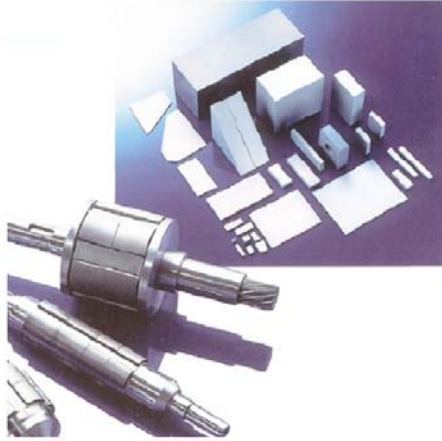




THE RECYCLING AND FUTURE SELECTION OF PERMANENT MAGNETS AND POWDER CORES



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- This presentation covers the following topics:
 - The need to recycle;
 - Aspects to consider when designing with magnets;
 - RoSH ;
 - WEEE;
 - The recycling of permanent magnets and powder cores; and
 - Magnet designs for the future.



Why recycle magnetic materials ?

- As concerns grow over the state of the Earth's environment and the amount of natural resources remaining, regulations and directives are brought in (by the EU for example) to limit how much material is thrown away at the end of a product's life cycle.
- Two examples are :
 - **Directive 2002/96/EC on Waste Electrical & Electronic Equipment (WEEE)**
 - **Directive 2000/53/EC on End of Life Vehicles**

- The natural resources on Earth are depleting.
- The amount of material being thrown away has increased over the last few decades - much of this material could be recycled/re-used.
- Countries are starting to implement laws that force companies and households to recycle more of their waste.
- In the European Union, this is in the form of Directives.



Why recycle magnetic materials ?

- These directives and other laws/regulations bring about the need to recycle a larger percentage of materials found in the products to minimise further damage to the environment.
- This includes the need to recycle permanent magnets and powder cores.
- The amount of material to be recycled from each product is set to increase over time.
- Hence the recyclability of magnetic materials directly affects the future choice of such materials in new product lines.

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- The Directives, Regulations and Laws affect nearly all companies.
- The amount of materials to be recycled are set to increase over time.
- Permanent magnets and powder cores can be recycled. This will be discussed later.
- The ease and cost of recycling different materials will be factors for new products.



Factors affecting Magnet Material Selection

The choice of magnet material for a given application is governed by standard factors such as :-

- Cost.
- Energy product of material.
- Maximum operating temperature.
- Stability of output with respect to operating temperature range.
- Stability of output with respect to other external demagnetising forces e.g. armature currents.
- Operating environment e.g. high humidity.

- The density of magnets and ultimately the total weight of magnets used is set to become an issue. For comparison purposes example densities of materials are as follows:-

- SmCo 8.35-8.4 g/cm³
- NdFeB 7.5 g/cm³
- Alnico 7.3 g/cm³
- Ferrite 4.8-4.9 g/cm³
- FM-60 bonded ferrite 3.72 g/cm³
- bonded SmCo 5.5 g/cm³
- bonded NdFeB 5.1 g/cm³



Magnet Material Selection cont.

- ROHS and WEEE are now new factors in determining magnet material selection.
- The introduction of ROHS means that the actual constituents within magnetic materials is a factor in material selection for some companies.
- The introduction of WEEE affects how companies recycle components in their products so the recyclability of component materials is of increasing importance.
- So what exactly is ROHS and WEEE ?

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- ROHS and WEEE need to be taken into account for new and existing products.
- ROHS affects the selection of the material as it is related to the constituents of the materials themselves.
- WEEE relates to the recycling and re-use of materials in certain products.



The Restriction of Hazardous Substances in Electrical and Electronic Equipment (ROHS) Directive (2002/95/EC)

- Who does it affect?

Manufacturers, sellers, distributors and recyclers of electrical and electronic equipment containing lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls or polybrominated diphenyl ethers. This Directive covers the same scope as the Directive on Waste Electrical and Electronic Equipment (WEEE) except for medical devices and monitoring and control instruments. It also applies to electric light bulbs and light fittings in households.

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- The ROHS Directive states that certain chemicals are not to be used in Electrical and Electronic Equipment.
- ROHS and WEEE are linked to each other.



The Restriction of Hazardous Substances in Electrical and Electronic Equipment (ROHS) Directive (2002/95/EC)

- What is its purpose?

The Directive aims to:

protect human health and the environment by restricting the use of certain hazardous substances in new equipment; and to complement the WEEE Directive.

- ROHS complements the WEEE directive by restricting the use of certain substances that are regarded as hazardous.
- This only applies to new Electrical and Electronic equipment.



The Restriction of Hazardous Substances in Electrical and Electronic Equipment (ROHS) Directive (2002/95/EC)

• From 1 July 2006 new electrical and electronic equipment must not contain lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBBs) or polybrominated diphenyl ethers (PBDEs). These must be replaced by other substances.

- The hazardous chemicals are:-
 - Lead
 - Mercury
 - Cadmium
 - Hexavalent Chromium
 - Polbrominated biphenyls (PBBs)
 - Polybrominated biphenyl ethers (PDBEs)

- Other substances must be used to replace the above.



The Restriction of Hazardous Substances in Electrical and Electronic Equipment (ROHS) Directive (2002/95/EC)

• Certain applications are exempt from the requirements of the Directive including mercury in certain types of fluorescent lamps, lead in the glass of cathode ray tubes, electronic components and fluorescent tubes, lead in electronic ceramic parts and hexavalent chromium as an anti-corrosion of the carbon steel cooling system in absorption refrigerators. The exemptions will be reviewed every four years.

- There are some exemptions.
- The exemptions are reviewed on a 4 yearly basis.



The Restriction of Hazardous Substances in Electrical and Electronic Equipment (ROHS) Directive (2002/95/EC)

Swift Levick Magnets SmCo and Alnico do not contain any of following restricted substances :-

Lead

Cadmium

Mercury

Hexavalent Chromium

Polybrominated Biphenyl (PBB's)

Polybrominated Diphenyl Ethers (PBDE's)

- The SmCo and Alnico produced by Swift Levick Magnets is ROHS compliant.



EC Directive 2002/96/EC on Waste Electrical and Electronic Equipment (WEEE)

- 6 million tonnes of waste electrical and electronic equipment was disposed of in Europe in 1998. Of this, 1.2 million tonnes was plastic, 27000 tonnes was lead, 8 tonnes was mercury and 3.6 million tonnes was metal (source AEA Technology).
- In 2005, the UK seeks to introduce legislation on electrical and electronic equipment in relation to its composition and the levels to which it should be recycled. This legislation has its origin in the EC Directives relating to WEEE and to the Restriction of Hazardous Substances (ROHS) in WEEE.

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- The amount of waste electrical and electronic equipment disposed of each year is colossal.
- Because of this the WEEE Directive sets out to force the recycling of WEEE to reduce the amount of material dumped in waste sites.
- WEEE and ROHS are linked to each other.



What does WEEE mean?

- If the product uses an electric current or electromagnetic fields to work properly to satisfy the primary purpose of the product then that product potentially falls under the WEEE regulations.
- The producer of the product has to take into account recycling of that product.
- WEEE appears to take effect from the 13th August 2005 in UK.
- For the latest information and full details, see <http://www.dti.gov.uk/sustainability/weee/index.htm>

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- If an electric current or an electromagnetic field is required for a product to carry out its primary purpose, then that product may be affected by the WEEE Directive.
- The producers of affected products have responsibilities for the recycling/re-use of their products.
- The DTI website has much more information on WEEE.



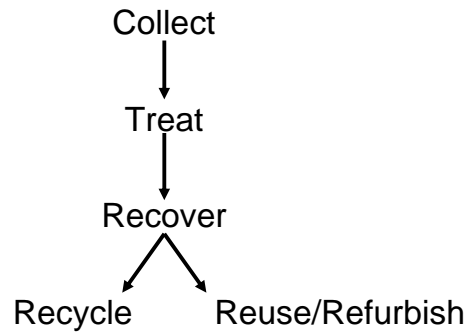
Examples

- A birthday card with an electronic circuit in it is not affected by WEEE as the circuit is not part of the primary purpose.
- The permanent magnet motor in a vacuum cleaner is needed in the primary purpose and so the whole vacuum cleaner is affected by the WEEE regulations. The vacuum cleaner producer will need to be able to recycle a percentage of its product.

- A birthday card does not need an electronic circuit to be a card so it is not affected by WEEE.
- A vacuum cleaner needs its motor to provide the suction of air to perform the cleaning product. It therefore is affected by WEEE.



What happens?



- The producers have to arrange for the collection of their product, the treatment of their product (e.g. to clean it, remove contaminants, etc), to recover parts and to then either recycle or re-use/refurbish.
- The Directive require that this all needs to be accounted for with correct documentation.
- The crossed out bin symbol is to be part of the labelling of new products that are to comply with the WEEE Directive.



Requirements of the WEEE directive

- Separate collection of Waste Electrical and Electronic Equipment from households and businesses.
- Producers do not have to collect themselves but must have 'End-of-Life' plans for all products and finance the recovery of WEEE.
- Recovery and recycling to set targets.
- Accurate records to show the effect of the recycling programmes.

- WEEE directive is to be reviewed at EU level in 2008.

- The Directive gives strict instructions on how much product need to be recovered and recycled.
- Accurate records need to be kept by the producers.
- The producers must prove they have met their obligations.
- The WEEE directive is to be reviewed in 2008.



How much is to be recycled/re-used?

- 70-80% recovery by an average weight per appliance (exact amount depends on product category).
- 50-75% reuse and recycling of components, materials and substances by an average weight per appliance (exact amount depends on product category).

- The exact amount that has to be recovered and re-used/recycled depend on the product category.
- The DTI has more information on the categories and the amounts.
- If in doubt you should consult the DTI.



Is your product affected?

- The DTI web site has much more information also has the WEEE documentation containing a decision tree to help companies determine if their products fall under WEEE regulations.

<http://www.dti.gov.uk/sustainability/weee/index.htm>

- The WEEE Regulations 2004 should be available from the Stationary Office.

<http://www.hmsso.gov.uk/>

- The WEEE Directive is available from HMSO and general information and advice is available from the DTI.



Examples of exempt products

- Large scale stationary industrial tools - machine/system consisting of a combination of equipment, systems or products, and assembled only to be used in fixed industrial applications.
- Products intended specifically to protect national security and for a military purpose.
- Implanted or infected medical products.

- Some products are exempt:-
 - Some large scale stationary industrial tools;
 - Some military products; and
 - Some medical products.



Collection and Treatment of WEEE

- Swift Levick Magnets can recycle some permanent magnet materials and some of our assemblies.
- We do not collect, treat, recycle or re-use other materials.
- Because of the above, Swift Levick Magnets is not:-
 - registered as an Authorised Treatment Facility (ATF)
 - registered as a Designated Collection Facility (DCF)
- We have confirmed and clarified this situation with DEFRA (Department of Food, Environment and Rural Affairs <http://www.defra.gov.uk>).

- What can Arnold offer?
- We cannot collect full products, even if our materials form part of the full product.
- We can only recycle certain permanent magnet materials and powder cores.



Compliance with ROHS and WEEE

- Arnold Magnetic Technologies will work with companies on ROHS and WEEE.
- For example, SmCo and Alnico from Swift Levick Magnets (UK part of Arnold) is ROHS compliant. Arnold Powder Cores are also ROHS compliant.
- Also, for example, Swift Levick Magnets can recycle SmCo and Alnico which will help to contribute to customers' WEEE compliance.

- Arnold will assist companies who are working on ROHS and WEEE compliance.
- We will review each situation individually.



Recycling of SmCo magnets

- SmCo reprocessing involves re-melting the alloy, adjusting the alloy chemistry through a second melt then processing as a raw material.
- Variations in additives from one manufacturer to another may cause compositional or use limitations.
- It is prohibitively expensive to re-refine the material.
- When recycled material can be identified as made by one manufacturer, it may be reprocessed with economic benefit through reclaim of the high cost rare earths and cobalt content.

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- The high costs of the rare earth elements and cobalt allow the recycling of SmCo to be potentially economically viable.
- SmCo produced by SLM is easier to recycle as we know the constituents of our own magnets.
- Unwanted additives (used by other producers) and excess glue may make recycling too costly.



Recycling of SmCo magnets cont.

- SmCo produced by Swift Levick Magnets (SLM) can be re-used by SLM provided the level of contamination is not too high.
 - Glue on the magnet surfaces should not be a major issue if small amounts only are present.
 - Contamination may be caused by the environment of the application.
- SmCo produced by other manufacturers may be re-usable by SLM but it depends on the constitution of the material.
- We will look at any enquiry for the recycling of SmCo and will offer assistance where possible.

- The ability to recycle and its cost effectiveness depends on the amount to recycle and its quality.



Recycling of Ferrite magnets

- Ferrite is an inexpensive raw material which must go through an expensive, energy consuming reprocessing to be usable as a starting material.
- Different additives are used by manufacturers which combined can poison the formulation.
- The end product, being "ceramic" in nature, is more suited for structural applications such as roadbed and crushed aggregate fill applications.
- It is our experience that ferrite is not bought back much by the actual producers of ferrite magnets.
- Arnold Magnetic Technologies cannot offer to recycle ferrite magnets as we do not produce these magnets.

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- Ferrite magnets are inexpensive to produce.
- Ferrite magnets are expensive to reprocess.
- Additives can 'poison' the formulation.
- It is unlikely that ferrite can be recycled without a financial loss to the producer.
- It may not be WEEE 'friendly'.



Recycling of NdFeB magnets

- When the rare earth (especially NdFeB) magnet has degraded or shows signs of corrosion, it is likely that the material will not reprocess satisfactorily and will require refining to remove oxides and hydroxides.
- Re-melting contaminated NdFeB magnets provides for low yields and is often not economical.
- Most NdFeB magnets are Nickel plated.
- By having the plating, the magnets become more complex to recycle.

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- Corrosion of NdFeB makes reprocessing more difficult.
- Plated magnets increase the complexity of reprocessing.
- Reprocessing yields are low.



Recycling of NdFeB magnets cont.

- It is our experience that NdFeB is not bought back much by the actual producers of NdFeB magnets.
- Unwanted NdFeB is also often used in hardcore for road construction.
- Arnold Magnetic Technologies cannot offer to recycle NdFeB magnets.

- It is not always economical for the NdFeB producers to reprocess NdFeB.
- It is currently unlikely that the producers will take back NdFeB.
- NdFeB is thus potentially not so WEEE 'friendly'.



Recycling of Alnico magnets

- As in ferrite and rare earth magnets, each manufacturer has established compositions utilizing small amounts of additives to achieve specific magnetic and physical characteristics.
- The mixing of magnets from these manufacturers can result in an undesirable combination of additives.
- When magnet reclaim can be restricted to one manufacturer, it is possible to recycle the raw material with good success. As the pricing for nickel and cobalt cycle high, recycling becomes even more desirable.

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- Unknown additives make recycling of magnet materials more complicated, more expensive and hence less desirable.
- When the magnets are known to be from a single manufacturer, recycling is more practical, particularly if recycling your own product.
- When Ni and Co prices are high, recycling can be more desirable.



Recycling of Alnico magnets cont.

- Alnico magnets are produced by Arnold Magnetic Technologies.
- If the Alnico magnets are our own and are still of good quality then we are in a position to be able to recycle the magnets.
- Alnico magnets that are contaminated (e.g. excessive glue, Alnico made by other producers that contain dopants not used by Arnold) are more difficult for us to recycle.
- We will review any request for recycling Alnico and will assist where we can.

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- Contaminants are undesirable.
- If the quality and volume offered is good then recycling is more economically viable.



Recycling of Flexmag flexible magnets.

- Flexmag produces flexible magnetic strip and sheet.
- To recycle its products, the scrap is ground up and put it back through the system as a raw material.
- Recycling cannot be done with any magnet that has paper, polypropylene or adhesive, because these do not break down at the required temperature.
- However, the vinyl can be recycled with the magnet.
- As the magnet material itself is inexpensive, it may not be cost effective to ship it from the UK back to the USA.

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- Flexible magnets such as flexible ferrites can be inexpensive to produce so the cost of shipping abroad to the original suppliers may make reprocessing uneconomical.
- The cost of exporting magnets to a producer will affect the recyclability of any magnet material.



Technology behind the recycling of magnets

- Patents exist for the recovery of scraps of rare earth magnets (e.g. JP58136728, JP2002348632).
- Patents exist for the separation and recovery of rare earth metals (JP62187112, JP58193331).
- Patents also exist for the recovery of magnetic powder from bonded magnet materials (e.g. JP2001143916, JP2001110615).

- Many patents exist for the recycling of permanent magnets and for the recovery of elements from the magnets.
- The exact reprocessing and recovery processes will vary from producer to producer.
- Sometimes specialist companies are used to reclaim the materials on behalf of the producer.



Recycling of POWDER CORES

- Arnold Magnetic Technologies produces powder cores in its China facility in Schenzhen:-
 - SuperMSS™ (Sendust)
 - Molybdenum Permalloy Powder (MPP)
 - Hi-Flux™
- The powder cores are ROHS 2000/95/EC compliant.
- We will offer to take back powder cores from the field provided the quality of the cores is good.

- Arnold also manufactures powder cores.
- Arnold powder cores can be taken back and reprocessed if the quality is acceptable.



Designing for the future

- Future designs need to be such that the components are :-
 - free from banned chemicals.
 - made smaller (reduced weight and volume).
 - easier to reclaim.
 - easier to recycle.
 - easier to re-use / refurbish.
 - *longer lasting ?*
 - *able to comply with any stricter revisions to existing Directives or new Directives?*

Regulations/Directives are likely to get stricter with time.

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- Are the products ROHS compliant?
- Are the products WEEE compliant?
- How much will it cost to have the products recovered and recycled/reused/refurbished?
- When the Directives are reviewed, what will happen? Will they get stricter? Will more products come under the Directives?



Summary

- The components used in future products need to be considered in terms of ROHS and WEEE compliance. This may involve design improvements.
- Not all magnet materials are as easy to recycle.
- SmCo, Alnico and Powder Cores can be recycled but is primarily dependent on the material quality.
- NdFeB and ferrite magnets may cause WEEE issues as some producers refuse to buy back their magnets.
- **Arnold Magnetic Technologies can assist on appropriate magnet selection, design improvement, WEEE and ROHS. Our web page is <http://www.arnoldmagnetics.com>**

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- New designs need to be considered in terms of ease of recycling and cost of recycling.
- Are the ferrite and NdFeB magnets a good choice longer term?
- Will magnet manufacturers realise they can help their customers?

- Arnold Magnetic Technologies can provide assistance on designs and on the taking back of some magnet materials for recycling.
- We can take those materials we know we can get recycled provided the quality is good and the volume is sufficient. We would look at each request individually. Our own products are the easier to recycle as we know their compositions.
- If in doubt please contact your nearest Arnold representative.