-Cd batteries since 1993.
- (3) New rechargeable batteries were introduced and dramatically increased in volume.

### **What is the reason?**

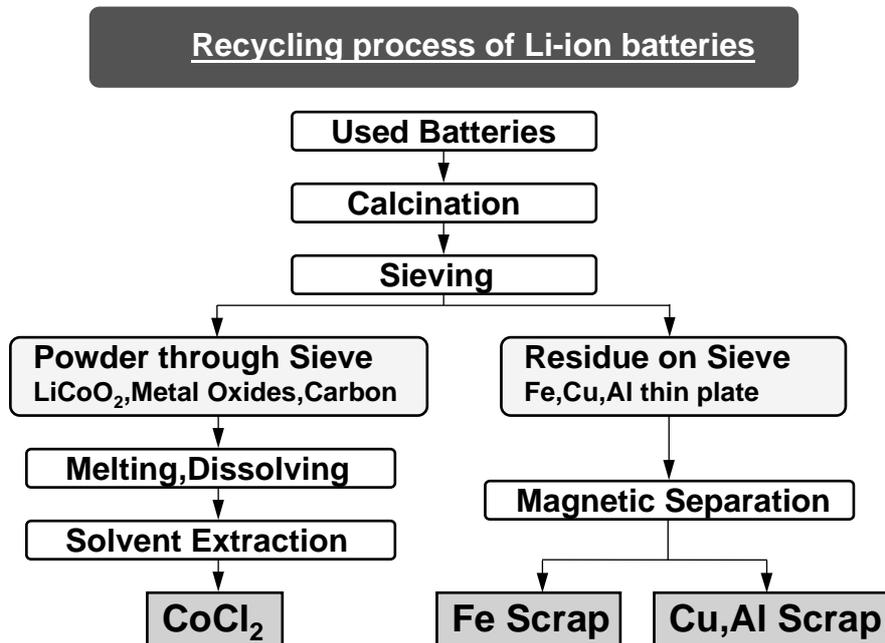
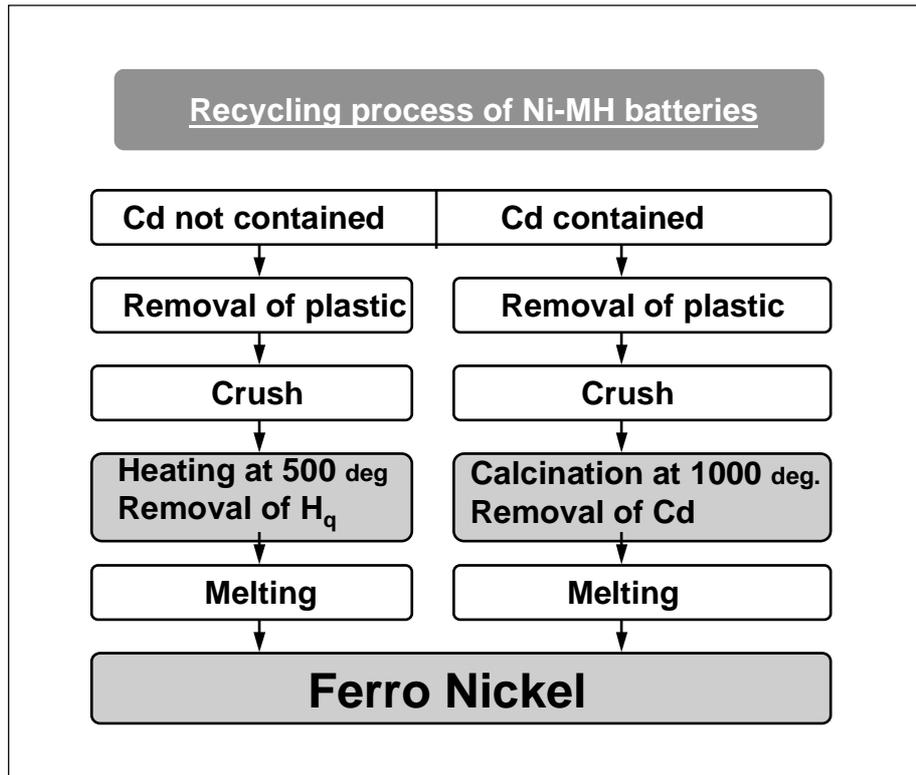
- (1) Valuable natural resources.**
- (2) Development of new recycling technologies.**
- (3) Mixed with Ni-Cd batteries, a lot of other used rechargeable batteries to appear.**

### **How to promote?**

- (1) We collect Ni-Cd, sealed lead-acid, Ni-MH Li-ion batteries (all rechargeable).**
- (2) We promote collection of all batteries in close co-operation with industries, and with the support of the government and municipalities**

**What is the action plan?**

- (1) Evaluation of recyclers with new technologies (Ni-MH, Li-ion).**
- (2) Separate collection by color coding system.**
- (3) Effective PR activities for maximising collection rates.**
- (4) Financially satisfied system.**
- (5) Demand of government's support.**



## **How to Collect Portable Ni-Cd Secondary Batteries Efficiently: A Consumer's Point of View**

**Emmanuel Beaurepaire, Secretary of the Battery Working Group, France**

How to collect portable used Ni-Cd secondary batteries efficiently? This is one of the questions the Battery Working Group tried to answer when, between March 1996 and February 1997, they discussed the issue of the collection and recycling of primary and secondary batteries in France.

This group, which I led, was set up at the request of the second French consumers association, the AFOC (Consumer Association of the FO Trade Union).

The Battery Working Group is composed of:

- representatives of consumer organisations;
- representatives of environmental protection organisations;
- representatives of local authorities;
- representatives of French official organisations: Agence de l'Environnement et de la Maîtrise de l'Energie - ADEME (Agency for Environment and Energy Management) and Institut National de la Consommation - INC (National Institute for Consumer Affairs);
- representatives of the primary and secondary batteries industry (metal suppliers notably);
- companies which have developed recycling processes.

The objective of this working group was to try and find out the best solution in the prospect of the transcription into French law of the European Directive of 1991 concerning batteries which contain certain dangerous substances.

Representatives of the administration, local authorities, manufacturers and distributors gave their opinions. In addition, the Swiss and Dutch systems for the collection and recycling of batteries were presented.

At the end of these meetings, in February 1997, the working group sent to the French administration and to the European authorities a report whose title was "Proposals for the Collection and Recycling of Portable Primary and Secondary Batteries in France". Copies of this report in English are available on request.

It should be underlined that concerning Ni-Cd batteries, reflection was only focused on those secondary batteries which consumers can easily extract from their appliances.

In the case of Ni-Cd batteries that are not accessible to the consumer - generally for security or technical reasons - their recycling would inevitably entail the setting up of a collection and disassembly procedure for these devices (computers, domestic, etc.).

## 1 - Consumer behaviour and expectations

The reflection on batteries made it possible, in particular thanks to the participation of representatives of consumer organisations and environmental protection organisations, to better understand consumers' behaviour, notably concerning used batteries.

- Consumers do not know saline batteries, alkaline batteries, Ni-Cd batteries and Ni-MH batteries: they only know a "source of electric energy" other than electricity, to which they give the generic name of "battery".
- Used portable batteries are part of the wastes which attract consumers' attention and which, for this reason, they would be willing to extract from their domestic wastes with a view to recycling. A survey made in France in 1996 by an organisation specialised in public opinion surveys confirmed this view: a panel of consumers were asked which kind of wastes they selectively sorted. Glass was the first waste selected (86%), cardboard and medicines were rated 54%. It is to be noted that, concerning glass and cardboard, those results are normal in so far as collection has already existed for a long time. More surprising is the fact that medicines and, above all, portable batteries were mentioned, the latter being rated at some 37%, whereas there is no organised collection circuit. There are only limited operations, notably for button cells. Between the two phases of the survey (1994-1996), the public's interest in portable batteries increased from 25 to 37%.
- Consumers intuitively think that used batteries can be dangerous (for health, security and the environment), which leads them to keep batteries at home and ask for collection and removal actions from the different organisations concerned (distributors, local authorities, etc.).
- Consumers, in particular young consumers, have already been made aware of the importance of the issue of button cell collection in France, for instance in the course of actions led by the Croix-Rouge (Red Cross) and benevolent organisations or by environmental protection associations. They will be all the more active when generalised and organised collection is proposed to them.

Being aware of the fact that the regeneration of materials contained in portable batteries cannot totally make up for collection and recycling costs, consumers are willing to accept a slight increase in the sale price of batteries on the condition that the system set up will be as flexible and simple as possible and, above all, that the price increase corresponds to the sums necessary for the financing actions which will really be taken. Moreover, they want this system to be as transparent as possible in order to avoid all abuses.

Taking into account this state of affairs and considering that recycling the whole set of portable batteries is technically possible, and that processing units exist, the Battery Working Group has come down in favour of global collection.

This solution has also been adopted for efficiency's sake: global collection is the sole means to get the highest rate of recovery for Ni-Cd, lead and mercuric oxide batteries.

In addition, it will make it possible to solve the problem of pollution by substances at least as dangerous as lead and cadmium.

It should be remembered that alkaline and saline batteries, and other secondary batteries, contain electrolytes considered to be dangerous and metals such as mercury, zinc, manganese and nickel which present risks of pollution and toxicity. This is particularly true of mercury, the amount of which is still, as it has been for a great number of years, quite important in lots of used batteries currently processed.

Consumer and environmental protection associations have been particularly watchful on that point. Indeed, their representatives do not understand why there should be an obligation to collect and recycle lead and Ni-Cd batteries, and mercuric oxide batteries, and no obligation for alkaline and saline batteries which contain - as wastes - mercury amounts 10 to 20 times as important as the levels announced for products currently commercialised. This situation has been stated following analyses made of the battery sets being processed by recycling organisations. Environmental pollution risks exist for mercury as well as cadmium and lead.

To sum up, consumers cannot make a distinction between the different types of portable batteries and consider all these products as more or less poisonous. They are ready to make an effort to bring back portable batteries, but they demand simple collection systems. Finally, they will accept a higher purchase price for new batteries in so far as the increase is effectively being used for recycling and the system set up is flexible in its structures and transparent as to its operation.

## **2 - Assessment of experiences concerning the collection of portable Ni-Cd secondary batteries abroad**

With a view to finding solutions for the collection of portable Ni-Cd batteries, the different experiences realised abroad make it possible to come to interesting conclusions.

### **Germany**

A voluntary agreement was signed in 1988 between the manufacturers and importers of portable batteries, aiming at the development of batteries containing little or no dangerous substances on the one hand and, on the other, at the collection, through distributors, of portable batteries containing mercury, lead and cadmium.

Some nine years or so afterwards, one can draw the following conclusions:

- The development of alternative products is not easy. Several alternative solutions to Ni-Cd batteries have been studied, but they cannot be available for all applications.
- The system which was set up turned out to be hardly efficient: only 30% of the total number of portable primary and secondary batteries aimed at have been collected. The majority of these batteries have been scattered in the environment through landfilling and incineration.

In order to obtain more significant results, Germany decided in April 1997 to make the collection and recycling of all portable primary and secondary batteries compulsory. After the signing of the regulation, manufacturers and distributors will be obliged to take back mercuric oxide, Ni-Cd and lead batteries. Six months later this obligation will be extended to all batteries.

### **Norway**

A system of Ni-Cd battery collection has been set up, and a regulation obliges distributors to take back Ni-Cd batteries brought by consumers. Yet importing manufacturers are under no obligation to take back used products from distributors. These products are managed by a national network processing dangerous wastes. A recent study demonstrated that some distributors do not play their role. Moreover, a lack of information has been clearly brought to the fore, notably concerning ways of processing recovered batteries. Consumers were poorly informed about the dangers of the products concerned, and distributors did not know they were obliged to take back used batteries.

The majority of Ni-Cds taken back by the national network principally came from the oil industry and the military sources. Small quantities came from distributors.

Quite recently, importers of portable batteries and integrators suggested to Norwegian authorities the following programme:

- Producers and importers are responsible for the collection and recycling of secondary batteries (Ni-Cd, Ni-MH, Li-ion).
- This operation will be financed by a voluntary contribution amounting to the cost of collection, sorting and recycling.
- Norwegian authorities underlined the fact that all portable primary and secondary batteries contain harmful substances, and asked producers and importers to make a study concerning the collection costs for all types of batteries.

Similar experiences in other Scandinavian countries demonstrated similar difficulties.

### **Switzerland, Belgium, the Netherlands, Austria**

In these countries, where the solution of collecting all types of batteries was chosen, the collection rate objectives are very high: up to 80% on average. It is interesting to notice that, in these countries, recycling enterprises like finding Ni-Cd batteries in the mixed lots they collect. They are an additional source of revenue, since recyclers are paid about 15 FF/kg for mixed sets whereas recycling Ni-Cds only costs 3 or 4 FF/kg.

### **Japan**

A law was enacted in 1993 on the collection and recycling of used Ni-Cd batteries. It aimed at the reclamation of natural resources.

Early in 1997, the Battery Association of Japan decided to collect all types of portable secondary batteries: Ni-Cd, lead, Ni-MH and Li-ion secondary batteries. The reason for the broadening of their policy is that all these types of batteries contain reclaimable natural resources and that recycling technologies are now available. Above all, experience showed that in the course of Ni-Cd collection other types of secondary batteries using another technology were collected at the same time in not insignificant quantities. Thus, global collection and recycling of all secondary batteries turned out to be the answer to Japanese consumers' expectations.

### 3 - Assessment of experiences concerning collection of Ni-Cd batteries in France

In the field of portable batteries, the tonnage distribution of used Ni-Cd batteries in different domains of activity is as follows (year basis 1995):

Household electrical appliances and video	220 tonnes	35%
Power tools equipment	40 tonnes	7%
Computers	140 tonnes	23%
Telecommunications	100 tonnes	5%
Small batteries for toys/small models	120 tonnes	19%
Total	620 tonnes	100%

It is quite clear that in certain big sectors of the industry the signing of voluntary agreements, by all importing manufacturers in the same field of activity, could favour the collection and recycling of Ni-Cd batteries.

Besides, due to a decrease in sales of portable Ni-Cd batteries in certain countries and, in the mean time, an increase in the number of used Ni-Cd batteries, it is necessary today to consider a global system for all technologies, all the more so as among the processed batteries you will find more and more Ni-MH and Li-ion secondary batteries.

#### **An experience concerning collection of Ni-Cd batteries in small equipment**

Ecovolt is an association, set up in France by manufacturers and importers of electro-portable machines in the field of small equipment, for the collection and recycling of used batteries used in these tools (cordless screwing and drilling machines, etc.).

Ecovolt now has 14 members, in particular Black & Decker, Bosch, Facom, Hitachi, Hilti, Makita, Maire and Skil.

The member companies represent 90% of the market for electro-portable machines operating with batteries. In 95% of cases, the batteries concerned are the Ni-Cd type.

Portable equipment working with batteries is sold either to the general public or to professionals through different distribution channels, notably supermarkets specialised in "do-it-yourself" equipment, traditional hardware shops, industrial stores, back-to-back direct selling, door-to-door selling and mail order selling.

Distributors take back all used batteries of the brands of member companies bought by their customers. These batteries are then taken back by their manufacturers and importers, which have them recycled at the SNAM. The costs of collection, sorting and recycling (plus administrative costs) are distributed among members of Ecovolt, in proportion to the collected quantity.

This flexible and economical system, which concerns the only organisations responsible for the commercialisation of these products, could be extended to the collection and recycling of Ni-Cd batteries

for domestic appliances, video, games, etc. But such an extension implies the setting up of a financing system and generalisation to all portable rechargeable batteries, taking into account that in other industry fields Ni-Cd is not as much used as it is for small equipment.

### **Experience of a portable Ni-Cd batteries manufacturer: SAFT**

Since 1992, SAFT has committed itself to taking back all its customers' used Ni-Cd batteries (industrial and portable) in order to recycle them. This programme operates in North America and Europe.

At the beginning, the programme had only to face some kind of inertia, so that its implementation was very slow and really started in 1994. Since then, quantities have been increasing slightly year after year. Yet only 2% of portable Ni-Cd batteries are recovered by this means (the recovery rate of industrial Ni-Cd batteries is far more important), which can easily be explained by selling conditions.

SAFT sells portable Ni-Cd secondary batteries to customers who integrate or incorporate them in appliances whether or not they are removable (domestic appliances, small equipment, computers, games, etc.). The commitment made by SAFT to take batteries back concerns those customers. Therefore, the system can only work if integrators take back devices and batteries from consumers. It is at the level of final consumers that the incentive must be given; thus portable Ni-Cd batteries could follow their marketing cycle in reverse order.

In reality, a few difficulties are to be deplored: customers feel as if they were much too independent from their supplier, which prevents them from taking advantage of free competition between manufacturers.

This recovery system cannot therefore work efficiently, except in the framework of an international agreement among all producers of Ni-Cd batteries and the devices in which these batteries are integrated. This agreement will inevitably comprise, at least, the whole range of secondary batteries.

### **Collection experience with mass distribution and among retailers**

There is specific collection experience with mass distribution and among retailers concerning one category of battery (notably button cells), which makes it possible to draw conclusions about the collection of Ni-Cd batteries.

#### ***The IKEA experience: a distribution channel for housing and furnishing products***

In France the Swedish company has set up global collection of portable batteries in four of its stores. This will afterward be extended to all of its stores.

Initially, the collection concerned only button cells containing mercury, but experience showed that customers returned all types of portable batteries. So IKEA had to set up a global collection which is quite successful, certain stores recovering up to a tonne of batteries each month whereas only a tonne per year was expected.

It is to be noted that the behaviour of consumers would be identical if they had to bring back only Ni-Cd batteries. Since they cannot make the distinction between them, they bring back all types of batteries.

***The experience of Natures et Découvertes***

Nature et Découvertes is a group of 32 stores selling products pertaining to the knowledge of nature. In 1991 it started the collection of button cells containing mercury, but stores quite rapidly had to face problems: the staff and customers demanded global collection, which was only an illustration of reality. Indeed, beside containers the public would place saline or alkaline primary batteries and secondary batteries.

***The experience of 1000 et une Piles (a French group of stores specialised in the sale of portable batteries)***

The first thing to be noticed is that consumers are given no information as to the harmfulness (for security and for the environment) of batteries.

Generally speaking, 25-30% of customers bring back used batteries to make sure they purchase the right kind. For watches (mercury batteries) 95% of consumers bring back the used batteries. Concerning portable Ni-Cd batteries, one customer out of three comes back with a used battery.

An information campaign gives very good results for the recovery of batteries. The press campaign which followed the release of the working group report induced consumers to bring back used batteries. In the absence of a financing system, recovered batteries are now being stored since the chain cannot pay for the recycling.

***The experience of Auchan: A food distribution channel***

The experience of Auchan is interesting in so far as this important distribution channel started a collection implying *solely* saline and alkaline batteries, in partnership with a French recycling company. The distribution channel had quite rapidly to face a problem - the recovery of products other than the ones intended: Ni-Cd, Ni-MH and even car batteries using lead. At this time in its collection launching period, Auchan recovers an average of 100 kg of batteries per month and per store (average 10-12,000 persons/day).

All the persons responsible for managing batteries made the same analysis:

- There are great expectations from consumers who want to get results;
- The recovery should concern all types of batteries to increase consumers' involvement;
- Stores are ready to make collection easier if there is a financial system.

#### **4 - What solutions should we propose to increase the number of portable Ni-Cd secondary batteries collected and recycled?**

The analysis of consumers' expectations and the assessment of experiences in France and abroad make it possible to propose two solutions (the former is a minimal solution and the latter a maximal one) to increase considerably the number of portable Ni-Cd batteries collected:

- collection of portable secondary batteries (apart from saline and alkaline batteries) through specialised shops (tobacconists, video, small equipment, telecommunications, computers and household appliances stores)

The principle of this type of collection - customers bring their used secondary batteries back to the purchase location - offers a great number of advantages:

- ◇ It is thus possible to use the same channel - in reverse order - as in commercialisation: retailers - suppliers - wholesalers - manufacturers.
- ◇ A good human relationship is established, so that the retailer is in a situation to induce customers to bring batteries back. Offering to collect batteries is also a means for the retailer to create customer loyalty.
- ◇ Customers often come back to the retailer with their used batteries, among other reasons to make sure they buy the same item.
- ◇ It is a means of collecting by industrial sector, allowing voluntary agreements with producers and hence greater efficiency of the system.
- ◇ For targeted markets (small equipment, microcomputers, video, etc.) this type of collection is an appropriate answer, as technology transfer exists for a great many applications. The success of the system is guaranteed since there are no distortions, the cost increase for recycling being financed whatever the technology.

Nevertheless,

- ◇ Retailers will inevitably collect saline or alkaline batteries, in quantities that are more or less important, which threatens to reduce their involvement and to put the whole system into question.
  - ◇ To operate efficiently, the financing must be thought of beforehand, which for instance was not the case for French regulatory projects.
  - ◇ Ni-Cd batteries, having the same shape as alkaline and saline batteries, will be found in household waste since they are not taken into account in this system.
- "all products" collection, notably at the level of mass distribution and local communities

This is the general solution proposed by the Battery Working Group. Global collection will make it possible for the consumer to bring all the batteries back to a single location: from alkaline batteries (for toys) to button cells for watches, through batteries for camescopes. Collection will have to be made in stores and at retailers, as this is where consumers buy their primary and secondary batteries.

Possibly local communities can take back used batteries, but only in the framework of toxic waste collection (paints, solvents, neon and chemical products, etc.). The container should be the same throughout the country in question, and communications should be set up at the national level to give consumers a better incentive.

It is quite obvious that the choice made between these two solutions will take other factors into account such as economic criteria, the existence of recycling channels, the environmental expectations of the population, and the real situation concerning pollution.

In France, in the course of its reflections, the Battery Working Group treated the idea of collecting the whole range of secondary batteries, considering that this solution presented a great many advantages. For environmental reasons, they finally gave their support to global collection of all types of batteries. In fact, participants noticed that all portable primary and secondary batteries can induce pollution: lead, cadmium and mercury, but also electrolytes. All the electrolytes in these batteries are likely to be released to the environment after the degradation of their case. Nowadays, mercury content levels 10 to 20 times higher than the maximum authorised for commercialisation are recorded for collected battery sets.

In conclusion, therefore, experience shows that consumers make no distinction between a Ni-Cd battery, another secondary battery and a primary battery. Moreover, the impact of harmful substances present in certain battery types is insufficiently or erroneously taken into account. Even a campaign of information will not modify their behaviour, which - inevitably - tends towards simplicity. The collection and recycling of portable primary and secondary batteries will make it possible to meet this situation and to solve a great number of problems associated with dispersal of dangerous substances in the environment.



# **Collection and Recycling of Ni-Cd Batteries in Germany**

**Heinz-Albert Kiehne, ARGE BAT Arbeitsgemeinschaft Gerätebatterien beim  
Fachverband Batterien im ZVEI (Germany)**

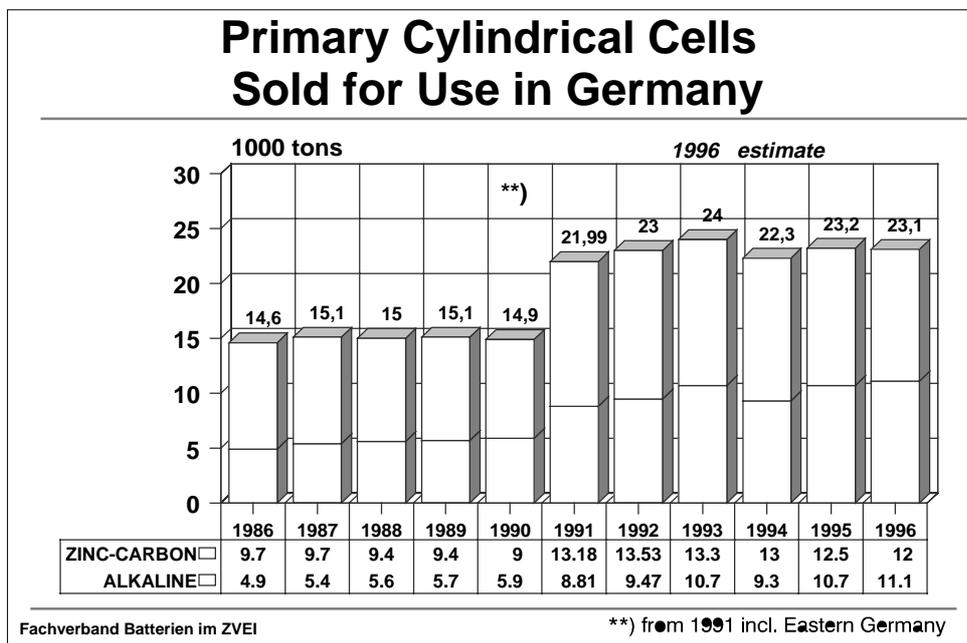
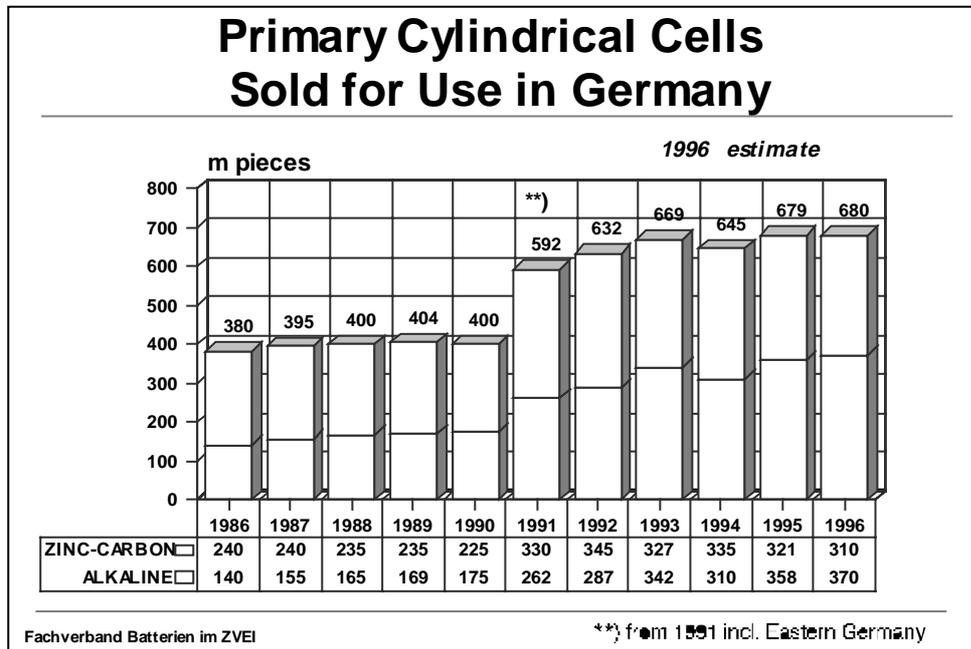
- 1. Collection and Recycling Conforming to the Voluntary Commitment of 1988**
- 2. Statistical Figures on Portable Batteries (Sales)**
- 3. Collection 1996 via Trade**
- 4. Return Quantities 1991-1997**
- 5. The “Freeriders”**
- 6. Costs and Cost Estimates**
- 7. Topics of the German Battery Decree**
- 8. Future Return Scheme for Spent Portable Batteries**

## **1. Collection and Recycling Conforming to the Voluntary Commitment of 1988**

**(State of the Art in Germany, 1997)**

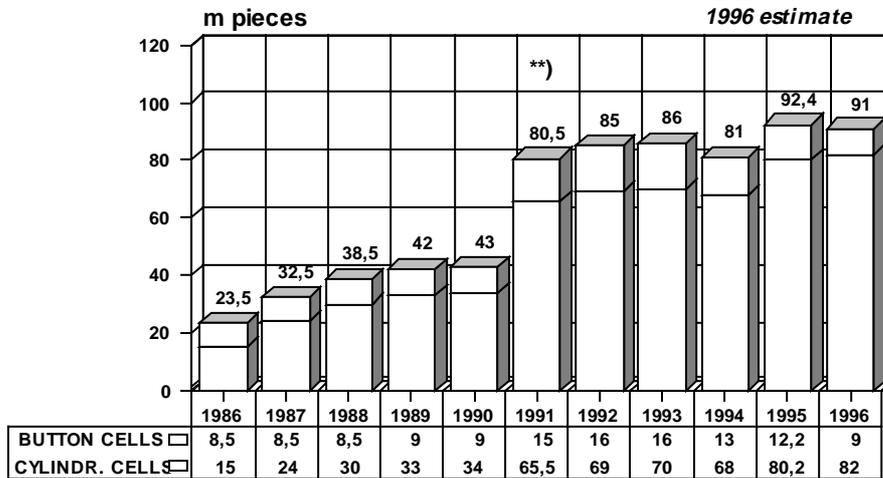
- Return and recycling of industrial types is traditionally 100%.
- Collection of portable Ni-Cd batteries since 1988 is based on a voluntary commitment.
- Return and recycling are organised and financed by ARGE BAT, whose members are battery manufacturers and importers.
- Trade gets cost-free collection boxes, to be shipped as postal parcels to NIREC in Dietzenbach. NIREC performs all handling and manual sorting and ships the Ni-Cd batteries to SNAM in France.
- Since 1996, Ni-Cd batteries are also recycled by ACCUREC in Mülheim, a new recycling plant in Germany.
- The German Battery Decree of 1998 requires the collection of all spent batteries, preferably for recycling.

2. Statistical Figures on Portable Batteries (Sales)



- ⇒ Zinc-carbon and alkaline cells (90% of all portable batteries in volume and weight) have to be collected by trade and manufacturers beginning mid 1998.
- ⇒ The user returns all batteries and cells without differentiating according to size or electrochemical system. Therefore the mix of batteries has to be sorted.
- ⇒ Ni-Cd batteries go to recycling, zinc-carbon and alkaline batteries to special landfills.

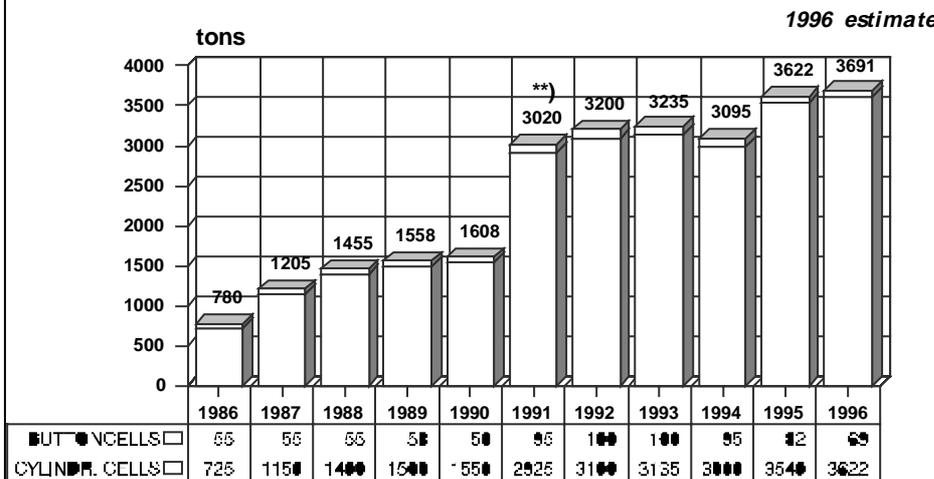
## Ni-Cd and Ni-MH Batteries Sold for Use in Germany



Fachverband Batterien im ZVEI

\*\*) from 1991 incl. Eastern Germany

## NiCd and Ni-MH Batteries Sold for Use in Germany

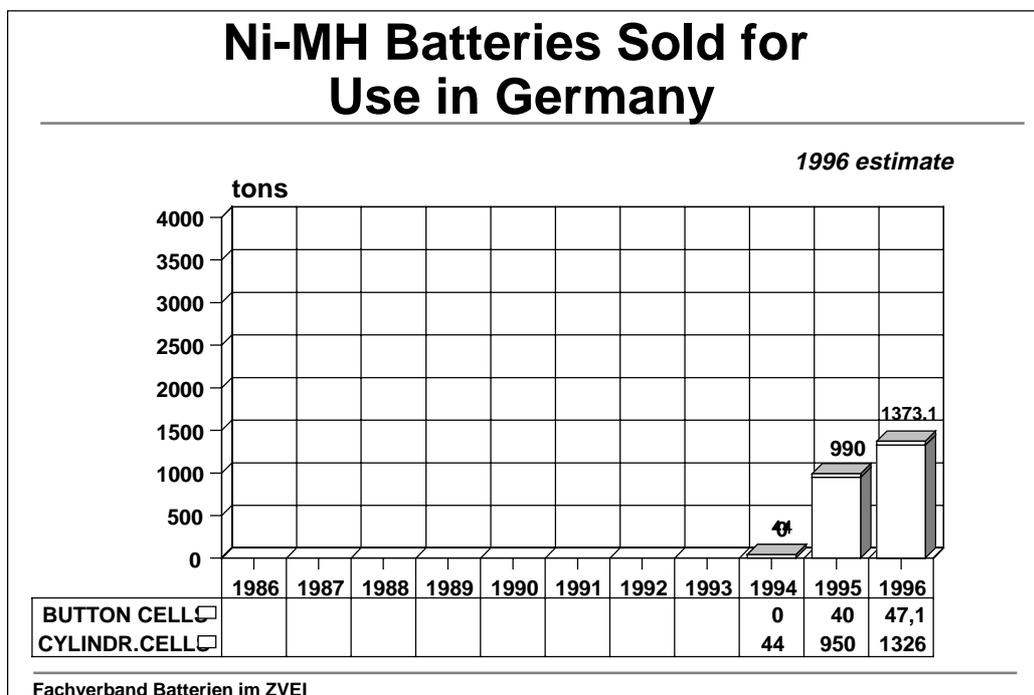
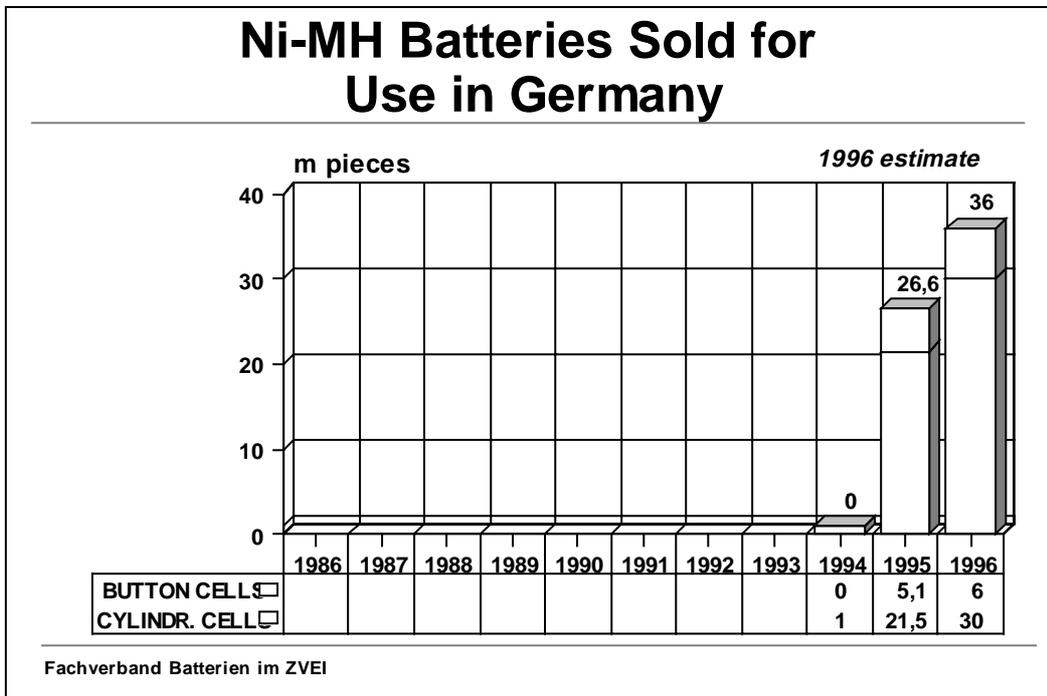


Fachverband Batterien im ZVEI

\*\*) from 1991 incl. Eastern Germany



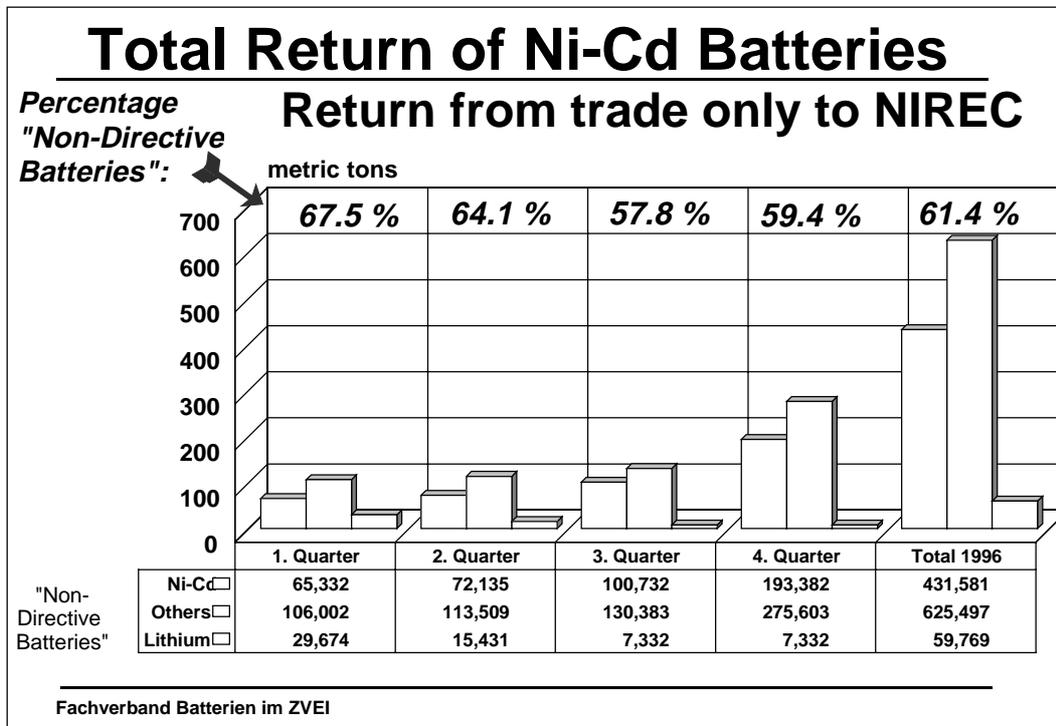
⇒ Ni-Cd batteries lose market share ...



⇒ Ni-MH batteries substituted for Ni-Cd batteries in special applications.

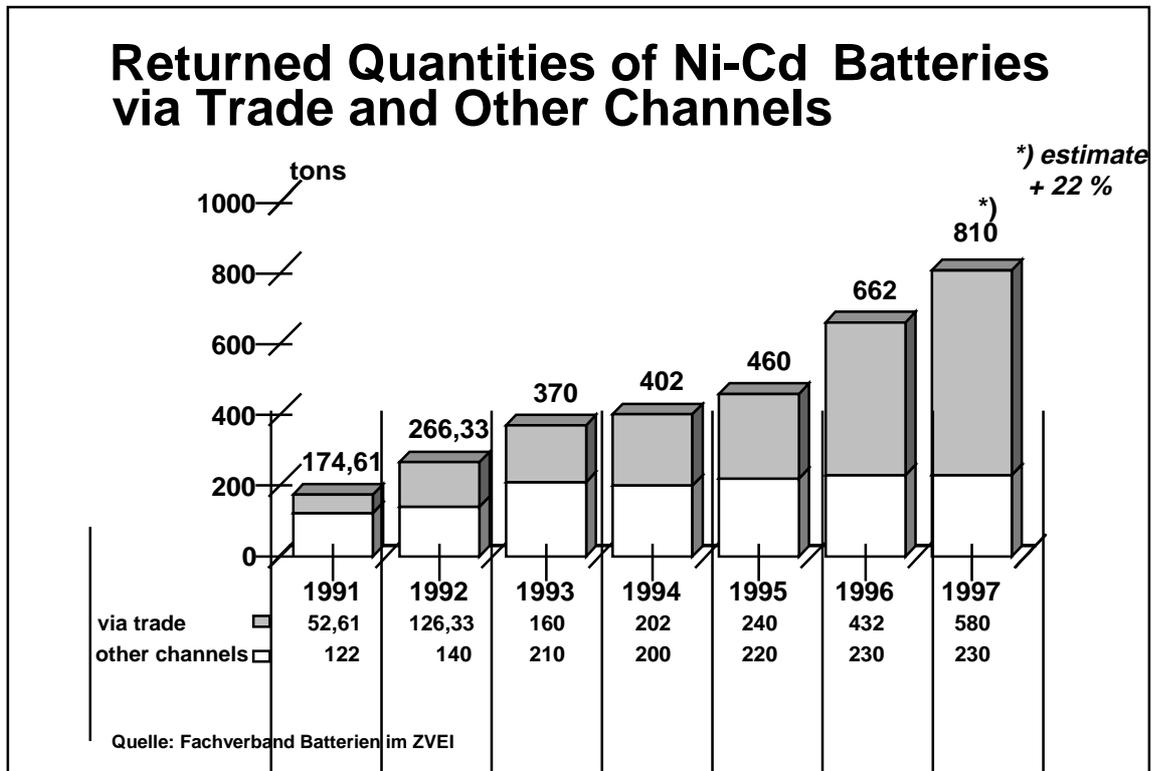
⇒ Rechargeable lithium-ion batteries, e.g. for mobile phones, are taking market shares from both battery types.

3. Collection 1996 via Trade



⇒ 431 tonnes of Ni-Cd batteries collected by trade in 1996.

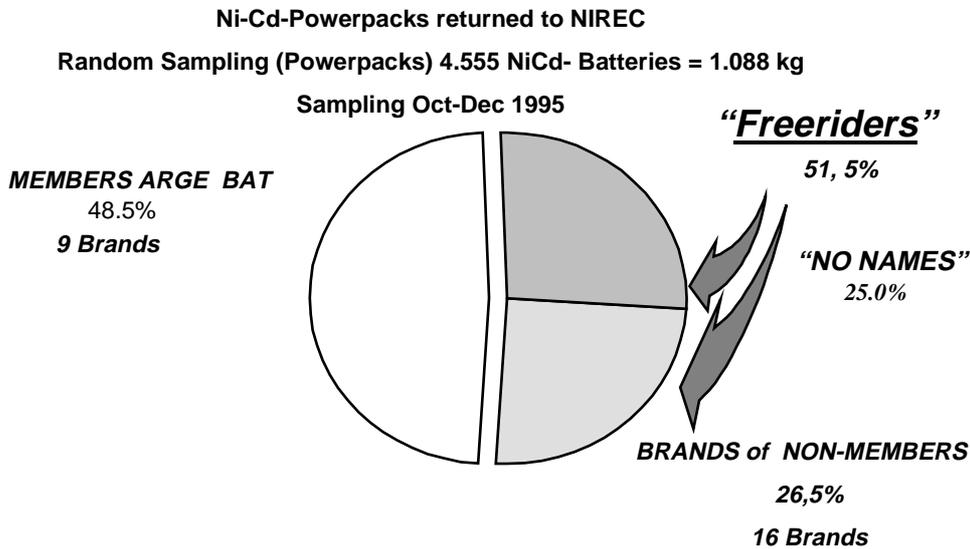
## 4. Returned Quantities 1991-1997



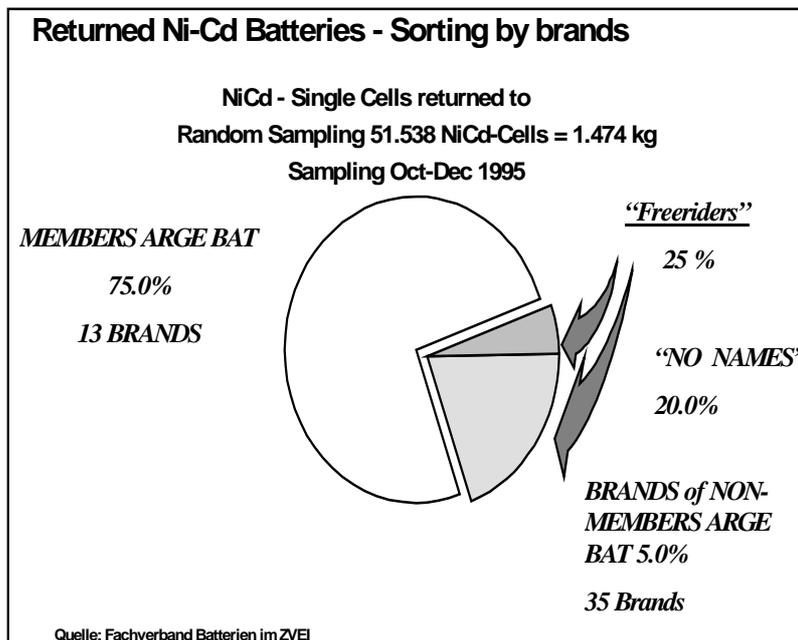
⇒ Volume of collected and recycled Ni-Cd batteries is steadily increasing.

5. The “Freeriders”

**Returned Ni-Cd Batteries - Sorting by brands**



Quelle: Fachverband Batterien im ZVEI



Quelle: Fachverband Batterien im ZVEI

⇒ The “freerider problem” can only be solved by a decree. Voluntary commitments are not the right method.

## 6. Costs and Cost Estimates

### Annual Budgets and Real Costs ARGE BAT

	Budget	Real costs
• 1990:	m DM 3.500	m DM 0.480
• 1991:	m DM 3.500	m DM 0.729
• 1992:	m DM 3.500	m DM 1.353
• 1993:	m DM 4.400	m DM 2.849
• 1994:	m DM 3.900	m DM 2.029
• 1995:	m DM 4.087	m DM 1.917
• 1996:	m DM 2.955	m DM 3.270
• 1997:	m DM 4.120	
• 1998:	m DM 4.890	

Fachverband Batterien im ZVEI

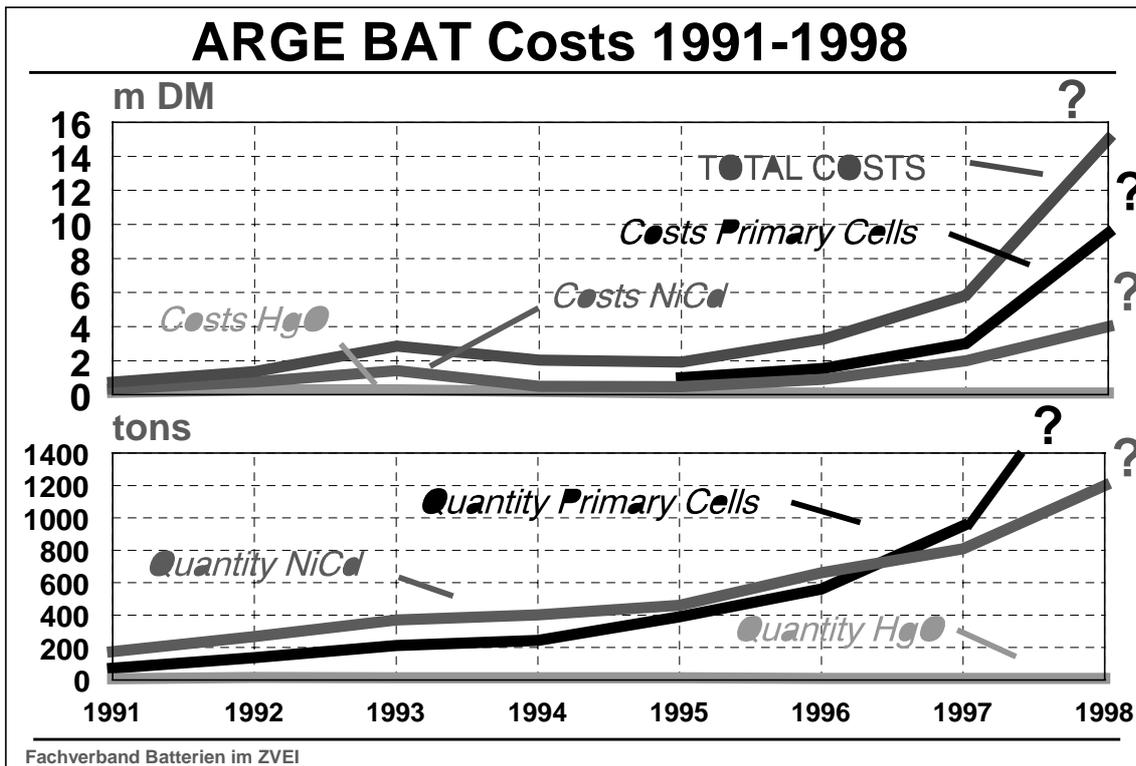
⇒ The future budget for the collection and recycling/disposal of all portable batteries is expected to be between 50 and 100 million DM.

## Specific Costs

DM / t

Activity	Costs 1995	Estimated Costs 1999
Recycling NiCd cells	750	750
Recycling NiMH cells	0	0
Recycling Button cells	7500	5000
Disposal Lithium cells	3150	2000
Disposal Primary cells	1150	1200
Recycling Primary cells		1200
Logistics	1320	500
Sorting	1250	300

Fachverband Batterien im ZVEI



⇒ Costs will increase ...

### Costs Per Unit Not Included in Sales Prices

IEC Type	System	1992	1995	1999 *
R 6 / LR 6	Zinc-Carbon Alkaline	0.26 DM	0,10 DM	0,05 DM
KR 15 / 51	NiCd	0.28 DM	0,11 DM	0,06 DM

*\* cost reduction due to lower costs for logistics and sorting*

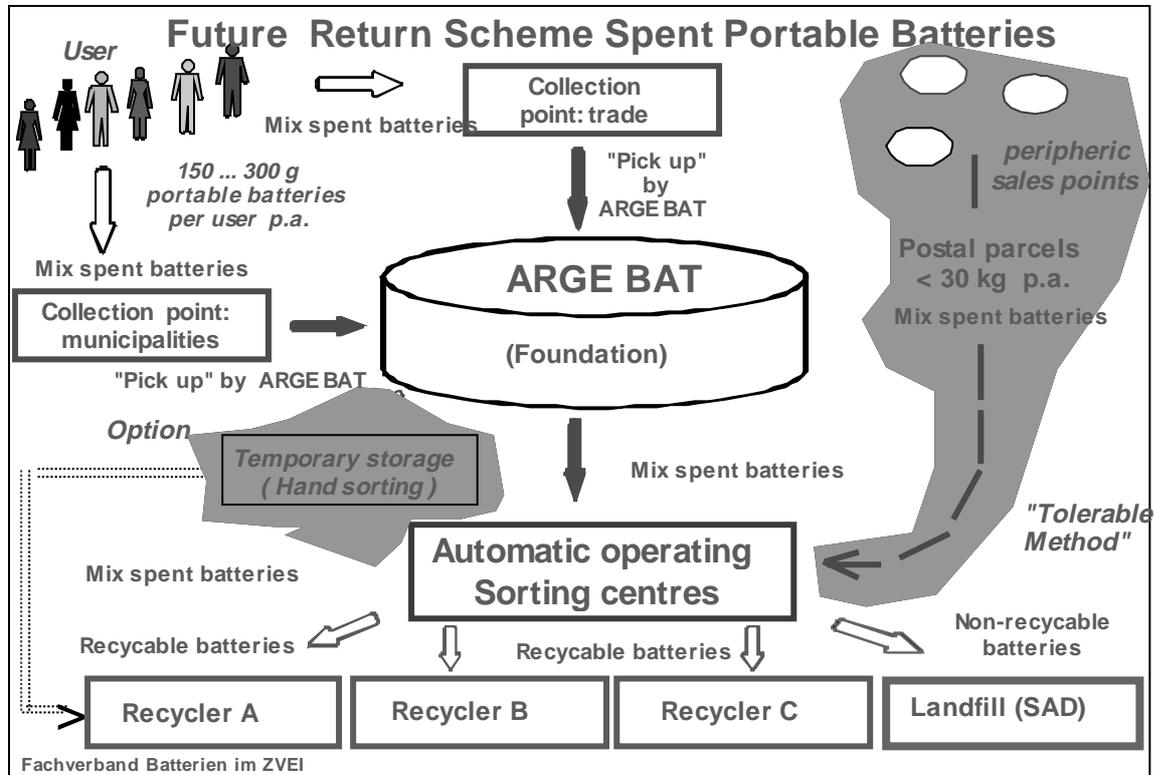
Fachverband Batterien im ZVEI

⇒ Specific costs will decrease, because of better conditions when bigger volumes have to be handled and processed.

## **7. Topics of the German Battery Decree**

- Marking of batteries to conform to EU Directive.
- Return free of charge for the user by trade and municipalities.
- Return free of charge from trade and municipalities to manufacturers and importers.
- A "Common Return System" has to be established for returning batteries independently of system, brand or origin.
- Financing of the "Common Return System" by manufacturers and importers in relation to their market shares.
- Manufacturers and importers not using the "Common Return System" have to demonstrate that their own system (e.g. reverse distribution) has comparable efficiency.
- Starter batteries bought for replacement have to be charged with a deposit of DM 15 if no spent battery is returned.
- User has the duty (by decree) to return spent batteries.

### 8. Future Return Scheme for Spent Portable Batteries





# The Situation with Regard to Collection and Recycling of Electric Vehicle Batteries

**Philippe Ulrich, SAFT, France**

## Preamble

Cars have been a vital part of modern human life around the world during the 20th century. They have largely contributed to the economic development that can be seen in all countries of the world.

There is no doubt that the increase of communication and various technological improvements are brought about largely by the automobile industry. This is particularly true in any country under development, as we see now in Asia.

Unfortunately, the internal combustion engine also produces a lot of pollution. It is largely responsible for our city pollution.

## 1. Analysis of city pollution

The following indications will give a good picture of the amount of pollution in our major cities generated by automobiles. They clearly indicate that the pollution created by tail pipe emissions is alarming, especially in large cities like Paris. The problem of car emissions is much more serious in cities than on highways. The readings are from two to five times higher in a city.

Table 1 shows the amount of various components resulting from car exhausts.

**Table 1: Pollution by type of travel**

	Highways	Large avenues	Paris ring road
<b>CO (mg/m<sup>3</sup>)</b>	<b>3.3</b>	<b>14.8</b>	<b>16.1</b>
<b>NO (µg/m<sup>3</sup>)</b>	<b>439</b>	<b>698</b>	<b>888</b>
<b>Benzene (µg/m<sup>3</sup>)</b>	<b>16</b>	<b>99</b>	<b>95</b>
<b>Black smoke (µg/m<sup>3</sup>)</b>	<b>142</b>	<b>325</b>	<b>352</b>

*Source: INRETS*

Several studies also indicate the evolution of automobiles' use in a modern city transportation system. Indications by various government agencies and independent organisations show the average distance travelled by city drivers.

Table 2 shows clearly that the average distance is relatively short. The figures given are for France. Reports from other European countries show very similar figures.

**Table 2: Average distance travelled by city drivers**

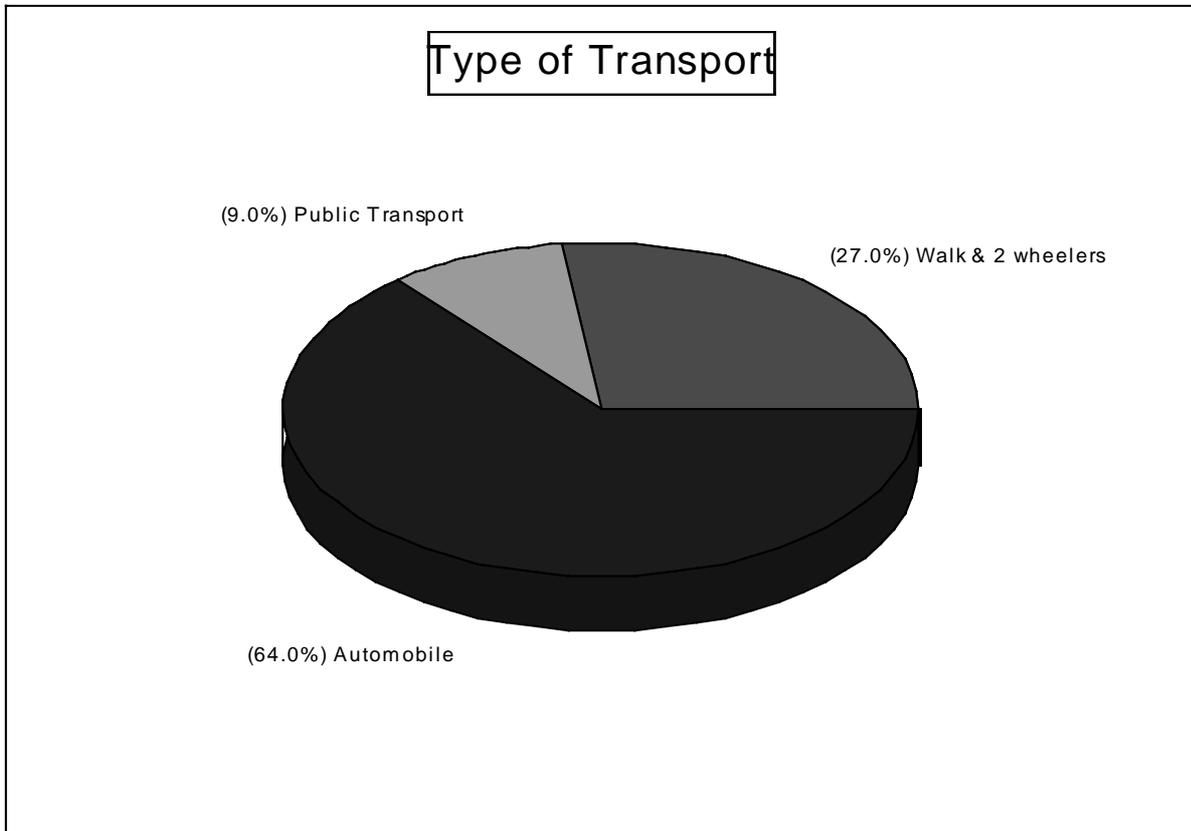
	<b>In 1994</b>	<b>Evolution 1982-1994</b>
<b>Qty of movement per person per day</b>	<b>3.2</b>	<b>-6%</b>
<b>Average distance per trip (in km)</b>	<b>7.2</b>	<b>+30%</b>
<b>Total number of km per day</b>	<b>22.9</b>	<b>+30%</b>
<b>Average speed (km/h)</b>	<b>25.3</b>	<b>+34%</b>

*Source: INRETS*

From this first analysis, the reasons for travel in a city must be analysed further. The two following charts give interesting indications of average car usage compared with other forms of city transportation. The conclusion is that private cars are still the major type of transportation.

Figure 1 shows that automobiles represent almost two-thirds of a city transportation system, while public transport is less than 10%. The balance is made up by walking or two-wheelers.

**Figure 1**



Source: INRETS

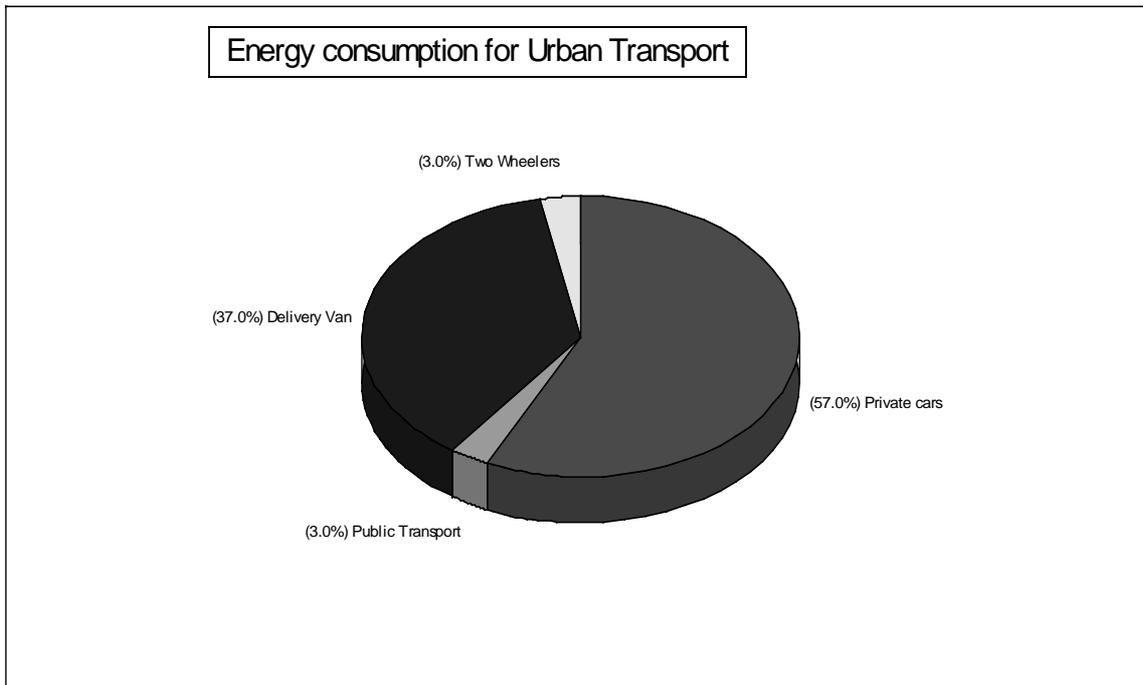
Figure 2 analyses the reasons for travel. It shows that almost half of all journeys are made for the purpose of shopping and driving to work. Only 11% are for leisure activity that could involve a longer driving range.

**Figure 2**

*Source: INRETS*

There is no doubt that cars will remain with us and our city environment for a long time. Their unique mobility will not be easily replaced by public transport, for example.

If we consider now the total energy consumption for city transportation, we can see from Figure 3 that the automobile is the largest consumer of energy. Public transport represents only 3%. It is also clearly indicated that delivery vans represent more than a third of city movements and energy consumption. For obvious reasons, delivery vans for postal delivery, telecommunications, plumbing and other services cannot and will never use public transport.

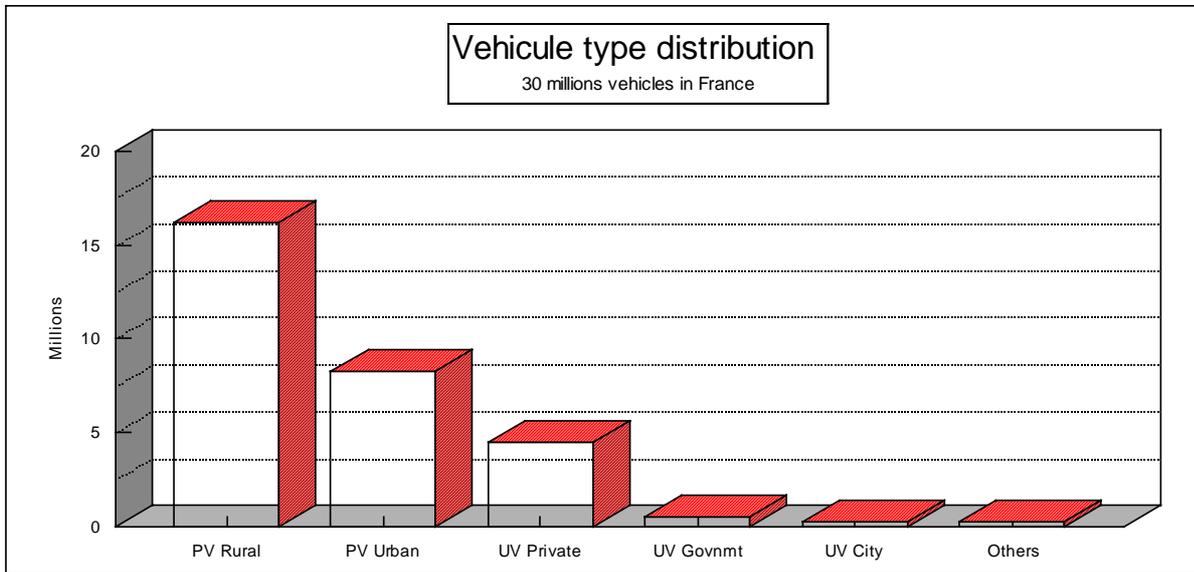
**Figure 3**

Source: ADEME

Based on the overall figures, if we consider the situation of France, with almost 60 million people and a total number of cars reaching 30 million, more than 50% of cars are used in cities.

Figure 4 shows car distribution between rural and urban usage and, in the city, the split between private owners, private companies and other government users.

**Figure 4**



Source: French market

Note: PV: Private Vehicles

UV: Utilitarian Vehicles (delivery vans)

As stated earlier, cars will not be eliminated from our cities. However, they could be replaced by electric vehicles, the technology for which has shown strong progress in recent years. This progress is mainly in battery development and overall car reliability.

What are the benefits of electric vehicles?

We saw in the various studies available that the average driving distance is around 25 km, but various questions are raised regarding the pollution created by battery-powered vehicles.

Why would EVs produce less pollution in the city?

Are EVs reliable and economical?

How and how much should batteries be recycled?

## 2. Electric vehicle solutions

Today several vehicles are already sold through regular OEM dealerships, with reasonable pricing considering their low volume of production. If the comparison is made between cost of ownership rather than initial purchase price, EVs' cost per km is fairly reasonable in comparison with the equivalent IC engine counterpart.

Table 3 shows the cost of French EVs versus gas and diesel vehicles. VAT is indicated separately, in order to evaluate the EV cost independently of additional taxes, which can vary between countries.

**Table 3: Cost comparison between electric and thermal engines (US\$)**

	Electric	Internal combustion 1100 cc gas	Internal combustion 1500 cc diesel
Acquisition cost	13 930	7 540	8 931
VAT (20.6%)	2 870	1 553	1 840
License tax	83	167	167
Subsidies	-2 500	0	0
<b>Total</b>	<b>14 383</b>	<b>9 260</b>	<b>10 938</b>
Annual cost			
Battery lease	1 010	0	0
Insurance	500	783	900
Parking fees	0	667	667
Car tax	43	43	43
Utilisation cost (per year)			
Fuel or electricity	150	832	427
Maintenance	303	506	503
<b>Cost per annum</b>	<b>3 805</b>	<b>3 989</b>	<b>3 908</b>
<b>Cost per kilometre</b>	<b>0.38</b>	<b>0.40</b>	<b>0.39</b>

Note: The calculation is based on actual cost of car, gas, insurance and parking fees in Paris.

Average usage: 10 000 km per year over 12 years.

Fuel consumption (gas and electricity) is that recorded for city car usage.

Source: ADEME

The first evaluations made of cost give some interesting benefits for an EV solution. The subsidies at the initial stage are necessary for the first pushes towards a price reduction that will come inevitably with larger volume. Various types of government support in different countries are helping EV acquisition. The battery lease is an excellent tool that can be compared with monthly gas expenses.

The total number of possible EVs in a modern city can be estimated at:

- 4% of private users
- 10% of other urban users, based on Figure 4 (mainly delivery vans).

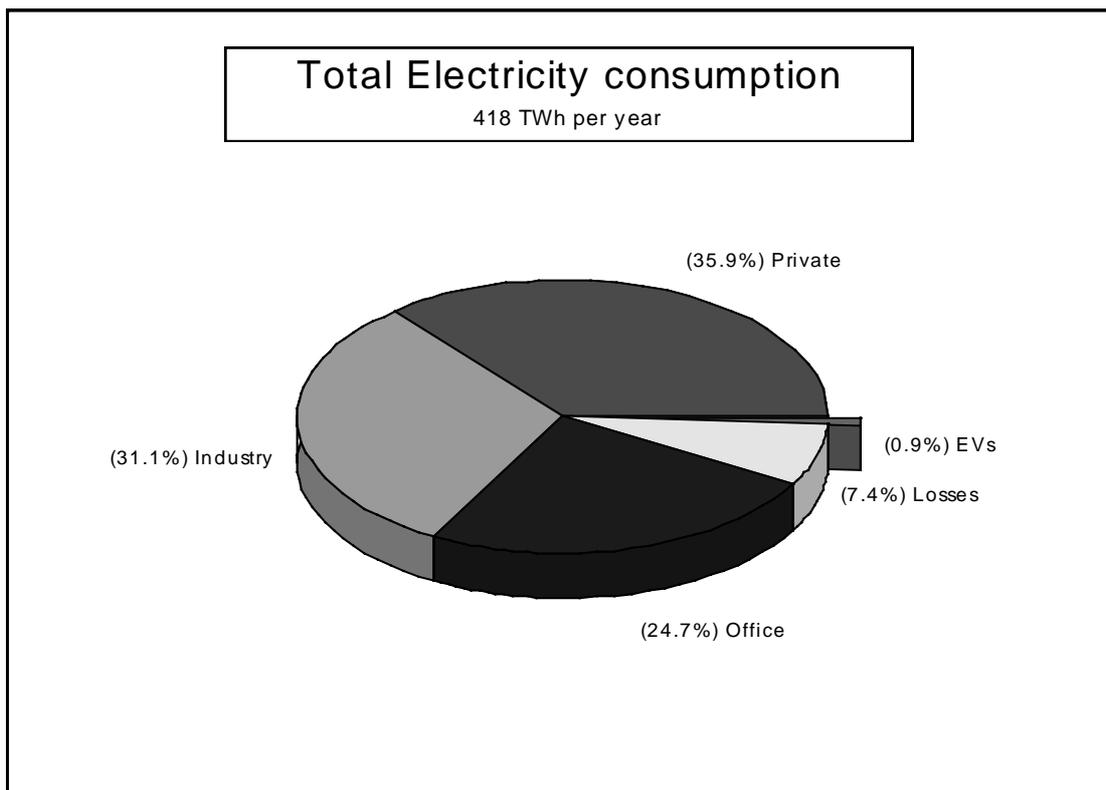
The percentages give a rough total of one million EVs for an area with a population 60 million people. These figures are realistic and achievable.

In terms of energy consumption, all those EVs represent a very small amount of electricity compared with the overall country usage.

Figure 5 gives the details. Less than 1% of annual electricity production will be devoted to EV recharge. This is based on EV consumption of 18 kWh per 100 km.

This total energy can be easily handled by existing power plants.

**Figure 5**



Source: EDF

### 3. What kind of battery must be used?

Various EVs are already in the streets of several European and American cities. Although the electric vehicle has been brought to market with significant autonomy in terms of kilometres, a lot of users are considering a longer range in order to see a real take-off of the market. Initially manufacturers considered the lead-acid battery because of its economical acquisition cost, but it is definitely not reliable enough to be used in modern EVs.

Table 4 shows the difference between various battery technologies for an EV with a range of more than 100 km. This comparison demonstrates without any doubt that advanced batteries will be the only solution for a 150-200 km range.

All the calculations have been made with a 800 kg car chassis (excluding battery weight). All battery weights are indicated in kilograms.

**Table 4: Battery weight (in kg) as a function of autonomous distance in km**

	<b>Lead-acid 35 Wh/kg</b>	<b>Ni-Cd 50 Wh/kg</b>	<b>Ni-MH 70 Wh/kg</b>	<b>Li-ion 120 Wh/kg</b>
<b>Autonomy</b>	<b>Battery weight</b>	<b>Battery weight</b>	<b>Battery weight</b>	<b>Battery weight</b>
<b>80 km</b>	<b>350</b>	<b>220</b>	<b>146</b>	<b>80</b>
<b>100 km</b>	<b>500</b>	<b>300</b>	<b>191</b>	<b>100</b>
<b>150 km</b>	<b>1100</b>	<b>545</b>	<b>325</b>	<b>162</b>
<b>200 km</b>	<b>2700</b>	<b>940</b>	<b>500</b>	<b>232</b>

This shows without any doubt that for 160 km (100 miles) Ni-Cd and Ni-MH will be able to suit the market demand for light, reliable and long-lasting batteries. Ultimately, Li-ion will give the necessary range at an even more affordable price with less weight.

SAFT has been a pioneer in offering the best and most economical industrialised solution with the Ni-Cd battery. The first SAFT EV line is capable of producing batteries for 5000 EVs a year. Based on this experience, mass production of Ni-MH batteries is going to be introduced before the end of this century.

#### 4. SAFT battery proposal and solutions

The electric vehicle requires giving special attention to battery recycling. This was incorporated in French car makers' specifications with the data in Table 5.

**Table 5: Specifications for French cars**

80 km autonomy (mini)	Ni-Cd battery
10,000 km maintenance	Ni-Cd low maintenance
120,000 km life	Ni-Cd 3000 cycles demonstrated
Battery weight less than 300 kg	Ni-Cd, then Ni-MH
Recyclable	Ni-Cd easy and inexpensive

The battery solutions have been designed to last during the life of the EV. The batteries cannot be removed from the car body without specific tooling. Replacement batteries are not foreseen during the EV life. Recycling will take place during normal old EV collection. The batteries will be collected by the same network used for the cars themselves.

The million French EVs we indicated earlier would have the consequences shown in Table 6, in terms of total battery weight per year to be recycled. The figures are based on 100 km autonomy.

**Table 6: Effects of one million French EVs in terms of recycling (based on 100 km autonomy)**

Facts	Consequences	Solutions and Comments
EV life is around 12 years	84,000 EVs per year must be recycled	Batteries collected at EV collection centres
84,000 batteries per year	Equivalent to 25,000 tonnes of Ni-Cd batteries	This is equivalent to 15 truckloads per month coming from the 10 large city collection centres
25,000 tonnes of batteries	100% Ni-Cd recycling is already in place, easy to set up	In comparison, primary cells produce same amount in weight per year but not collected yet
Where are the recycling centres that exist today?	2 in Europe 1 in USA	SNAM France SAFT Sweden INMETCO USA
Cost of recycling	Will be included in the EV price	Ni-Cd recycling cost of \$150-200/EV included in the car salvage value

As we can see, the Ni-Cd recycling solution already exists. Battery collection will be managed using the same channels that are in place for other materials used in modern cars. Compared with lead-acid batteries, the total weight of Ni-Cd and Ni-MH batteries that would be manipulated and recycled will be five to seven times less. This is due to the combination of lead-acid batteries' heavy weight and too short life.

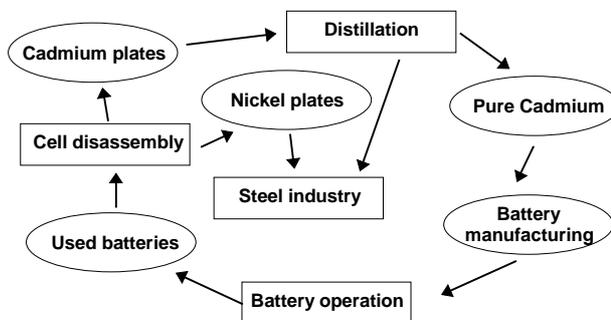
## 5. Recycling the batteries

Today the recycling of Ni-Cd batteries (Figure 6) is a very simple process:

- The battery is drained of electrolyte, which is neutralised.
- The battery is disassembled.
- Plastic material is recycled and reused.
- Steel- and nickel-based material is melted for use in making stainless steel.
- Cadmium plating is distilled and pure cadmium is reused for new battery production.

Ni-MH batteries should use very similar recycling processes and should most probably have even lower cost, thanks to higher volume.

**Figure 6**



## **Conclusions**

The electric vehicle is a viable solution to reduce city pollution without impairing the movement of people.

The general reduction of car exhaust in our cities is absolutely essential. This can be achieved thanks to more EVs, without an increase in pollution due to power plant production. No increase in electric power production is necessary.

Recycling facilities for EVs' Ni-Cd batteries are already in place and can be used immediately. The installation of Ni-MH batteries will be possible as the market grows. Industrial installation of this type of batteries should be relatively easy.

Battery collection will take the same route as car collection channels.

The cost of recycling will be included in EV prices and will be affordable.

The recycling capacity is sufficient today and will expand with growing demand.

## **Acknowledgements:**

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EDF: Electricité de France

PSA: Peugeot Citroën

## **Annex 1: Reports of Working Groups 1 and 2**

*Following the formal presentations, the Workshop divided into two Working Groups. The findings of these Working Groups were subsequently combined and are presented in the Summary of Workshop Activities. They are also presented individually in this annex.*

### **Report of Working Group 1**

#### **Goals**

- 1) Scope of the programme: Do we have to collect all batteries, or can we have selective collection programmes for rechargeable batteries only (Ni-Cd batteries in particular)?
  - What are the environmental benefits of recycling the various chemistry types vis-à-vis the value of recycled materials, their utility in creating new products, and the energy used to recycle?
  - If you focus on only one type, how do you educate the consumer to distinguish the desired chemistry for collection?
  - Is it better to start collecting one type and then expand to others, or the reverse?
- 2) Depending on the country's policy preference, should an industry voluntary approach or a government programme be selected?
  - Set realistic rates. We will never get 100% (cf. automotive lead-acid batteries) and it will take many years to achieve high targets.
  - Choose the more cost-effective management option between industry and government.
  - Any funds should be dedicated solely to collection and recycling.
- 3) Simple message to the consumer:
  - Easy recognition of recycling or collection symbols is necessary.
- 4) Return the maximum of the recycled materials back to the battery industry or for other uses.

## **Barriers**

- Consumers choose products, not battery chemistry. This can limit the effectiveness of a single-chemistry collection programme.
- Transportation, collection and storage regulations may inhibit programme development.
- Since there is no collection programme in some OECD countries, producers may not use recycle symbols as national authorities may consider such labels misleading.
- Collectors with used batteries that don't anticipate the cost of recycling may landfill the batteries since landfilling is cheaper.
- Programmes need to be designed so as to take antitrust laws into account.
- Multiple symbols are confusing to the consumer, difficult to put on the battery because of limited space, and may lead to incompatible programmes between countries.
- Transportation of vented/industrial cells with electrolyte: heavily regulated transport, but the best management of electrolyte may be at the recycling facility. Current policy pushes collectors to drain electrolyte to reduce the regulatory burden.

## **Drivers**

- Increased environmental awareness of end-users, governments and industry is promoting higher collection and recycling rates.
- A desire to improve the public image of companies (OEMs, battery manufacturers) is an additional factor.

## **Critical Steps for Success**

- To educate and motivate the consumer, be clear about what to do with the batteries and where to bring them back.
- Classify and target market/user segment and education effort: for example, emergency lighting is managed by professionals, whereas consumers are handling common OEM equipment; the strategies for education will be different.
- Corporate level management involvement is necessary in order to motivate retail employees to ensure collection success.
- Design efficient financing:
  - ◇ Anticipate slow start of collection and meanwhile concentrate on education;
  - ◇ Any charge to the consumer must be at the point of purchase, while the product still has value to the consumer.
- Programme design should consider whether the charge to the final consumer should be transparent.
- Tailor to country with respect to that country's regulations, policies, culture, etc.

- Co-operation between industry and government is essential.
- Take advantage of every possible take-back route that we can.
- Place a label on the packaging and/or product user manuals stating that the consumer has paid the fee for recycling the battery(ies) and so should bring it (them) back. That's part of the education side.

### **What's Gone Wrong?**

- Batteries get mixed in selective collection programmes, raising questions about their future management.
- Programmes are still young today; we may need more time to analyse problems.
- Failure to plan for a full programme cycle leads to lengthy storage times in the case of those batteries for which no recycling option is available.

### **How to Measure Success**

- Actual collection rate is one measure, but the utility is debatable.
- If the collection rate for a particular type of battery is comparable to its market share, the collection programme is likely to be a success.
- Comparing sales volume to amount recycled is inappropriate. It is necessary to develop or use an existing formula that takes into account the life of batteries, application, and other factors.
- If you analyse how many batteries are in household waste and compare the numbers from one year to the next, you can determine your improvement rate.
- Sales measures are units/dollars; collection measures are weights; and comparison is difficult.
- Do consumers understand and participate in programme?
- Final recycling rate compared to collection rate.
- Joint efforts to improve measures of success are desirable.

### **Benefits and Costs**

- Collection and recycling remove "hazardous" material from the waste stream.
- The high cost of collecting all batteries in order to keep the message to consumers simple may be necessary/useful at the initial stage of the programme.
- The costs are shared by all, including consumers.
- Collecting all batteries may improve the management of primary batteries, even if they are not recycled.
- If the use of cadmium in batteries is banned, what will we do with the recovered cadmium?

### **Suggestions for Establishing Programmes**

- Review existing programmes before creating new ones.
- The European Portable Battery Association (EPBA) and other international industry/government organisations should co-ordinate their efforts in the review of various measures of success and identify opportunities for voluntary harmonization.
- Encourage the use of internationally accepted symbols for marking batteries, recognising the limited space available.
- The issues of interest to OECD countries are more on the consumer role and service/distribution side. In general, industrial vented cells are considered to be well managed and subject to high collection and recycling rates.
- Design a finance system to minimise costs.
- Do not try to force harmonization of programmes in OECD countries at this time, as programmes are very young.
- Consider in the longer term how to help non-OECD countries as Ni-Cd use increases. For example:
  - \* technology transfer
  - \* helping develop facilities/collections.

## Report of Working Group 2

It was agreed that recycling of Ni-Cd batteries is technically feasible and desirable. The discussion focused on ways to encourage/enhance the collection and recovery of Ni-Cd batteries from end-users (e.g. consumers, hospitals, businesses). Some participants suggested that collection of all batteries could increase Ni-Cd collection rates. Since the focus of the Workshop was on Ni-Cd batteries, the Working Group agreed not to discuss recycling of all batteries at this time.

Lists of activities that could enhance recycling were first prepared for the following stages of Ni-Cd batteries' life cycle:

- production and distribution of batteries and products
- consumer use and recharging
- collection
- processing/sorting/recovery.

Based on these lists, priority activities that could contribute to efficient recycling programmes for Ni-Cd batteries were identified and consolidated into the following findings.

- 1) The two most important overall requirements of a successful programme are:
  - co-operative approaches (multilateral collaboration of all stakeholders, not unilateral)
  - financial support
    - \* Pre-payment built into the cost of the product
    - \* Money only goes to collection and recycling programmes.
- 2) End-user participation is the next most significant area influencing the success of a programme. The following three areas were also identified as priorities for attention:

### a) Development of global standards:

For ease of identification of individual batteries, and batteries which are permanently connected to appliances, by:

- labelling
  - \* colour coding (indicating battery chemistry)
  - \* use of recycling logo (three arrows symbol)
- easy removal from unit.

*The OECD should take the lead in standardising the above areas, in co-operation with all interested parties (e.g. IEC, ISO).*

**b) Education:**

- advertising, promotion (industry to be responsible)
- user manual (industry to be responsible)
- schools (government and industry jointly to be responsible)
- education by example (everyone to be responsible).

*The above measures should be funded by the pre-payment built into the cost of the product.*

**c) End-user considerations:**

- clear and simple message
- collection to be readily available through multiple take-back channels
- no cost to consumer at the point of collection
- incentives for return depending on local conditions.

3) The Group agreed that efficient administration of the programme would increase its success. The following activities were identified as priorities:

- market certainty
  - \* stable flow of materials
  - \* return on investment
  - \* end-product market for recovered materials
- streamlining of permitting and other requirements
- feed source free of non-recyclable materials
- high metal content and appropriate chemistry to support viable economic recycling operations.

## Annex 2: Selected List of Acronyms

ARGE BAT	German battery collection programme
BAJ	Battery Association of Japan
BEBALT	Belgian battery collection programme
BDAT	Best Demonstrated Available Technology
BESO	Swiss battery collection programme
CHBA	Canadian Household Battery Association
COBAT	Italian battery collection programme
ECOVOLT	French battery collection programme
ECTEL	European Telecommunications and Professional Electronics Industry
EPBA	European Portable Battery Association
EV	Electric vehicle
GPI	Gold Peak International (battery manufacturer)
HTMR	High-temperature metals recovery
ICdA	International Cadmium Association
IEC	International Electrotechnical Commission
INMETCO	International Metals Reclamation Company (Ni-Cd battery recycler)
ISO	International Organization for Standardization
JSBA	Japan Storage Battery Association
KBI	Kinsbursky Brothers Inc. (United States)
Li-ion	Lithium-ion (batteries)
Ni-Cd	Nickel-cadmium (batteries)
Ni-MH	Nickel-metal hydride (batteries)
OEM	Original equipment manufacturer
PRBA	Portable Rechargeable Battery Association (United States)
RBRC	Rechargeable Battery Recycling Corporation (United States)
REBAT	UK battery collection programme
RHF	Rotary hearth furnace
RWG	Rechargeable Working Group (of EPBA)
SAFT	Swedish battery manufacturer
SAFT NIFE	Swedish Ni-Cd battery metals recovery plant
SEAF	Submerged electric arc furnace
SNAM	Société Nouvelle d'Affinage des Métaux (French Ni-Cd battery metals recovery plant)
STIBAT	Dutch battery collection programme



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