Storage and Treatment of Flat Panel Displays - A quick guide

Quick guide 461_12 **Issued** 31/07/2012

What's this document about?

This document covers the main storage and treatment requirements for flat panel displays (FPDs) (i.e. TVs, computer monitors and laptops), specifically Liquid Crystal Displays (LCDs) which contain mercury backlights using Best Available Treatment Recovery and Recycling Techniques (BATRRT) as required by the Waste Electrical and Electronic Equipment (WEEE) Directive.

Document details

Who does this apply to?

This guidance has been produced to help Environment and PPC Officers ensure BATRRT compliance at all sites handling flat panel displays. Appendix 3 provides a site inspection checklist, which summarises the key issues raised by the guide. Whilst this is an internal guide it may be shared externally where appropriate to help deliver a consistent regulatory approach.

Related documents

Main issues covered by this guide

Feedback

Contact for queries

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Storage and handling standards

The focus of this compliance guide is on the storage and treatment of LCDs which are backlit with cold cathode fluorescent lamps (CCFLs) which contain mercury. More background information on these and other FPD types can be found in Appendix 2. LCDs make up the majority (approx 75%) of the FPD waste stream. These displays are hazardous waste due to the presence of the mercury backlights, which require removal under BATRRT.

Key Requirements:

1) LCD displays must be stored on an impermeable surface with sealed drainage. They must also be stored under weatherproof covering or in enclosed weatherproof containers to prevent mercury contaminated rainwater being generated and to facilitate refurbishment/re-use activities.

2) LCDs must be carefully stored and handled to prevent breakage of the fragile internal mercury backlights (figure 1 below). Dropping, crushing or compacting LCDs is not acceptable. To prevent breakage, LCDs should be stored in containers e.g. cages or stillages and packed to minimise movement during handling and transport. Where pallets are used, LCDs should be stacked to prevent toppling or crushing of the display units. Where stacking containers on top of each other precautions must be taken to prevent damage to the displays in containers underneath.

Fig 1: Good storage practice examples left and middle photos, compared to poor practice in right photo

3) Damaged or dropped LCDs are more likely to contain broken backlights and should be prioritised for processing. This may not be readily apparent by visual inspection alone, as internal backlights may have been broken by a shock pulse from dropping or shunting of a container. Shaking an LCD may give a crude indication if any internal lamps are broken. A portable mercury monitor can also be used to measure mercury levels around containers in reception areas.

4) To help distinguish between LCDs containing mercury backlights and those backlit with light emitting diodes (LEDs) which don't contain mercury, monitors may have a sticker on the back of the unit indicating their type. Where there is uncertainty it should be assumed that the display contains mercury backlights as this is the most common type of FPD.

5) Officers should visually check all waste and records received for LCDs containing mercury backlights (including laptops and notebooks) to ensure they are stored and treated separately in order to prevent any mercury contamination of other WEEE streams. The shredding or mixing/dilution of hazardous LCD displays with other small mixed WEEE streams is not BATRRT.

Storage and handling standards continued

6) Any LCD items containing lithium batteries (e.g. rechargeable lithium ion batteries in laptops) present a potential fire/explosion risk (e.g. if they short-circuit or are exposed to water) and should be stored appropriately to prevent damage (as detailed above).

Treatment requirements

The relevant treatment requirements of the WEEE Directive are contained in Defra's BATRRT guidance reproduced in Appendix 1. Waste FPDs must only be treated at sites that meet these requirements.

Based on current information and recent WRAP reports (see related documents) our position is that "*only manual treatment of LCDs (i.e. the manual extraction of the CCFLs whole and intact) will result in a realistic chance of capturing the mercury from individual lamps. Based on this information, we do not regard mechanical treatment of whole WEEE items which contain an LCD with a CCFL or extracted LCDs which still contain the CCFL to be meeting the requirement of BATRRT*."

Officers should ensure that treatment sites are only manually dismantling LCDs to remove the backlights intact, in line with our position above. If a site proposes to use alternative mechanical methods to treat LCDs, these will only be acceptable to us where we have agreed a method statement. This must demonstrate that the mercury is effectively captured and removed in a way that does not contaminate the residual waste fractions, and which prevents any fugitive releases.

Key requirements:

1) Where backlights are removed from LCDs there is potential for breakages to occur and mercury to be released either as odourless vapour, liquid droplets, amalgamated within lamp electrodes or adhered to visible powder (figure 2 below). In order to minimise any fugitive mercury releases, the removal of backlights must be done in a controlled area/sealed booth with appropriate air extraction and abatement i.e. local exhaust ventilation (LEV) to capture all dusts and vapour. An appropriately sized and maintained HEPA dust filter and impregnated carbon filter (e.g. iodide, bromide or sulphur which forms a chemical bond with mercury) is typically used to achieve this.

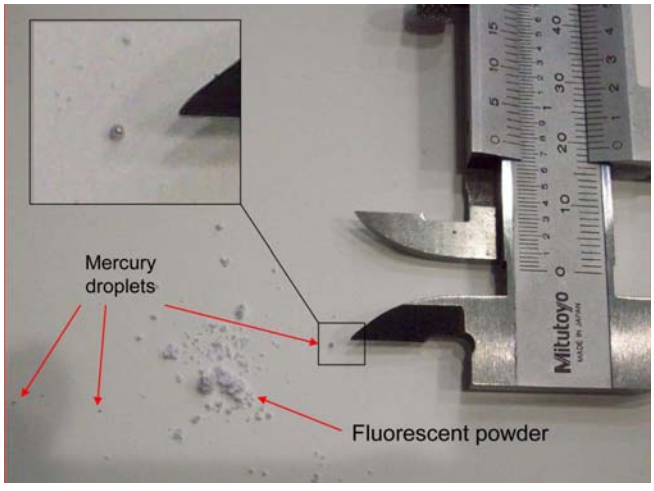

Fig 2: Mercury droplets and fluorescent powder released from a CCFL lamp breakage
Source (McDonnell and Williams, 2010)

Treatment requirements continued

2) The abated air from the controlled area/sealed booth must be continuously monitored for potential breakouts of mercury vapour. Where this is a point source emission to air outside of a building, the officer should check this is covered accordingly by the permit, with appropriate emission control limits as part of the operator's mercury management plan. Where the abated air is recycled inside the building the operator would also need to ensure that mercury levels comply with the appropriate workplace exposure limits regulated by the HSE.

3) Once removed, intact backlights should be packed to prevent breakage during transit and stored in securely lidded and robust weatherproof containers.

4) Whilst the aim of any manual treatment process should be the safe removal of intact lamps, due to their fragile nature, some breakages will inevitably occur. Any broken backlights must be stored in appropriate airtight sealed containers. Filling of these containers should be done in the controlled area/sealed booth to capture any mercury vapour. Airborne mercury levels within lamp storage areas can be checked using a mercury vapour indicator.

5) Any residues resulting from lamp breakages (including powder, glass and lamp components) should be removed from working areas using an appropriate industrial vacuum cleaner with mercury filters. The emptying of residues collected by the vacuum cleaner should be performed in the controlled area/sealed booth. Collected residues should be stored and handled as set out in key requirements 4 and 8.

6) Officers should ensure any backlights or residues are consigned as hazardous waste to an appropriately authorised site for further treatment to remove the mercury.

7) Officers should check that the quantities of backlights removed equate to the amount of LCD screens accepted and treated on site in order to verify that the screens have been properly treated. Whist this is difficult to measure precisely due to variations in screen size, lamp weight and number, figure 4 in Appendix 2 provides an indicative guide for officers as required.

8) Appropriate Health and Safety procedures should be followed by staff undertaking manual dismantling. The operator should have a management plan including COSHH, risk assessments and the provision of information and training for staff, including the use of appropriate personal protective equipment (PPE). This would include the wearing of coveralls or disposable overalls, lightweight gloves, chemical safety glasses/goggles or a face visor and safety shoes or boots. Significantly contaminated clothing should be removed and replaced immediately. Suitable respiratory protective equipment (RPE) may also be worn e.g. a half-face mask respirator with a Hg-P3 filter where appropriate (HSG53 states a maximum use time of 50 hours). Good hygiene procedures should also be followed to minimise exposure, such as hand washing and footwear protection in potentially contaminated areas. If officers have any concerns regarding an operator's H&S procedures on site they should inform the operator and raise them with the HSE as a Matter of Evident Concern. See related documents for more HSE information.

Hazardous waste coding

Flat panel displays are categorised under 4 main EWC entries, depending on source and if they contain hazardous components or not. (see '*Classification of Electronic Display Devices'* in related documents for more information).

1) 16 02 13* discarded equipment containing hazardous components other than those mentioned in 16 02 09 to 16 02 12

2) 16 02 14 discarded equipment other than those mentioned in 16 02 09 to 16 02 13

3) 20 01 35* discarded electrical and electronic equipment other than those mentioned in 20 01 21 and 20 01 23 containing hazardous components

4) 20 01 36 discarded electrical and electronic equipment other than those mentioned in 20 01 21, 20 01 23 and 20 01 35

For separately collected LCD screens that contain fluorescent backlights, the appropriate code would be 20 01 35* where they are from a household or equivalent to household in size or type. Only industrial sized or non household type LCD screens (e.g. hospital equipment) would be coded as 16 02 13*.

A fluorescent tube used as a backlight is a hazardous component. If a piece of waste electronic or electrical equipment contains a hazardous component, then the equipment is classified as hazardous. It does not matter how big or small the hazardous component is compared to the size of the equipment.

The fluorescent tube backlights will contain mercury and are identified as hazardous components by virtue of EWC entry 20 01 21* fluorescent tubes and other mercury-containing waste (absolute hazardous entry).

If the hazardous components referenced above are removed from the equipment, so long as there are no other hazardous components present, the equipment will cease to be hazardous.

For plasma and LED displays which do not contain any hazardous components either 20 01 36 or 16 02 14 is appropriate.

Permitting requirements

Any sites storing, preparing for reuse or treating waste flat panel displays will need either an appropriate permit or exemption, either T11 (up to 1,000 tonnes per year) or S2 (storage only).

If the site you regulate is dismantling TVs, PC monitors or laptops, processing components or recovering mercury, then please ensure that the facility holds the correct type of permit.

From a health and safety perspective, operators also have to comply with the Workplace Exposure Limit (WEL) for mercury of 20 microgrammes/m^3 8 hour time-weighted average. This was implemented in the UK on 18th December 2011 (more information in related documents).

Health and Safety considerations during site visits

Compliance officers would not normally be expected to enter areas where the mercury concentration and/or the duration of the visit were such that respiratory protective equipment (RPE) or personal mercury monitors were deemed necessary. However, they should continue to assess their risk of mercury exposure during visits, and ensure they take all reasonable precautions and appropriate actions to maintain their Health & Safety accordingly.

At treatment sites the operator should be undertaking regular occupational and ambient air monitoring for mercury. If staff have concerns they should ask to see operators risk assessments/ monitoring to satisfy themselves that any mercury releases are being managed effectively on site. Any serious concerns should be reported to the HSE as a Matter of Evident Concern.

More information from the HSE on controlling mercury exposure risk is in the related documents below.

Related documents

Waste Electrical and Electronic Equipment Directive
http://ec.europa.eu/environment/waste/weee/legis_en.htm

Guidance on Best Available Treatment Recovery and Recycling Techniques (BATRRT) and treatment of Waste Electrical and Electronic Equipment (WEEE) November 2006
http://archive.defra.gov.uk/environment/waste/producer/electrical/documents/weee-batrrt-guidance.pdf

LCD Regulatory position statement http://www.environment-agency.gov.uk/static/documents/Business/MWRP_RPS_111_LCD_treatment_-_Aug_2011.pdf

Classification of Electronic Display Devices
http://publications.environment-agency.gov.uk/PDF/GEHO0612BUQI-E-E.pdf

WRAP reports on flat panel recycling and LCD mercury backlights
http://www.wrap.org.uk/content/flat-panel-display-recycling-technologies-0

HSE main page for waste management sector
http://www.hse.gov.uk/waste/index.htm

Health & Safety inspection standards for WEEE processing facilities (see appendix 3 for control of exposure to mercury)
http://www.hse.gov.uk/foi/internalops/sims/manuf/3_11_01/index.htm#a3

Respiratory protective equipment at work – a practical guide, HSE
http://www.hse.gov.uk/pubns/books/hsg53.htm

The Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (RoHS)
http://www.bis.gov.uk/nmo/enforcement/rohs-home

Fig 2: McDonnell, T. J. & Williams, K. S. (2010) 'Commercial recycling of LCD and its challenges:A UK perspective', 9th International Electronics Recycling Congress, ICM AG, ed., (Switzerland): in Salzburg, Austria. 20 January.

Fig 4: McDonnell, T.J. 2011. *A Study on Recycling Liquid Crystal Televisions and Monitors and the Impact of Mercury on the Processes.* PhD Thesis University of Central Lancashire.

Appendix 1: Extract from Defra's "Guidance on Best Available Treatment Recovery and Recycling Techniques (BATRRT) and treatment of Waste Electrical and Electronic Equipment (WEEE)" November 2006

Gas discharge lamps

91. The WEEE Directive requires that:

"Gas discharge lamps must be removed, and that Mercury must be removed."

92. Gas discharge lamps are defined as lamps in which light is produced by an electrical discharge through a gas. The discharge can either be through gases (such as xenon, neon and carbon dioxide) or through metal vapour (such as mercury or sodium).

93. The treatment process for fluorescent lamps involves shredding followed by separation into glass, metal and powder (which contains mercury). The separation process should be designed to prevent fugitive emissions of mercury vapour or dust. The separation process can use either a dry or a wet process; the main advantage of the wet process is that it can separate a wider range of lamps. However, the main disadvantage of this process is the requirement for treatment of the water.

94. Recovery of the powder (which contains the bulk of the mercury) and its storage in appropriate labelled containers will be regarded as evidence that the mercury has been removed for the purposes of Annex II to the WEEE Directive.

Liquid crystal displays

95. The WEEE Directive requires:

"removal of LCDs (together with their casing if appropriate) if either:
• they have a surface area greater than 100 square centimetres; i.e. larger than 4 inches by 4 inches, or
• they are back-lighted with a gas discharge lamp."

96. Liquid crystal displays (LCDs) are used in a wide variety of applications. Liquid crystals are embedded between thin layers of glass and electrical control elements. A cellular phone display can contain about 0.5mg of liquid crystals, a 'notebook' display about 0.5g.

97. LCDs used in computer monitors (and in LCD televisions) are larger than 100 square centimetres, and are also back-lighted with gas discharge lamps. These will need to be removed, and the backlights will then need to be separated from the LCD. Removed gas discharge back-lights and LCDs should be stored separately in appropriate labelled containers.

Appendix 2:

Composition of main flat panel display types (LCDs, LEDs & Plasma)

There are three main types of flat panel display: LCDs, LEDs and Plasma. Liquid crystal displays (LCDs) are commonly used in laptops, TV and computer monitors. Most are backlit with cold cathode fluorescent lamps (CCFLs) which contain mercury which form the focus of this guide. It is estimated that there will be over 145,000 tonnes of flat panel displays in the waste stream by 2016/17.

Mercury backlights - The quantity of mercury found in a LCD varies by manufacturer and size of the unit. A typical backlight contains an average of 3.5mg of mercury according to manufacturers (figure 4), but some manufacturers are reported to use much higher concentrations, making average calculations difficult. The number and length of individual backlights typically increases with display size (figure 4). A laptop typically contains one backlight, a PC monitor between 1-5 backlights and a TV between 6-20 backlights depending on the size of the display. These fragile backlights are either individually protected in the unit (figure 3) or attached to the back panel with small plastic clips.

Fig 3: showing mercury backlights in typical TV and Laptop with protector strip (source WRAP report 2009)

Type	Screen size	Average Lamp Length mm	Average Lamp Width mm	Average Lamp Weight kg x10^{-3}	Number. of Lamps	Mercury Content[1] mg
LCD Monitor	15"	320	2.0	4	2	7.0
LCD Monitor	17"	350	2.0	6	4	14.0
LCD Monitor	19"	390	2.5	6	4	14.0
LCD Television	20"	430	2.5	9	6	21.0
LCD Television	26"	630	3.0	72	13	45.5
LCD Television	32-37"	805	4.0	115	16	56.0
LCD Television	42"	920	3.0	170	18	63.0

Fig 4: CCFL lamp characteristics used in LCD display equipment, based on CCFL manufacturer's data. Source (McDonnell, 2011) (Average lamp weight column is total lamp weight per monitor type, 1 kg x 10^{-3} = 1g)

According to the recent WRAP report (see related documents) mercury is distributed in several parts of the backlight, including attached to the nickel or molybdenum electrodes, in the tri-phosphor powders, burnt onto the glass and as free mercury vapour.

Mercury vapour is odourless and invisible. It readily vaporizes at room temperature, and increases with air movement, exposed surface area and heat. It readily adheres to a range of substances particularly non ferrous metals (e.g. gold, zinc, nickel, aluminum) and plastics potentially. Where poor treatment practices take place there is potential for contamination of waste fractions with mercury which is likely to present a continuing risk of future emissions/exposure.

Appendix 2:

Composition of main flat panel display types (LCDs, LEDs & Plasma) continued

The main components of a backlit LCD are shown below.

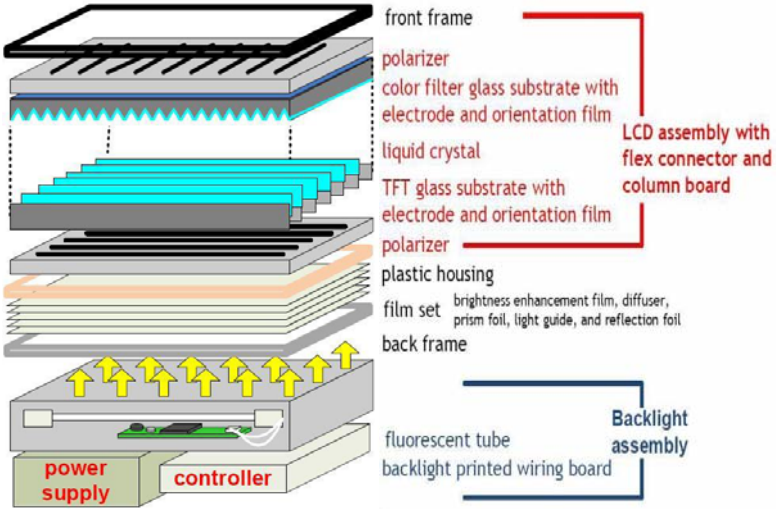

Fig 5: Section through a liquid crystal display (source WRAP report, March 2009)

Liquid crystals are a thin layer of molecules found in the thin film transistor (TFT) glass layer. Liquid crystals vary in composition and can contain varying amounts of potentially harmful chemicals including chromium, beryllium, cadmium, arsenic, poly-brominated organics, organo-halogen compounds and plasticisers. To date findings appear to indicate that they generally have a low toxicity to humans and are not mutagenic or show any significant bioaccumulation potential. The chemistry of the liquid crystals used however continues to evolve making toxicity assessment difficult.

Indium is also found in liquid crystal displays as a component of the indium tin oxide (ITO) conductive transparent coating, which is deposited on the display glass. Again, the quantities of ITO in LCD displays are relatively small, with a 15 inch unit typically containing around 500 mg. Indium is technically classified as a heavy metal and is believed to be moderately toxic, but there is less information available on indium tin oxide. The key health issue seems to be potential impact on the lungs associated with dust inhalation.

LED backlights - Newer types of LCD displays are backlit with light emitting diodes (LEDs) either using white or RGB (red, green and blue) LED arrays. LEDs vary in composition but may contain compounds of indium and gallium as nitrides, phosphides or arsenides. Some of the latest thin displays use organic LEDs (OLEDs) which aren't backlit, instead the pixels themselves light up. Since mid 2009 there was a switch to LED backlit screens but this is still relatively slow due to their higher costs, and the use of mercury backlights is expected to continue.

Based on current information we do not regard liquid crystals, LED or OLED backlight components to be hazardous waste (see 'classification of electronic display devices' in related documents for more information).

Appendix 2:

Composition of main flat panel display types (LCDs, LEDs & Plasma) continued

Plasma displays are generally used in large TVs. These aren't backlit and don't contain liquid crystals, the image is instead produced by the excitement of fluorescent coatings in the plasma. They are generally easily identifiable due to their shiny screen and are much thicker and heavier than other flat screen display types.

Based on current information, we do not currently regard plasma displays as hazardous waste (see 'classification of electronic display devices' in related documents).

The typical components of a plasma display are shown below.

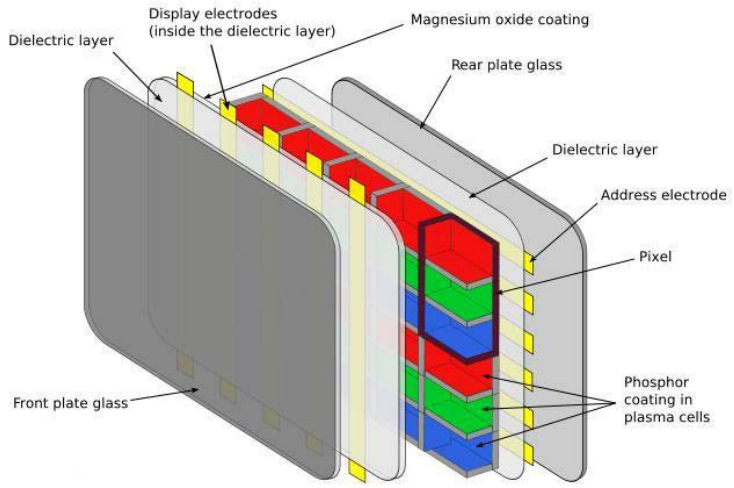

Fig 6: section through a typical plasma type display (source WRAP report, March 2009)

Fig 7: thick glass panels on plasma display and typically large circuit board with capacitors (source WRAP/ Bruce metals report 2009)

Whilst there are no backlights in plasma displays other components including the circuit board, on board batteries and capacitors will also need to be removed in line with BATRRT.

Appendix 3 – Site inspection checklist

Key Questions	CAR form Ref	Compliant or proposed CCS score
1. Are LCDs (i.e. TVs, computer monitors and laptops) stored on an area of impermeable surface with sealed drainage and stored under cover or enclosed weatherproof containers?	b1,b3,b4	
2. Are LCDs stored/handled in a way that prevents damage to the internal mercury backlights or laptop batteries? (see storage points 2 and 6)	c1,c2,c3,c4	
3. Are LCDs effectively segregated from other WEEE wastes stored on site?	c4	
4. Are LCD displays containing mercury backlights treated on site? *If Yes, go to Q6 and continue. If No, go to Q5 and finish.*	a1	
5. Are LCDs sent to an appropriate permitted facility for treatment?	c2,g2	
6. Are LCDs manually dismantled in a controlled area/sealed booth with air extraction and abatement (HEPA and carbon filters) with continuous monitoring to minimise any fugitive mercury vapour/dust releases (see treatment points 1 and 2)?	b1,b4,b5	
7. Are removed intact backlights carefully packed in secure lidded robust weatherproof containers?	b4,c4	
8. Are any contaminated residues (including broken backlights and powders) stored in appropriate air tight sealed containers?	b4,c4	
9. Is an appropriate vacuum cleaner with carbon filters used to clean up any mercury spillages/ contaminated residues (see treatment point 5)?	b4,b5,c4	
10. Are the backlights and other mercury containing wastes sent to an appropriate permitted facility for treatment/recovery?	c2,g2	
11. Are wastes produced classified/coded appropriately, and consigned as hazardous waste in the case of backlights, or other mercury contaminated wastes?	c2,g2	
12. Do the quantities of backlights removed roughly equate to the number of LCD units treated on site (see Appendix 2 fig 4)?	c2,c4	
13. Are there any Health and Safety concerns re: site operations? If so inform the operator and raise with the HSE accordingly as a Matter of Evident Concern.	N/A	