Health and Safety Executive

Exposure to substances hazardous to health in foundries

Prepared by the Health and Safety Executive

RR1115
Research Report

Prepared 2017
First published 2017

Tackling the causes of occupational lung disease is a key priority for HSE. Foundry workers are potentially exposed to a wide range of hazardous substances, including, for example, respirable crystalline silica (RCS), metal fumes and dust, that can cause lung (and other) cancers and chronic obstructive pulmonary disease (COPD).

This work was undertaken to understand current exposures to hazardous substances in the foundry industry, to identify examples of good control practice, and to establish benchmark standards of control for the industry.

Many examples of good practice were found, which, if adopted across the foundry industry, would ensure effective control of exposure to hazardous substances. The challenge for the industry is to share and adopt the good control practice identified; this will require positive engagement with the workforce, representative bodies and management at all levels.

This report and the work it describes were funded by the Health and Safety Executive (HSE). Its contents, including any opinions and/or conclusions expressed, are those of the authors alone and do not necessarily reflect HSE policy.

HSE Books

Health and Safety Executive

Exposure to substances hazardous to health in foundries

Joan Cooke, Andrew Simpson, Dr Timothy Yates and Diane Llewellyn
Health and Safety Executive
Harpur Hill
Buxton
Derbyshire SK17 9JN

ACKNOWLEDGEMENTS

We would like to thank the Cast Metals Federation (CMF) for their partnership in this work and the foundries and individual workers who participated.

KEY MESSAGES

Exposure control options across the numerous foundry processes and tasks are significantly different and not 'one size fits all'. Common issues have been identified and the key messages are:

- All stakeholders at all levels, including the shop floor, trade unions, management and trade associations have been fully engaged with this work. This was a key factor in bringing about workplace improvements. For the wider industry to achieve a similar success it will also require positive engagement at all levels.
- Reasonably practicable measures exist that can ensure adequate control of exposure for all the foundry processes examined in this project, where there is the potential for worker exposure to hazardous substances that can cause cancer and / or serious respiratory disease.
- The correct use and maintenance of engineering controls and personal protective equipment (PPE) is critical to the success of any control strategy. There is scope for significant improvements in this area.
- Examples of good practice exist across the sector, but more could be done to share and adopt this good practice in a consistent way to ensure that exposures are controlled to as low as reasonably practicable.
- Benchmarks of control can be identified for specific foundry tasks and selected substances, which, if followed, should adequately control exposure to hazardous substances and reduce the future burden of ill-health in the industry.

EXECUTIVE SUMMARY

Introduction

This report describes a research project conducted by HSE; the aim was to identify benchmarks of exposure control for the foundry industry which could be used by HSE to develop examples of good control practice, and to review and update existing guidance.

The specific objectives were:

- To visit a selection of foundries undertaking high health risk processes to measure worker exposure levels to key hazardous substances and to identify good control practice
- To establish a reference baseline exposure dataset and identify controls that are technically achievable and reasonably practicable to implement, based on the measurements and observations.
- To use these examples of good control practice to develop task-specific control benchmarks

Foundry workers are potentially exposed to a wide range of substances hazardous to health including: respirable crystalline silica (RCS) and other mineral dusts, metal fume and dust, polycyclic aromatic hydrocarbons (PAHs), welding fumes, oil mist, aromatic amines, benzene, binding agents (organic chemicals, tar, coal) and other constituents of ferrous foundry particulate (FFP) all of which can cause occupational diseases such as cancer and chronic obstructive pulmonary disease (COPD).

This project was developed by CHASAC (Castings Health and Safety Advisory Committee), a tripartite partnership working group, to target key health issues in foundries.

Methodology

In total 14 foundries volunteered to be visited. At each foundry an occupational hygiene survey was carried out that included an assessment of exposure controls, management controls and exposure monitoring for substances hazardous to health. The latter consisted of air sampling and biological monitoring (BM) of substances to which foundry workers were exposed which included inhalable and respirable dusts, inhalable and respirable ferrous foundry particulate (FFP), RCS, a range of volatile organic compounds (VOCs) and toxic metals.

Each participating foundry received a comprehensive site visit report containing all the results, with interpretation, advice and recommendations if applicable.

Table 1. Findings, outcomes and recommendations

	Finding	Outcome	Recommendations
1	Manual mould making with sand was found to cause significant exposure to inhalable dust. This was not expected as the sand / resin / catalyst mixture was typically damp.	Compressed air was used to blow loose sand off moulds at all foundries carrying out manual mould making. The high velocity of the compressed air would re-suspend this dust into the airborne phase. The position of the dispense point of the mixer was such that the sand mixture often passed downwards through the workers' breathing zone.	Other methods to remove the loose sand should be considered if possible. Some foundries have investigated the use of a vacuum but found it to be inefficient. Identified benchmark standards of control are: • Provide engineering controls such as enclosure or extraction for compressed air blow down of moulds • Ensure that the dispense point of the mixer is as close as possible to the mould box • Dispense the sand mixture at as slow a speed as practicable to reduce dust generation • Use respiratory protective equipment (RPE) to control exposure to particulate as a last resort
2	Carbon monoxide was identified as a component of fume released at casting, cooling and knockout.	There is the potential for workers in the vicinity of these areas to be exposed to carbon monoxide.	Local exhaust ventilation (LEV) may not be practicable at all foundries; hence the identified benchmark standard of control for this exposure would be to provide effective general ventilation to dilute levels of carbon monoxide.
3	Employers used consultants for exposure monitoring. HSE does not consider some of the monitoring methods used as valid.	Employers were using potentially unreliable data in their risk assessments.	When commissioning exposure monitoring, employers should request that inhalable FFP / dust is sampled using validated methods.
4	Employers used consultants to carry out LEV thorough examination and test (TExT). Some of these reports were unsuitable and could not be deemed as a TExT.	The businesses concerned did not have a TExT in accordance with Regulation 9 of the Control of Substances Hazardous to Health (COSHH) Regulations 2002 (as amended)[1].	Employers should ensure that the consultant they employ is aware that a TExT (and report) in accordance with Regulation 9 is required. The benchmark standard of control would be to ensure that they are competent to provide that service.

	Finding	Outcome	Recommendations
5	A previous HSE investigation found benzene exposures at one foundry greater than the workplace exposure limit (WEL) during casting when using benzene sulphonic acid (BSA) catalyst. A re-visit carried out as part of this study after the company had substituted the BSA for xylene sulphonic (XSA) found that benzene exposures were significantly reduced.	This was a successful example of substitution.	Replacing BSA with another catalyst that does not contain benzene must be considered (as a benchmark standard of control) where reasonably practicable. It is however appreciated that this is not straightforward and care needs to be taken so the quality of the casting is not affected.
6	LEV design could be improved in most foundries. Examples of incorrect LEV design at some foundries included poor containment or capture (dependent upon the type of hood).	Some systems could be re-designed with little effort (such as adjustments to booths) and some others had more fundamental design issues, such as the incorrect type of hood used in the first place.	When choosing LEV, the energy of the work process and the size of the contaminant cloud are amongst the factors that should be taken into consideration.
7	LEV maintenance was not carried out on a regular basis at all foundries.	Not all employers carried out in-house maintenance checks and damaged LEV was noted at most. The latter will affect system performance and in some cases lead to additional exposures.	Foundries are a harsh environment for LEV systems. The benchmark standard of control is to carry out regular maintenance and visual checks for wear and tear to keep them performing as they should.

	Finding	Outcome	Recommendations
8	There were deficiencies in PPE programmes at some foundries.	Incorrect gloves used when moulding, core making and knockout which would not offer sufficient protection against binder chemicals, some of which are known skin sensitisers. Workers wore their own clothes in some foundries. This can lead to contamination being spread away from the workplace. Gloves and RPE were removed frequently throughout the shift and often left on workbenches when not in use. Five employers had no formal maintenance regimes in place for re-usable RPE. At two foundries this included breathing air quality checking for air fed RPE.	Employers should ensure that the PPE chosen offers adequate protection for the task, is properly stored to prevent contamination and is well maintained. Face-fitting needs to be carried out for tight fitting RPE. The benchmark standards of control for PPE are task specific.
9	Not all workers wore available PPE, some wore it incorrectly.	The incorrect use of PPE highlighted a lack of training and / or supervision. One employer acknowledged that refresher training could be beneficial.	Employers should review their training provision so they meet their statutory duties under the COSHH Regulations 2002 (as amended)[1], to provide employees with training sufficient enough for them to know how and when to use control measures.
10	Incorrect use of LEV included not moving captor hoods close to the workpiece, standing between the extraction and the workpiece and using fans in the vicinity of the extraction.	The incorrect use of LEV highlighted a lack of training and / or supervision.	

	Finding	Outcome	Recommendations
11	Exposures from some automated processes were not significantly different to those from corresponding manual processes. However this may be attributed to poor maintenance.	Automation of a process removes operator contact (and also reduces the number of workers exposed). Automation of some processes was rare (moulding, fettling), whereas for some others (shotblasting and core making) automation was common. Automation can, for some tasks, reduce exposure to hazardous substances, however, instances of poor maintenance were observed which lead to exposures greater than existing exposure limits.	Employers should ensure that they have procedures in place to ensure good maintenance of automated systems to prevent exposure to the operators.

CONTENTS PAGE

1. INTRODUCTION

1.1 BACKGROUND

Foundry workers are potentially exposed to a wide range of substances hazardous to health including respirable crystalline silica (RCS) and other mineral dusts, metal fume and dust, polycyclic aromatic hydrocarbons (PAHs), welding fumes, oil mist, aromatic amines, benzene, binding agents (organic chemicals, tar, coal) and other constituents of ferrous foundry particulate (FFP). These can cause occupational diseases such as cancer and chronic obstructive pulmonary disease (COPD).

Previous research carried out for HSE showed that in 2005 in Great Britain (GB) there were an estimated 25 attributable cancer deaths per year amongst steel foundry workers[2]. An independent 1994 epidemiological study of steel foundry workers found an increased risk of lung cancers[3].

This project was developed by CHASAC (Castings Health and Safety Advisory Committee), a tripartite partnership working group, to target key health issues in foundries.

1.2 AIM AND OBJECTIVES

The aim of this work was to identify benchmarks of exposure control for the foundry industry that could be used by HSE to develop leading indicators of good control practice, and to review and update existing guidance.

The specific objectives were:

- To visit a selection of foundries undertaking high health risk processes to measure worker exposure levels to key hazardous substances and to identify good control practice.
- To establish a reference baseline exposure dataset and identify controls that are technically achievable and reasonably practicable to implement, based on the measurements and observations.
- To use these examples of good control practice to develop task-specific control benchmarks.

2. PROJECT APPROACH

This section details how the different types of foundries were selected, the protocol of the visits, how the project fitted in with other HSE research, the selection of benchmark foundries and the statistical methods used. The initial planning was carried out in partnership with the Cast Metals Federation (CMF). The first step of the project was to get an understanding of the types of foundries, the substances used or generated, and the potential exposures.

2.1 FOUNDRY EXPOSURE SCENARIOS

Foundries fall into two categories dependent on the metal used. Ferrous foundries use iron or alloys containing iron and steel, and non-ferrous foundries use any other metals (e.g. aluminium). Items produced in a foundry are termed castings. The casting is formed when molten metal is poured into a mould which is typically made from sand, though there are foundries that use no sand. The silica sand can be mixed with chemicals (resins and catalysts) to form chemically-bonded moulds or with bentonite, coal dust and water to form greensand. These chemicals are termed the 'binder system'.

A resin binds the sand; examples are isocyanate-based resin (urethane), furfuryl alcohol-based resin (furan) and phenol formaldehyde resin (alkali phenolic). A catalyst 'cures' the sand / resin mixture; examples include benzene sulphonic acid (BSA), xylene sulphonic acid (XSA) and triethylamine. This wide variety of resin / catalyst options and the approximately 20 different foundry types (See Appendix 1) means that there are many potential foundry / binder system combinations. The CMF stated that this could lead to approximately 160 'exposure scenarios'.

The CMF identified the combinations with higher potential for worker exposure to hazardous substances (i.e. substances causing serious respiratory disease and cancer), to which approximately 15,000 foundry workers (75 % of the total workforce) could be exposed. The metal used (iron, steel or aluminium) and foundry process (jobbing or automated) were considered along with binder system type. This gave the following list of 15 foundry types:

- Iron foundry, jobbing, greensand binder.
- Iron foundry, automated, greensand binder.
- Steel foundry, jobbing, greensand binder.
- Steel foundry, automated, greensand binder.
- Aluminium foundry, jobbing, greensand binder.
- Aluminium foundry, automated, greensand binder.
- Iron or steel foundry, furan binder with benzene sulphonic acid catalyst.
- Iron or steel foundry, furan binder without benzene sulphonic acid catalyst.
- Aluminium foundry, furan binder with benzene sulphonic acid catalyst.
- Aluminium foundry, furan binder without benzene sulphonic acid catalyst.
- Iron foundry, urethane binder.
- Steel foundry, urethane binder.
- Aluminium foundry, urethane binder.
- Iron or steel foundry, alkali phenolic binder.
- Aluminium foundry, alkali phenolic binder.

Foundries were recruited by the CMF to cover the list above.

2.2 FOUNDRY PROCESSES

The stages of the sand foundry process are illustrated in Figure 1:

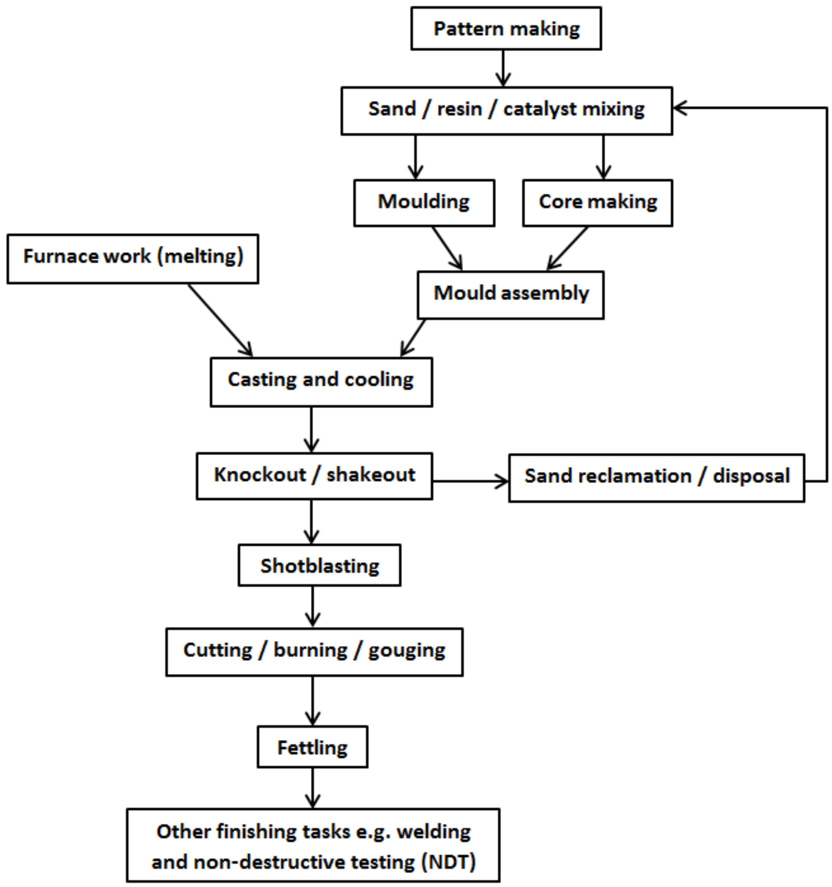


Figure 1 The stages of the sand foundry process (CMF)

Sand / resin / catalyst mixing
For both greensand (silica sand, bentonite, coal dust and water) and chemically-bonded sand (silica sand, resin and catalyst) the components are mixed together ready for moulding or core making.

Moulding
The sand mixture is dispensed into a mould box containing the pattern and compacted into the contours of the pattern until the box is full. The mould box is then left until ready to cast (greensand) or left to air set (chemically bonded).

Core making
This can be done manually or is automated (the latter is usually termed either cold or hot box systems). The manual method is similar to moulding but a smaller core box is used instead of a mould box.

The cold / hot box systems are enclosed. The empty core box is placed inside and the system closed. The sand / resin mixture is then blown into the core box via an internal mechanism. A gaseous catalyst is then pumped into the box to set the core. The box is taken from the machine and the core removed.

Mould assembly
The different sections of the mould and core system are assembled ready for casting.

Furnace work (melting)
The metal that the casting is to be made from is loaded into a furnace and heated until molten.

Casting and cooling
Molten metal is manually poured into assembled moulds and left to cool.

Knockout / shakeout
This removes the casting from the sand mould and can be done on both hot and cooled castings. The process can be automatic, semi-automatic or manual. The used sand is then reclaimed.

Automated lines are available whereby the mould is made, cast and knocked out with minimal operator contact.

Sand reclaim
This is the breakdown of lumps of used sand so it can be used again. Greensand tends to be mechanically broken down whereas sand containing chemical binders typically goes through a combination of mechanical and thermal reclamation.

Shotblasting
This technique removes residual sand from the casting. Shot (e.g. steel bearings) are blasted at the casting at a high velocity. This can be done manually or in an enclosed cabinet.

Cutting, burning and gouging

At some foundries excess metal is removed using cutting, burning or gouging techniques prior to fettling. Power tools such as grinders are used for cutting and gouging with burning carried out using powder-burning lances.

Fettling
This is carried out to remove excess metal from castings (termed burrs, runners and risers) and typically uses power tools such as angle grinders.

Other finishing tasks

These can include non-destructive testing (NDT) where the casting is inspected for defects. This can be carried out using x-rays or dye penetrant. Welding may then be carried out to repair cracks and faults.

2.3 MEASUREMENT STRATEGY

Potential exposures at each stage of the foundry process were determined to develop the measurement strategy. Some of these exposures would be to the raw materials used:

- Inhalable dust or FFP* from the sand and metal.
- Respirable dust or FFP* from the sand and the metal.
- RCS from the sand.
- Isocyanates, formaldehyde, phenol from the resins (urethane resins contain isocyanate, alkali phenolic resins contain formaldehyde and phenol).
- Azo dyes from the dye penetrant used in NDT.

Some would be to process-generated substances:

- Isocyanates, formaldehyde, benzene, xylene, toluene, PAHs and other volatile organic compounds (VOCs) from the thermal decomposition of the binder systems.
- Metal dust and fume from the fettling and melting processes respectively.
- Aromatic amines from the thermal decomposition of the binder systems and metabolism of the dye penetrant within the body.
- Sulphur dioxide (SO_2), carbon monoxide (CO) and oxides of nitrogen (NO and NO_2) in areas where knockout, casting and cooling are carried out.

All these substances were considered in order to tailor the measurement strategy to individual foundries, binder systems and work tasks. To summarise:

- <u>All</u> work tasks except NDT had the potential for exposure to respirable and inhalable FFP / dust so this was typically measured for all volunteer workers.
- Workers carrying out moulding, core making, casting or knockout were potentially exposed to VOCs including formaldehyde.
- Exposure monitoring for isocyanate was carried out on mould makers, core makers, casters and knockout / shakeout workers if isocyanates were present in the binder system.
- Furnace workers would potentially be exposed to metal fume.
- Workers carrying out fettling, cutting / burning / gouging and welding would potentially be exposed to metal dust and fume.
- NDT workers using a dye penetrant (CI Solvent Red 164) that could potentially metabolise in the body to form aniline and ortho-toluidine (o-toluidine).

The full list of substances measured for each work task can be seen in Appendix 2. The Great Britain (GB) regulatory position on the substances including hazard statements[4], exposure limits[5, 6], and biological monitoring guidance values (BMGVs) can be seen in Appendix 3.

2.4 SITE VISIT PROTOCOL

The detailed visit and sampling protocol is at Appendix 4. All foundries visited were located in GB. The visits were two and a half days long to cover all the stages of the process. This included a half day preliminary walkthrough of the sites.

The occupational hygiene surveys carried out at each site consisted of:

- Exposure monitoring (both air sampling and BM) on potentially exposed workers and

* The term FFP relates to ferrous (iron or steel) foundries, dust relates to non-ferrous foundries

- Assessment of working practices and exposure controls, including:
    - Management processes (e.g. COSHH - assessments, worker training etc.).
    - Engineering controls, qualitatively (using smoke to visualise airflow, dust lamps to highlight particulate invisible to the naked eye) and where possible, quantitatively (using anemometers).
    - PPE suitability and management programmes.
    - Completion of an occupational hygiene questionnaire to ensure all relevant data were captured (Appendix 5).

A comprehensive occupational hygiene visit report was written for each foundry containing all exposure monitoring results, comparisons with exposure limits, opinions on the adequacy of exposure controls and, where appropriate, recommendations for improvements. Copies of this report were issued to the participating foundry and the local HSE inspector.

2.5 SAMPLING METHODS

Exposure measurements (both air sampling and BM) were carried out at each stage of the foundry process. Air sampling included both long-term (representative of the worker shift) and task-based samples. BM (urine) samples were collected post-shift on the day of sampling and also the following two working days.

Air sampling was carried out using methods in accordance with relevant HSE Methods for the Determination of Hazardous Substances (MDHS)[7] or British Standard ISO methods.

Analysis of the urine samples was carried out using either United Kingdom Accreditation Service (UKAS) or HSE in-house methods. The majority of the in-house methods have their quality assessed by participation in external quality assurance schemes.

Direct reading instruments were used to measure levels of nitrogen monoxide (NO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2) and carbon monoxide (CO) in knockout, and casting / cooling areas.

Details of the measurement methods used can be found in Appendix 6.

2.6 STRATEGIC RESEARCH PROGRAMME (SRP)

In parallel to this work HSE has also set up a larger project, termed the ‘Health Impact and Health Surveillance Strategic Research Programme (SRP). The SRP will study respiratory symptoms and lung functions in GB foundry workers exposed to hazardous substances, over a three year period and investigate the risks for chronic asthma and chronic obstructive pulmonary disease (COPD). The results of this study will be combined with those from the SRP in order to investigate (so far as is possible) the potential link between exposure and symptoms/early markers of disease.

2.7 STATISTICAL ANALYSIS

Statistical analysis targeted 14 key hazardous substances from air samples (RCS, inhalable and respirable FFP and dust, chromium, lead, manganese, nickel, benzene, isocyanates, phenol, xylene, toluene, formaldehyde, furfuryl alcohol), and three from urine samples (aniline, o-toluidine and

PAHs). Air samples were analysed for workers performing nine tasks - moulding, core making, furnace work, casting, knockout, finishing (i.e. burning/cutting/gouging), shot blasting, fettling and welding. The urine samples were analysed for workers performing NDT (aniline and o-toluidine) and moulding, core making, knockout, finishing (i.e. burning/cutting/gouging) and welding (PAHs).

Air and BM results with a high degree of uncertainty (i.e. air sample pump flow rates outside recommended values, and low / high creatinine for urine samples) were excluded from the data set. The data were then broken down by work task, site and level of automation per task (to illustrate the effect of automation on exposure): see Section 3.3 (Findings); Tables 2 to 17 and Box plots 1 to 14, Appendix 9.

3. FINDINGS

3.1 FOUNDRY TYPES VISITED

Fourteen foundries were visited during the project. From the original list of 15 combinations of foundry type and binder system, the following were covered:

- Iron foundry, jobbing, greensand
- Steel foundry, jobbing, greensand
- Iron or steel foundry, furan binder with BSA catalyst
- Iron or steel foundry, furan binder without BSA catalyst
- Iron foundry, urethane binder
- Steel foundry, urethane binder
- Aluminium foundry, urethane binder
- Iron or steel foundry, alkali phenolic binder
- Aluminium foundry, alkali phenolic binder

In addition, the visits also covered:

- Iron and steel foundry, sodium silicate binder
- Aluminium die casting
- Iron die casting

One foundry visited used a water mist suppression system to control dust exposures. The efficacy of this system as a control measure was assessed during a second visit and this is reported separately in section 3.12.

An iron foundry was visited to assess what effect the substitution of BSA catalyst by XSA would have on benzene exposures during casting. In 2011 some workers at this foundry had exposures to benzene greater than the GB WEL when casting. At the time they were using BSA but had since then switched to XSA. These findings are reported in section 3.12. No occupational hygiene questionnaires were completed for this visit.

3.2 COSHH RISK ASSESSMENTS

Three foundries did not have COSHH risk assessments at the time of their visit. One completed an assessment during the writing of their report but this needed more detail and information to be suitable and sufficient. Another was in the process of employing a consultant to implement a new health and safety system which would include COSHH risk assessments. Advice was given in site visit reports.

For the other foundries, assessments needed more information / detail. How much was needed varied. Four were in the process of reviewing their systems and re-writing all their assessments. One foundry had employed an external consultant to advise them on health and safety matters. This consultant had written their COSHH risk assessment but it needed a lot of extra detail in order to be suitable and sufficient. Again, advice was given in the site visit reports.

3.3 WORK TASKS, EXPOSURE CONTROLS AND EXPOSURES

Each part of the foundry process is detailed below, along with the exposure controls and a basic summary of the exposure monitoring results. Box plots for key substances broken down by task and automation are in Appendix 9.

Regarding the exposures quoted within this report: In epidemiology, exposure refers to a person's dose. However, in occupational hygiene it refers to potential exposure as it does not take into account the protection afforded by RPE. The occupational hygiene definition is in accordance with draft BS EN 689 (16/30325183 DC), where exposure limits are to be compared with measured exposures outside of RPE, and does not take into account the use and effectiveness of RPE. Where exposure is mentioned in this paper, it refers to the occupational hygiene definition.

3.3.1 Moulding

Most foundries carried out manual moulding. Three foundries had automated systems.

During manual moulding, the first point of worker contact with the sand (greensand or chemically bonded) was at the dispense point of the mixer. The sand was compacted into the mould box and around the pattern either by hand or rod. Inhalation exposure to the sand mixture occurred:

- When using compressed air to blow off loose sand from prepared moulds. This re-suspends sand particles in the airborne phase.
- When manually compacting the sand into the patterns. Workers' heads (and hence breathing zones) were often close to the sand mixture as it was dispensed into the mould box.

Dermal exposure to the chemicals (some of which are known skin sensitisers) within the sand mixture could occur if:

- Tools (for example, rods) were not used to provide a safe-working distance between the sand mixture and the skin.
- No gloves or incorrect gloves were worn.

In smaller foundries, manual moulding was typically done in open areas alongside other processes such as casting and cooling. Larger foundries had more space and room to segregate processes, therefore minimising numbers of other workers in the vicinity.

Two foundries had automated systems, termed vertical moulding lines, which mould, cast and knockout. These were operated with minimal operator contact with greensand and fumes from casting. Castings exited the line after the knockout stage. One line had leaking seals leading to the potential for inhalation exposure to particulate (evidenced by an exposure to inhalable FFP greater than the WEL). These were large, automated systems which required a lot of space.

Exposure controls

One foundry had an enclosed, automated machine for greensand moulds (termed a 'mould master'), with no operator contact with the sand until it had been compacted into the mould box.

Engineering controls consisted mainly of forced mechanical general ventilation i.e. roof fans / vents (seven foundries). The remaining foundries relied upon open doors to aid air movement and dilution. LEV was not commonplace for moulding and was only present at two foundries in the form of fixed captor hoods at the mixer dispense point. LEV use, design and maintenance are discussed in further detail in section 3.6.

Typical PPE consisted of chemical protective gloves (four foundries), or general purpose gloves (seven foundries) and coveralls (10 foundries). Disposable RPE was worn at four foundries and a powered RPE hood was worn at one foundry due to worker preference. PPE suitability, use and maintenance are discussed in further detail in section 3.8.

Exposures

Summary exposure data for manual and automated moulding are presented in Tables 2 and 3 (see also box plots 1 – 14 in Appendix 9).

Table 2 8-hr TWA exposures to key substances during manual moulding

Substance	Exposure Limit	No. Samples	Exposures (mg/m^3 unless otherwise stated)		No. > Exposure Limit	No. with	
			Median	Max		LEV	RPE
RCS	0.1 mg/m^3	31	0.020	0.14	1	7	3
Respirable FFP or dust*	4 mg/m^3	31	0.45	1.6	0	7	3
Inhalable FFP or dust*	10 mg/m^3	35	6.0	22	11	7	3
Chromium	0.5 mg/m^3	35	0.0025	0.080	0	7	3
Lead	0.15 mg/m^3**	35	0.0030	0.089	0	4	2
Manganese	0.5 mg/m^3	35	0.0090	0.048	0	7	3
Nickel	0.5 mg/m^3	35	0.0030	0.040	0	7	3
Benzene	1 ppm	47	0.10 ppm	0.39 ppm	0	8	1
Isocyanates	0.02 mg/m^3	5	0.0012	0.0028	0	1	0
Phenol	2 ppm	17	0.19 ppm	1.7 ppm	0	4	1
Xylene	50 ppm	29	0.030 ppm	1.5 ppm	0	7	1
Toluene	50 ppm	47	0.060 ppm	50 ppm	0	8	1
Formaldehyde	2.5 mg/m^3	32	0.12	0.39	0	4	0
Furfuryl alcohol	none	15	0.050 ppm	0.79 ppm	N/A	7	1

* - FFP (from iron and steel) has WELs of 10 mg/m^3 (inhalable dust) and 4 mg/m^3 (respirable dust). Particulate generated from non-ferrous metals becomes subject to the COSHH Regulations 2002 (as amended) at concentrations in air exceeding 10 mg/m^3 (inhalable dust) and 4 mg/m^3 (respirable dust).

** - lead is subject to the Control of Lead at Work (CLAW) Regulations 2002 and has an Occupational Exposure Limit (OEL) rather than a WEL.

All median exposures were less than the relevant exposure limits. Approximately 30 % of the inhalation exposures to inhalable FFP and dust exceeded 10 mg/m^3 (the concentration at which inhalable dust becomes subject to the COSHH Regulations 2002 (as amended)), LEV was not present and RPE was not worn. One RCS exposure exceeded the WEL (LEV was present and RPE was worn), one lead exposure exceeded 0.075 mg/m^3 (50% of the OEL) and is classed as significant exposure under the CLAW Regulations 2002 (LEV was not present and RPE was not worn). One toluene exposure was at the WEL of 50 ppm (LEV was present and RPE was worn).

Table 3 8-hr TWA inhalation exposures to key substances during automated moulding

Substance	Exposure Limit	No. Samples	Exposures (mg/m^3 unless otherwise stated) Median	Max	No. > Exposure Limit	No. with LEV	RPE
RCS	0.1 mg/m^3	6	0.019	0.065	0	4	0
Respirable FFP or dust*	4 mg/m^3	6	0.42	0.85	0	4	0
Inhalable FFP or dust*	10 mg/m^3	6	4.6	15	1	4	0
Chromium	0.5 mg/m^3	6	0.0040	0.01	0	4	0
Lead	0.15 mg/m^3**	6	0.0065	0.025	0	4	0
Manganese	0.5 mg/m^3	6	0.0080	0.029	0	4	0
Nickel	0.5 mg/m^3	6	0.025	0.040	0	4	0
Benzene	1 ppm	6	0.050 ppm	0.10 ppm	0	2	0
Isocyanates	0.02 mg/m^3	0	-	-	-	-	-
Phenol	2 ppm	6	0.10 ppm	0.17 ppm	0	2	0
Xylene	50 ppm	0	-	-	-	-	-
Toluene	50 ppm	6	0.050 ppm	0.050 ppm	0	2	0
Formaldehyde	2.5 mg/m^3	2	0.050	0.060	0	0	0
Furfuryl alcohol	None	0	-	-	-	-	-

* - FFP (from iron and steel) has WELs of 10 mg/m^3 (inhalable dust) and 4 mg/m^3 (respirable dust). Particulate generated from non-ferrous metals becomes subject to the COSHH Regulations 2002 (as amended) at concentrations in air exceeding 10 mg/m^3 (inhalable dust) and 4 mg/m^3 (respirable dust).

** - lead is subject to the CLAW Regulations 2002 and has an OEL rather than a WEL.

All median exposures were less than the relevant exposure limits, with only one exposure (inhalable FFP) exceeding its WEL. This worker was at the vertical moulding line with leaking seals (mentioned previously). LEV was present and RPE was not worn.

Air sampling for PAHs was carried out on six manual mould makers in the first three visits. There is no WEL with which to compare the results, but they were found to be in agreement with previous HSE cross-industry research[8]. Air sampling was discontinued after these three visits with the reliance being placed on BM instead to identify exposures for the remaining visits. The BM results from all foundries were within the range for those with no occupational exposure (up to 0.4 µmol/mol creatinine) with the exception of two (manual moulding), which were slightly higher, but significantly less than the BMGV of 4 µmol/mol creatinine. See Table 18, section 3.4 for all PAH BM results.

3.3.2 Core making

Core making was carried out manually using the same mixer type as moulds or in enclosed automated systems known as either hot or cold boxes. Occasionally, finer or virgin sand was used.

For manual core making, as with moulding, the first potential for inhalation exposure to the sand mixture would be at the dispense point of the mixer when packing the sand into the core box. Dermal exposure to the binder chemicals could occur if the worker was in direct contact with the sand mixture (e.g. no tools used) with either no or incorrect gloves worn. Compressed air was not used to blow down cores. Rough edges on the cores were typically sanded down by hand or removed by knife. There would be some potential for inhalation exposure to dust, but as this was intermittent and took seconds this would be minimal.

When making cores using automated hot or cold box systems, operators had no contact with the sand mixture until the cores were finished. These systems were usually extracted and were more enclosing than those recommended in the COSHH Essentials direct advice sheet FD5 (see Section 3.6 for more details).

Manual core making was typically done in open areas of the foundry near other process such as casting and cooling and located (though not always) alongside moulding. Hot / cold box core making was usually segregated in another part of the foundry.

Six foundries used both manual and automated methods, six carried out manual core making and one foundry used the core box method only.

Exposure controls

Engineering controls were applied to manual core making at three foundries; one set their cores in a booth and the other two had captor hoods at the dispense point. As with moulding, most relied upon forced mechanical general ventilation. LEV use, design and maintenance are discussed in further detail in section 3.6.

Typical PPE consisted of chemical protective gloves (four foundries), with general purpose gloves worn at the remaining nine foundries, coveralls at eight foundries and optional at another and RPE optional at two foundries. PPE suitability, use and maintenance are discussed in further detail in section 3.8.

Exposures

Summary exposure data for manual and automated core making are presented in Tables 4 and 5 (see also box plots 1 – 14 in Appendix 9).

Table 4 8-hr TWA exposures to key substances during manual core making

Substance	Exposure limit	No. Samples	Exposures (mg/m^3 unless otherwise stated)		No. > Exposure Limit	No. with	
			Median	Max		LEV	RPE
RCS	0.1 mg/m^3	10	0.013	0.11	1	2	0
Respirable FFP or dust*	4 mg/m^3	11	0.28	0.79	0	2	0
Inhalable FFP or dust*	10 mg/m^3	12	4.0	7.2	0	2	0
Chromium	0.5 mg/m^3	12	0.0050	0.020	0	2	0
Lead	0.15 mg/m^3**	12	0.0035	0.0070	0	2	0
Manganese	0.5 mg/m^3	12	0.0050	0.021	0	2	0
Nickel	0.5 mg/m^3	12	0.0018	0.020	0	2	0
Benzene	1 ppm	15	0.030 ppm	0.27 ppm	0	3	0
Isocyanates	0.02 mg/m^3	2	0.0012	0.0017	0	1	0
Phenol	2 ppm	3	0.12 ppm	0.28 ppm	0	0	0
Xylene	50 ppm	9	0.050 ppm	0.07 ppm	0	3	0
Toluene	50 ppm	15	0.030 ppm	0.57 ppm	0	3	0
Formaldehyde	2.5 mg/m^3	15	0.080	0.35	0	3	0
Furfuryl alcohol	none	7	0.0050 ppm	1.15 ppm	-	1	0

* - FFP (from iron and steel) has WELs of 10 mg/m^3 (inhalable dust) and 4 mg/m^3 (respirable dust). Particulate generated from non-ferrous metals becomes subject to the COSHH Regulations 2002 (as amended) at concentrations in air exceeding 10 mg/m^3 (inhalable dust) and 4 mg/m^3 (respirable dust).

** - lead is subject to the CLAW Regulations 2002 and has an OEL rather than a WEL.

All median exposures were less than the relevant exposure limits. One RCS exposure slightly exceeded the WEL (LEV was not present and RPE was not worn).

Table 5 8-hr TWA exposures to key substances during automated core making

Substance Exposure Limit	Exposure limit	No. Samples	Exposures (mg/m^3 unless otherwise stated)		No. > Exposure Limit	No. with	
			Median	Max		LEV	RPE
RCS	0.1 mg/m^3	9	0.020	0.035	0	2	0
Respirable FFP or dust*	4 mg/m^3	10	0.29	0.82	0	2	0
Inhalable FFP or dust*	10 mg/m^3	13	2.7	11	1	5	0
Chromium	0.5 mg/m^3	13	0.0020	0.004	0	5	0
Lead	0.15 mg/m^3**	13	0.0030	0.0030	0	5	0
Manganese	0.5 mg/m^3	13	0.0060	0.050	0	5	0
Nickel	0.5 mg/m^3	13	0.0025	0.0060	0	5	0
Benzene	1 ppm	18	0.050 ppm	0.30 ppm	0	5	0
Isocyanates	0.02 mg/m^3	4	0.0023	0.0062	0	1	0
Phenol	2 ppm	18	0.055 ppm	0.80 ppm	0	5	0
Xylene	50 ppm	6	0.050 ppm	0.20 ppm	0	3	0
Toluene	50 ppm	18	0.085 ppm	7.4 ppm	0	5	0
Formaldehyde	2.5 mg/m^3	2	0.060	0.080	0	0	0
Furfuryl alcohol	none	5	0.050 ppm	0.10 ppm	-	3	0

* - FFP (from iron and steel) has WELs of 10 mg/m^3 (inhalable dust) and 4 mg/m^3 (respirable dust). Particulate generated from non-ferrous metals becomes subject to the COSHH Regulations 2002 (as amended) at concentrations in air exceeding 10 mg/m^3 (inhalable dust) and 4 mg/m^3 (respirable dust).

** - lead is subject to the CLAW Regulations 2002 and has an OEL rather than a WEL.

All median exposures were less than the relevant exposure limits. One inhalable FFP / dust exposure exceeded 10 mg/m^3 (the concentration at which inhalable dust becomes subject to the COSHH Regulations 2002 (as amended)), LEV was not present and RPE was not worn. Exposure levels for automated and manual core making exposures were comparable.

All BM PAHs results were within the range for those with no occupational exposure (up to 0.4 µmol/mol creatinine). See Table 18, section 3.4 for all PAH BM results.

3.3.3 Furnace work

Most foundries (11) had dedicated furnace workers who worked at the furnace for the majority of their shift (though some would also help with casting). Their job was to load the furnace with metal, wait for it to melt, take samples for quality control tests, make additions if required and remove the crust (slag) on top of the molten metal.

In five smaller foundries, furnaces were in the same vicinity as other tasks such as moulding, core making, casting and cooling. Some of the larger foundries had either separate areas or were of such size that partial segregation was possible. All furnaces were manually operated.

Exposure controls

One foundry used worker rotation; after four hours at the furnace the worker would change jobs. It was not made clear why, but this would have served to reduce exposures to metal fume for that individual.

Six foundries had dedicated extraction at the furnaces: five used canopy hoods and one lid extraction. A further six relied upon forced mechanical general ventilation, either roof fans (five foundries) or wall-mounted extraction fans behind each furnace (one foundry). One foundry had no LEV and no forced mechanical ventilation. Visual inspection showed that LEV hoods at furnaces appeared to be effective at controlling fume but that this effectiveness was often compromised when the furnace was tilted to pour its contents, as the hoods were often not moveable. LEV use, design and maintenance are discussed in further detail in section 3.6.

PPE was worn principally to protect against heat and molten metal. This was in the form of coveralls or jackets and trousers (12 foundries) and gloves (all foundries). One foundry did not supply coveralls to their furnace worker. RPE was worn at five foundries and available for use at a further two. Types were either disposable or re-usable. PPE suitability, use and maintenance are discussed in further detail in section 3.8.

Exposures

Summary exposure data for manual furnace work are presented in Table 6. There was no automation of furnaces at any of the foundries visited (see also box plots 1 – 14 in Appendix 9).

Table 6 8-hr TWA exposures to key substances during furnace work

Substance	**Exposure limit**	**No. Samples**	**Exposures (mg/m^3 unless otherwise stated)**		**No. > Exposure limit**	**No. with**	
			Median	**Max**		**LEV**	**RPE**
RCS	0.1 mg/m^3	20	0.012	0.070	0	11	4
Respirable FFP or dust*	4 mg/m^3	20	0.48	1.2	0	11	4
Inhalable FFP or dust*	10 mg/m^3	38	4.2	28	3	19	6
Chromium	0.5 mg/m^3	36	0.0060	0.23	0	19	6
Lead	0.15 mg/m^3**	36	0.0050	0.28	1	19	6
Manganese	0.5 mg/m^3	36	0.032	0.37	0	19	6
Nickel	0.5 mg/m^3	38	0.0030	0.071	0	19	6
Benzene	1 ppm	14	0.040 ppm	0.19 ppm	0	6	6
Isocyanates	0.02 mg/m^3	1	0.00011	0.00011	0	1	1
Phenol	2 ppm	4	0.12 ppm	0.16 ppm	0	0	0
Xylene	50 ppm	13	0.030 ppm	0.050 ppm	0	6	6
Toluene	50 ppm	14	0.030 ppm	0.22 ppm	0	6	6
Formaldehyde	2.5 mg/m^3	7	0.040	0.060	0	3	3
Furfuryl alcohol	none	5	0.0050 ppm	0.060 ppm	-	0	3

* - FFP (from iron and steel) has WELs of 10 mg/m^3 (inhalable dust) and 4 mg/m^3 (respirable dust). Particulate generated from non-ferrous metals becomes subject to the COSHH Regulations 2002 (as amended) at concentrations in air exceeding 10 mg/m^3 (inhalable dust) and 4 mg/m^3 (respirable dust).

** - lead is subject to the CLAW Regulations 2002 and has an OEL rather than a WEL.

Three workers' exposures to inhalable FFP / dust exceeded 10 mg/m^3 (the concentration at which inhalable dust becomes subject to the COSHH Regulations 2002 (as amended)). One of these also had an exposure to lead greater than the exposure limit. No lead was cast at this foundry on the day of the visit. This exposure occurred from the furnace worker sweeping up around the furnaces, as previous work had included leaded gun metal (see also section 3.5). Neither LEV nor RPE was used / worn. Of the other two inhalable FFP / dust exposures greater than 10 mg/m^3, one also carried out some moulding during their shift. LEV was present over the furnace, and visual inspection showed it to be effective in controlling fume. RPE was also worn, which would have reduced exposure further. The third worked at a foundry where RPE was optional for furnace work and did not wear RPE. Here, not all workers face-fit tested. All other exposures were less than the relevant exposure limits.

BM for PAHs was carried out when furnace workers carried out other tasks such as mould making, casting or knockout. All results except two were within the range for those with no occupational exposure (up to 0.4 µmol/mol creatinine). The two that exceeded this value were significantly less than the BMGV of 4 µmol/mol creatinine. See Table 18, section 3.4 for all PAH BM results.

3.3.4 Casting

Manual casting was carried out at 13 foundries (this included the foundry that had substituted BSA for XSA). A vessel containing molten metal was operated either by overhead crane or manual lifting device and emptied into prepared mould boxes. Fume was seen to come from the sand moulds while casters were in the immediate vicinity. Due to thermal lift, this fume tended to rise upwards toward the foundry roof.

At most foundries, casting was carried out within the open foundry area, near to moulding areas. One foundry carried out casting at night which meant that only those workers casting were potentially exposed to the fume. Another carried out casting at the end of the shift leaving the castings to cool overnight with no-one in the vicinity.

Automated casting was carried out at one of the foundries with a vertical moulding line, resulting in no contact of the operator with molten metal fume. The other foundry with one of these lines had an operator positioned at the casting point, tipping the ladle into the moulds as they progressed down the line.

There was one foundry that (in addition to its traditional sand foundry areas) carried out some casting on vertical spin beds (pipe manufacture). The ladle containing molten metal was operated by overhead crane and its contents tipped onto the spin bed. The operator was outside of this enclosed area. No sand was present.

Exposure controls

Worker rotation was in place at one foundry as a worker had previously been exposed to carbon monoxide (CO) greater than the WEL. Job rotation occurred every three hours. Another foundry used worker rotation in one of its areas, working one hour casting and one hour carrying out other duties. No reasons were given for this but it would have served to reduce individual exposures.

All except three foundries relied on forced mechanical general ventilation rather than LEV and one site had no LEV or forced mechanical general ventilation, but employed a water mist suppression system to minimise dust / fume during castings in one area. This is discussed in section 3.12. LEV was present at two foundries carrying out manual casting (one of which was the manual casting at the vertical casting moulding line). The automated vertical moulding lines were extracted. LEV use, design and maintenance are discussed in further detail in section 3.6.

For manual casting, PPE consisted of coveralls / jackets / trousers (11 foundries), gloves (12 foundries), RPE (four foundries) and visors (13 foundries). Protective clothing was not worn at two foundries, when casting. One foundry did not supply it, and at the other it was available, but not seen to be worn. PPE suitability, use and maintenance are discussed in further detail in section 3.8.

Exposures

Summary exposure data for manual and automated casting are presented in Tables 7 and 8 (see also box plots 1 – 14 in Appendix 9).

Table 7 8-hr TWA exposures to key substances during manual casting

Substance	**Exposure limit**	**No. Samples**	**Exposures (mg/m^3 unless otherwise stated)**		**No. > Exposure Limit**	**No. with**	
			Median	**Max**		**LEV**	**RPE**
RCS	0.1 mg/m^3	12	0.010	0.090	0	2	3
Respirable FFP or dust*	4 mg/m^3	12	0.59	1.7	0	2	3
Inhalable FFP or dust*	10 mg/m^3	11	6.6	22	5	2	3
Chromium	0.5 mg/m^3	10	0.012	0.040	0	2	3
Lead	0.15 mg/m^3**	10	0.0055	0.010	0	2	3
Manganese	0.5 mg/m^3	10	0.031	0.051	0	2	3
Nickel	0.5 mg/m^3	11	0.0050	0.030	0	2	3
Benzene	1 ppm	15	0.10 ppm	0.52 ppm	0	1	0
Isocyanates	0.02 mg/m^3	1	0.0049	0.0049	0	1	0
Phenol	2 ppm	5	0.050 ppm	0.30 ppm	0	1	0
Xylene	50 ppm	10	0.14 ppm	0.84 ppm	0	1	0
Toluene	50 ppm	15	0.050 ppm	3.2 ppm	0	1	0
Formaldehyde	2.5 mg/m^3	11	0.15	0.65	0	0	0
Furfuryl alcohol	none	6	0.050 ppm	0.10 ppm	-	1	0

* - FFP (from iron and steel) has WELs of 10 mg/m^3 (inhalable dust) and 4 mg/m^3 (respirable dust). Particulate generated from non-ferrous metals becomes subject to the COSHH Regulations 2002 (as amended) at concentrations in air exceeding 10 mg/m^3 (inhalable dust) and 4 mg/m^3 (respirable dust).

** - lead is subject to the CLAW Regulations 2002 and has an OEL rather than a WEL.

All median exposures were less than the relevant exposure limits; however, approximately half of the exposures to inhalable FFP / dust exceeded 10 mg/m^3 (the concentration at which inhalable dust becomes subject to the COSHH Regulations 2002 (as amended)). Of these LEV was present at one with RPE also worn and at another RPE was provided. The remaining three foundries had neither LEV nor RPE available for casting. Some RCS exposures approached the WEL.

Table 8 8-hr TWA exposures to key substances during automated casting

Substance	Exposure limit	No. Samples	Exposures (mg/m^3 unless otherwise stated)		No. > Exposure limit	No. with	
			Median	Max		LEV	RPE
RCS	0.1 mg/m^3	4	0.045	0.060	0	4	1
Respirable FFP or dust*	4 mg/m^3	4	0.61	0.92	0	4	1
Inhalable FFP or dust*	10 mg/m^3	4	3.8	7.5	0	3	0
Chromium	0.5 mg/m^3	4	0.010	0.020	0	3	0
Lead	0.15 mg/m^3**	4	0.0045	0.010	0	3	0
Manganese	0.5 mg/m^3	4	0.025	0.050	0	3	0
Nickel	0.5 mg/m^3	4	0.0075	0.020	0	3	0
Benzene	1 ppm	1	0.050 ppm	0.050 ppm	0	1	0
Isocyanates	0.02 mg/m^3	0	-	-	-	-	-
Phenol	2 ppm	1	0.050 ppm	0.050 ppm	0	1	0
Xylene	50 ppm	1	0.050 ppm	0.050 ppm	0	1	0
Toluene	50 ppm	1	14 ppm	14 ppm	0	1	0
Formaldehyde	2.5 mg/m^3	0	-	-	-	-	-
Furfuryl alcohol	none	1	0.050 ppm	0.050 ppm	-	1	0

* - FFP (from iron and steel) has WELs of 10 mg/m^3 (inhalable dust) and 4 mg/m^3 (respirable dust). Particulate generated from non-ferrous metals becomes subject to the COSHH Regulations 2002 (as amended) at concentrations in air exceeding 10 mg/m^3 (inhalable dust) and 4 mg/m^3 (respirable dust).

** - lead is subject to the CLAW Regulations 2002 and has an OEL rather than a WEL.

All exposures were less than the relevant exposure limits. Fully automated casting was carried out at one site and some automation carried out at another and as such, the dataset is small. From the data in Tables 7 and 8, it can be seen that the majority of exposures were comparable between automated and manual casting with the exception of benzene (exposure greater for manual), and toluene (exposure greater for automated). Assumptions cannot be made with certainty as to whether automation reduces exposure due to the small dataset.

SO_2, NO and NO_2 background levels during casting and cooling were of little concern, however average CO levels over the majority of the shift approached the 8-hr TWA WEL of 30 ppm (at one foundry this level was exceeded). There were also spikes in concentrations that were significantly higher than 30 ppm.

Air sampling for PAHs was carried out on six casters (manual) in the first three visits. Again the results were found to be in agreement with previous HSE cross-industry research and so reliance was placed on BM to identify exposures for the remaining visits. All BM results except one (manual), were within the range for those with no occupational exposure (up to 0.4 µmol/mol creatinine). The one that exceeded this was significantly less than the BMGV of 4 µmol/mol creatinine. See Table 18, section 3.4 for all PAH BM results.

3.3.5 Knockout / shakeout

This was done by both manual and automated methods, on hot and cold castings. There was the potential for significant amounts of dust and fume to be released, especially if the castings were still hot. Some foundries used different methods dependent upon the casting.

Manual methods included:

- Removing the sand using a small pneumatic drill (one foundry).
- Lifting the mould box with an excavator or forklift truck (FLT) and letting it fall on the floor (three foundries).
- Removing the sand with a sledgehammer (one foundry).
- Using a pecker attachment on a telehandler to chip away at the sand (one foundry).

Some foundries used a combination of the methods above.

Semi-automated and automated systems were often connected to the sand reclamation process whereupon the lumps were broken down. These included:

- Putting the mould into a booth with a vibrating grille at the base, the vibratory action removed the sand and transferred it to sand reclaim (six foundries).
- Fully automated and enclosed knockout within the vertical casting lines (two foundries). For these, the worker was at the exit end of the process, which should have minimised their exposure potential.

None of the excavators, FLT or telehandlers were fitted with in-cab filtration.

Exposure controls

Knockout (including automated) was segregated at eight foundries. Segregation by distance was carried out at four foundries and by time (end of shift or at night) at four foundries. Segregation minimises the number of people in the vicinity.

Ten foundries had dedicated LEV at knockout (though two of these also had other knockout areas with no LEV). These were the semi-automated and automated systems mentioned above. LEV use, design and maintenance are discussed in further detail in section 3.6.

PPE worn during knockout / shakeout consisted of coveralls (10 foundries), gloves (12) and some form of RPE (seven foundries; this included optional wear (one foundry), and for emergencies (one foundry). One foundry supplied nuisance dust masks. Three foundries did not provide coveralls to their knockout workers. PPE suitability, use and maintenance are discussed in further detail in section 3.8.

Exposures

Summary exposure data for manual, semi-automated and automated knockout are presented in Tables 9, 10 and 11 (see also box plots 1 – 14 in Appendix 9).

Table 9 8-hr TWA exposures to key substances during manual knockout

Substance	Exposure limit	No. Samples	Exposures (mg/m^3 unless otherwise stated)		No. > Exposure limit	No. with	
			Median	Max		LEV	RPE
RCS	0.1 mg/m^3	8	0.027	0.090	0	3	3
Respirable FFP or dust*	4 mg/m^3	8	0.77	1.2	0	3	3
Inhalable FFP or dust*	10 mg/m^3	8	4.6	32	1	3	3
Chromium	0.5 mg/m^3	8	0.0050	0.010	0	3	3
Lead	0.15 mg/m^3**	8	0.0050	0.015	0	3	3
Manganese	0.5 mg/m^3	9	0.005	0.15	0	3	3
Nickel	0.5 mg/m^3	8	0.0030	0.0080	0	3	3
Benzene	1 ppm	3	0.045 ppm	0.99 ppm	0	1	3
Isocyanates	0.02 mg/m^3	0	-	-	-	-	-
Phenol	2 ppm	2	0.43 ppm	0.83 ppm	0	1	1
Xylene	50 ppm	1	0.010 ppm	0.010 ppm	0	0	1
Toluene	50 ppm	3	0.14 ppm	0.15 ppm	0	1	3
Formaldehyde	2.5 mg/m^3	4	0.095	0.22	0	2	2
Furfuryl alcohol	none	2	0.023 ppm	0.045 ppm	-	1	1

* - FFP (from iron and steel) has WELs of 10 mg/m^3 (inhalable dust) and 4 mg/m^3 (respirable dust). Particulate generated from non-ferrous metals becomes subject to the COSHH Regulations 2002 (as amended) at concentrations in air exceeding 10 mg/m^3 (inhalable dust) and 4 mg/m^3 (respirable dust).

** - lead is subject to the CLAW Regulations 2002 and has an OEL rather than a WEL.

All median exposures were below the relevant exposure limits, however one inhalable FFP / dust exposure exceeded 10 mg/m^3 (the concentration at which inhalable dust becomes subject to the COSHH Regulations 2002 (as amended)), LEV was not present and RPE was not worn. One benzene exposure was at the WEL (LEV was not present, RPE was provided but offered protection against particulate only). Some RCS exposures approached the WEL.

Table 10 8-hr TWA exposures to key substances during semi-automated knockout

Substance	Exposure limit	No. Samples	Exposures (mg/m^3 unless otherwise stated)		No. > Exposure limit	No. with	
			Median	Max		LEV	RPE
RCS	0.1 mg/m^3	1	0.010	0.010	0	1	1
Respirable FFP or dust*	4 mg/m^3	1	0.19	0.19	0	1	1
Inhalable FFP or dust*	10 mg/m^3	3	7.1	10	1	3	2
Chromium	0.5 mg/m^3	3	0.0020	0.010	0	3	2
Lead	0.15 mg/m^3**	3	0.004	0.068	0	3	2
Manganese	0.5 mg/m^3	3	0.020	0.020	0	3	2
Nickel	0.5 mg/m^3	3	0.0030	0.0050	0	3	2
Benzene	1 ppm	3	0.090 ppm	0.12 ppm	0	3	3
Isocyanates	0.02 mg/m^3	0	-	-	-	-	-
Phenol	2 ppm	0	-	-	-	-	-
Xylene	50 ppm	2	0.035 ppm	0.060 ppm	0	2	2
Toluene	50 ppm	3	0.020 ppm	0.060 ppm	0	3	3
Formaldehyde	2.5 mg/m^3	2	0.14	0.23	0	2	2
Furfuryl alcohol	none	1	0.0050 ppm	0.0050 ppm	N/A	1	1

* - FFP (from iron and steel) has WELs of 10 mg/m^3 (inhalable dust) and 4 mg/m^3 (respirable dust). Particulate generated from non-ferrous metals becomes subject to the COSHH Regulations 2002 (as amended) at concentrations in air exceeding 10 mg/m^3 (inhalable dust) and 4 mg/m^3 (respirable dust).

** - lead is subject to the CLAW Regulations 2002 and has an OEL rather than a WEL.

All median exposures were less than the relevant exposure limits with one inhalable FFP / dust exposure being 10 mg/m^3 (the concentration at which inhalable dust becomes subject to the COSHH Regulations 2002 (as amended)), LEV was present and RPE was worn.

Table 11 8hr-TWA exposures to key substances during automated knockout

Substance	Exposure limit	No. Samples	Exposures (mg/m^3 unless otherwise stated)	No. > Exposure limit	No. with LEV	No. with RPE
RCS	0.1 mg/m^3	1	0.080	0	1	0
Respirable FFP or dust*	4 mg/m^3	1	0.31	0	1	0
Inhalable FFP or dust*	10 mg/m^3	1	5.5	0	1	0
Chromium	0.5 mg/m^3	1	0.0040	0	1	0
Lead	0.15 mg/m^3**	1	0.0020	0	1	0
Manganese	0.5 mg/m^3	1	0.021	0	1	0
Nickel	0.5 mg/m^3	1	0.0025	0	1	0
Benzene	1 ppm	0	-	-	-	-
Isocyanates	0.02 mg/m^3	0	-	-	-	-
Phenol	2 ppm	0	-	-	-	-
Xylene	50 ppm	0	-	-	-	-
Toluene	50 ppm	0	-	-	-	-
Formaldehyde	2.5 mg/m^3	0	-	-	-	-
Furfuryl alcohol	none	0	-	-	-	-

* - FFP (from iron and steel) has WELs of 10 mg/m^3 (inhalable dust) and 4 mg/m^3 (respirable dust). Particulate generated from non-ferrous metals becomes subject to the COSHH Regulations 2002 (as amended) at concentrations in air exceeding 10 mg/m^3 (inhalable dust) and 4 mg/m^3 (respirable dust).

** - lead is subject to the CLAW Regulations 2002 and has an OEL rather than a WEL.

As there was only one sample in the dataset (one worker who was at the exit end of the vertical casting line) conclusions cannot be made as to whether fully automating the knockout processes reduced employee exposure. Median exposures for semi-automated and manual knockout were broadly comparable in Tables 9 and 10. However, the box plots (Appendix 9) imply that for inhalable FFP / dust, semi-automation may have an effect as the maximum exposure and exposure range are lower, though this assumption cannot be made with certainty due to the small dataset.

Levels of SO_2, NO, NO_2 and CO were measured at one foundry. SO_2, NO and NO_2 were of little concern, however the CO level averaged 14 ppm, almost half the WEL.

Air sampling for PAHs was carried out on some knockout workers in the first three visits. Again the results were found to be in agreement with previous HSE cross-industry research and so the reliance was placed on BM to identify exposures. Most BM results were within the range for those with no occupational exposure (up to 0.4 µmol/mol creatinine); there were five (3 manual, 2 automated) which slightly exceeded it, but were significantly less than the BMGV of 4 µmol/mol creatinine. See Table 18, section 3.4 for all PAH BM results.

3.3.6 Sand reclaim

At all foundries except one sand reclaim was closely tied in with the knockout process and was not carried out by dedicated members of staff. At these foundries sand reclamation was fully enclosed and extracted, and so there was no operator exposure.

The exception was one foundry that carried out manually-operated mechanical greensand reclamation. Sand lumps from knockout were fed into a hopper by shovel or sweeping where they were broken down into granules via a series of belts and tools. These granules (ready to be used again) were sprayed out of the back of the machine against the wall of the foundry. This would significantly increase RCS exposure potential for anyone in the vicinity. LEV was not used for this task and RPE was not worn. Task-specific exposure monitoring when carrying out sand reclaim in this way was not carried out, therefore there are no results tables. The foundry manager indicated during the visit that they would discontinue use of the system.

3.3.7 Shotblasting

Nine foundries carried out shotblasting using fully enclosed and extracted machines, minimising operator contact and exposure.

One foundry used a semi-enclosed and extracted system in which the castings entered an automated enclosure via plastic strip curtains.

One foundry carried out shotblasting manually; this involved an operator working in an extracted room blasting off residual sand using a lance.

A further two foundries used a mixture of techniques, one using both a semi-enclosure as described above along with a fully extracted and enclosed system, and the other used a fully enclosed and extracted system and manual techniques as described above.

Exposure controls

Extraction was provided for all shotblasting techniques used. LEV use, design and maintenance are discussed in further detail in section 3.6.

PPE at the foundries carrying out manual shotblasting consisted of gloves, coveralls (all foundries except one) and air-fed RPE. PPE suitability, use and maintenance are discussed in further detail in section 3.8.

Exposures

Summary exposure data for automated shotblasting are presented in Table 12 (see also box plots 1 – 14 in Appendix 9).

Table 12 8-hr TWA exposures to key substances during automated shotblasting

Substance	Exposure limit	No. Samples	Exposures (mg/m^3 unless otherwise stated)		No. > Exposure limit	No. with	
			Median	Max		LEV	RPE
RCS	0.1 mg/m^3	3	0.060	0.13	1	3	3
Respirable FFP or dust*	4 mg/m^3	4	0.83	0.94	0	4	4
Inhalable FFP or dust*	10 mg/m^3	3	5.7	6.6	0	3	2
Chromium	0.5 mg/m^3	3	0.014	0.024	0	3	2
Lead	0.15 mg/m^3**	3	0.0015	0.0015	0	3	2
Manganese	0.5 mg/m^3	3	0.077	0.19	0	3	2
Nickel	0.5 mg/m^3	3	0.021	0.039	0	3	2
Benzene	1 ppm	3	0.060 ppm	0.070 ppm	0	3	2
Isocyanates	0.02 mg/m^3	0	-	-	-	-	-
Phenol	2 ppm	1	0.050 ppm	0.050 ppm	0	1	1
Xylene	50 ppm	3	0.050 ppm	0.58 ppm	0	3	2
Toluene	50 ppm	3	0.025 ppm	0.050 ppm	0	3	2
Formaldehyde	2.5 mg/m^3	2	0.10	0.15	0	2	1
Furfuryl alcohol	none	3	0.050 ppm	0.050 ppm	-	3	2

* - FFP (from iron and steel) has WELs of 10 mg/m^3 (inhalable dust) and 4 mg/m^3 (respirable dust). Particulate generated from non-ferrous metals becomes subject to the COSHH Regulations 2002 (as amended) at concentrations in air exceeding 10 mg/m^3 (inhalable dust) and 4 mg/m^3 (respirable dust).

** - lead is subject to the CLAW Regulations 2002 and has an OEL rather than a WEL.

Median exposures were all less than relevant exposure limits. One exposure measurement for RCS exceeded the WEL (LEV was present and RPE was worn to attenuate exposure).

3.3.8 Fettling

Fettling can be automated or manual. The former was not common and only seen at two foundries. Manual fettling involved the use of high energy power tools such as angle grinders or grinding wheels. This had the potential to create significant amounts of dust containing metals and RCS. Fettling tended to be segregated from moulding, core making and casting areas.

Exposure controls

Exposure controls (both engineering and PPE) were in use at most of the foundries. The majority of fettling at one foundry was done by a remotely operated automatic system. Another foundry carried out mostly manual fettling with some cutting done in an enclosed, automated system. All others carried out manual fettling only.

Most manual fettling was carried out under LEV. Various LEV hood types were used. These included: partial enclosures, receiving hoods, downdraught benches and captor hoods. One foundry did not use LEV and another two carried out some fettling with no LEV present (though forced mechanical general ventilation was present at one of these). LEV use, design and maintenance are discussed in further detail in section 3.6.

PPE consisted of coveralls (10 foundries), gloves (12 foundries), powered RPE (seven foundries), half mask RPE (four foundries) and aprons (eight foundries). Two foundries did not provide coveralls and two foundries did not provide RPE. PPE suitability, use and maintenance are discussed in further detail in section 3.8.

Exposures

Summary exposure data for manual and automated fettling are presented in Tables 13 and 14 (see also box plots 1 – 14 in Appendix 9).

Table 13 8-hr TWA exposures to key substances during manual fettling

Substance	Exposure limit	No. Samples	Exposures (mg/m^3 unless otherwise stated)		No. > Exposure limit	No. with	
			Median	Max		LEV	RPE
RCS	0.1 mg/m^3	39	0.010	0.38	5	28	31
Respirable FFP or dust*	4 mg/m^3	39	0.97	7.3	3	28	31
Inhalable FFP or dust*	10 mg/m^3	41	7.6	86	17	32	34
Chromium	0.5 mg/m^3	41	0.020	7.2	7	32	34
Lead	0.15 mg/m^3**	41	0.0040	0.20	1	32	34
Manganese	0.5 mg/m^3	41	0.040	1.8	4	32	34
Nickel	0.5 mg/m^3	41	0.020	4.07	6	32	34
Benzene	1 ppm	4	0.030 ppm	0.030 ppm	0	4	4
Isocyanates	0.02 mg/m^3	0	-	-	-	-	-
Phenol	2 ppm	2	0.025 ppm	0.040 ppm	0	2	2
Xylene	50 ppm	4	0.030 ppm	0.030 ppm	0	4	4
Toluene	50 ppm	4	0.21 ppm	0.42 ppm	0	4	4
Formaldehyde	2.5 mg/m^3	1	0.050	0.050	0	1	1
Furfuryl alcohol	none	0	-	-	-	-	-

* - FFP (from iron and steel) has WELs of 10 mg/m^3 (inhalable dust) and 4 mg/m^3 (respirable dust). Particulate generated from non-ferrous metals becomes subject to the COSHH Regulations 2002 (as amended) at concentrations in air exceeding 10 mg/m^3 (inhalable dust) and 4 mg/m^3 (respirable dust).

** - lead is subject to the CLAW Regulations 2002 and has an OEL rather than a WEL.

Median exposures were all less than the relevant exposure limits; however, a significant number of exposures exceeded relevant limits / concentrations at which they become a substance hazardous to health. These were:

- RCS (LEV present and RPE worn at four foundries, LEV not present but RPE worn at the fifth foundry),
- Respirable FFP / dust (LEV present and RPE worn at two foundries, LEV not present but RPE worn at the third foundry),
- Inhalable FFP / dust (LEV present and RPE worn at 14 foundries, LEV not present but RPE worn at three foundries),

- Chromium (LEV was present and RPE worn at all seven foundries),
- Lead (LEV was not present but RPE was worn),
- Manganese (LEV was present and RPE worn at three foundries, LEV was not present but RPE worn at the fourth foundry). Two of these were from a foundry casting manganese steel.
- Nickel (LEV was present and RPE worn at all six foundries).

The exposures of 86 mg/m^3 (inhalable FFP), 7.2 mg/m^3 (chromium) and 4.07 mg/m^3 (nickel) in Table 13 were from the same worker. Two of the LEV booths at this foundry had low (<0.2m/s) and uneven face velocities. In addition, these booths were also too small to contain the casting and workers were also seen to be working outside the influence of them.

Table 14 8-hr TWA exposures to key substances during automated fettling

Substance	Exposure limit	No. Samples	Exposures (mg/m^3 unless otherwise stated)		No. > Exposure limit	No. with	
			Median	Max		LEV	RPE
RCS	0.1 mg/m^3	5	0.033	0.046	0	4	2
Respirable FFP or dust*	4 mg/m^3	5	0.37	0.93	0	4	2
Inhalable FFP or dust*	10 mg/m^3	5	2.6	17	1	4	2
Chromium	0.5 mg/m^3	5	0.0040	0.98	1	4	2
Lead	0.15 mg/m^3**	5	0.0020	0.0060	0	4	2
Manganese	0.5 mg/m^3	5	0.014	0.11	0	4	2
Nickel	0.5 mg/m^3	5	0.0025	0.77	1	4	2
Benzene	1 ppm	1	0.030 ppm	0.030 ppm	0	1	1
Isocyanates	0.02 mg/m^3	0	-	-	-	-	-
Phenol	2 ppm	0	-	-	-	-	-
Xylene	50 ppm	1	0.030 ppm	0.030 ppm	0	1	1
Toluene	50 ppm	1	0.030 ppm	0.030 ppm	0	1	1
Formaldehyde	2.5 mg/m^3	0	-	-	-	-	-
Furfuryl alcohol	none	0	-	-	-	-	-

* - FFP (from iron and steel) has WELs of 10 mg/m^3 (inhalable dust) and 4 mg/m^3 (respirable dust). Particulate generated from non-ferrous metals becomes subject to the COSHH Regulations 2002 (as amended) at concentrations in air exceeding 10 mg/m^3 (inhalable dust) and 4 mg/m^3 (respirable dust).

** - lead is subject to the CLAW Regulations 2002 and has an OEL rather than a WEL.

Median exposures were less than relevant exposure limits, however one exposure measurement for inhalable FFP / dust exceeded 10mg/m^3 (the concentration at which inhalable dust becomes subject to the COSHH Regulations 2002 (as amended)), LEV was present and RPE was worn, one chromium exposure exceeded the WEL (LEV was present and RPE was worn), and one nickel exposure exceeded the WEL (LEV was present and RPE was worn).

Automated fettling was not common and hence the dataset was small. A larger sample size would be required before robust conclusions could be made.

3.3.9 Cutting, powder burning and gouging

Cutting and / or powder burning was carried out to remove excess metal from the casting, prior to fettling. Gouging (also carried out with power tools such as grinders) was carried out to remove defects / cracks. In some foundries cutting was incorporated into fettling. Three foundries carried out either cutting, powder burning or gouging as separate tasks to fettling. All three methods could create the potential for significant exposures to metal dust / fume. One foundry used semi-automated plasma cutting, but exposures for this task were not monitored.

Exposure controls

LEV was in the form of extracted booths, either large walk-in systems (worker and casting inside), or smaller booths with the casting either inside or in front of the booth and the work directed into the booth. LEV use, design and maintenance are discussed in further detail in section 3.6.

PPE at all three foundries consisted of coveralls, battery or airfed powered RPE and gloves. PPE suitability, use and maintenance are discussed in further detail in section 3.8.

Exposures

Summary exposure data for manual cutting, burning and gouging are presented in Table 15 (see also box plots 1 – 14 in Appendix 9). There was no automation of this process.

Table 15 8-hr TWA exposures for key substances during manual cutting, burning and gouging

Substance	Exposure limit	No. Samples	Exposures (mg/m^3 unless otherwise stated)		No. > Exposure limit	No. with	
			Median	Max		LEV	RPE
RCS	0.1 mg/m^3	1	0.27	0.27	1	1	1
Respirable FFP or dust*	4 mg/m^3	1	10	10	1	1	1
Inhalable FFP or dust*	10 mg/m^3	2	75	150	1	2	2
Chromium	0.5 mg/m^3	2	8.6	17	1	2	2
Lead	0.15 mg/m^3**	2	0.0050	0.0050	0	2	2
Manganese	0.5 mg/m^3	2	0.38	0.73	1	2	2
Nickel	0.5 mg/m^3	2	4.6	9.2	1	2	2
Benzene	1 ppm	2	0.070 ppm	0.080 ppm	0	2	2
Isocyanates	0.02 mg/m^3	0	-	-	0	0	0
Phenol	2 ppm	0	-	-	0	0	0
Xylene	50 ppm	2	0.010 ppm	0.010 ppm	0	2	2
Toluene	50 ppm	2	0.20 ppm	0.24 ppm	0	2	2
Formaldehyde	2.5 mg/m^3	0	-	-	-	-	-
Furfuryl alcohol	none	0	-	-	-	-	-

* - FFP (from iron and steel) has WELs of 10 mg/m^3 (inhalable dust) and 4 mg/m^3 (respirable dust). Particulate generated from non-ferrous metals becomes subject to the COSHH Regulations 2002 (as amended) at concentrations in air exceeding 10 mg/m^3 (inhalable dust) and 4 mg/m^3 (respirable dust).

** - lead is subject to the CLAW Regulations 2002 and has an OEL rather than a WEL.

Again this was not a large dataset, but of the results obtained, exposure measurements exceeded respective exposure limits for RCS (LEV present and RPE worn), chromium (LEV present and RPE worn), manganese (LEV present and RPE worn), nickel (LEV present and RPE worn) and inhalable and respirable FFP (LEV was present and RPE was worn). There were two BM results for PAHs for this task, both of which were within the range for those with no occupational exposure. (up to 0.4 µmol/mol creatinine). See Table 18, section 3.4 for all PAH BM results.

The exposures of 150 mg/m^3 (inhalable FFP), 10 mg/m^3 (respirable FFP), 0.27 mg/m^3 (RCS), 17 mg/m^3 (chromium) 0.73 mg/m^3 (manganese) and 9.2 mg/m^3 (nickel) in Table 15 were from the same worker. The LEV systems used by this worker were those discussed previously for exposures in Table 13.

3.3.10 Non-destructive testing

This was typically carried out using either dye penetrant (noted at four foundries) or X-rays (noted at one foundry). Two foundries used both techniques. Two foundries did not carry out NDT, one foundry had reportedly not done NDT for a very long time and details were not noted for a further three foundries.

CI Solvent Red 164 is an azo dye with a vivid red colour. It has been suggested that this dye has the potential to metabolise within the body and liberate the aromatic amines, aniline and ortho-toluidine[9]. In response, HSE initiated research that included measuring urinary levels of aniline and ortho-toluidine in NDT workers, including foundry workers. This research showed that urinary levels of these two amines were no higher than those in the general population[10].

Methods of application of dye penetrant during NDT included:

- Aerosol can outside in the open air (one foundry) with the worker wearing RPE and chemical protective gloves (various materials were available).
- Sponge application in one area and low pressure spray gun in another (one foundry). Both methods were carried out under extraction. RPE and chemical protective gloves were worn.
- Spray can with chemical protective gloves and no LEV or RPE.
- Aerosol, no LEV used but RPE and chemical protective gloves worn.
- Brush application so no aerosol generated (one foundry). LEV not needed and no RPE was worn. Chemical protective gloves were used.
- Brush application and also some aerosol can use (one foundry). Both were carried out with no LEV or RPE, nitrile-coated general purpose gloves were worn.

LEV use, design and maintenance are discussed in further detail in section 3.6. PPE suitability, use and maintenance are discussed in further detail in section 3.8.

Results of BM analysis

A summary of the BM results for aniline and o-toluidine is presented in Table 16.

Table 16 BM results for NDT workers

Substance	No. Samples	Concentration (µmol/mol creatinine)		No. > BMGV	No. with		BMGV	Reference range unexposed people
		Median	Max		LEV	RPE		
Aniline	32	2.4	11	0	7[†]	7[†]	~900	<10
o-Toluidine	32	1.2	4.4	-	7[†]	7[†]	-	<5

[†] Information on RPE and LEV usage was not collected for four of the 32 samples.

The median concentrations of both substances were within the reference range for people with no occupational exposure. One aniline result slightly exceeded this value. The BMGV for aniline was not exceeded; there is no guidance value for ortho-toluidine.

3.3.11 Welding

Cracks and faults highlighted by NDT were repaired by welding. The crack would be gouged out as described in section 3.3.9 then sent to the welder to repair. Welding is known to generate significant amounts of fume. Welding fume[11] is internationally classified as possibly carcinogenic to humans (IARC classification group 2B[†]). Although primarily associated with stainless steel welding, this classification is not limited to stainless steel fume. It covers all welding fume.

The constituents of welding fume vary from metal to metal and with techniques used. For example, when welding stainless steel (which contains chromium and nickel) using metal inert gas (MIG), welding fume can contain about 18% chromium but most of it is ‘trivalent’ chromium. Fume from stainless steel manual metal arc (MMA or stick) welding contains less chromium (up to 8%) but most of it is the more hazardous ‘hexavalent’ chromium (a carcinogen)[12].

Nine foundries carried out welding; three used MMA welding techniques (two on stainless steel and one on manganese steel), three used tungsten inert gas (TIG) techniques (two on stainless steel, one on aluminium and iron) and one used metal inert gas (MIG) techniques on cast iron.

The process was segregated from the main areas of the foundry, either located on its own or within the fettling area.

Exposure controls

LEV was used at six foundries. This was in the form of a bay with fixed-slot extraction to the rear (one foundry), booths (one foundry, which also used a captor hood at another welding location) and captor hoods (four foundries). PPE consisted of coveralls (eight foundries), gloves (noted at six foundries), powered or air-supplied RPE (five foundries) and half mask RPE (one foundry). LEV use, design and maintenance are discussed in further detail in section 3.6. PPE suitability, use and maintenance are discussed in further detail in section 3.8.

Exposures

Summary exposure data for manual welding are presented in Table 17 (see also box plots 1 – 14 in Appendix 9). There was no automation of this process.

[†] *The International Agency for Research on Cancer (IARC) is the specialised cancer agency of the World Health Organization. Classification Group 2B = Possibly carcinogenic to humans.*

Table 17 8-hr TWA exposures to key substances during manual welding

Substance	Exposure limit	No. Samples	Exposures (mg/m^3 unless otherwise stated) Median	Max	No. > Exposure limit	No. with LEV	RPE
RCS	0.1 mg/m^3	3	0.015	0.060	0	3	3
Respirable FFP or dust*	4 mg/m^3	3	3.0	23	1	3	3
Inhalable FFP or dust*	10 mg/m^3	9	6.4	29	4	9	6
Chromium	0.5 mg/m^3	9	0.023	0.66	1	9	6
Lead	0.15 mg/m^3**	9	0.0035	0.061	0	9	6
Manganese	0.5 mg/m^3	9	0.10	5.5	3	9	6
Nickel	0.5 mg/m^3	9	0.046	0.33	0	9	6
Benzene	1 ppm	4	0.045 ppm	0.080 ppm	0	4	3
Isocyanates	0.02 mg/m^3	0	-	-	-	-	-
Phenol	2 ppm	0	-	-	-	-	-
Xylene	50 ppm	4	0.025 ppm	0.030 ppm	0	4	3
Toluene	50 ppm	4	0.025 ppm	0.33 ppm	0	4	3
Formaldehyde	2.5 mg/m^3	0	-	-	-	-	-
Furfuryl alcohol	none	2	0.050	0.050	-	2	2

* - FFP (from iron and steel) has WELs of 10 mg/m^3 (inhalable dust) and 4 mg/m^3 (respirable dust). Particulate generated from non-ferrous metals becomes subject to the COSHH Regulations 2002 (as amended) at concentrations in air exceeding 10 mg/m^3 (inhalable dust) and 4 mg/m^3 (respirable dust).

** - lead is subject to the CLAW Regulations 2002 and has an OEL rather than a WEL.

Median exposures were below relevant exposure limits. Four inhalable FFP / dust exposures exceeded 10 mg/m^3 (the concentration at which inhalable dust becomes subject to the COSHH Regulations 2002 (as amended)). Of these four, one worker also carried out some fettling (LEV was present and RPE worn), one extraction booth was ineffective (this was also the worker with the respirable FFP / dust exposure of 23 mg/m^3), though RPE was worn, one captor hood was too small (RPE was not worn) and one worker did not work within the capture zone of the LEV hood (RPE was not worn). Some air movers (fans) also interfered with capture. Other exposures exceeding their exposure limit were chromium (one, LEV present and RPE not worn) and manganese (three, LEV present and RPE worn at two foundries and LEV present and RPE not worn at one foundry). Two of the manganese exposures greater than the WEL were from workers at a foundry casting manganese steel.

There were five BM results for PAHs for this task; none exceeded the range for those with no occupational exposure (up to 0.4 µmol/mol creatinine). See Table 18, section 3.4 for all PAH BM results.

3.4 POLYCYCLIC AROMATIC HYDROCARBONS (PAHS)

After the initial three visits, air sampling for PAHs was replaced by BM. A summary of PAH BM results is presented in Table 18.

Table 18 BM results for PAHs

Task	No. Samples	No. > 0.4 µmol/mol creatinine*	No. > BMGV (4 µmol/mol creatinine)	No. with	
				LEV	RPE
Moulding	62	2	0	9	0
Core making	45	0	0	22	0
Furnace work	12	2	0	3	3
Casting	18	1	0	3	6
Knockout / shakeout	19	5	0	16	9
Cutting, burning, gouging	2	0	0	2	2
Welding	5	0	0	2	2
Mixed tasks**	72	3	0	25	16

* The reference range for those with no occupational exposure is up to 0.4 µmol/mol creatinine.
** Some workers undertook a variety of moulding, core making, casting and knockout/shakeout.

The reference range for those with no occupational exposure is up to 0.4 µmol/mol creatinine. The majority of results fell within this range. Those that exceeded this value were less than the BMGV.

BM for PAHs was not conducted on fettlers and shotblasting workers. There was a small number of results for cutting, burning, gouging and welding.

The number of samples where LEV was used and RPE worn does not directly correlate with the corresponding columns in Tables 2 to 11, 15 and 17 due to the following reasons:

- Not all workers involved in air sampling supplied urine samples
- Where urine samples were supplied there were up to three urine samples per worker (as per section 2.5 sampling methods)
- Urine samples containing high and low levels of creatinine were excluded (as per section 2.7 statistical analysis)

3.5 CLEANING

Details of the cleaning regimes at 11 foundries were gathered. Cleaning was often carried out at the end of the shift, though at one foundry it was carried out throughout the day by a worker on a ‘ride on’ sweeper that had rotating brushes at ground level similar to a road sweeper. At nine foundries, manual dry sweeping using brushes / brooms was carried out. One foundry used an industrial vacuum (type unknown) to do the majority of cleaning with dry brushing in awkward corners. One of the foundries carrying out manual sweeping had an industrial vacuum cleaner available but this was not used as it was reported to be ineffective.

LEV was not available for cleaning and RPE (tight fitting) was mandatory at five foundries (including the ride on sweeper driver) and optional at one. Face fit testing had been carried out at two of the foundries (though at one of these not on all workers).

Cleaning exposures were measured at only two foundries. One task-based exposure to inhalable FFP of 5.2 mg/m^3 (over a 43 minute sampling period) was obtained whilst sweeping up in a core making area. Another ‘furnace’ worker at a different foundry had 8-hr TWA exposures to inhalable dust of 27.8 mg/m^3 (above the concentration at which inhalable dust becomes subject to the COSHH Regulations 2002 (as amended), lead of 0.28 mg/m^3 and copper of 3.9 mg/m^3, with the latter two being greater than their respective exposure limits. This worker had spent their shift cleaning and dry sweeping (as mentioned previously in section 3.3.3).

3.6 LOCAL EXHAUST VENTILATION (LEV)

LEV was present in some form at all foundries. For LEV to be effective it has to be of the right design, used correctly and be checked and maintained so that it is in good condition and continues to offer the level of control it was designed to provide. Having LEV systems commissioned when initially installed should provide the user with evidence that the system is providing adequate control. The commissioning report along with the user manual for the system can be used as a baseline for all future thorough examination and tests (TExT – See Section 3.6.3 for more detail). Commissioning can also be carried out retrospectively on systems that do not have user manuals.

3.6.1 Design of LEV

HSE COSHH Essentials provides guidance in the form of direct advice sheets for exposure control options for various industries. There is a series specific to foundries (FD Series[13]). These include:

a) Advice sheet FD2 Molten metal fume: Melting – LEV in the form of an extracting hood above the furnace.

b) Advice sheet FD3 Molten metal fume: Pouring and casting – Forced mechanical general ventilation.

c) Advice sheet FD4 Sand plant – Segregate and enclose as much as possible.

d) Advice sheet FD5 Coremaking and shell moulding (small scale) – LEV in the form of an extracted booth. No sheet for larger castings.

e) Advice sheet FD6 Knock-out, shakeout, etc – LEV in the form of extracted tables or booths.

f) Advice sheet FD7 Fettling small castings – LEV in the form of an extracted booth, similar to a glove box with very small castings using a receiving hood on a grinding wheel.

g) Advice sheet FD8 Fettling large castings – LEV in the form of a large extracted booth with a turntable inside.

h) Advice sheet FD9 Abrasive blasting small castings in a cabinet – LEV in the form of a small fully enclosed cabinet, for example a glove box.

i) Advice sheet FD10 Gouging - LEV in the form of an enclosed extracted booth.

j) Advice sheet WL19 Surface preparation: Pressure blasting (medium-sized items) – LEV in the form of fully enclosed extracted booth with operator inside[14].

There were examples of both good and poor LEV design at the foundries visited. Some of the designs offered more effective control than that described in the relevant FD guidance sheet(s). Good design consisted of extracted enclosures which removed the need for operator contact such as:

- Hot / cold core boxes
- Fully enclosed shotblasting machines (eliminating the need for the operator to be potentially exposed as in FD9 and WL19 above)
- Enclosed and extracted cutting (part of the fettling process)

- A fettling booth with a retractable roof to allow larger castings to be placed within it via overhead crane (in accordance with FD8 above).

Examples of poor design that did not meet the standard in the COSHH Essentials direct advice sheets included:

- A shakeout booth that had uneven face velocities and poor containment, due partly to the extraction face being a series of circular holes to the rear wall of the booth. After the visit the foundry altered these holes to slots which significantly improved containment.

- A receiving hood used for grinding at one foundry was located too far away from the grinder to be effective.

- Receiving hoods for fettling and linishing – as recommended in advice sheet FD7 'Fettling small castings'. When visualising the air flow using smoke tubes, there was good capture when not in use. However, when in use these often failed to capture all the dust (visualised with a dust lamp). To be effective these hoods have to be big enough to receive the dust / fume and also have a high enough velocity so that they can 'empty as quickly as they are filled'[15].

- A captor hood used when welding was much smaller than the generated contaminant cloud, leading to partial capture.

- Captor hoods used for fettling at one foundry were too small for some of the castings. This type of LEV is not recommended for energetic processes as the contaminant cloud is difficult to control[17]. COSHH Essentials recommends large extracted booths.

- Some fettling booths were too small for the castings. This meant that in some cases the casting was outside of the booth and therefore outside the influence of the LEV.

- One foundry had welding LEV with no air cleaner. The exhaust to atmosphere was located near to an inlet to the building which meant that welding fume re-entered the workplace.

3.6.2 Use of LEV

LEV can be adequate for the task but if not used properly it will fail to provide sufficient control. All but two foundries had some issues with LEV use that would have an adverse effect on its efficiency. These included:

- Some captor hoods were not close enough to the source during welding. These need to be positioned close to the process to be effective, ideally within one duct diameter[15].

- The use of air movers, fans and open doors adjacent to or in the vicinity of LEV. Most LEV systems are susceptible to draughts and the less enclosure they offer to the contaminant source the more pronounced this will be. For captor hoods, the effective capture zone will shrink and for booths, turbulence can be generated at the face, resulting in exposure to the worker.

- Fettlers stood between castings and the extraction obstructing the airflow. This can cause a build-up of contaminant in front of the worker.

- A rubber mat (presumed to be there to control vibration exposure) covered the surface of a downdraught fettling booth. This blocked the extraction, which could, in turn, result in exposure to the worker.

- Castings located outside of booths during fettling. For a booth to be efficient the process needs to be inside it and any contaminant (in this case particulate) contained within it.

- A build-up of broken moulds and sand in front of an LEV system meant further moulds could not be broken up within its influence.

- An adjustable jig was present in a fettling bay but not used. These are recommended in HSE Guidance HSG 258[15] as the casting can be moved up and down and turned around, allowing the worker to remain out of the way of the airflow.

Where applicable this information was reported back to the foundries in the site visit report.

3.6.3 Maintenance and testing of LEV

Foundries are a harsh environment for LEV systems. Heat, molten metal splashes, site transport and abrasive sand can damage hoods, filters and ductwork which can in turn affect the system performance. It is therefore important to carry out checks on both the condition and performance of a system.

Maintenance checks

In-house checks of LEV systems varied from documented daily checks and measurements to no formal procedures. The latter related to four foundries though one of these was in the process of setting up a formal regime. A breakdown of in-house checks and frequencies includes:

Daily checks:	Pressure differentials taken (two foundries) with one comparing these to values on the LEV TExT
	Visual checks of dust deposits (one foundry)
	Functionality checks (one foundry)
Weekly checks:	Pressure differentials across filter units (one foundry)
	Face velocities and visual inspections (one foundry)
	Condition of filters (two foundries) with one also carrying out occasional checks on airflow using smoke
Annual checks:	Cleaning of filter bags (one foundry)

One foundry had LEV systems in several areas which were tested by two different consultants. One consultant had provided log books for the systems they tested which contained details for daily, weekly and monthly testing. The other systems on site did not undergo in-house checks. No reasons were given for this.

Airflow or pressure indicators fitted to LEV hoods are a useful visual tool for the user to know whether or not the system is working within set parameters. Of the foundries visited:

- Four did not have them.

- One did not have them but was planning to retrofit them.

- At two foundries some hoods were fitted with them and some not.
- Two foundries had airflow indicators fitted to almost all their hoods.
- At four foundries no information was gained as to whether indicators were present or not.

An indicator of poor maintenance is unrepaired damage to systems. Damage was noted at most of the foundries. Examples included:

- Damaged ductwork.
- Damage to LEV hoods.
- Heavy dust deposits on filters leading to poor performance.
- Leaking seals / broken hinges. This led in one foundry to sand escaping from the system.

At two foundries, compressed air was used to clean LEV filters. This re-suspends a significant amount of dust into the operator's breathing zone.

Thorough examination and test of LEV

In accordance with Regulation 9 of the COSHH Regulations 2002 as amended[1] ('Maintenance, Examination and Testing of control measures'), LEV systems should undergo a TExT at least every 14 months. Schedule 4 of this Regulation specifies shorter frequencies for certain processes. The relevant frequencies for foundries are:

Ferrous foundries - Fettling and shotblasting LEV should undergo a TExT at six monthly and monthly intervals respectively.

Non-ferrous foundries – All systems should undergo a TExT on a six monthly basis (apart from shotblasting which is monthly).

Paragraph 185 of the COSHH Regulations 2002 (as amended) states that '*the examination and test should ensure that the LEV plant can meet its intended operating performance for adequately controlling hazardous substances for the purposes of regulation 7*'.

Five foundries carried out LEV TExT at frequencies in accordance with Schedule 4 of Regulation 9, though two of these were not issued as a TExT (3.6.4). Eight foundries carried out their TExT at a lower frequency.

The commissioning of LEV systems is an important step in ensuring that they will offer adequate exposure control. The intended operating performance of an LEV system is determined and documented during this stage. The commissioning report should confirm that the system performs as originally designed and delivers adequate exposure control. It should also provide a reference against which maintenance checks and TExTs can be compared.

The majority of the foundries did not have commissioning reports for their systems: one foundry had reports for two of their newer systems, but none for the remainder. It is possible to retrospectively commission LEV systems and one foundry had done that for all their systems. Remaining foundries did not have commissioning reports.

3.6.4 TExT Reports

TExT reports should state what methods have been used, the results of any measurements, an opinion as to whether the system is performing to design specifications and whether it achieves adequate control. All but one of the foundries had TExT reports (one foundry had some systems tested and some not). At all sites where reports were available, they were compared to a list of what should be in a comprehensive TExT report[15]. The results of that comparison were fed back within the site visit report. In many case the reports were deficient. Typical elements of missing information were:

- The system's intended performance.
- How the operator used the LEV.
- Some dimensions of hoods and ducts.
- Some face, capture and duct velocity measurements.
- Work activities carried out.

Most reports gave opinions as to whether the system offered adequate control and recommendations on control improvements. Not all foundries had acted on these.

Two foundries had commissioned reports from the same consultant. This consultant would not issue the report as a TExT stating:

'Whilst our surveyor has completed the operational tests, nevertheless we are unable to issue the Statutory Thorough Examination Report as required by the COSHH Regulations, as these Regulations demand the Thorough Examination can only be completed when an Initial Appraisal or Commissioning Report is available for reference.'

It would be more helpful to the foundries if the consultant offered to carry out the initial appraisal / commissioning report retrospectively or made it clear from the start that the report would not be classed as a TExT.

3.7 GENERAL VENTILATION

All foundries except two had forced mechanical general ventilation. Details were not noted for one, and one foundry did not have any. The most common was roof fans. Not all were turned on during the site visits and at one foundry only two were on with one significantly slower than the other. One foundry had wall-mounted extraction fans directly behind their furnaces and it was noted that the extracted air came back into the building through the nearby roller shutter door.

Roller shutter doors were often left open to aid air movement and dilution. However, as mentioned in 3.6.2 if the doors were in close proximity to LEV they could adversely affect its performance.

3.8 PERSONAL PROTECTIVE EQUIPMENT (PPE)

For PPE to be an effective control measure it has to be suitable for the job and hazard, fit the wearer, be used correctly and, if applicable, maintained in a good condition.

3.8.1 Suitability for the job

Some tasks were clearly recognised as needing a high level of PPE, for example fettling and manual shotblasting (due to the potential for significant exposures to RCS) and furnace work (due to the potential for molten metal burns and splashes). The potential for exposure to hazardous substances was not as well recognised for some other tasks such as mould making as there were occasions where unsuitable PPE was worn. Examples of both adequate and inadequate PPE worn at the foundries follow.

Examples of adequate PPE selection:

- Molten metal protective clothing, worn at the majority of foundries when carrying out furnace work.
- Flame retardant / heat resistant clothing, worn at most foundries for most tasks.
- Compressed air-fed RPE for shotblasting, worn at two foundries. These offer an assigned protection factor (APF)[‡] of 40 and 1000 (HSE Guidance HSG53 'Respiratory protective equipment at work a practical guide'[16]).
- Powered RPE helmet / hood type systems for fettling / cutting / burning, worn at seven foundries and also at one foundry for shotblasting. These have APFs of between 10 and 40[16] depending on filters used (though the latter would be the preferred protection factor). This type of RPE can be comfortably worn for the majority of a worker's shift.

Examples of inadequate PPE:

- Fabric gloves for mould / core making / knockout; these gloves would offer little protection against the chemicals in the binder systems, some of which were known skin sensitisers.
- Powdered latex gloves; natural rubber latex proteins have the potential to cause asthma[17].
- No molten metal protective clothing available for casting (one foundry), or available but not worn (one foundry).
- Workers' own clothes were worn at some foundries; this is considered bad practice as these workers will then spread contamination beyond the work area and potentially off site into their own homes and / or public areas.
- RPE offering protection against particulate only with no protection against organic vapours when carrying out NDT.
- Incorrect gloves used when handling dye penetrant for NDT.

3.8.2 Effectiveness of PPE

Although PPE may be adequate for the task, its effectiveness in practice depends upon how it is used, stored and maintained and the training given to the wearer. Poor or no training can lead to incorrect use and storage, and consequently potential exposure to any contaminants. Poor maintenance may lead to faults and defects that can also lead to worker exposure. Chemical

[‡] *Assigned protection factor (APF) is a number rating that indicates how much protection that an item of RPE is capable of providing.*

protective gloves and tight-fitting RPE need to fit the wearer. For the latter, face-fit testing should be carried out.

Use, storage and face-fit testing

Most workers used their PPE correctly, though there were instances where this was not the case. There were also occasions where workers did not wear the PPE issued to them. Examples were:

- Handling sand / binder mixture with bare hands. This would lead to dermal exposure to binder chemicals, some of which are known skin sensitisers.

- Gloves and coveralls not worn (when available) during casting, a task which has the potential for serious burns.

- RPE worn below the nose, covering the mouth only, which would not prevent inhalation exposure.

- Tight-fitting RPE worn with stubble, which affects the seal between mask and face. Research has found that RPE protection could be significantly reduced where stubble is present, generally worsening as facial hair grows[18].

Most workers had lockers in which to store PPE at the end of their shift for re-use the next day. RPE and gloves were put on and taken off numerous times throughout the shift and there were occasions where both were stored on workbenches when not worn. This can lead to contamination on the inner surfaces. On more than one occasion RPE masks were observed to be dirty on the inside.

The COSHH ACoP[1] in relation to Regulation 7 'Prevention or control of exposure to substances hazardous to health' states that tight-fitting RPE (disposable and re-useable) should be face-fit tested, using a suitable method and by a competent person. Most foundries supplied both tight-fitting masks and loose-fitting powered RPE hood type systems; which was used, was task-dependent. Loose-fitting RPE does not need face-fit testing. Of the foundries visited:

- Four carried out face-fit testing for all applicable masks.

- One foundry carried out face-fit testing on half masks, but not disposable masks.

- Eight foundries did not carry out face-fit testing

- One foundry had carried out a program of face-fit testing, but some workers had refused to take part.

RPE maintenance regimes

It is a requirement of Regulation 9 'Maintenance, examination and testing of control measures' of the COSHH Regulations 2002 (as amended) that re-usable RPE undergoes *'thorough examination and, where appropriate, testing*' at '*suitable intervals'*.

It is also a requirement that PPE is:

a) 'properly stored in a well-defined place;

b) checked at suitable intervals; and

c) when discovered to be defective, repaired or replaced before further use.'

Disposable RPE does not need to be maintained, examined and tested; however re-usable RPE (including half masks, powered and air fed systems) does. HSE guidance, HSG 53, paragraph 90 states that '*Thorough examination and tests should be carried out at least once a month. However, if the RPE is used only occasionally, an examination and test should be carried out before use, and in any event the interval should not exceed three months'*.

Of those foundries that used re-usable RPE (11), six carried out and recorded their checks. These ranged from monthly (four) to annually (two), though one of the latter carried out annual maintenance on one type of RPE but had no procedures for other re-usable types. The remaining five foundries had no formal maintenance, examination and test in place. Three foundries used only disposable RPE.

The ACoP to Regulation 9 of the COSHH Regulations states that the quality of breathing air supplied to compressed air fed RPE should be *'tested at suitable intervals, depending on the task and the frequency of use*'. HSE Guidance (HSG 53, Appendix 3) states that the frequency should be based upon a risk assessment, but '*they should take place at least every three months, and more often when the quality of air cannot be assured to these levels'*. Four foundries used this type of RPE, one tested the breathing air quality on a monthly basis, one tested annually and the other two had no formal procedure for carrying this out at the time of the research visit.

Training in use of PPE

One foundry had carried out training in use of protective gloves in the past and considered they needed to carry out refresher training (but hadn't done so at the time of the research visit); another foundry had carried out some basic verbal training in glove use. No other foundries had carried out training in protective gloves.

Most foundries (10) had carried out training in use of RPE, though at two foundries this was not recent. This was done either in-house by a supervisor or via an external provider (RPE supplier or occupational health professional).

Training in donning and doffing disposable coveralls was carried out at one foundry and another had given basic training via a video. No other foundries had carried out training on coveralls.

3.9 EXPOSURE MONITORING

Most foundries were familiar with exposure monitoring and 12 had employed consultants to carry it out. The frequency was annually at seven foundries and every two to three years at three foundries. Two foundries had monitored exposure in the past and another had not carried out monitoring. Substances measured included inhalable and respirable FFP, metals (e.g. lead, nickel manganese, chromium), RCS, VOCs (e.g. benzene, phenol, furfuryl alcohol), formaldehyde, CO, isocyanates and SO_2, though not all were measured at each foundry.

Consultant reports contained recommendations on improvements to exposure control which most foundries had acted upon.

One consultant (at four foundries) had used a gravimetric determination of cyclone grit pot contents to estimate inhalable dust exposures. However this methodology is not validated and hence the results may not be reliable.

Regulation 6 ('Assessment of the risk to health created by work involving substances hazardous to health') of the COSHH Regulations 2002 as amended state that '*The risk assessment shall include* *considerations of – the results of monitoring of exposure in accordance with regulation 10'*. One foundry did state that exposure monitoring should periodically be carried out for RCS and FFP, that past exposures to phenol and formaldehyde were below WELs, and that future monitoring would continue. Three other foundries made reference to exposure monitoring in their assessments, but did not include the results. There was no reference to exposure monitoring in the COSHH risk assessments at other foundries.

3.10 HEALTH SURVEILLANCE

Eleven foundries recognised that exposure to the substances and processes used could lead to ill health in the workers, and as such had health surveillance programmes in place. This was annual at eight foundries, six monthly at one and the frequency was unclear at the other two. Lung function / spirometry tests were carried out at 11 foundries (evidence of an understanding of the respiratory risks) with additional checks carried out at some such as:

- Skin assessments / questionnaires
- Hearing tests
- Hand arm vibration (HAV) assessments / questionnaires (where applicable e.g. fettlers)
- Eye tests

Other medicals relating to radiation work, work at height, shiftwork and forklift truck driving were also carried out at one foundry.

3.11 TRAINING

Induction and on-the-job training covering various topics including health and safety was carried out at all the foundries. Twelve foundries stated that they had carried out some training on hazardous substances, symptoms of ill-health and use of control measures. Refresher training for health and safety was reportedly carried out at 10 foundries but the frequency was unclear.

3.12 EXAMPLES OF OTHER EXPOSURE CONTROL APPROACHES

During the research visits two examples of other control measures not previously referenced were seen. These are discussed below.

3.12.1 Assessment of water mist suppression as a dust control measure (only in place at one foundry)

A ferrous foundry visited during the pilot phase employed a water mist suppression system to control dust levels during casting. This was a series of mains-supplied spray heads in the ceiling of the building. Water was released intermittently from the heads as a fine mist during casting. A follow-up visit was carried out to assess the efficacy of this system. Air sampling for inhalable and respirable FFP was carried out during two time periods of casting, one with the system off and again when it was on. For both casting periods personal sampling was carried out on two casters, and a mould maker who was within the vicinity. Two static air samples were also collected within the area. Sample periods were between 21 and 42 minutes for the personal samples and 48 and 57 minutes for the static samples. Table 19 summarises the results.

Table 19 Results from assessing efficacy of a water mist suppression system

Task	Inhalable FFP (mg/m^3)		Respirable FFP (mg/m^3)	
	Water mist off	Water mist on	Water mist off	Water mist on
Casting	6.2	24	0.70	1.7
Casting	16	1.2	1.1	1.2
Moulding	3.8	8.5	0.70	1.2
Static sample in vicinity	4.1	4.2	0.70	1.1
Static sample in vicinity	3.0	3.8	0.80	1.1

The results above imply that in this case the water mist suppression system at this foundry did not reduce exposure to inhalable or respirable FFP.

3.12.2 Substitution

In 2011, an iron foundry was visited as part of a HSE investigation. The 8-hr TWA exposures to benzene during casting (using BSA) had ranged from 1.0 ppm to 2.4 ppm with task-based exposures during one cast of 8.2 ppm and 8.7 ppm (over time periods of 11 and 12 minutes respectively).

As a consequence of this investigation the foundry had substituted the BSA catalyst for one containing XSA. Assessments of the effect of this substitution on workers' exposure to benzene during casting were carried out as part of this study. The results are presented in Table 20.

Table 20 Benzene exposures before and after substitution of BSA catalyst to XSA

Task	2011			2015		
	ppm		BM µmol/mol creatinine	ppm		BM µmol/mol creatinine
	8-hr TWA	Task-based		8-hr TWA	Task-based	
Casting	2.3	8.2	7.8	0.20	0.20	2.1 - 3.0
Supervisor	2.4	8.7	2.5	0.20	0.20	1.3 - 2.3
Furnace worker	1.0	-	-	0.10	0.30	-
Furnace worker	1.4	-	3.2	-	-	-

The results imply that in this case, at this foundry, substituting BSA for XSA reduced exposure to benzene when casting.

3.13 BIOLOGICAL MONITORING

In previous HSE research work[19, 20, 21, 22] BM has proven to be a useful tool in measuring worker exposure to hazardous substances. However in this project it was not as useful. The reasons for this included:

- Some substances do not have reference values such as BMGVs with which to compare results (e.g. copper, ortho-toluidine, tungsten).

- Manganese in urine is not a good measure of exposure. Only approximately 1% of the absorbed dose is excreted in urine[23] and there is little correlation between atmospheric and urinary concentrations[24]. Exposure to manganese represents a serious chronic health risk and can occur in foundries, depending upon the metal used. Five inhalation exposures (from two foundries) were greater than the WEL. Four were from a foundry that cast manganese steel. HSE research is currently underway to establish a suitable BM technique for manganese.

- The preferred BM method for inorganic lead exposure is analysis of blood, rather than urinary lead levels.

- BM for toluene was adversely affected by the presence of ortho-cresol. Ortho-cresol is a urinary metabolite for toluene; however, it is known to be generated in some foundry processes. The presence of ortho-cresol in the work environment will cause significant, positive interference in the urine assay. For example, a relatively low exposure to ortho-cresol of 0.02 ppm could result in a urinary concentration of approximately twice the American Biological Exposure Indices (BEI)[§] for Toluene[25].

3.14 EATING AND DRINKING

Eating and or drinking (from open cups) were observed in contaminated areas at most foundries. Doing this without also washing hands (observed at one foundry) can lead to exposure via inadvertent ingestion[26]. This subject is being covered in a CMF project on behavioural change entitled ‘Foundry supervisors: Influencers and authors of change – The role of supervisors and foremen in changing behaviour’. Further information on this project can be obtained through the CMF.

[§] *American BEI’s are health based BM values set as guidelines for use by industrial hygienists in making decisions regarding safe levels of exposure to various chemical substances and physical agents found in the workplace.*

4. DISCUSSION

4.1 MOULDING

At most foundries moulding was carried out manually. There was the potential for inhalation exposure to particulate (inhalable and respirable) containing RCS, and both inhalation and dermal exposure to binder chemicals, some of which are known skin sensitisers.

Exposure by inhalation was not viewed as significant by the foundries as the sand was often damp, therefore, LEV and RPE were not common and there was a reliance on general ventilation for air movement and dilution. LEV (present at two foundries carrying out manual moulding) was in the form of a fixed captor hood at the dispense point of the mixer. An extracted booth is recommended in the relevant COSHH Essentials direct advice sheet (FD5) as the most effective. Though it should be noted that FD5 relates to core making and shell moulding (small scale) and most of the moulds seen in this work were larger in size than the FD5 illustration. There is no direct advice sheet for making larger sized moulds.

Probable causes of the inhalation exposures obtained were the positioning of the dispense point from the mixer (the sand mixture often passed downwards through the workers breathing zone) and compressed air blowing of moulds to remove loose sand. These exposure potentials were not controlled. Two foundries indicated that they plan to develop extraction systems to use when carrying out compressed air blow down of moulds.

Control of dermal exposure to binder chemicals was often poor with the potential for exposure not always recognised. Tools that would create a safe working distance were not used and fabric gloves (i.e. not chemically protective) were often worn which would not provide an effective barrier between skin and binder chemical.

The effect of automation on worker exposure during moulding appeared to be negligible. However, there was a much smaller dataset for automation so firm conclusions cannot be made. It would require a larger sample size before firm conclusions could be drawn.

4.2 CORE MAKING

Manual core making was similar to manual moulding albeit on a smaller scale and with the exception that compressed air was not used to blow down cores. Enclosed and extracted core making (hot / cold boxes) were commonplace and appeared to be effective. These were more enclosing than the booths recommended in the HSE COSHH Essentials direct advice sheet (FD5). Core making exposures were generally lower than for moulding, and comparisons between automated and manual showed comparable exposures.

Some manual core making had LEV (booths or captor hoods) and none of the core makers had RPE.

Incorrect gloves, which would not offer sufficient protection against binder chemicals (some of which are known skin sensitisers) were seen to be used.

Workers wore their own clothes in some foundries. This can lead to contamination being spread away from the workplace.

Gloves and RPE were removed frequently throughout the shift and often left on workbenches when not in use.

Five employers had no formal maintenance, examination and test regimes in place for re-usable RPE. At two foundries this included breathing air quality checking for air fed RPE. Employers should ensure that the PPE chosen offers adequate protection for the task, is properly stored to prevent contamination and is well maintained. In addition, face-fitting needs to be carried out for tight fitting RPE.

4.3 FURNACE WORK

The potential for serious burns from molten metal was widely recognised, and all but one foundry supplied molten metal or flame resistant protective clothing and gloves.

Furnace workers are potentially exposed to inhalable FFP / dust and metal fume, the constituents of which can depend upon the furnace feedstock. For example a furnace worker at a foundry that cast manganese steel had a manganese exposure approaching the WEL. At approximately half the foundries this potential was reduced by LEV. Others relied upon on forced mechanical general ventilation. One foundry used worker rotation, (four hours at the furnace and four doing another job) and one foundry had no LEV and no mechanical general ventilation. RPE was used as a control option at just under half of the foundries (as the primary control at one foundry and in conjunction with LEV or forced mechanical general ventilation at four).

Three exposures to inhalable FFP / dust exceeded 10 mg/m^3 (the concentration at which inhalable dust becomes subject to the COSHH Regulations 2002 (as amended)). One of these workers carried out some moulding as well as furnace work. One exposure to lead exceeded the OEL, the furnace had not been in use and the worker had carried out dry sweeping during his shift. This is commented on in the cleaning section 3.5.

Quantitative assessments of furnace LEV systems were not carried out due to access limitations. Visually they appeared to be effective in receiving the molten metal fume, however, when the furnaces were tipped to pour their contents into the ladle, the fume was no longer under the influence of the LEV.

4.4 CASTING

Casting (and resultant cooling) generates a significant amount of fume potentially containing inhalable and respirable FFP / dust, CO and thermal decomposition products of the binder chemicals.

Exposure controls included segregation of the process by casting when other workers were not in the vicinity (on the night shift and at the end of the shift). The latter prevented workers being in the vicinity during cooling, reducing their exposure time. This would be effective in reducing exposures, however it is not workable at all foundries. Two foundries used worker rotation, this would have reduced individual exposures, but increased the number of those exposed.

Two foundries had automated and extracted production lines for moulding, casting and knockout, thus reducing worker contact. LEV was only present for casting at one foundry, with forced mechanical general ventilation (roof fans) more commonly used. The relevant COSHH Essentials direct advice sheet for casting (FD3) recommends that pouring and casting is '*done in a designated area with effective fume dispersal*' and that RPE with an APF of 20 should be worn. Measured CO levels showed that at some foundries the general ventilation and air movement needed to be improved. Where applicable this was recommended in site visit reports. It should be noted that FD3 relates to molten metal fume and does not consider thermal decomposition products of the binder chemicals and these should also be taken into consideration when selecting RPE.

Some of the RPE systems worn (at four foundries) would not offer protection against the thermal decomposition products of the binder chemicals. At two foundries protective clothing was not worn when casting. One did not supply it and at the other it was available but not seen to be worn. This puts the workers at serious risks of burns from the molten metal.

For manual casting, five inhalable FFP / dust exposures exceeded 10 mg/m^3 (the concentration at which inhalable dust becomes subject to the COSHH Regulations 2002 (as amended)). It was noted that some casters helped out with other tasks when not casting. Automated casting exposures appeared to be lower than manual for inhalable FFP / dust, but comparable for the other substances.

4.5 KNOCKOUT / SHAKEOUT

Significant amounts of fume and dust were generated during knockout. At one foundry CO was also measured. Exposure controls such as LEV, automation and segregation (e.g. carried out in another area or carried out on the night shift with no one else in the building) were in place. Segregation would reduce exposure to others by minimising the number of people in the vicinity, but the exposures of the knockout worker still needed to be controlled and this was not always the case. The benzene exposure of one worker carrying out manual knockout on a night shift was at the WEL. LEV was not available and the RPE worn only offered particulate protection and was not face-fit tested. Benzene is a carcinogen and under the COSHH Regulations 2002 (as amended) its exposure control should only be treated as adequate if exposure is reduced to as low a level as is reasonably practicable (ALARP), in this case, exposure to benzene was not adequately controlled.

Manual knockout tended to be carried out with no LEV. The relevant COSHH Essentials direct advice sheet (FD6) recommends RPE with an APF of 20 or more be worn for manual knockout. RPE was not always worn and when it was worn it was not always face-fit tested. It should be noted that FD6 refers to control of exposure to RCS and doesn’t consider thermal decomposition products such as benzene.

Semi-automated knockout was typically carried out in an extracted booth. Not all these booths managed to contain the dust and fume generated for reasons such as uneven air flow, low airflow or nearby fans causing turbulence. One foundry successfully carried out improvements to their booth following the research visit.

Dermal exposure could occur when handling the moulds either during manual knockout or when placing them into extracted booths (though larger moulds were transported by overhead crane). Again, dermal exposure to chemicals present in the sand was not recognised, and the gloves worn would not always provide chemical protection.

The results show manual and semi-automated knockout have comparable exposures. However, the box plots in Appendix 9 show that for inhalable FFP / dust, semi-automation appears to have an effect on control as the maximum exposure and exposure range were lower. However, as this was a small dataset (four samples) this should be treated as an indication only.

4.6 SAND RECLAIM

The majority of semi-automated and automated knockout was connected to the sand reclaim process, where the sand was removed from the castings under extraction and then transferred to enclosed sand reclamation plants. This was the case at all of the foundries except one. Leaking seals were noted at the sand reclamation plant of one foundry which was a probable contribution to an inhalable FFP exposure above the WEL for a worker in the vicinity.

The exception was mechanical breakdown of lumps of greensand mould debris in a mechanical grinding machine. The granulated sand exited the back of the machine in the form of a spray. Exposure to this spray was not controlled by either LEV or PPE and anyone working close by would potentially have been exposed to particulate containing RCS. The foundry indicated during the visit that they would discontinue use of the mechanical grinding machine.

4.7 SHOTBLASTING

This was a widely recognised significant source of exposure to RCS and was carried out in enclosed automated or semi-automated machines at most foundries. Exposures of workers operating the automated systems were less than exposure limits with the exception of one RCS result. It was not clear why this exposure was greater than the WEL; however good maintenance is important for these systems as leaking seals could increase exposure potential.

Where manual shot blasting was carried out it was done in enclosed extracted rooms with just the operator present wearing heavy-duty powered RPE. In theory, providing the LEV and the RPE were well maintained and working as they should, and the room was kept under negative pressure, control should have been adequate. However, manual shotblasting was not witnessed being carried out so no comments can be made on the adequacies of exposure controls in use.

4.8 FETTLING

Fettling castings can result in exposure to dust, RCS and metal particulate. Enclosed and automated fettling (reducing the potential for worker contact and thus exposure to hazardous substances and hand arm vibration), was not common and only seen at two foundries. As mentioned previously in section 4.7, good maintenance is essential for these as leaks could result in workers in the vicinity being exposed.

Most fettling was manual using power tools such as grinders. This was recognised as a significant source of dust, RCS and metal particulate exposure and as such, typical controls were LEV in conjunction with RPE. RPE was mostly powered hood or helmet type systems with some tight fitting RPE worn. Two foundries did not supply RPE, instead choosing to rely on LEV. In both instances the LEV did not offer full control of the contaminant generated.

LEV systems included downdraught tables, captor hoods, receiving hoods and booths. Engineering controls were often not adequate due to incorrect design (e.g. captor hoods used for large castings, booths too small to fit castings in) poor maintenance (e.g. blocked filters / extraction face, low airflows) and not being used correctly (e.g. working on the casting outside of the booth, adjacent fans affecting containment). Receiving hoods were often in place around grinding wheels but were found to be ineffective when in use due to particulate being directed back towards the user. COSHH Essentials direct advice sheets FD7 and FD8 recommend extracted grinding wheels, cabinets or booths dependant on the size of the casting.

Of the 90 exposure measurements of inhalable and respirable FFP / dust, there were 21 greater than 10 and 4 mg/m^3 respectively (the concentrations at which both become subject to the COSHH

Regulations 2002 (as amended)). Five RCS exposures exceeded the WEL, and some metal exposures (chromium, manganese, nickel and lead) also exceeded exposure limits, though most of these exposures would be minimised by RPE.

The powered RPE systems used were adequate in theory for fettling, but their efficacy at some foundries was reduced by a lack of maintenance and in some cases storage on benches in contaminated areas.

Box plots 1-14, and Tables 13 and 14 show that the range of RCS exposures was lower for automated than for manual but the automated median was higher. For inhalable FFP / dust, manganese, lead and chromium the exposure range was lower for automated than for manual systems. This is, however a weak indication as the dataset for automated systems is very small.

4.9 CUTTING, BURNING AND GOUGING

These were manual processes using tools similar to that of fettlers and as such relied upon both LEV and PPE for exposure control. LEV consisted of booths. Of the three foundries carrying out these processes, booths were seen in use at only one. These provided adequate containment of the contaminant which was directed into the booth.

Again, the RPE worn would be adequate in theory provided it was working as it should and was well maintained. Maintenance was carried out at two of the three foundries.

This was a very small dataset (up to two samples per analyte). Some exposures were greater than the WEL for RCS, chromium, manganese and nickel. Inhalable and respirable FFP / dust exposure measurements were also greater than 10 and 4 mg/m^3 respectively (the concentrations at which both become subject to the COSHH Regulations 2002 (as amended)). It would require a larger sample size before firm conclusions can be drawn as to whether or not these exposures are typical.

4.10 NON-DESTRUCTIVE TESTING

NDT using dye penetrant was carried out at six foundries. There are recommendations and guidance on the HSE website for the use of dye penetrant containing CI Solvent Red 164, and these include avoiding spray application to reduce the potential for inhalation exposure, the use of extraction where vapours or spray may be released, avoiding skin contact, and frequent changes of gloves[27].

Brush / sponge application techniques were used at some foundries, therefore LEV was not needed. However the HSE recommendations were not always followed as spray cans were used at three foundries, (though one switched over to brush application straight after the research visit), and incorrect PPE was worn at three foundries (either RPE or gloves); again changes were made at one foundry during the visit.

Urinary levels of aniline and ortho-toluidine were measured around the range for those with no occupational exposure. This agrees with the findings of previous HSE research into users of dye penetrant containing CI Solvent Red 164[10].

4.11 WELDING

Welders are potentially exposed to metal fume and harmful gases, the constituents of which depends upon the metal being worked on along with the type of welding and the equipment used.

At the foundry casting manganese steel, two measured welding exposures to manganese were greater than the WEL. Four inhalable dust / FFP exposure measurements were also greater than 10 mg/m^3, and one respirable FFP / dust exposure was significantly greater than 4 mg/m^3 (the concentrations at which both become subject to the COSHH Regulations 2002 (as amended)). The WEL was also exceeded for chromium exposure.

LEV (booths or captor hoods) were used to control exposures at most of the nine foundries. However not all these were effective (wrong design, captor hood not big enough, not working close to the hood). RPE was worn at approximately half of the foundries.

4.12 CLEANING

Most foundries cleaned up using dry sweeping techniques. This will re-suspend settled dust leading to an extra source of exposure to particulates which will contain RCS and metals. For example, the lead OEL was exceeded for a furnace worker who swept up at a foundry that had recently cast leaded gunmetal. This and other potential exposures were uncontrolled as low dust cleaning techniques were not used, and although tight fitting RPE was available when sweeping (mandatory at four foundries and optional at one) face fit testing was not carried out at all.

One of the foundries had an industrial vacuum cleaner available, but carried on sweeping as they found the vacuum ineffective.

The 'furnace' worker mentioned above had 8-hr TWA exposures to inhalable dust of 27.8 mg/m^3, lead of 0.28 mg/m^3 and copper of 3.9 mg/m^3, with the latter two being greater than their respective exposure limits. One task-based exposure to inhalable FFP of 5.2 mg/m^3 (over a 43 minute sampling period) was obtained at another foundry whilst sweeping up in a core making area.

4.13 LOCAL EXHAUST VENTILATION (LEV)

The installation of LEV requires a financial investment for a company and it is important to buy adequate, well designed systems and maintain them. Examples of poor design, maintenance and use of LEV were noted during this work (Section 3.6.1). Some systems observed could be re-designed with little effort (e.g. adjustment of extraction at rear of booths from holes to slots) and some others had more fundamental design issues, such as the incorrect type of hood used.

Not all foundries carried out in-house maintenance checks and damaged LEV was noted at most. The latter will affect system performance and lead to elevated exposures (e.g. leaking seals in the sand reclamation plant).

As mentioned previously, foundries are a harsh environment for LEV systems. As such maintenance and visual checks for wear and tear are doubly important to keep the systems performing as they should.

Incorrect use of LEV was often seen which can be due to a lack of training on, or awareness of the importance of control measures. Where possible the research team demonstrated to workers:

- The effect of moving the captor hood closer to the source (using smoke to visualise airflow)
- Improvements in LEV performance when adjacent fans were turned off (again using smoke)

Not all foundries were aware of the frequencies set out in Schedule 4 of COSHH Regulation 9 for LEV TExT. Five carried out TExT in accordance with this.

Consultants' TExT reports varied in detail, with some missing details such as duct measurements. Reports tended to contain recommendations that not all foundries had acted upon.

The majority of foundries did not have commissioning reports for their systems. This means that they have no assurance that their system is performing as originally designed and providing adequate control. Commissioning can be done retrospectively to provide assurance to the owners and users.

4.14 PERSONAL PROTECTIVE EQUIPMENT (PPE)

There were deficiencies in PPE programmes at some foundries. Examples included:

- Protection against substances hazardous to health was not considered for all tasks where exposure might occur, e.g. fabric gloves for moulding, core making and knockout.
- Tight fitting RPE was worn for prolonged periods at some foundries. HSG 53[16] recommends wear times of up to an hour for this type of RPE.
- Workers were seen to wear their own clothes in some foundries. This can lead to contamination spread off site and workers continuing to be exposed.
- Not all workers wore available PPE or wore it incorrectly. The importance of PPE as a control measure should be included in training.
- PPE was typically stored in lockers at the end of the shifts, however gloves and RPE were removed frequently throughout the shift, and these were often left on workbenches where they could become contaminated.
- Five foundries had no formal maintenance regimes in place for re-usable RPE.
- Not testing breathing air quality for compressed air fed RPE on a monthly basis.
- Face-fit testing on tight fitting RPE was not carried out at eight foundries.

4.15 COSHH RISK ASSESSMENTS

Not all foundries had COSHH risk assessments. Those that had them did not write them on a task basis and they also lacked detail in some areas. One foundry had employed a consultant to write their assessments; a great deal more detail was required in order for them to be suitable and sufficient.

4.16 EXPOSURE MONITORING

This was carried out by consultants at the majority of the foundries and most had acted upon the recommendations in the reports (e.g. limiting the time spent casting due to CO levels). In general, exposure monitoring was not properly linked to COSHH risk assessments and the review of control efficacy.

One consultant had used a method to measure some of the inhalable FFP / dust samples using a technique which was not validated. It is important that when a foundry employs a consultant to carry out their monitoring that they specify it should be carried out in accordance with validated methods.

4.17 TRAINING

Training on substances hazardous to health, and the use of control measures was carried out at most foundries. However this could be improved with refresher training for employees / managers as there were some instances of incorrect PPE worn and the wrong LEV used.

Training has been carried out for the managers of the eight foundries visited under the Health SRP, with four of these foundries also volunteering for a series of worker briefings by HSE SD as a strand of the work entitled ‘behavioural change’. Some of this training has been on the use of exposure controls such as LEV and RPE along with practical demonstrations. These were well received and it is hoped that this will bring about a better awareness. The impact of this training will be assessed during re-visits as part of the on-going SRP work.

4.18 WATER MIST SUPPRESSION AND SUBSTITUTION

Based upon the results obtained during a second visit, the water mist suppression system at an individual iron foundry did not reduce exposures to inhalable or respirable FFP. This was possibly because the spray heads were located in the ceiling of the building, and the resultant water / dust mixture fell down past the breathing zones of the workers.

Substitution of BSA by XSA during iron casting was shown to significantly reduce exposure to benzene. This substitution involved effort in making sure the mix was right so as not to affect the quality of the casting.

4.19 BIOLOGICAL MONITORING

Previous HSE research has shown BM to be very useful in measuring worker exposures. It has not proved as useful during this work due to a number of factors including a lack of reference values such as BMGVs, BM not being the preferred method or analytical interferences. Hence, with the exception of aniline and ortho-toluidine for NDT and comments on PAHs, all exposure monitoring results quoted in this report are for air sampling.

4.20 EATING AND DRINKING

One route of exposure for hazardous substances is inadvertent ingestion. This can occur by eating or drinking in contaminated areas or not washing hands before eating. This was seen during the project and this subject is being covered in a CMF project on behavioural change. Further information on this project can be obtained through the CMF.

4.21 COMMON PROCESS AND EXPOSURE CONTROL FAILINGS

Some exposure control failings were common across foundries. These were highlighted and fed back to the companies in their individual site visit reports. Some, along with recommendations for improvements are listed below:

- COSHH risk assessment lacking details – The assessment should form the very start of the exposure control process as it enables employers to make decisions about what the worker might be exposed to, how exposure can occur (all routes) and what control measures are needed. The HSE website has advice on how to conduct a COSHH risk assessment.

- Dermal exposure to binder chemicals - The potential for dermal exposure was often overlooked. Some binder chemicals are known skin sensitisers. The potential to use tools / rods should be considered when mould and core making, and if this cannot be done then chemical protective gloves would offer more protection than fabric gloves.

- Compressed air use to blow loose sand off moulds – This was carried out at all foundries and is a probable contributor to inhalable FFP / dust and RCS exposures. Some foundries have tried other methods of removal such as vacuuming but have not been successful. There are two foundries currently hoping to install LEV systems for this task. It is hoped that their experiences will be shared via the CMF to encourage other foundries to so the same.

- Poor LEV design was often seen that would not offer adequate control of exposure; these included captor hoods not large enough for the contaminant source, receiving hoods not close enough to the source and booths that were too small for the castings. Hood selection and design are critical to the performance of an LEV system and must match the source, process and how the operator carries out that process. This is discussed and emphasised in HSG 258[15].

- LEV use – Training workers in the importance of control measures will greatly improve their understanding of LEV. This has been done at some foundries during worker briefings as part of the SRP. This can be done visually using smoke tubes / generators (commercially available) by foundry management. There are some videos that show common processes and sources available through the HSE website. Though not directly applicable to foundries, one shows how much dust can be re-suspended by compressed air use and one shows effective capture during welding[28].
- LEV maintenance and test – Regular maintenance of LEV systems is important to ensure that they continue to offer effective control. Not all foundries carried out in-house maintenance, meaning that issues such as blocked filters, leaking seals, broken hinges and damaged ductwork can be missed. All these can affect the performance of the system and lead to elevated exposures. Not all foundries carried out their TExT at the frequencies stated in Regulation 9 of the COSHH Regulations.

- There were occasions when PPE was not worn when available or not worn correctly (e.g. gloves not worn when handling sand mixture, PPE not worn during casting and RPE worn covering the mouth only). With regard to not wearing PPE when it is available, COSHH Regulation 8 'Use of control measures' places a duty on employees to '*make full and proper use of any control measure*'. There are training resources available on the HSE website for selection and use of RPE[29].

4.22 BENCHMARK STANDARDS OF CONTROL

The results from this work confirm and support the following as benchmark standards of control.

Mould making

- Ensure that the discharge point of the mixer is as close as possible to the mould box.

- Dispense the sand mixture at a slow speed to minimise dust emissions.

- Substitute BSA catalyst for alternatives such as XSA (this is not a ‘quick fix’ and care needs to be taken so as to not affect casting quality).

- Provide engineering controls such as enclosure or extraction for compressed air blow down of moulds.

- Control dermal exposure to binder chemicals by use of tools to create a safe working distance between the sand mixture in conjunction with chemical protective gloves.

- Use RPE.

Core making

- Where reasonably practicable consider enclosed and automated core making (cold or hot box) or addition of the catalyst within an extracted booth.

- Ensure that the discharge point of the mixer is as close as possible to the core box.

- Dispense the sand mixture at a slow speed to minimise dust emissions.

- Substitute BSA catalyst for alternatives such as XSA (this is not a ‘quick fix’ and care needs to be taken so as to not affect casting quality).

- Control dermal exposure to binder chemicals by use of tools to create a safe working distance between the sand mixture in conjunction with chemical protective gloves.

- Use RPE.

Furnace work

- Provide effective LEV and / or mechanical general ventilation to dilute molten metal fumes.

Casting

- Provide effective general ventilation to reduce exposure to particulate and CO (LEV may not be practicable at all foundries as casting may be carried out in different locations).

- RPE with a minimum APF of 20 for particulates and protection against VOCs should also be worn. Powered RPE with hoods would be more comfortable to wear.

Knockout

- The ideal exposure control would be enclosure.

- Containment of the particulate and fume can be improved by flexible strips to the front of booths. Avoid the use of air movers / fans in the immediate vicinity as they can reduce the effectiveness of the extraction.

- Where this isn’t available or practicable a combination of RPE (APF 20) and LEV (booths, extracted tables) or remote handling in a segregated area can be used.

Shotblasting

- Fully enclose the process in either enclosed / automated systems (these are common within the industry) with no operator contact, or

- Provide an extracted, enclosed cabin / room for manual shotblasting with the operator wearing heavy-duty specialised RPE.

Fettling

- Adequate control during manual fettling can only be achieved with a combination of LEV and RPE (preferably powered hood type systems). Both systems should be well maintained.

- LEV choices can include booths, receiving hoods, down draught booths. Captor hoods are not suited to high energy processes such as fettling. If booths are used then ensure the casting is inside it (within its influence) and preferably on a jig.

- Do not place air movers / fans in close proximity to the LEV as they will reduce effectiveness.

Cleaning

- Dry sweeping should not be allowed as it re-suspends settled particulate leading to additional exposure. Vacuum equipment to dust class M (medium hazard) classification should be used.

LEV maintenance and test

- Carry out regular maintenance of LEV systems to ensure that they continue to perform as they should.

- Ensure that LEV TExTs are carried out at the frequencies in schedule 4 of COSHH 2002 (as amended).

- Ensure that a competent person carries out the TExT and that the report from this test establishes that control is adequate.

RPE

- To be an effective control option RPE should be of the correct type, be stored properly (and not left on contaminated surfaces) and in the case of tight fitting RPE, be face-fit tested to the wearer (this includes disposable masks).

- Re-usable RPE should undergo regular maintenance and examination; this also includes breathing air quality tests (compressed airline fed RPE).

Other processes

Benchmark standards of control have not been identified specifically for finishing tasks such as cutting, burning and gouging (the benchmark standards of control for fettling would apply here). Welding was also not covered, however COSHH Essentials have a range of direct advice sheets which offer guidance on exposure control measures for welding and associated tasks (including cutting techniques)[30]. Finally, NDT was not covered but the guidance contained within Sector Information Minute (SIM) 03/2008/10[27] remains current.

5. CONCLUSION

This work has identified benchmarks of control for specific foundry tasks and selected substances, which, if followed, should adequately control exposure to hazardous substances and reduce the future burden of ill-health in the industry.

Exposure to a range of substances hazardous to health occurs in foundries. The risk management approach should take into consideration the whole range of substances that can give rise to long latency health risks and all routes of exposure.

This project has helped HSE and the foundry industry to obtain a better understanding of occupational exposure to substances in the foundry process that can cause cancer and respiratory disease.

There are some work tasks that the foundry industry has long recognised as having health risks, such as furnace work, knockout, fettling and shotblasting. However this study has highlighted other sources of inhalation exposure to dusts and RCS (compressed air blow down and position of dispense point, both in mould making), and potential dermal exposure to chemicals, including sensitisers (core making).

Compressed air should not be used to blow down loose sand on moulds without adequate control.

Exposures to manganese greater than the WEL were measured. As the majority of these elevated exposures were from workers at a foundry casting manganese steel, it can be assumed that the higher the manganese content the greater the potential for exposure. This is especially important for finishing activities such as fettling and welding.

There is the potential for workers in the vicinity of casting and cooling to be exposed to CO.

Where BSA is used in the binder system, benzene exposures can be significantly reduced by switching to XSA. This is not a simple substitution as preparatory work needs to be carried out to ensure that the correct mix is used so as not to affect the quality of the casting.

The importance of LEV design, the different hood types (and their limitations) and maintenance were not always fully understood when purchasing and using LEV. A better awareness would ensure that the correct LEV is designed, purchased, installed, commissioned, maintained, used and tested as intended in order to be an effective control.

In some cases consultants (employed by the foundries) were not supplying a compliant TExT (Regulation 9 of COSHH). A number of air sampling reports also contained inhalable FFP / dust measurements that were not collected using validated measurement methodology.

Dry sweeping was carried out at most foundries. This dust can contain RCS and metals from foundry feedstock. This task was the cause of an exposure to lead greater than the OEL. Dry sweeping re-suspends settled dust into the airborne phase. Dry sweeping should not be allowed and, instead, vacuum equipment to dust class M (medium hazard) classification should be used.

Whilst most foundries had acted upon their consultant's recommendations in exposure monitoring reports, the findings of these reports were not always clearly linked to risk assessment and on-going reviews of control efficacy.

6. REFERENCES

1. The Control of Substances Hazardous to Health Regulations 2002 as amended, Approved Code of Practice and guidance, L5 6th ed HSE Books, 2013. Available as a download from http://www.hse.gov.uk/pubns/priced/l5.pdf (accessed 27/05/16).

2. L Rushton, S Bagga, R Bevan, T P Brown, J W Cherrie, P Holmes, S J Hutchings, L Fortunato, R Slack, M Van Tongeren, C Young. The burden of occupational cancer in Great Britain, overview report. HSE Research Report RR931. HSE Books, 2010. Available as a download from http://www.hse.gov.uk/research/rrpdf/rr931.pdf (accessed 20/07/17).

3. T Sorahan, A M Faux, M A Cooke, 1994. Mortality among a cohort of United Kingdom steel foundry workers with special reference to cancers of the stomach and lung, 1946-90. Journal of Occupational and Environmental Medicine Vol.50 No.3 pp316-322

4. European Chemicals Agency information on chemicals. Available at http://echa.europa.eu/information-on-chemicals (accessed 24/03/16).

5. Workplace exposure limits Containing the list of workplace exposure limits for use with the Control of Substances Hazardous to Health Regulations (as amended). 2011. EH40/2005 HSE Books, 2011. Available as a download from http://www.hse.gov.uk/pubns/priced/eh40.pdf (accessed 26/05/16).

6. Control of lead at work Regulations, 2002 Approved Code of Practice and guidance. L132, 3rd ed, HSE Books. Available as a download from http://www.hse.gov.uk/pubns/priced/l132.pdf (accessed 27/05/16).

7. Methods for the Determination of Hazardous Substances (MDHS) series. Available as a download from http://www.hse.gov.uk/pubns/mdhs/ (accessed 27/05/16).

8. J Unwin, J Cocker, E Scobie, H Chambers, 2006. An assessment of occupational exposure to polycyclic aromatic hydrocarbons in the UK. Annals of Occupational Hygiene Vol 50, pp 395-403. Available as a download from http://annhyg.oxfordjournals.org/content/50/4/395.full (accessed 26/07/16).

9. Selinski S, Kopps S, Prager H.-M, v. Mende S, Thiel R, Jungmann O, Zumbe J, Bolt H.M, Blaszkewicz M, Hengstler J.G, Golka K. Bladder cancer in crack testers applying azo dye-based sprays to metal bodies. Leibniz Research Centre for Working Environment and Human Factors. WATCH/2011/4 Available as a download http://www.hse.gov.uk/aboutus/meetings/iacs/acts/watch/251011/watch-2011-4.pdf

10. J Cooke. 2011. The supply and use of CI Solvent Red 164 as a penetrant dye in the detection of cracks in metal components. WATCH/2011/4. Available as a download from http://www.hse.gov.uk/aboutus/meetings/iacs/acts/watch/251011/watch-2011-4.pdf (accessed 27/05/16).

11. Illness caused by welding fume and gases. Available as a download http://www.hse.gov.uk/welding/illness.htm (accessed 26/07/16).

12. Welding fume facts - What is it and what does it do to you. Available as a download http://www.hse.gov.uk/welding/fume-facts.htm (accessed 27/05/16).

13. COSHH Essentials in foundries, direct advice sheets. All sheets (FD0 through to FD14) available as downloads from http://www.hse.gov.uk/pubns/guidance/fdseries.htm (accessed 26/07/16).

14. COSHH Essentials advice sheet WL19 Surface preparation: Pressure blasting (medium-sized items). Available as a download from http://www.hse.gov.uk/pubns/guidance/wl19.pdf (accessed 26/07/16).

15. Controlling airborne contaminants at work - A guide to local exhaust ventilation (LEV), HSG258. 2nd ed, HSE Books, 2011. Available as a download from http://www.hse.gov.uk/pubns/priced/hsg258.pdf (accessed 27/05/16).

16. Respiratory protective equipment at work; A practical guide. HSG53 4th ed, HSE Books, 2013. Available as a download from http://www.hse.gov.uk/pubns/priced/hsg53.pdf (accessed 27/05/16).

17. Selecting latex gloves. Available at http://www.hse.gov.uk/skin/employ/latex-gloves.htm (accessed 24/03/16).

18. S Frost and A H Harding. The effect of wearer stubble on the protection given by Filtering Facepieces Class 3 (FFP3) and Half Masks. HSE Research Report RR1052, HSE Books, 2015. Available as download http://www.hse.gov.uk/research/rrpdf/rr1052.pdf (Accessed 24/03/16).

19. C Keen, E Tan, J McAlinden, P Woolgar, P Smith. Exposure to hexavalent chromium, nickel and cadmium compounds in the electroplating industry. HSE Research Report RR963, HSE Books, 2013. Available as a download http://www.hse.gov.uk/research/rrpdf/rr963.pdf (accessed 24/03/16).

20. J Cocker, J R Cain, P Baldwin, K McNally, K Jones, 2009. A survey of occupational exposure to 4,4′-methylene-bis (2-chloroaniline) (MbOCA) in the UK. Annals of Occupational Hygiene Vol 53, pp. 499 – 507. Available as a download from (http://annhyg.oxfordjournals.org/content/53/5/499.full?sid=73db3b9d-d22f-4534-92a8-c045f30e4833).

21. C Keen, M Coldwell, K McNally, P Baldwin, J McAlinden, J Cocker, 2012. A follow up study of occupational exposure to 4,4'-methylene-bis(2-chloroaniline) (MbOCA) and isocyanates in polyurethane manufacture in the UK. http://www.ncbi.nlm.nih.gov/pubmed/21501672 (accessed 26/07/16).

22. K Jones, J Cocker, M Piney, 2012. Isocyanate exposure control in motor vehicle paint spraying: evidence from biological monitoring. Annals of Occupational Hygiene Vol. 57 No.2 pp 200-209. Available as a download from http://annhyg.oxfordjournals.org/content/57/2/200 (accessed 26/07/16).

23. R Lauwerys and P Hoet Industrial chemical exposure; guidelines for biological monitoring. 3rd ed, Boca Raton Florida, Lewis Publishers, 2001.

24. P Apostoli, R Lucchini, and L Alessio, 2000. Are current biomarkers suitable for the assessment of manganese exposure in individual workers? American Journal of Industrial Medicine Vol.37 No. 3 pp283-290.

25. Bieniek G, 1997. Urinary excretion of phenols as an indicator of occupational exposure in the coke-plant industry. International Archives of Occupational and Environmental Health Vol.70 pp334–340.

26. Y Christopher, S Semple, GW Hughson and JW Cherrie 'Inadvertent ingestion exposure in the workplace' Phase I Literature review. HSE Research Report RR551, HSE Books, 2007. Available as a download from http://www.hse.gov.uk/research/rrpdf/rr551.pdf (accessed 5/08/16).

27. The use of liquid dye penetrants containing the azo compound CI Solvent Red 164 in the detection of flaws or cracks in metal components, SIM 03/2008/10, HSE website. Available as a download from http://www.hse.gov.uk/foi/internalops/sims/manuf/3_08_10.htm (accessed 5/08/16).

28. LEV Common processes and sources – LEV. HSE, 2015. Available at http://www.hse.gov.uk/lev/common-processes.htm (accessed 26/07/16).

29. HSE Respiratory Protective Equipment Resources http://www.hse.gov.uk/respiratory-protective-equipment/resources.htm (accessed 5/08/16).

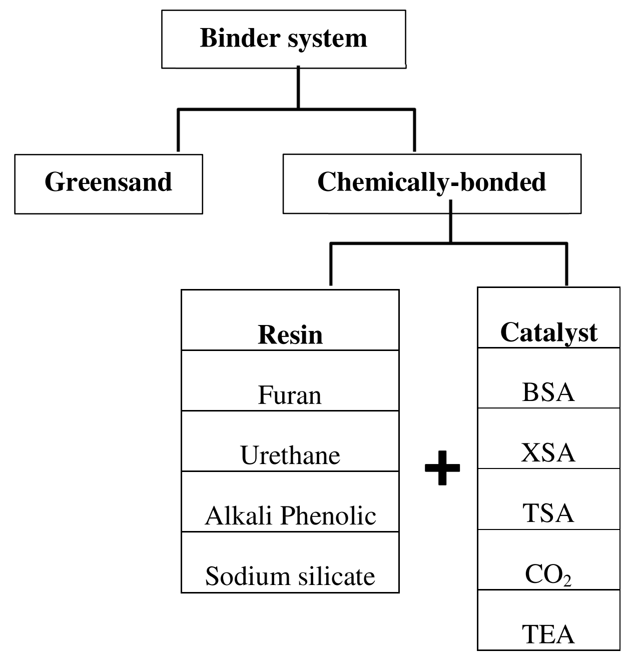
30. HSE COSHH Essentials Direct Advice Welding http://www.hse.gov.uk/coshh/essentials/direct-advice/welding.htm (accessed 5/08/16).

7. APPENDICES

7.1 APPENDIX 1 FOUNDRY TYPES AND BINDER SYSTEMS

Metal	Workplace type
Iron	Large, automated
Iron	Large jobbing
Iron	Small automated
Iron	Small Manual
Steel	Large automated
Steel	Large jobbing
Steel	Small automated
Steel	Small Manual
Aluminium	Large automated
Aluminium	Large jobbing
Aluminium	Small automated
Aluminium	Small, Manual
Aluminium	Die casting
Copper alloys	Sand casting
Copper alloys	Die casting
Zinc	Die casting

+



Note: The above is not a definitive list of foundry / resin / catalyst types

Notes:
BSA – Benzene sulphonic acid
XSA – Xylene sulphonic acid
TSA – Toluene sulphonic acid
CO_2 – Carbon dioxide
TEA - Triethylamine

7.2 APPENDIX 2 SAMPLING STRATEGY

The table below presents the substances sampled for in each step of the foundry process (see Section 2.3, Foundry processes, potential exposures and sampling strategy in the Methodology section)

Task	Inhalable dust (or FFP)	Inhalable Metals* #	Respirable dust (or FFP)	RCS	VOCs *	Aromatic amines^ *	Isocyanate *	PAHs* †	1,3-Butadiene	Formaldehyde
Moulding	X	X	X	X	X		X		X	X
Core making	X	X	X	X	X		X		X	X
Furnace work	X	X	X	X						
Casting	X	X	X	X	X	X	X	X	X	X
Knockout / shakeout	X	X	X	X	X	X	X	X	X	X
Fettling	X	X	X	X						
Welding	X	X								

For those substances marked with * biological monitoring (BM) was also carried out

BM for aniline, ortho toluidine and para toluidine was carried out on workers who carried out NDT with dye penetrant containing CI Solvent Red 164

- This was a general screen for metals that included chromium, lead, manganese and nickel

^ - The amines concerned were aniline, methylenedianiline, o-toluidine and p-toluidine

† - Polycyclic aromatic hydrocarbons

Carbon monoxide, oxides of nitrogen and sulphur dioxide were also measured at some foundries using a direct reading instrument (DRI).

7.3 APPENDIX 3 REGULATORY POSITION FOR THE SUBSTANCES SAMPLED

(BMGV's quoted as µmol/mol creatinine unless otherwise stated)

A / BM	Substance	Human health hazard statement code [4]	WEL [5]	BMGV	Source	Notes
A	Ferrous foundry particulate (FFP)	N/A	10 mg/m^3 Inhalable 4 mg/m^3 Respirable	-	Process generated & raw material	-
A BM	Aluminium (Metal dust)	N/A	10 mg/m^3	BAT = 250	Process generated	-
A BM	Cobalt	H317, 334	0.1 mg/m^3	BEI = 20 (approx)	Process generated	Sen
A BM	Cadmium	H330[A], 341, 350, 361, 372[B]	0.025 mg/m^3	BEI = 4	Process generated	Carc (metal)
A	Chromium (NOT Chromium VI)	[C]	0.5 mg/m^3	GB BMGV = 10	Process generated	-
A	Iron oxide fume (As Fe)	[C]	5 mg/m^3 10 mg/m^3 (STEL)	-	Process generated	-
A	Magnesium oxide fume	[C]	4 mg/m^3	-	Process generated	-
A BM	Copper	[C]	0.2 mg/m^3 (fume) 1 mg/m^3 (dust & mist) 2 mg/m^3 (dust and mist STEL)	-	Process generated	-
A	Manganese	[C]	0.5 mg/m^3	-	Process generated	-
A	Lead	See table key and notes	0.15 mg/m^3 OEL [6]	-	Process generated	-
BM	Tungsten	[C]	5 mg/m^3 10 mg/m^3 STEL	-	Process generated	-
A BM	Nickel	H317, 351, 372[B]	0.5 mg/m^3	23 †	Process generated	Sk
A	Respirable crystalline silica (RCS)	[C]	0.1 mg/m^3	-	Process generated & raw material	-
A BM	Benzene	H304, 315, 319, 340, 350, 372[B]	1 ppm	BEI = 12 EKA = 21 #	Process generated	Carc Sk
A BM	Furfuryl alcohol	H302[D], 312[D], 319, 331[E], 335, 351, 373[B,F]	-	-	Process generated	-
A BM	Toluene	H304, 315, 336, 361 (d)[G], 373[B,F]	50 ppm 100 ppm STEL	BEI = 310 (approx)	Process generated	Sk
A	Isopropanol	H319, 336	400 ppm 500 ppm STEL	-	Process generated & raw material	-
A BM	Xylene	H312[D], 315, 332[D]	50 ppm 100 ppm STEL	GB BMGV = 650mmol/mol creatinine	Process generated	Sk
A BM	Phenol	H301[E], 311[E], 314, 331, 341, 373[B,F]	2 ppm 4 ppm (STEL)	BEI = 300 BAT = 175 mmol/mol creatinine	Process generated & raw material	Sk
A BM	Ortho-Cresol	H301[E], 311[E], 314	-	BEI = 310	Process generated	-
A	Ethylbenzene	H304, 332[D], 373 (hearing organs)	100 ppm 125 ppm STEL	BAT = 160 BEI = 110 mmol/mol creatinine	Process generated	Sk
A BM	Isocyanates (various)	N/A	0.02 mg/m^3 0.07 mg/m^3 STEL	GB BMGV = 1 (all isocyanates)	Raw material	Sen
BM	Aniline	H301[E], 311[E], 317, 318, 331[E], 341, 351, 372[B]	4 mg/m^3	BAT = 900	Process generated	Sk
BM	Methylenedianiline	H317, 341, 350, 370[B], 373[B,F]	0.01 mg/m^3	GB BMGV = 50	Process generated	Carc, Sk
BM	o-Toluidine	H301[E], 319, 331[E], 350	0.89 mg/m^3	-	Process generated	Carc, Sk
BM	PAHs (various)	N/A	-	GB BMGV = 4	Process generated	Some are carcinogenic
A	Formaldehyde	H301[E], 311[E], 314, 317, 331[E], 341, 350	2.5 mg/m^3 2.5 mg/m^3 STEL	-	Process generated	-

A = air sampling carried out, BM = biological monitoring carried out

Table key and notes

WEL – Workplace Exposure Limits, British exposure limits

BMGV – Biological Monitoring Guidance Value

ECHA – The European Chemicals Agency, the driving force in implementing the EU's chemicals legislation for the protection of human health and the environment.

CLP - The Classification, Labelling and Packaging Regulations. This introduces into the EU the globally harmonised system for classifying and labelling chemicals.

REACH – Registration, Evaluation, Authorisation & restriction of Chemicals (REACH) is a regulation of the European Union, adopted to improve the protection of human health and the environment from the risks that can be posed by chemicals.

Human health and hazard statement codes:
All codes were taken from the Information on chemicals section of the ECHA website. Those quoted are the harmonised classifications from Annex VI to the CLP Regulations. It should be noted that these are subject to updates. Those quoted (along with notes [A] through to [G] below) are current as of 26th May 2016.

[*] - Hazard class and category codes - Acute Tox. 2 – The classification as obtained from Annex VII shall then substitute the minimum classification indicated in the annex if it differs from it.

[B] - The classification under 67/548/EEC indicating the route of exposure has been translated into the corresponding class and category according to this regulation, but with a general hazard statement not specifying the route of exposure as the necessary information.

[C] - See the abridged summary of notified classifications in the C & L inventory on the ECHA website

[D] - Hazard class and category codes - Acute Tox. 4 – The classification as obtained from Annex VII shall then substitute the minimum classification indicated in the annex if it differs from it.

[E] - Hazard class and category codes - Acute Tox. 3 – The classification as obtained from Annex VII shall then substitute the minimum classification indicated in the annex if it differs from it.

[F] - Hazard class and category codes –STOT RE. 2– The classification as obtained from Annex VII shall then substitute the minimum classification indicated in the annex if it differs from it.

[G] - In order not to lose information from the harmonised classifications for fertility and developmental effects under 67/548/EEC, the classifications have been translated only for those effects classified under that directive.

Lead metal - There is currently there is no harmonised classification for lead metal. A harmonised classification for has been included in the 7th ATP proposal of Commission (Follow-up to the 13th Meeting of Competent Authorities for REACH and CLP (CARACAL) 26 – 27 – 28 November 2013, February 12 2014)

H301 – Toxic if swallowed
H302 – Harmful if swallowed
H304 – May be fatal if swallowed and enters airways
H311 – Toxic in contact with skin
H312 – Harmful in contact with skin
H314 – Causes severe skin burns and eye damage
H315 – Causes skin irritation
H317 – May cause an allergic skin reaction
H318 – Causes serious eye damage
H319 – Causes serious eye irritation
H330 – Fatal if inhaled
H331 – Toxic if inhaled
H332 – Harmful if inhaled
H335 – May cause respiratory irritation
H336 – May cause drowsiness or dizziness
H340 – May cause genetic defects

H341 – Suspected of causing genetic defects
H350 – May cause cancer
H351 – Suspected of causing cancer
H361 – Suspected of damaging fertility or the unborn child
H372 – Causes damage to organs through prolonged or repeated exposure (Category 1)
H373 – May cause damage to organs through prolonged or repeated exposure (Category 2)

BMGV:
† - 90th percentile from HSE's biological monitoring database

- At the GB WEL of 1ppm the level of S-PMA (the marker for benzene) would be around 21µmol/mol creatinine.

BAT – German Biological Tolerance Value for occupational exposures.

BEI – Biological Exposure Index – ACGIH (American Conference of Government Industrial Hygienists)

EKA – Expositionsaquivalente fur Krebserzeugende Arbeitsstoffe (Biological equivalent to an airborne limit) for carcinogenic substances (Germany)

Sen – Capable of causing occupational asthma

Sk - Can be absorbed through the skin

Carc - Capable of causing cancer and/or heritable genetic damage

7.4 APPENDIX 4 SITE VISIT PROTOCOL

HSE
Health & Safety
Executive

LLHR Foundry project

Visit and sampling protocol

The main objectives of the visits are to observe the way that workers normally carry out their duties. HSE will not be getting in their way or taking them away from their work. HSE staff on site will include: two scientists from HSE's Buxton laboratory, one Specialist inspector of occupational hygiene (in some cases two) and the local general inspector.

It is envisaged that each visit will take two working days in order to cover all four stages of the founding process. This will include an assessment of exposure controls, to include management controls (COSHH assessments, worker training, health surveillance etc.), qualitative and, where possible quantitative assessment of engineering controls, and PPE. Quantitative exposure assessments will be made using a combination of air sampling and biological monitoring. HSE would like permission to take photographs of site processes. These photographs will not be communicated outside of HSE without the company's authorisation.

Air sampling will be carried out on personnel involved in the main foundry processes listed below.

1. Mould/core making
2. Metal melting/casting
3. Knockout, fettling, sand reclamation
4. Finishing, including NDT and welding

The founding process will vary from one foundry to another. The main variables include:

- The mould/core making system in use
- The metals/alloys being melted and cast
- The extent of mould sand recycling
- The size and physical layout of the foundry
- The degree of automation in the foundry

Air sampling will focus on personal sampling to allow direct measurement of inhalation exposures. Static sampling will be conducted where it may generate relevant additional information.

Biological monitoring (BM) over several days, where possible will be used to provide information on total body burden. This allows a quantitative assessment of exposure by all routes.

The measurement strategy will be tailored for each foundry, dependant on the variables listed and the consent of each worker involved. An outline of what will be carried out on each worker as follows:

Mould/core making

The main agents of concern in this area are general dust, RCS and the organic binders and associated curing agents used to make moulds and cores.

Air sampling will be conducted for inhalable dust, respirable dust including RCS, and the specific organic binders and curing agents in use at each foundry or substances which may be generated during the process. It is envisaged that these will include isocyanates, phenol, formaldehyde, furfuryl alcohol and volatile organic compounds (VOCs) Where measurement methods exist, biological monitoring will also be conducted for the organic binders and curing agents.

Melting/casting

The main agents of concern at this stage are general dust, metal fume, toxic gases such as carbon monoxide, sulphur dioxide and oxides of nitrogen and the thermal decomposition products from the organic binders. These may include benzene, polycyclic aromatic hydrocarbons (PAH), aromatic amines and low molecular weight isocyanates, depending upon the binder system in use.

Air sampling will be conducted for inhalable and respirable dust, metal fume and thermal decomposition products of the organic binders (benzene, VOCs, furfuryl alcohol, formaldehyde).

BM will be conducted for metals and thermal decomposition products of the organic binders, where measurement methods exist (PAH, aromatic amines, isocyanates).

Direct reading instruments will be used to determine levels of toxic gases.

Knockout/fettling

The main agents of concern at this stage are dust (including metal dust) and RCS.

Air sampling will be conducted for inhalable and respirable dust, metals, and RCS.

No BM will be conducted on workers involved in this stage of the process.

Finishing

The main agents of concern at this stage are dust, azo dyes used for NDT of the castings and welding fume.

Air sampling will be conducted for inhalable and respirable dust and metal/welding fume.

BM will be conducted for metals (where significant amounts of welding or grinding are undertaken) and the carcinogens which are potential metabolites of the azo dyes (ortho-toluidine and aniline).

It may be the case that in some foundries the mould making and casting are carried out by the same people during the working shift. In these cases personal samplers will be worn that will measure exposures for both tasks.

A full occupational hygiene visit report will be produced for each site, which will include the monitoring results, opinions on the adequacy of exposure controls plus recommendations/advice on improvements where appropriate. A copy of this report will be given to the participating foundry after it has been seen by their general inspector. Prior to formal issue of the report the site will be given the opportunity to comment on its factual accuracy with respect to site and process descriptions.

7.5 APPENDIX 5 OCCUPATIONAL HYGIENE QUESTIONNAIRE

Survey of the use and control of exposure to
Long Latency Health Risk (LLHR) Substances in Foundries

1. **General Details**

Make introductions, thank for assistance, explain project.
Name of Person completing visit report:________________________________

Date:_________

Foundry Contact: ______________________________________

Foundry Name: ______________________________________

Client Number:________________________________
(Obtainable from FOCUS/COIN/ORION)

Location Number:____________________________________

(Obtainable from COIN/FOCUS/ORION)

Address:____

____

Postcode:________________________

Phone Number:___________________

E-mail address:___________________

FOD Contact: ___________________

SIC Code: _____________
(Obtainable from FOCUS/COIN/ORION)

2. Description of business and historical picture

Points to include: • Brief description of what the company does. • Location of HQ, if different from above. • How long has the company been using/generating substances known to cause long latency health risks (LLHR)? • Any major changes to the process over the years

3. Process and company details

Process details
Additional notes:

(Add number and any comments into appropriate box)	
Number of sites in the UK?	
Total number of employees in the company?	
Total number of employees on this site?	
Total number of employees potentially exposed to LLHR substances?	
(a) Gender of the potentially exposed work force? *(Number of males and females)*	
(b) Average age of the potentially exposed workforce? *(As a range)*	
(c) Average experience of the potentially exposed workforce? *(Number of years of service, as a range)*	
Length of shift? *(In hours)*	
Number of days worked per week?	

(Tick appropriate box)	Yes	No
Are LLHR substances supplied as raw materials?		
Are LLHR substances generated as part of the process or as intermediate products?		
Are the LLHR substances the final product?		

Average quantity of each LLHR substance handled? *(Grams, kilogram/ litre etc)*	
Life cycle of each LLHR substance on-site? *(Fill in quantity and give a description of the life cycle of each LLHR substance from delivery to export)*	

4. Delivery/Supply/Storage of LLHR substances

(If you do not take delivery of LLHR substances you may ignore this section, otherwise fill in as necessary)

Description of task/tasks:	
Number of deliveries per year?	
Total number of employees exposed directly?	
Total number of employees exposed indirectly?	
Duration of exposure per delivery *(In minutes)*?	
Description of controls used for task/tasks *(PPE/ RPE /LEV/Engineering controls/Managements controls etc)*:	
Adequacy of controls rating (Write a number in box for rating) 1 = Very effective. 2 = Effective. 3 = Partially Effective. 4 = Ineffectual.	
Recommendation on reasonably practicable improvements:	

5. Use/Process Generation/Manufacture of LLHR substances - Mould/core making

(Fill in as necessary)

Description of task/tasks:	
Total number of employees exposed directly?	
Total number of employees exposed indirectly?	
Duration of exposure per shift (In minutes)?	
Description of controls used for task/tasks *(PPE/ RPE /LEV/Engineering controls/Managements controls etc)*:	
Adequacy of controls rating (Write a number in box for rating) 1 = Very effective. 2 = Effective. 3 = Partially Effective. 4 = Ineffectual.	
Recommendation on reasonably practicable improvements:	

6. Use/Process Generation/Manufacture of LLHR substances - Metal melting/casting

(Fill in as necessary)

Description of task/tasks:	
Continuous or batch process?	
If batch process number per week/year?	
Total number of employees exposed directly?	
Total number of employees exposed indirectly?	
Duration of exposure per shift (In minutes)?	
Description of controls used for task/tasks *(PPE/ RPE /LEV/Engineering controls/Managements controls etc)*:	
Adequacy of controls rating (Write a number in box for rating) 1 = Very effective. 2 = Effective. 3 = Partially Effective. 4 = Ineffectual.	
Recommendation on reasonably practicable improvements:	

7. Use/Process Generation/Manufacture of LLHR substances - Knockout, fettling, sand reclamation

(Fill in as necessary)

Description of task/tasks:	
Total number of employees exposed directly?	
Total number of employees exposed indirectly?	
Duration of exposure per shift (In minutes)?	
Description of controls used for task/tasks *(PPE/ RPE /LEV/Engineering controls/Managements controls etc)*:	
Adequacy of controls rating (Write a number in box for rating) 1 = Very effective. 2 = Effective. 3 = Partially Effective. 4 = Ineffectual.	
Recommendation on reasonably practicable improvements:	

8. Use/Process Generation/Manufacture of LLHR substances - Finishing, including non-destructive testing and welding

(Fill in as necessary)

Description of task/tasks:	
Total number of employees exposed directly?	
Total number of employees exposed indirectly?	
Duration of exposure per shift (In minutes)?	
Description of controls used for task/tasks *(PPE/ RPE /LEV/Engineering controls/Managements controls etc)*:	
Adequacy of controls rating (Write a number in box for rating) 1 = Very effective. 2 = Effective. 3 = Partially Effective. 4 = Ineffectual.	
Recommendation on reasonably practicable improvements:	

9. Cleaning and Maintenance

(Fill in as necessary)

Description of task/tasks:	
Total number of employees exposed directly?	
Total number of employees exposed indirectly?	
Duration of exposure per shift (In minutes)?	
Description of controls used for task/tasks *(PPE/ RPE /LEV/Engineering controls/Managements controls etc)*:	
Adequacy of controls rating (Write a number in box for rating) 1 = Very effective. 2 = Effective. 3 = Partially Effective. 4 = Ineffectual.	
Recommendation on reasonably practicable improvements:	

10. Disposal

(If you do not have to dispose of LLHR substances you may ignore this section, otherwise fill in as necessary)

Description of task/tasks:	
Total number of employees exposed directly?	
Total number of employees exposed indirectly?	
Duration of exposure per shift (In minutes)?	
Description of controls used for task/tasks *(PPE/ RPE /LEV/Engineering controls/Managements controls etc)*:	
Adequacy of controls rating (Write a number in box for rating) 1 = Very effective. 2 = Effective. 3 = Partially Effective. 4 = Ineffectual.	
Recommendation on reasonably practicable improvements:	

11. Packing and Export

(If you do not pack or export LLHR substances you may ignore this section, otherwise fill in as necessary)

Description of task/tasks:	
Total number of employees exposed directly?	
Total number of employees exposed indirectly?	
Duration of exposure per shift (In minutes)?	
Description of controls used for task/tasks *(PPE/ RPE /LEV/Engineering controls/Managements controls etc)*	
Adequacy of controls rating (Write a number in box for rating) 1 = Very effective. 2 = Effective. 3 = Partially Effective. 4 = Ineffectual.	
Recommendation on reasonably practicable improvements:	

12. Downstream Uses of the LLHR substance

(If you manufacture or act as an intermediate for the supply of LLHR substances to another workplace please fill in this section).

Description of uses:	
Typical quantity supplied per use per year (grams, kilos)?	

13. Management systems for LLHR substances (COSHH Assessment)

	Yes	No	Elaborate if necessary
Is there a COSHH assessment? (Tick appropriate box and obtain photocopies where possible)			
Any other formal operating procedure relevant to the safe handling of the LLHR substances? (Please specify and obtain photocopies where possible)			
If Yes to above. Adequacy of COSHH assessment (Tick if company has carried out the following and elaborate if necessary)	Yes	No	Elaborate if necessary
Does the assessment cover potential for elimination, substitution and/or segregation of the process?			
Covers all groups of workers exposed?			
Hazard evaluation adequate?			
Assessment covers all health risks?			
Assessment covers all tasks carried out?			
Assessment covers frequency and duration of exposure?			
Identifies measure needed to adequately control exposure?			
Introduced control measures do not increase the overall risk to health and safety?			
Reliable control measures used?			
Takes account of all routes of exposure – inhalation, skin absorption and ingestion?			
Outlines how control measures are examined tested and maintained?			
Assessment identifies monitoring requirements?			
Assessment identifies Workplace Exposure Limits (WEL's)?			
Assessment identifies health surveillance requirements?			
Is there an appointed health provider?			
Details information and training on the safe use of LLHR substances?			
Emergency procedures to deal with spillages?			
Is assessment of risk regularly reviewed?			

14. Examinations of engineering controls

(Tick appropriate box and elaborate if necessary)	Yes	No	Elaborate (why systems not checked etc)
Are LEV control systems thoroughly examined and tested by a competent person **every 14 months**?			
Does the thorough examination include the following?			
(a) Visual check of key parts internal/external?			
(b) Measurement of key operational parameters?			
(c) Production of record of key data including procedures for remedying faults in required time scale?			
Is regular maintenance and inspections carried out to check whether system is working within normal parameters? (Please indicate whether inspection done daily or weekly)			
Does the maintenance/inspection include the following?			
(a) Visual checks for deposits in workplace/around enclosure/ around ducting carried out?			
(b) Airflow checks, anemometer, smoke tubes, dust lamps, in-line static pressure measurements?			
(c) Is there a record of checks?			
(d) Procedure for maintenance if checks fail?			
Where does the exhausted air go?			
(a) Discharge stack 3 m or more above roof? atmosphere?			
(b) Discharge terminal suitable to prevent air re-entry into building?			
(c) Discharge terminal not positioned near air intakes for the building?			
(d) Passes through an electrostatic/scrubber/cyclone/ filter/bag etc?			
For filters and bags only ask the following?			
What types of filters/bags are used?			
How often are filters/bags changed?			
How are filters/bags changed? *(Description)*			

Types of LEV used (Tick appropriate box and elaborate as necessary)		Are improvements practicable?		
		Yes	No	Comment if necessary
Total enclosure				
Partial enclosure				
Laminar flow booth				
Down flow booth				
Fume cupboard				
Receptor hood				
Movable hood				
Canopy hood				
Slot exhaust				
Other (please specify)				

General ventilation only				
Rating (Write a number in box for rating) 1 = Very effective. 2 = Effective. 3 = Partially Effective. 4 = Ineffectual.				

15. RPE and PPE Management Programme

RPE	RPE not used	Airline/ BA	Full face	Half mask	Disposable
Type of RPE? (If used tick appropriate box)					

RPE	Routinely	Specific tasks	Specify tasks:
How is RPE used? (Tick appropriate box)			

(Tick appropriate box and comment as necessary)	*Comments*
How did you select your RPE?	
Has training in the use of RPE been carried out?	
Has face-fit testing been carried out?	
How is in-use RPE stored?	
How often are disposable mask changed? (Frequency)	
How often are filter on half mask changed? (Frequency)	
How often are airline/BA maintained? (Frequency)	
Are there records of airline/BA examinations and tests?	

16. PPE Gloves

Gloves	Gloves not used	Reusable	Disposable
Type of Gloves? (If used tick appropriate box)			

Gloves	Routinely	Specific tasks	Specify tasks:
How are Gloves used? (Tick appropriate box)			

(Comment as necessary)	*Comments*
Glove material (nitrile, natural rubbers, PVC etc)?	
How do you select appropriate gloves?	
How often are glove changed? (Frequency)	
How are in-use gloves stored? (Only applies to reusable glove)	
Is training in the use of gloves given?	

17. PPE Coveralls

Coveralls	Coveralls not used	Reusable	Disposable
Type of Coveralls? (If used tick appropriate box)			

Coveralls	Routinely	Specific tasks	Specify tasks:
How are Coveralls used? (Tick appropriate box)			

(Fill in what is done if necessary)	*Comments*
Coverall material (Tyvek, cotton, poly/cotton etc)?	
How do you select your coveralls?	
Is training in the donning and doffing of coveralls given?	
How often are coveralls changed? (Frequency)	
Are storage facilities provided for PPE?	
How often are coveralls cleaned? (Only applies to reusable PPE)	

18. Monitoring (Regulation 10)

(Tick appropriate box and elaborate if necessary)	Yes	No	Elaborate
Do you carry out air monitoring?			
Was personal monitoring carried out?			
Was static monitoring carried out?			
How often do you carry out monitoring? *(Frequency)*			
Was a described method used?			
What action have you taken as a result of the monitoring?			
Have the employees been informed of the results?			

(Tick appropriate box and elaborate if necessary)	Yes	No	Elaborate
Do you carry out biological monitoring?			
(Tick appropriate box and fill in as necessary)	Yes		No
Would you allow your employees to participate in a voluntary BM survey?			
Roughly how many workers would participate?			
Who will act as the point of contact for the BM survey? (Give contact details)			

19. Information, instruction and training

(Tick appropriate box and elaborate if necessary)	Yes	No	Elaborate
Do you have training records for your employees?			
Do you carry out induction training for your employees?			
Have employees been informed of the hazards/ risks associated with the use of the LLHR substances?			
Are employees aware of the possible symptom associated with the LLHR substances?			
Have employees been informed of how to use and operate the controls measures put in place to protect them from the LLHR substances?			
Do you carry out on-the job training?			
Do you use external training?			
Do you carry out refresher training on H&S?			

20. Precautions against contamination

(Tick appropriate box and elaborate if necessary)	Yes	No	Elaborate
Employees do not eat, drink, smoke or apply cosmetics in work area?			
Are adequate washing facilities provided?			
Do employees use the washing facilities provided?			
Appropriate warning signs are prominently displayed?			

21. General Information on Communication

For the intervention strategy ask the following questions, so we can obtain information on the appropriate media to use.

(Tick appropriate box, elaborate where necessary and write number in column))

Where do you obtain information on hazardous substances?	Yes	No	Elaborate
Safety Data Sheet			
Trade Association			
Website			
What types of media do you prefer to receive information from?	Yes	No	Elaborate
Consultant *(Face to face)*			
Inspector *(Face to face)*			
Letter			
E-mail			
Leaflets including SDSs			
Website			
Trade magazine			
Trade exhibition			

Trade/Professional association (direct communication)			
DVD/Video/CD.ROM			
Guidance publications			
Conferences			
Safety awareness days			
Others			

22. Overall Rating

Use the information collected from the above questions and your observations to rate the company overall in terms of the eight principals of good practice.

(Write number in rating column using the criteria at bottom of table. Consider if improvements can be made to the current practice and comment if necessary).		Are Improvement Practicable		
	Rating	Yes	No	Comments if necessary
(a) Design and operate processes and activities to minimise emission, release and spread of substances hazardous to health.				
(b) Take into account all relevant routes of exposure - inhalation, skin and ingestion – when developing control measures.				
(c) Control exposure by measures that are proportionate to the health risk.				
(d) Choose the most effective and reliable control options that minimise the escape and spread of substances hazardous to health.				
(e) Where adequate control of exposure cannot be achieved by other means, provide, in combination with other control measures, suitable protective equipment.				
(f) Check and review regularly all elements of control measures for their continuing effectiveness.				
(g) Inform and train all employees on hazards and risks from substances with which they work, and the use of control measures developed to minimise the risks.				
(h) Ensure that the introduction of measures to control exposures does not increase the overall risk to health and safety.				
(Write number in rating column) *1 = Achieved in full. 2 = Achieved in part. 3 = Not achieved. 4 = Not attempted.*				

7.6 APPENDIX 6 SAMPLING AND ANALYSIS METHODS

7.6.1 Air monitoring methods

Substance	Sampling	Analysis
Inhalable FFP / dust & metals	Membrane filter (DM 800 or GLA 500) in an IOM sampling head connected to a sampling pump aspirated at 2 l/min (MDHS 14/3, superseded, see below)	Inhalable dust – Gravimetric (MDHS 14/3, since superseded, see below)
		Metals - Analysed in accordance with BS ISO 15202-2 and BS ISO 15202-3 using Inductively coupled plasma – atomic emissions spectrometry (ICP-AES)
Respirable FFP / dust & RCS	Membrane filter (DM 800 or GLA 500) in a cyclone sampler connected to a sampling pump aspirated at 2.2 l/min (MDHS 14/3, superseded, see below)	Respirable dust – Gravimetric (MDHS 14/3, superseded, see below)
		RCS – X-ray diffraction (MDHS 101, superseded, see below)
Polycyclic aromatic hydrocarbons (PAH) *	Glass fibre filter in IOM (Institute of occupational Medicine) sampling head backed by XAD-2 sorbent tube connected to a sampling pump aspirated at 2 l/min (In house method based on ISO/12884:2000)	Solvent extraction (cyclohexane) gas chromatography – mass spectrometry (GC/MS) (BS ISO 12884:2000)
Aromatic amines *	Acid coated filter in IOM sampling head connected to a sampling pump aspirated at 2 l/min (MDHS 75, superseded, see below)	High performance liquid chromatography – photodiode array (MDHS 75)
VOCs	Passive Tenax sorbent tube (In-house method based on MDHS 80)	Automated thermal desorption – gas chromatography – flame ionisation detection (MDHS 80)
1-3 butadiene *	Passive Carbopack sorbent tube (In-house method based on MDHS 63/2)	Automated thermal desorption – gas chromatography – flame ionisation detection (MDHS 63/2)
Formaldehyde	Passive SKC UMEx-100 badge (MDHS 102)	High performance liquid chromatography – ultra violet (UV) -visible spectrometry (MDHS 102)
Isocyanates #	1-(2-methoxyphenyl)piperazine coated glass fibre filter in an IOM sampling head connected to a sampling pump aspirated at 2 l/min (MDHS 25/3, superseded, see below)	High pressure liquid chromatography with a combination of ultra violet (UV) spectrometry, electrochemical detection and mass spectrometry-mass spectrometry
NOx, SO_2, CO	Measured using a Multirae direct reading instrument (DRI) with electrochemical sensors	

* Not monitored by air sampling in Phases 1 and 2, # Not monitored by air sampling after the pilot phase unless present in the binder system
(ISO/12884:2000)- Air quality – Determination of total (gas and particle phase) polycyclic aromatic hydrocarbons in ambient air

MDHS (Methods for the Determination of Hazardous Substances :
14/3 - General Methods for Sampling and Gravimetric Analysis of Respirable and Inhalable Dust (Superseded by MDHS 14/4 General methods for sampling and gravimetric analysis of respirable, thoracic and inhalable aerosols June 2014)
25/3 - Organic isocyanates in air (Superseded by MDHS 25/4 Organic isocyanates in air December 2014)
75 - Aromatic amines in air and on surfaces (Superseded by MDHS 75/2 Aromatic amines in air and on surfaces in June 2014)
80 - Volatile organic compounds in air
101 - Crystalline silica in respirable airborne dust (Superseded by MDHS 101/2 Crystalline silica in respirable airborne dust in September 2014
102 - Aldehydes in air

7.6.2 Biological monitoring analysis methods

Substance	Instrumentation
Aluminium Cadmium Cobalt Copper Nickel	Inductively coupled plasma spectroscopy coupled with mass spectrometry (ICP-MS)
Chromium Tungsten	ICP-MS with Collision Cell Technology
Aniline S-phenyl mercapturic acid (S-PMA), the marker for benzene exposure Ortho-Toluidine Para-Toluidine	Liquid chromatography coupled with tandem mass spectrometry (LC-MS-MS)
Phenol ortho-Cresol (marker for toluene exposure)* 4,4-methylenedianiline (MDA) plus other markers for the various Isocyanates	Gas chromatography – mass spectrometry (GC-MS)
Methyl hippuric acid (MHA), marker for xylene exposure)	High performance liquid chromatography coupled with UV Visible detection (HPLC – UV/VIS
1-hydroxypyrene, marker for polycyclic aromatic hydrocarbon (PAH) exposure	HPLC with fluorescence detection

* Whilst ortho-cresol is a urinary metabolite for toluene, the presence of ortho-cresol itself in the work environment will cause a significant, positive interference in the urine assay, for example, a relatively low exposure to ortho-cresol of 0.02 ppm could result in a urinary concentration of approximately twice the American Biological Exposure Indices (BEI) for Toluene[28]

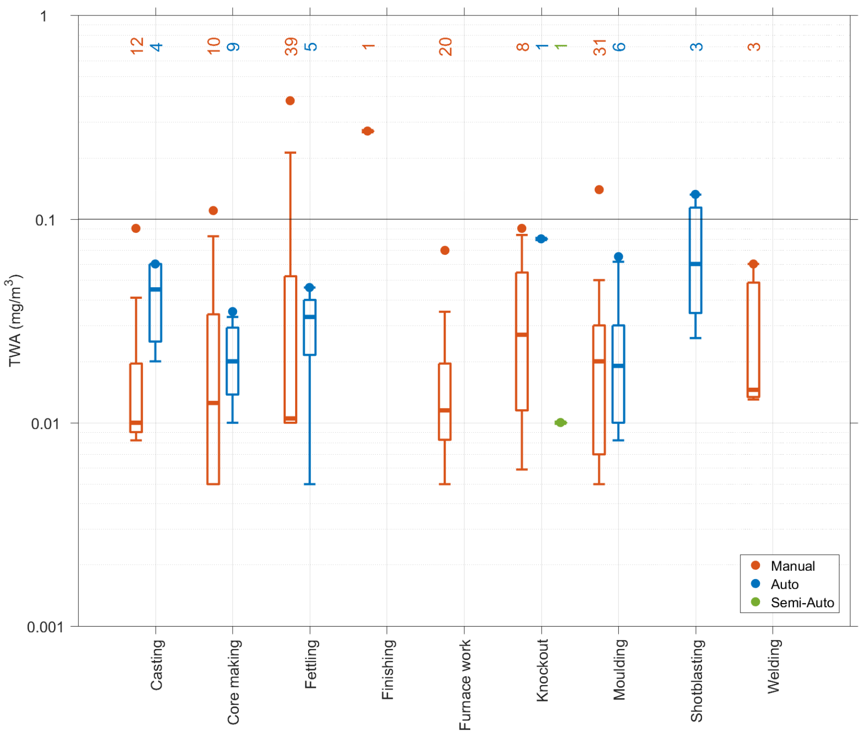
7.7 APPENDIX 7 DICTIONARY OF TERMS FOR JOB CATEGORISATION

OH2214 LLHR Foundry Project Dictionary of Processes/Jobs Version 2 – 02/03/2015	
Process	Job
Furnace work - ferrous metals	Melting
	Melting / Casting
	Static sample, general
	Moulding / Casting / Knockout mixed
	QC testing (not used with this process)
Furnace work – non-ferrous metals	Melting
	Cleaning / sweeping
	QC testing (not used with this process)
Moulding	Greensand
	Furan with Sulphonic Acid
	Urethane
	Alkali Phenolic
	Disa Line (automated)
	Sodium silicate
	Furan without Sulphonic Acid (not used with this process)
	FA/Lactic Acid (not used with this process)
Core Making	Greensand
	Furan with Sulphonic Acid
	Urethane
	Alkali Phenolic
	Sodium silicate
	Furan without Sulphonic Acid (not used with this process)
	FA/Lactic Acid (not used with this process)
Pattern making	Woodworking and gluing
Casting	Cranedriver
	Ladleman/pourer
	Clamper
	Disa Line (automated)
	Static sample, general
Knockout	Mould breaker

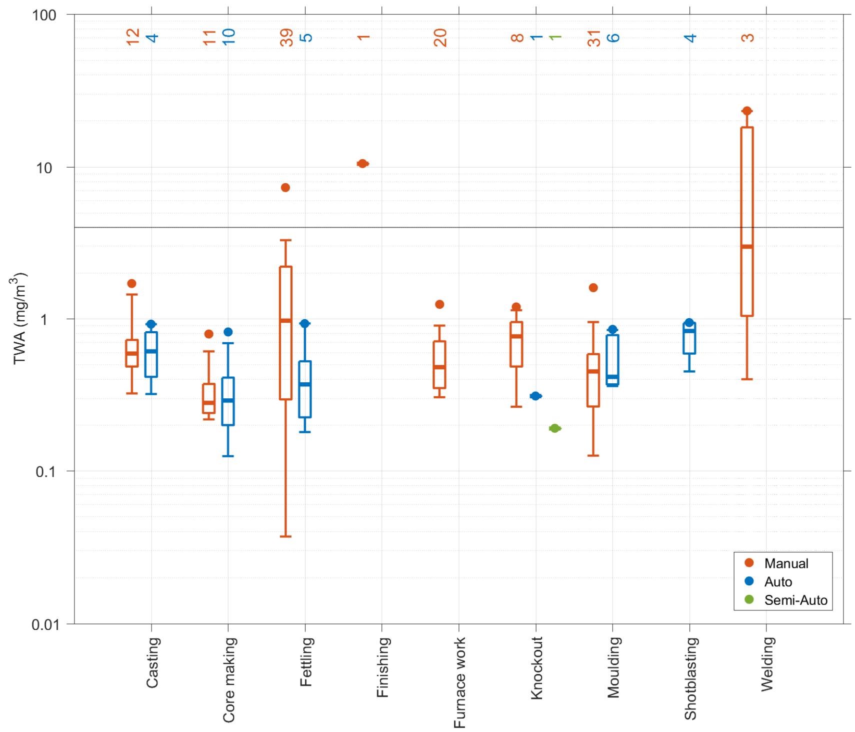
	Manual vibrator
	Semi-auto vibrator
Fettling	Grinding
	Linishing
Finishing	Cutting
	Burning
	Gouging
	Welding repair
	Non-destructive testing (NDT) dye pen
	Heat Treatment
Foundry work	Supervisor
	Maintenance
	Shot blasting
	Static sample, general
	Job not known
	Paint sprayer
Foundry work – ferrous metals	Moulding / Casting / Knockout mixed
	Fork- lift truck driver
	Shot blasting
	Static sample, general
	Cleaning / sweeping
	QC testing
Foundry work – non-ferrous metals	Moulding / Casting / Knockout mixed
	Moulding (Alkali Phenolic) & casting
	Static sample, general

7.8 APPENDIX 8 BOX PLOTS OF DATA FROM TABLES 2 THROUGH TO 17

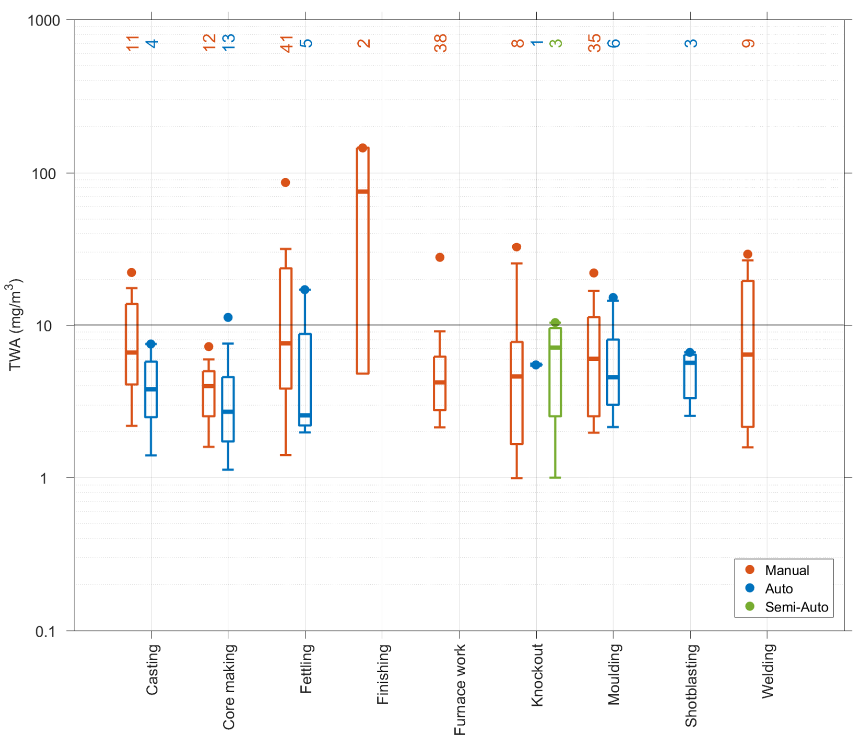
Points show the maximum exposure, boxes indicate the 25th and 75th percentiles (with the central line indicating the median) and whiskers show the 10th and 90th percentiles. The coloured numbers above the points give the number of measurements. The horizontal line indicates the exposure limit.



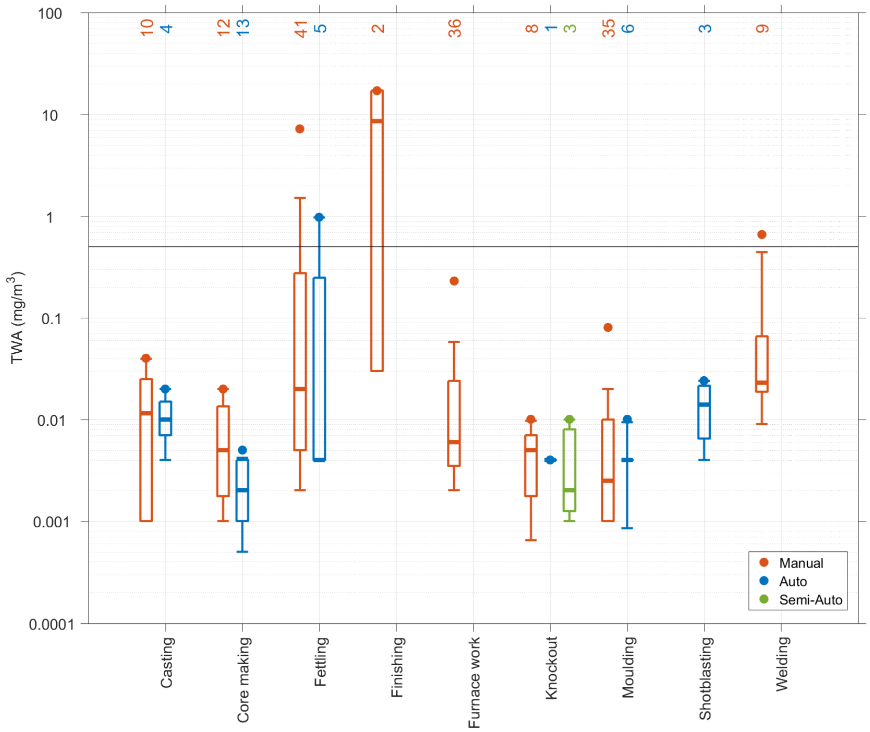
Box plot 1 RCS exposure relative to WEL broken down by task and automation.



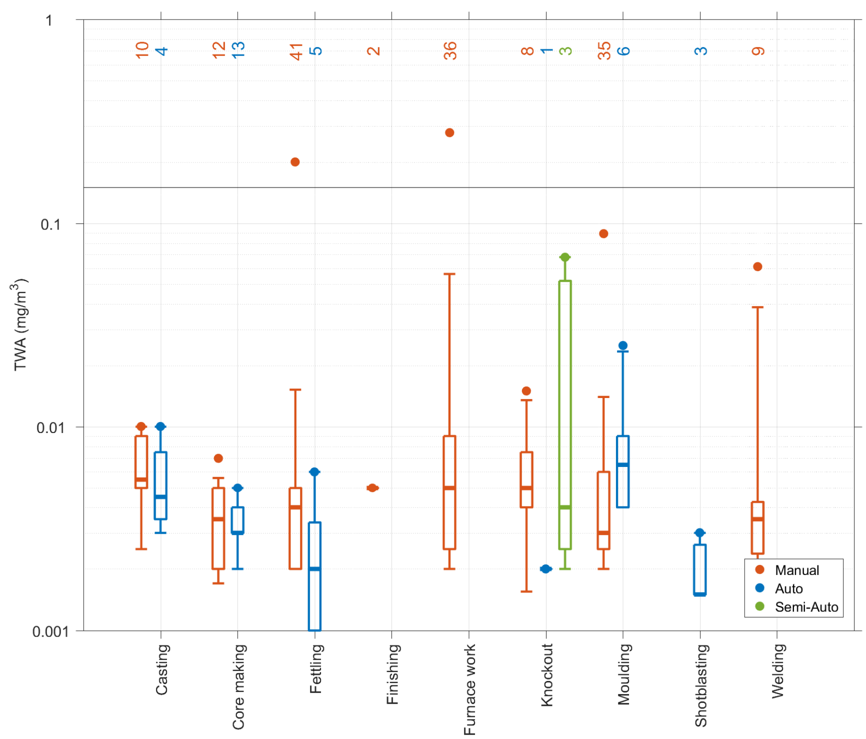
Box plot 2 Respirable FFP and dust exposure relative to WEL/level at which COSHH applies broken down by task and automation.



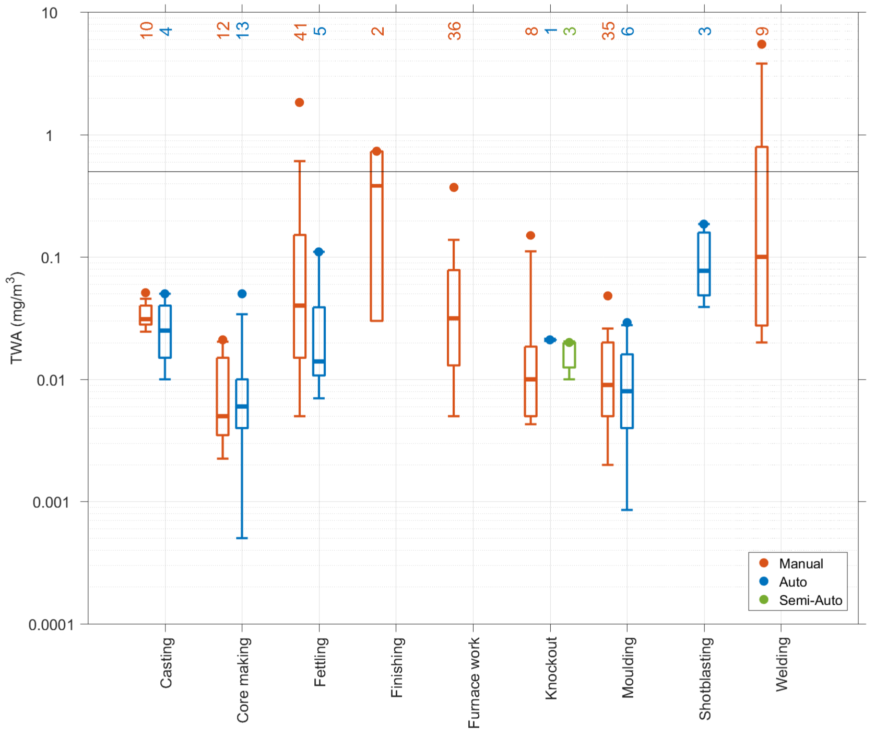
Box plot 3 Inhalable FFP and dust exposure relative to WEL/level at which COSHH applies broken down by task and automation.



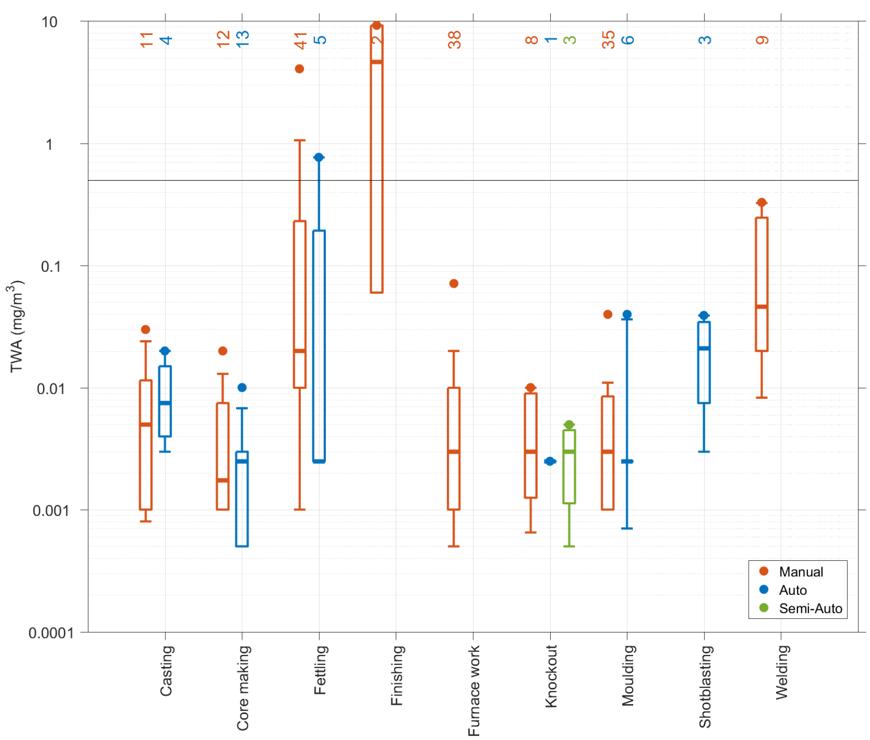
Box plot 4 Chromium exposure relative to WEL broken down by task and automation.



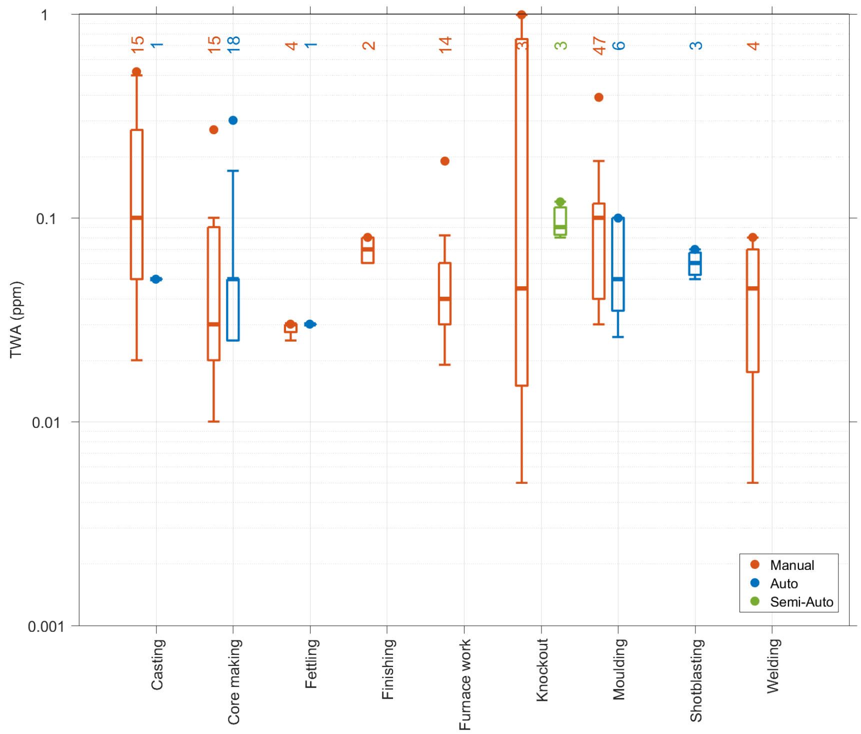
Box plot 5 Lead exposure relative to OEL broken down by task and automation.



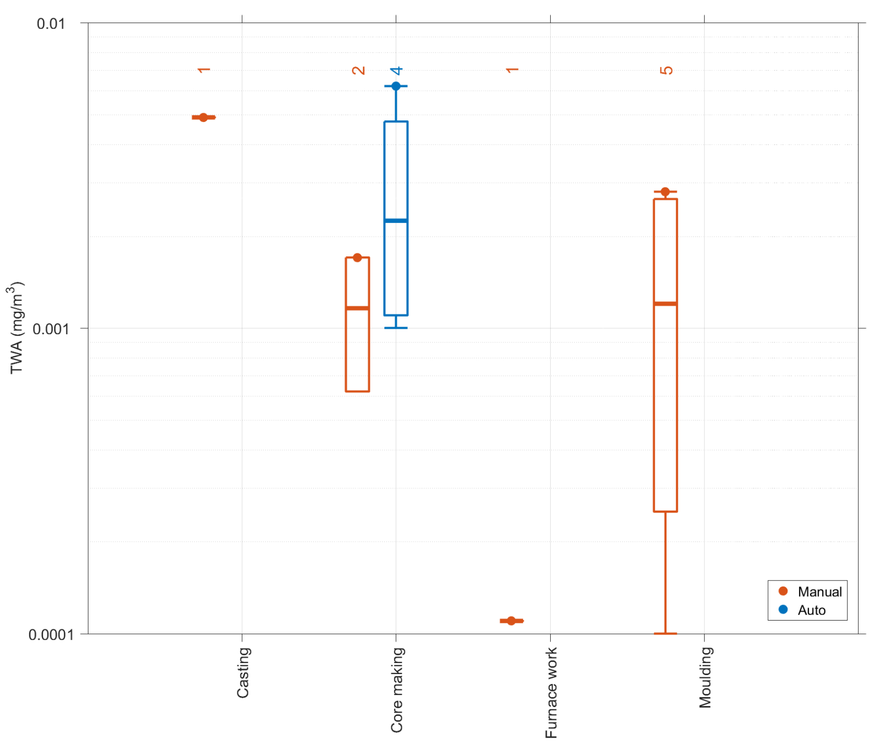
Box plot 6 Manganese exposure relative to WEL broken down by task and automation.



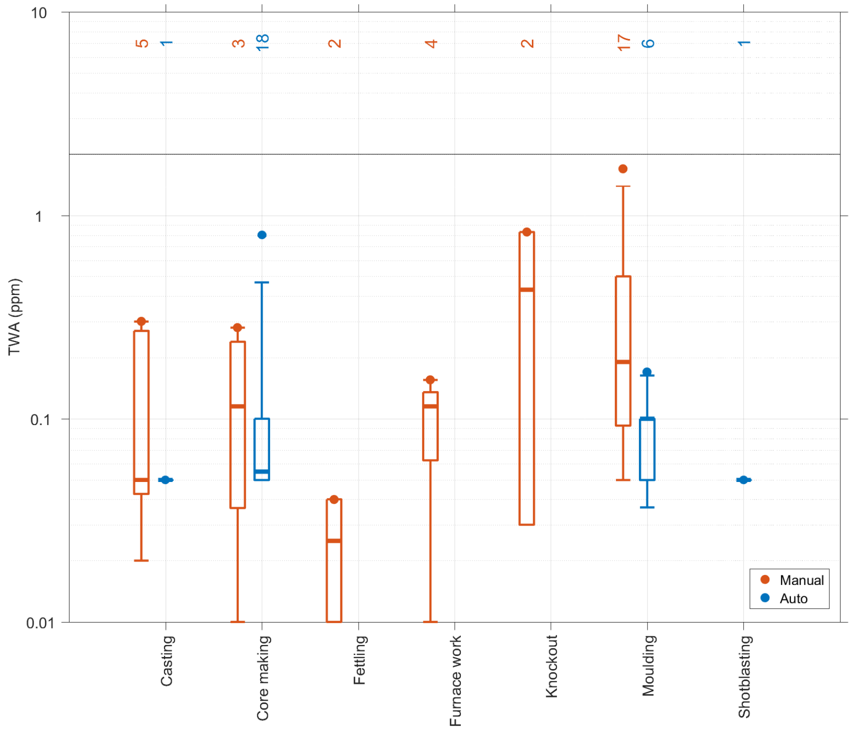
Box plot 7 Nickel exposure relative to WEL broken down by task and automation.



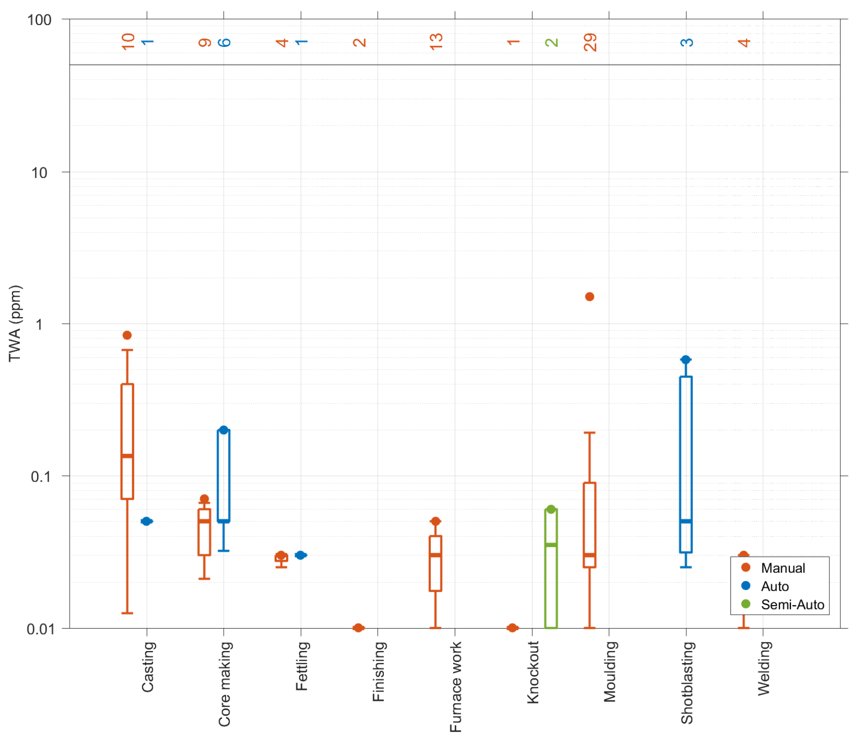
Box plot 8 Benzene exposure relative to WEL broken down by task and automation.



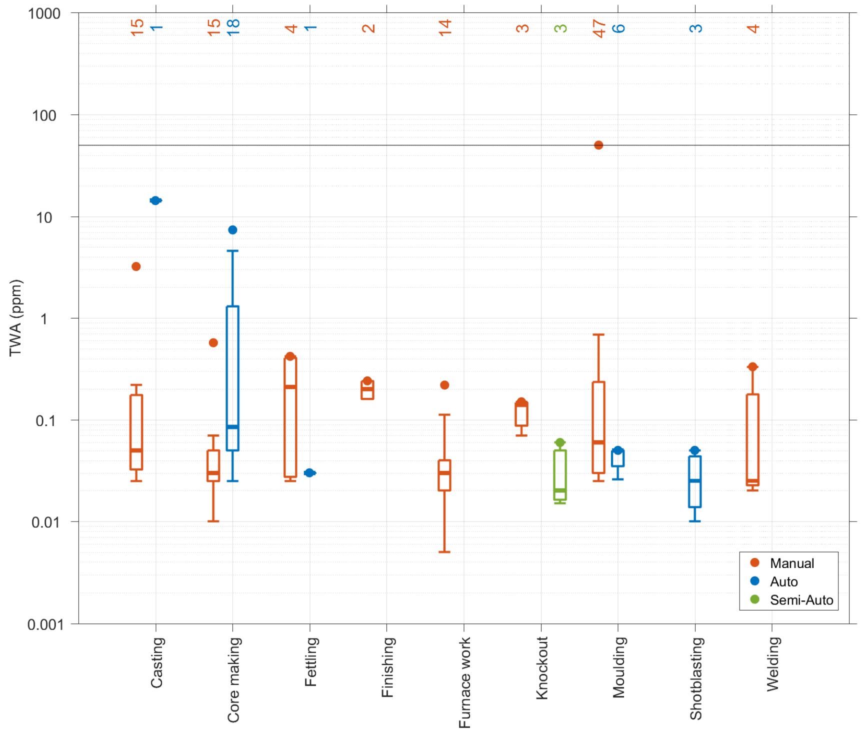
Box plot 9 Isocyanates exposure relative to WEL broken down by task and automation.



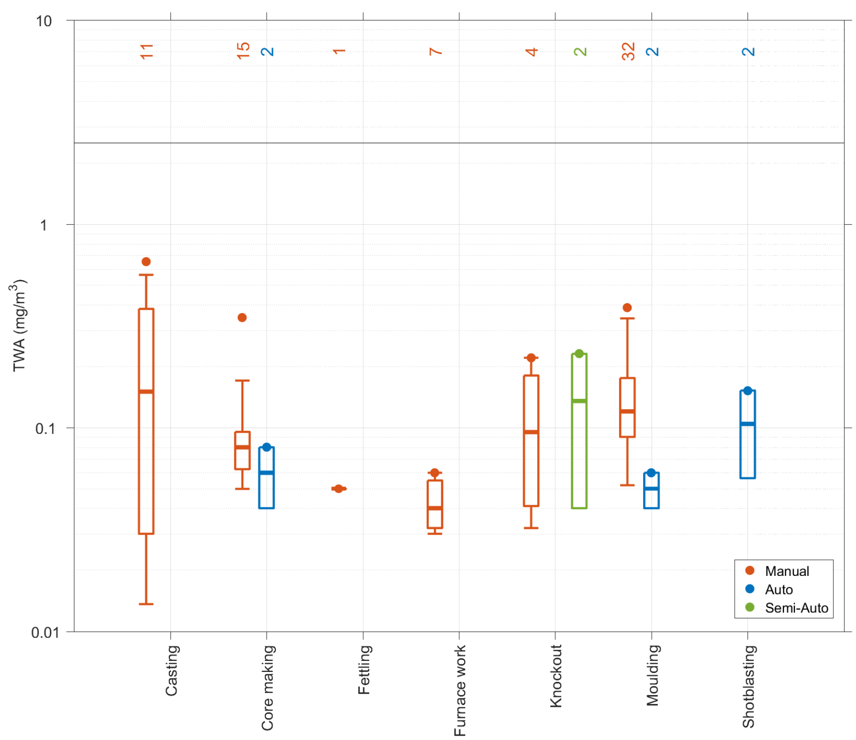
Box plot 10 Phenol exposure relative to WEL broken down by task and automation.



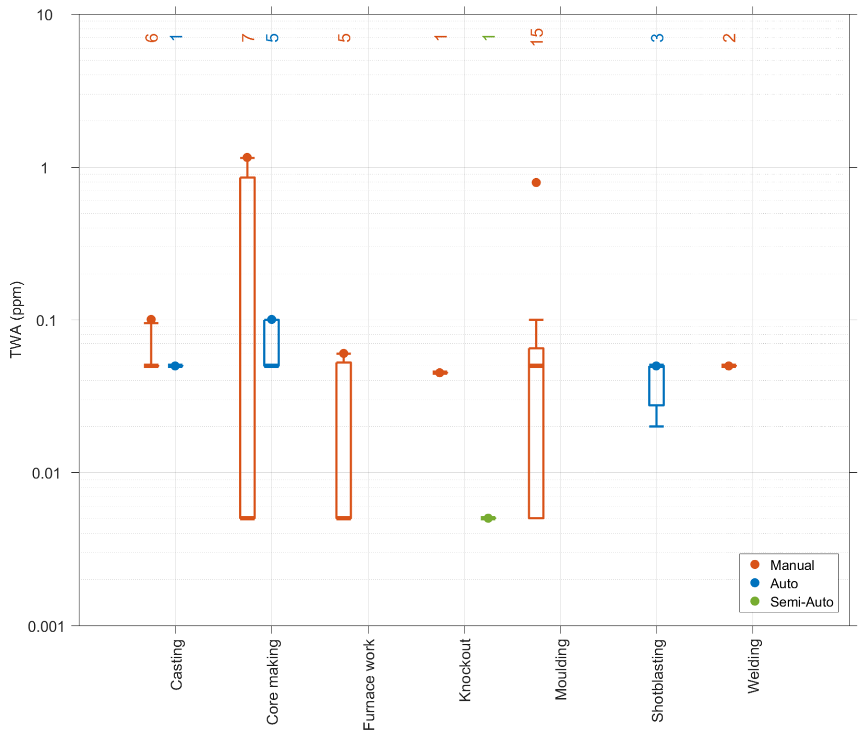
Box plot 11 Xylene exposure relative to WEL broken down by task and automation.



Box plot 12 Toluene exposure relative to WEL broken down by task and automation.



Box plot 13 Formaldehyde exposure relative to WEL broken down by task and automation.



Box plot 14 Furfuryl alcohol exposure broken down by task and automation.

Health and Safety Executive

Published by the Health & Safety Executive 08/17

Health and Safety Executive

Exposure to substances hazardous to health in foundries

Tackling the causes of occupational lung disease is a key priority for HSE. Foundry workers are potentially exposed to a wide range of hazardous substances, including, for example, respirable crystalline silica (RCS), metal fumes and dust, that can cause lung (and other) cancers and chronic obstructive pulmonary disease (COPD).

This work was undertaken to understand current exposures to hazardous substances in the foundry industry, to identify examples of good control practice, and to establish benchmark standards of control for the industry.

Many examples of good practice were found, which, if adopted across the foundry industry, would ensure effective control of exposure to hazardous substances.
The challenge for the industry is to share and adopt the good control practice identified; this will require positive engagement with the workforce, representative bodies and management at all levels.

This report and the work it describes were funded by the Health and Safety Executive (HSE). Its contents, including any opinions and/or conclusions expressed, are those of the authors alone and do not necessarily reflect HSE policy.

RR1115