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RoHS – CHANGING PRODUCTS TO CONFORM TO THE NEW EUROPEAN UNION RoHS REGULATIONS

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ABSTRACT
In February 2009 the consultant for the European Union's Directorate General responsible for the environment recommended that over 30 RoHS (Reduction of Hazardous Substances) exemptions be phased out starting in December 2009 through July 31, 2014[1]. Some exemptions were for narrow applications used in special products, but most have been widely used throughout the electronics industry. Due to the critical nature of some of these exemptions and the varying dates for their phaseout, the logistics for compliance with the new requirements will be considerably more complex than it was for the original 2006 RoHS regulations.

A strategy has been implemented within IBM to tackle the challenges associated with converting data systems, product design, and supply chains to meet the revised RoHS regulations. Considerable attention has been given to ensure that clear distinctions are made among parts/products that are compliant with differing expiration criteria. For example, a given part can be compliant to the 2006 regulation while another part may be compliant to an expiration date effective Dec 31st, 2009…and so on. Data management systems must mirror these differing part compliancies and ensure that product environmental compliancy data is current. Suppliers must be well-informed and familiar with the new EU requirements and must agree to differentiate their products in step with the new regulations. This differentiation can be accomplished by either a part number change or some other agreed to method between the Original Equipment Manufacturer (OEM) and the Contract Manufacturer (CM) or raw material supplier. A product compliance approach will be outlined and presented here using the proposed EU RoHS exemption phase-out dates as stated in the February 2009 consultant report.

Strategies must consider product life cycles so that unnecessary changes are not made to products that will be withdrawn from the market before the exemption phase out expiry dates are effective. In some cases, it will be necessary to withdraw products from the market because the costs necessary for compliance conversion are not practical based on the remaining product lifecyle. Particular attention must be given to those situations where new compliant parts and their "usage" applications are coupled with product performance and reliability. For example, timing circuitry signal integrity is susceptible to device parasitic impedance changes which may not be evident in the device specifications but which may become evident in the "usage" application.

Finally, some 2013-2014 exemptions are not certain to be phased out and will be continued until the next exemption review period. It may not be possible or practical to eliminate these particular exemptions for a variety of reasons. For example, alternative material or part solutions are not available at all or alternative solutions are limited to prototype or beta level parts with very high reliability risks associated with implementation. Each exemption phase out approach and solution must be evaluated on its own merits.

Key words: RoHS, exemptions, environmental regulations

INTRODUCTION-STRATEGY
IBM has a large and diverse product line that is a mix of internally designed parts/subassemblies and externally designed assemblies. The various IBM branded product lines were at one time separate businesses units but are now aligned together in a single organization, System Technology Group (STG). However, branded remnants from the "old days" remain in the guise of differing IT systems and business processes to generate documentation, such as Bills of Materials (BOM) and engineering drawings, for new products. In addition, there still remain some product organizations outside the STG umbrella which manage legacy and custom order products. Spare parts shipments are managed by a single Service Planning organization for all of these system brands.

Fortunately, all internal product part numbers are in one parametric database and all product part number "tree" structures reside in a separate Product Manager (PM) database. A product tree structure is a hierarchy showing how each part number fits into a higher level assembly up through a top BOM part number. All of the top bill BOM part numbers found for any particular system are compiled into a 'brand file' for that system. Each product machine type structure has a unique brand file containing all part numbers for that particular product. For a given product brand file, the part number count can vary from one to the tens of thousands. The brand file part number database file

is the basis for all product analysis relative to RoHS environmental compliance.

To control exemption compliancy and effect changes, the following documents and databases are used.

1. *Control Specifications*: added to prints, contracts, purchase specifications.
2. *Product Content Declaration or PCD*: supplier declaration of conformity to a control specification (i.e. Material Composition Declaration)
3. *Part Parametric Database or I2E*: contains design and supplier validation data.
4. *Product Manager Database*: contains part number tree structure per brand
5. *Validation Report*: cross compares design and supplier data for consistency.

The following sections will describe the documents and databases outlined above in more detail.

CONTROL SPECIFICATIONS

Suppliers are not asked to comply with specific environmental regulations. Instead, suppliers are asked to meet control specifications that state IBM's criteria for compliance. Full compliance by suppliers to these control specifications allows IBM to responsibly declare compliancy.

Corporate and system product line environmental control specifications are available to suppliers as public documents included in a supply chain web portal. A corporate-wide materials specification, "Baseline Environmental Requirements for Supplier Deliverables to IBM [2]," has been included in the template for the part drawing title block on all engineering drawings released since about 1999. This specification lists all banned materials, restrictions on other materials, above certain levels, and certain chemicals used in manufacturing. This Engineering Specification (ES) is used to ensure compliance with all environmental regulations world-wide. It also specifies labeling requirements in support of environmental collection programs.

A second set of control documents are the so-called RoHS control documents which apply based on the system product line. One engineering specification, *ES 53P6233* [3], applies to those Server and Storage systems that are eligible for the European Union RoHS exemption 7b "Lead in solder for server, storage and storage array systems"[4]. Another engineering specification, *ES 97P3864* [5], applies to "non-server" applications, including Retail Stores Systems, which would not be eligible to use EU RoHS exemption 7b. One or the other of these two specifications has been referenced on all released engineering drawings since about 2003. These two engineering specifications outline what materials CAN be used as alternatives to the RoHS substances to build a product. All three engineering specifications above are publicly available.

The two RoHS control documents were created to ensure that appropriate materials are used to build product without impacting product reliability or performance. For example, un-mitigated pure tin plating is not permitted for devices with less than 1 micron lead-frame spacing. Acceptable pure tin plating mitigation practices include annealing, use of a nickel underlay, reflow, and bismuth alloying. Annealing and nickel underlay are by far the most common mitigation. In past years, sheet metal finishes were usually hexavalent chromate coatings on a zinc protective film. Zinc hexavalent chromate coatings were banned in the 2006 RoHS regulations. Several zinc trivalent coatings which meet the RoHS regulations, while maintaining adequate levels of corrosion protection, have been qualified.

The phase out of any exemption requires a modification to the RoHS control specifications. These engineering specification changes do not in themselves put into practice any material usage changes, but they do prevent any "re-pollution" of previously released part numbers. To effect any material usage change, it is necessary to release Engineering Changes (ECs) to replace affected parts.

PRODUCT CONTENT DECLARATIONS

A Product Content Declaration (PCDs) is a custom version of a Material Composition Declaration where suppliers document their stated adherence to the various engineering environmental specifications. A part is not considered to be fully compliant until the design drawing, or supplied engineering description document with compliance specifications, match the supplier statement. PCD data is contained in the part number database. Conflicts between supplier PCD data and designer specified requirements are not permitted and must be resolved without delay. Most "conflicts" are attributable to human error, but occasionally a PCD will confirm that a part was not built to the design and environmental specifications and must be remedied.

All exemptions are numbered within the PCD reporting template which allows PCD data to be analyzed to determine which part numbers reference which exemptions. For several exemptions the current EU TAC exemption phase out proposal dates [6] are based on specific applications within these exemptions rather than the exemption expiring entirely as written. In many cases, it is necessary to request details from the Suppliers to understand the specific applications that are utilizing the exemptions, and then decide which expiration dates apply. For example, Exemption 11 is split into 11a (lead used in c-press compliant pin connector) and 11b (lead used other then c-press compliant pin connector). This distinction is important because the proposed 11a exemption phase out expiry date is June 30, 2010 and the proposed exemption 11b phase out expiry date is December 31, 2012. This approach of exemption number customization is strategically important for efficient exemption phase out management. Usage of a consistent exemption numbering scheme through out the industry will eliminate future need

to go back to Suppliers and re-evaluate which applications are expiring within the exemptions.

PART CLASSIFICATIONS

Description

The corporate part number relational database (I2E) contains all relevant information for each individual part number. Each environmental attribute resides in a "field" with a defined "set" of allowable values. For example, each part number has a "RoHS Compliant By Design" field (RCBD) representing the design intention for that part number relative to RoHS compliancy. Each part number owner must enter the appropriate RCBD data field descriptor for that part. Table 1 shows the 2006 and 2009 RCBD descriptors. The new 2009 RCBD descriptors are somewhat arbitrary since there are exemptions that phase out at different times for different years. It has been decided to assign the definitions in the Table 1 comments column for the earliest phase out date for that particular year.

Part Numbers with Multiple Sources

Many part numbers are sourced from multiple suppliers. Exemption usage may be declared by only some suppliers. Each source's PCD form is entered into the database and the part number is credited with an exemption usage so long as at least one of the sources records the usage. To change the part from one with an exemption usage to one without requires a part number change that drops the suppliers reporting the exemption usage and retains the supplier or suppliers who do not record the exemption usage. It is NOT permitted to just drop the suppliers reporting an exemption usage while keeping the part number unchanged. Current inventory under the old part number would get mixed with the new inventory if using the same part number which is an unacceptable result.

Part Number Classifications and Change Rules

All part numbers are classified to a Business Application Code (BAC). Table 2 lists the BAC codes along with a brief description. Table 2 reflects the fact that over the past 15 years several once-separate product lines, that use different part number and release methodologies, have been merged. Some brands will change machine types and model numbers when compliancy status change…others will not. Out of necessity, these often disparate part number definitions were carried forward to avoid obsolescing data. This "carry forward" action has made product management more difficult but it hasn't proved to be an insurmountable obstacle.

Supplier Part Numbers

Supplier part number management is a very important element for effective change control. IBM part numbers often reference one, or more, unique supplier part numbers. On occasion, some suppliers may not find it advantageous to change their part numbers when materials usage change occurs. Rather, these suppliers will make a change and use date codes as a control criteria. In short, this date code methodology is unacceptable. It is not practical to control parts by date code in a world-wide manufacturing environment. Additionally, in the vast part number environment underlying the product lines of any OEM it would be impossible to control change without corresponding part number changes at all levels…from the supplier building block part number to the top bill part numbers that comprise the final system.

Unfortunately, in the real world, suppliers have made material usage changes without changing supplier part numbers and these actions have been tacitly accepted by OEMs without objection. The question now is; How do we manage current parts inventory given that those past material changes are now related to exemption usages that are being phased out?

A clear example of the situation mentioned above involves Multi-Layer Ceramic capacitors (MLCs) constructed using leaded dielectric materials. This material usage is the so-called 7c3 exemption that has a proposed expiry date of 31 December 2012. Some major MLC suppliers stopped using leaded dielectric materials as early as Y2000, others removed these materials in Y2006, and yet other manufacturers are still using them today. By analyzing world-wide inventory, it can be safely assumed that any IBM MLC part number from suppliers who phased out leaded dielectric materials in Y2000 are no longer in supplier or contract manufacturing inventory.

2006 RCBD entries	2009 RCBD entries	Comments
Not relevant for RoHS	Not Relevant for RoHS	Packaging materials, documents, consumable materials used in manufacturing
Not Compliant	Not Compliant	
Compliant by spec.	2006 Compliant by spec.	Part print references control specification
Compliant by design	2006 Compliant by design.	Part print does not reference control specification but is compliant by material selection
	2009 Compliant	Part is compliant up to June 30, 2010
	2010 Compliant	Part is compliant up to June 30, 2012
	2012 Compliant	Part is compliant up to June 30, 2013
	2013 Compliant	Part is compliant up to June 30, 2014
	Compliant w/o exemptions	Part is compliant without exemptions

Table 1. RoHS Compliant By Design Descriptors for 2006 and 2009.

BAC Code or Description	Description	Exemption Usage Change Rule
FRU	A **F**ield **R**eplaceable **U**nit	Exemption usage change requires a new P/N
PPN	A **P**roduction **P**ractice Part **N**umber…part exists only within the manufacturing line	Exemption usage change requires a new P/N
FAP	Part is both a FRU and a PPN	Exemption usage change requires a new P/N
Option	A hardware part number usually purchased as is from a supplier (OEM)	Exemption usage change requires a new P/N
BOMs	**B**ills **o**f **M**aterial-a paper list of real part number, generally at a relatively low level in the product tree structure	Exemption usage change does not require a BOM part number change but they do require a content change…i.e., at least one of the content part numbers must be changed.
MFIs	**M**anufacturing **F**eature **I**ndices-a paper list of real part numbers very similar to BOMs, generally at a very high level assembly in the product tree structure.	Same as BOMs
FBMs	**F**eature **B**ill of **M**aterials	Same as MFIs
A-character	The base system part number which relates to a machine type	Exemption usage change requires change to the A-character part number if that change affects any one part in the A-character BOM
20000 P/N	20000MTMN where MTMN means machine type/model number	The highest level of assembly part number which does not have to change with exemption usage change.

Table 2. Business Application Code Descriptions.

However, other supplier MLC part numbers that used leaded dielectrics and that were phased out in Y2006 may not be "safe" for use in exemption restricted products just yet. New internal part numbers are planned to be assigned to MLCs and to remove supplier part numbers from the approved source list for any parts that phased out lead dielectric usage in Y2006. The same methodology will be used for OEM (Original Equipment Manufacturer) parts.

Non-Compliant Part Numbers

Non-compliant part numbers may be scrapped when replaced by newer, compliant versions. However, scrapping hardware is a costly option, wastes perfectly functional parts, and is not the most environmentally responsible solution. As an alternative, most non-compliant parts are removed from the product structure (PM) but are retained in the parts database (I2E) with a unique identifier. These down-level parts are not usable in ordinary manufacturing but may be used for special orders where a specific regulatory environmental compliancy is not required. For example, a customer may request a product for use in a location which does not require RoHS compliancy or a customer may request a product for a military or critical medical application which does not require RoHS compliancy.

EXAMPLE OF PRODUCT TREE STRUCTURE CHANGE FOR ELIMINATING EXEMPTION USAGE

The part number change ground rules are fairly simple.

1. Any part number that can be ordered, stocked or sold must change.
2. Any group BOM (bill of material) or MFI (manufacturing feature index) part number's content must change.

As simple as these "rules" appear, the management difficulty is in the details. Table 3 illustrates a typical set of part number changes.

Table 3 shows a product tree structure that stops at the MFI level. This happens often. However, sometimes the FRU is both an orderable feature and a part within the base system or the A-character part number. For these parts, the A-character part number must change. A-character part numbers do not require PCDs because all the content part numbers have PCDs. Likewise, MFI (Manufacturing Feature Index) part numbers do not need to change as long as their content changes. FRUs (Field Replaceable Units) must change since they are field stocked for service and can remain in field inventory for many years. PPNs (Production Part Numbers) may or may not be changed depending on the floor control system in use at the particular manufacturing site. If the floor control is part number based the PPN part number must change. If the floor control is part number/serial number based changing the PPN part number is optional.

VALIDATION REPORT

The end goal for all data input and analysis is a "clean" validation report that lists each part number along with its critical environmental data. Ideally, all part numbers, regardless of classification type, have RCBD (**R**oHS **C**ompliant **b**y **D**esign) data that affirm the "correct" compliancy design intent. Additionally, all part numbers must have PCDs (**P**roduct **C**ontent **D**eclarations) that confirm the RCBD statement. Based on these two criteria the product is "certified" as "compliant". A "clean" validation report is a requirement prior to each new product launch.

Part Description	Part classification	Comments
Supplier p/n	NA	Must Change part number PCD: NA
IBM Building Block Part Number	PPN or FRU (FAP)	Must change part number New PCD required
Group BOM	BOM	Part Number Change not Required Content must change No PCD required BOM content has PCDs
Card Pop	PPN	Must change part number No PCD required
Card Pop + Mechanicals	PPN	Must change part number No PCD required
Assembly Part Number	FRU (Field Replaceable Unit)	Must change part number No PCD required if assembled in-house PCD required if purchased as is
Feature Code	MFI	Part Number change not required Content must change No PCD required

Table 3. Typical part number change requirements.

If there are discrepancies between RCDB and PCD data, corrective actions will be necessary to ensure compliancy. Table 4 summarizes some of the more common data field problems and corrective actions necessary to resolve discrepancies.

Data Field Entry	Definition	Comments
No Data	Unacceptable for RCBD Field	Requires Correction.
No Data	Unacceptable for PCD Field	Requires Correction
Non Compliant in RCBD Field	Part Number is not compliant by design	Requires explanation
Not Compliant in PCD Field	Supplier data shows that part is not compliant	Requires explanation

Table 4. Common data field problems and corrective actions.

The above text outlines a methodology for making exemption phase out changes. Before closing, exemption phase out items that may be of particular interest to Server or Storage products will briefly be discussed.

CRITICAL EXEMPTION PHASE-OUT ITEMS

There are over 30 RoHS regulation exemptions proposed for phase out that are referenced in the OKO Institute report to the European Union Technical Adaption Committee in March 2009 [1]. Table 5 is a selection of some of the most critical RoHS exemptions of particular interest to the industry, especially to the producers of Server and Storage equipment.

A number of the proposed exemptions to be phased out are particularly challenging. For example, the elimination of the exemption for lead in MLC (**M**ulti **L**ayer **C**eramic) dielectrics (exemption 7c3) was not anticipated. Almost every printed circuit board logic assembly uses numerous MLC capacitors, some of which contain lead within the dielectric material itself. Fortunately, the EU changed the initially proposed phase out expiry date from June 30, 2010 to December 31, 2012 which still makes the task difficult but not unachievable. There is a technical concern that changing dielectric materials may alter the component's parasitic capacitance which can affect critical timing circuits. The transition to lead-free MLCs may require product regression testing and technical qualification before any new part number changes are implemented. The proposed elimination of the high (>85%) lead content solders (exemption 7a) is also problematic, and particularly so for power MOSFETs which utilize high lead content solders for die attachment. It is not clear today if there is a viable industry technical solution for exemption 7a that is viable and achievable before December 31, 2013.

CONCLUSION

This article has described a recommended overall implementation and management methodology in anticipation of the elimination of many of the current RoHS exemptions. Considerable investment in part number parametric databases and analysis tools infrastructure has been made to support RoHS (and other) environmental regulations needed to provide an auditable data set and a set of engineering controlled procedures. Some of the proposed exemption phase outs will require significant resources for effective implementation and some exemptions will require technical invention.

Supplier involvement throughout the change processes is essential and so is world-wide employee awareness throughout the OEM system producer. The authors hope that this article will be useful to others facing the same management challenges in the IT industry.

Exemption No.	Description	Commentary
1-2	Mercury in fluorescent lamps Expiry Date July 31, 2014	Technical solution exists No problems anticipated
3	Mercury in special purpose fluorescent lamps Expiry Date Dec 31, 2012	Technical solution exists Supply base being surveyed
5a,b,c	Lead in glass Expiry Date July 31, 2014	No actions planned EU to review again in 2012
6a,b,c	Lead in steel, aluminum, Cu alloys Expiry date Dec 31, 2013	No actions planned EU to review again in 2012
7a	Lead in high melting type solders Expiry date June 30, 2013	Extremely problematic See below for discussion EU to review again in 2012
7b	Lead in solder for servers and storage and storage array systems, Expiry date July 31, 2014	Actions planned Major technical impact EU to review again in 2012
7c3	Lead in low voltage MLCs Expiry date Dec 31, 2012	Actions planned Major logistical effort
8b	Cadmium and its compounds in electrical contacts Expiry date Dec 31, 2014	Actions planned
11a	Lead usage in C-press compliant pin connection systems Expiry date July 1, 2010	Actions planned
11b	Lead usage in other than C-press compliant pin connection systems Expiry date Dec 31, 2012	Actions planned
12	Lead as a coating material for C-Ring thermal conduction module Expiry date June 30th, 2010	Exemption usage phased out for new systems as of 2008
14	Lead in solders with more than 80% and less than 85% lead used for microprocessor connections Expiry date Dec 31, 2010	A supplier specific exemption that will require a supplier solution

Table 5. Selection of critical RoHS exemptions and their proposed expiry dates.

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