Report by the Health and Safety Executive on the control and management of hazardous substances in semiconductor manufacturers in Great Britain in 2009
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Executive summary

Between March and September 2009, HSE carried out inspections at all 17 medium/large sized companies involved in the production of semiconductors (commonly known as silicon chips) in GB. These inspections aimed to establish whether the companies were achieving effective control of hazardous substances, and whether suitable management systems were in place to provide confidence in their continuing control. This work followed up a similar series of visits which were conducted in 2002.

The inspections were not targeted at a particular substance or health effect, and neither did they attempt to review all the hazardous substances that a company may use. The inspection teams assessed the overall systems and controls for hazardous substances by sampling a representative number of management systems and control methodologies for a range of selected substances and processes.

Issues relating to each visit were fed back to site management and employee representatives. Enforcement action was taken where necessary; seven improvement notices were issued to four different companies during the course of the inspections.

This report collates the key findings of the inspection visits, identifying areas of good practice as well as any learning points for the industry as a whole.

Summary of key findings

- In general, satisfactory arrangements were found for current control of hazardous substances, as well as for general health and safety issues.
- The key components of H&S management systems were largely in place and there were some good examples of commitment, giving HSE some confidence in likely continuing control. However there were weaknesses in implementation of some aspects in many companies such that we could not be fully assured of continuing control.
- There were some examples of good, or very good, practice for controlling exposure to hazardous substances, and there had been a number of improvements since 2002.
- Utilisation of improved technology and processes, and improvements in some management arrangements, has led to a reduced likelihood of exposure to hazardous substances for production operators since 2002.
- There was a good level of senior management commitment and awareness with some strong, visible leadership on health and safety, but there were some instances where this good intent was not translated into effective and robust control.
- There was insufficient focus on the potential exposure of people undertaking maintenance, cleaning and other auxiliary processes, and the possible effect of their work on others.
- ‘Compliance monitoring’ of high hazard situations, particularly non-production activities, was weak at several sites.
- There was widespread use of lagging indicators for monitoring of health and safety performance, but little use of leading indicators.
- Provision and use of occupational health services had not improved since 2002 and was often poorly targeted, resulting in limited contribution to legal compliance and management information.
- Few companies had satisfactory auditing and review arrangements for their management system for hazardous substances.
- High level, corporate oversight was often largely concentrated on safety rather than health issues.
Introduction

Background

1 In 1998 HSE responded to developing concerns about cancer at National Semiconductor UK Ltd (NSUK) in Greenock, by undertaking research into the cancer incidence and mortality of NSUK workers. A report\(^1\) of this work was published in December 2001. The research was inconclusive, but showed that the total number of women who had died was slightly fewer than would be expected in such a population and the total number of men, substantially fewer than expected. The total number of cancer cases was about the same as expected, and although more cases than expected were found for some specific cancers, the statistical significance varied. HSE recommended further studies to clarify the position.

2 HSE inspectors carried out inspections at 25 semiconductor manufacturing sites between February and May 2002. These inspections showed that overall, the industry had acceptable controls in place for the management of hazardous substances, including carcinogens, although improvements were required at some individual sites. The inspection report\(^2\) made a number of recommendations for the industry as a whole.

Inspections and report 2009

3 HSE advised industry representatives of proposals for a further programme of visits at a meeting of the Microelectronics Joint Working Group (MJWG) in May 2008. Between March and September 2009, HSE carried out visits to 17 of the previously visited semiconductor manufacturing sites; the other sites were no longer in production. These inspections aimed to confirm whether companies continued to have effective control of hazardous substances, and whether suitable management systems were in place to ensure continuing control. This report summarises the findings from those visits.

4 The report has two main sections. The first relates to the Control of Substances Hazardous to Health Regulations 2002 (as amended)\(^3\) (COSHH), and the findings give an indication of the current standard of control over all hazardous substances. The second part follows HSE’s standard approach to the management of health and safety, as set out in HSG65 - Successful health and safety management\(^4\). The findings in this section give an indication of the likelihood of the managerial arrangements to provide continued control over hazardous substances in the future. There is also a section providing an overview of our findings, and a section containing recommendations for action at an industry-wide level.

Legal requirements

5 COSHH requires companies to assess, control and monitor the risks associated with hazardous substances. The COSHH Approved Code of Practice (ACoP) gives guidance and methods for how companies can comply with the Regulations. The Regulations and ACoP include measures and guidance specifically related to substances classified as carcinogenic (i.e. cancer causing).

6 For carcinogenic substances, COSHH requires that companies implement measures to control the exposure of employees to ‘as low a level as is reasonably practicable’. This requirement means that companies are obliged to implement measures to reduce risk of exposure, regardless of the actual exposures observed, provided that the cost, time and effort required is not disproportionate. Arsenic, or
compounds of arsenic, which are classified as carcinogenic are present in some semiconductor manufacturing processes.

7 The Management of Health and Safety at Work Regulations 1999 (MHSW) require companies to make and implement arrangements for planning, organisation, control, monitoring and review of their preventive and protective measures for health and safety. HSE has published guidance on health and safety management in HSG65 - Successful health and safety management.

**Current research developments**

8 HSE funded a ‘follow up’ research study at NSUK, to seek to determine whether there is now any further evidence of a link between excess cancers reported in the workforce and their work. The study, carried out by HSE and The Institute of Occupational Medicine, is due to report in 2010.

9 The Semiconductor Industry Association in the USA is also conducting a relevant study. This study has much larger numbers of people involved and is also likely to report in 2010.

**Production context**

10 The processing techniques and the tooling required to make semiconductors have been improved since the 2002 HSE inspections. However, many of the basic processes, such as chemical vapour deposition and wet etching, still remain and generally use the same or similar substances, such as toxic gases, strong acids and solvents.

11 At the time of the visits, many companies had recently reduced output and staffing levels due to a global downturn in the economy. Although some companies had started to re-employ, head counts and production volumes were relatively low. The HSE inspection teams noted the additional difficulties for companies trying to maintain effective safety management systems without normal levels of stability within these companies as a whole.

**Further work**

12 HSE will review these findings in the light of the outcome of the research study at NSUK (para 8), and will discuss with the industry, its trade associations and trade unions development of a plan for sustaining and spreading good practice, and for securing improvement where needed.

**Overview of findings**

13 Conditions, and health and safety management arrangements encountered, were universally better than for an average manufacturing company. Most of the equipment and procedures necessary to prevent or control exposure to hazardous substances were in place and suitably applied. There were some examples of good, or very good, practice and there had been a number of improvements since 2002. With few exceptions there was strong and visible leadership on health and safety (H&S), however, this was not always translated into effective and robust control. There were opportunities for improvement at most sites.
14. The operational production process steps for semiconductor manufacture were generally well controlled, with many tasks being automated and enclosed. As a result, the possibility of production operators being exposed to hazardous substances was limited. Technological advances in the industry since the HSE inspection series in 2002, particularly with the process machinery, means that the likelihood of exposure to production operators had been reduced. For example, in some companies manual wet benches had been replaced by enclosed, automated systems. Additionally, several companies had removed some hazardous substances from the production process in recent years.

15. There have been some technological and process improvements applicable to maintenance, cleaning and servicing operations. However, the overall effect in terms of risk reduction to workers undertaking such work was limited. Many companies had rightly concluded that maintenance, servicing and cleaning operations had the highest potential for chemical exposures, mainly due to the reliance on safe systems of work and on personal protective equipment (PPE). However, the amount of effort companies expended to identify, control and monitor maintenance risks did not reflect their own conclusions on the level of risk.

16. Companies own monitoring results for airborne contaminants showed exposures were substantially less than relevant exposure limits. However, little consideration had been given to setting ‘in-house’ action levels based on historically achievable results which could be used to provide an early indicator of deterioration in performance, or loss of control. This was disappointing as the concept was widely used for quality control.

17. Overall, contractors working on-site were found to be well controlled. Contractors that were present every day or several times a week were often fully integrated into the company’s operating procedures. This integration is an example of good practice. However, since 2002 there had been an increase in the use of contractors working off-site to undertake some high hazard activities (eg cleaning contaminated plant). These off-site activities were not included within the scope of the 2009 inspections.

18. Local exhaust ventilation (LEV) systems were extensively used as a control measure to prevent or limit exposure to hazardous substances. There were many examples of good design, including computerised management and recording of the airflows, interlocking with process controls and visual indicators of LEV performance for the operator. However, there were also isolated examples of ineffective design of extensions, of modifications, and of tampering with low flow alarm settings. Few sites had in-house people trained to an appropriate standard for LEV design.

19. There were some good examples of integrating health and safety monitoring into other monitoring systems, for example those used for production management or quality systems. These integrated systems were largely based on production operators and technicians monitoring process parameters, equipment condition and the more simple maintenance procedures throughout their working shifts. Sometimes a baseline position and any deviations were recorded on a visible board and checked daily. However, several companies were weak on ‘compliance monitoring’ ie the monitoring of control systems and procedures that act, wholly or in part, to ensure H&S compliance. More specifically, where companies had detailed safe working procedures for a maintenance operation, few had suitable systems to confirm that the procedure was being followed.

20. The measures used by companies to track health and safety performance often gave the impression that their focus was on safety issues. All companies recorded the number of accidents they had each year and most had targets for reduction. However given the nature of the hazardous substances used and the history
of concerns about ill health, it was surprising to find that companies had few, if any, high level ‘metrics’ which satisfactorily demonstrated their performance on prevention of ill health. There was an almost complete reliance on lagging indicators of performance, with little or no consideration of leading indicators (see appendix 4).

21 The use of occupational health services by the industry was heavily concentrated on the management of sickness absence and promotion of ‘well being’. Although there was evidence of occupational hygiene advice in the COSHH assessment process, there was little evidence of occupational health input. Separation of the line management of H&S and occupational health specialists made integration more difficult. Additionally companies often relied on a contractor for occupational health services and accepted what was supplied rather than acting as an ‘intelligent customer’, specifying their needs and monitoring the delivery. In some cases the HSE team had doubts about the competence of the occupational health personnel to provide the specific inputs needed to the management of hazardous substances. These findings on OH mirrored the findings from the 2002 inspections.

22 There were a few occasions where companies appeared slow to fully investigate abnormal results from biological monitoring tests. Investigations into possible work-related causes were delayed while other non-work-related causes were investigated. There was also a disappointing misunderstanding at a few sites about the restrictions required on handling of health data, which had led to the underuse of aggregated data to inform managerial decision making.

23 Despite a strong focus on auditing and review to provide assurance of their arrangements for product quality and environmental compliance, few companies had extended this rigour to their H&S management system. Some contractors commented on the apparent informality of auditing that was carried out on their activities. It is likely that many of the issues identified in this report could have been identified by effective audit and review.

Control of hazardous substances

The Control of Substances Hazardous to Health Regulations 2002 (as amended) is the most relevant legislation that employers need to consider when protecting persons from potential risks due to exposure to hazardous substances. The following section follows the main requirements of COSHH.

Assessment of the risk to health

COSHH requires a suitable and sufficient assessment to be made of the risk to health from work with hazardous substances and identification of the steps necessary to meet the requirements of the regulations.

24 COSHH assessments (CA) had been carried out at all the sites visited, and were generally found to be of a good standard. There were many examples of sensible and effective risk control measures being adopted. Employees were usually aware of the assessments and had easy access to them.

25 In some cases, a document entitled ‘COSHH assessment’, as presented by the company, initially appeared weak. However, in all these cases further investigation revealed supporting documentation that strengthened the CA. For example, working procedures that amplified and explained the CA and the steps necessary to achieve control were commonplace, but the companies had not identified them as being part of the ‘COSHH assessment’.
26 The majority of companies had chosen to complete the CA process in-house. The few that had not were aware of the limitations of CAs produced by consultants and had taken, or were taking, steps to address them. All the sites had sufficient expertise available to enable them to carry out suitable CAs. Better CAs were often found where companies had adopted a team approach to the CA process, sometimes formalising the approach using Review Boards, or similar formal cross-workforce groups. Sites that had such workforce engagement were seen to generate good quality CAs and develop sensible and effective risk control measures.

27 Where weaknesses in CAs were seen, it was often a failure to fully utilise the knowledge and experience available. In a few companies, the CAs could have been improved with an appropriate level of both occupational health (OH) and occupational hygienist input. This specialist advice was usually contracted in, but was often limited to delivering monitoring activities (eg environmental or personal exposure monitoring, or health surveillance) rather than being involved in assisting to identify the risks and the appropriate controls.

28 In carrying out CAs, some companies placed a strong focus on the hazard presented by a substance, and covered both normal working procedures and maintenance activities on the same CA. In these companies, often the emphasis of the CA was on controlling exposure to the production operators. However, when challenged, the companies agreed that the level of risk was potentially higher for non-production work. It was therefore surprising that the type and amount of detail in the CA was not proportionate to, and did not reflect, the levels of risk.

29 In all companies, there was evidence of periodic review of CAs to ensure they remained up to date and relevant. There were also some good examples of companies reacting to new information - taking prompt and effective action to review and revise CAs. For example, several companies had received a recent update from their supplier of n-Methyl Pyrrolidone notifying them of a change in the classification of the health effects of this substance, and as a result had revisited their CA and considered if any changes to working procedures were required.

30 A potential weakness in the CA process was indentified in companies that conducted research and development (R&D). The procedures for assessment and introduction of substances to the R&D laboratories, and for subsequent pilot trials in the workplace, was often less strict than for production chemicals. This is often seen in companies that conduct both research and production operations. In a few companies this weakness gave rise to hazardous substances being available in work areas without proper CAs being in place, and therefore uncertainty about the adequacy of controls. In one case, the failings were significant enough to result in an enforcement notice.

Prevention of exposure and control of substances

*COSHH requires that the exposure of employees to hazardous substances is prevented, or where that is not reasonably practicable, adequately controlled.*

Substitution or removal from the workplace

31 Since the last series of visits in 2002, many companies had replaced substances with less hazardous alternatives, or reduced the quantity of substance used in the process. The reasons for these actions were not always clear. It could have been one or a combination of: technology advancement, changes in manufacturing priorities, conscious decision to reduce health risks; or environmental or commercial reasons. Whatever the initiator, the end result was the same - reduced potential health risk.
32 Several companies used external contractors to undertake work such as quartz-ware cleaning. This effectively removed the hazardous processes from the site, but shifted the potential hazard elsewhere. Where external companies perform such services the primary responsibility for H&S lies with the contract company. Semiconductor manufacturers appeared to meet their legal responsibility to pass the contractor appropriate information about the hazards and risks. However, they could probably do more to demonstrate they were not simply exporting the risk and promote effective control of risk at the contractor’s premises.

**Control - Enclosure**

33 Several companies had the advantage of having relatively modern, purpose built facilities. These facilities usually incorporated a higher level of safety features, such as coaxial toxic gas pipework with the space between the two pipes monitored to detect any leaks from the inner, gas carrying, pipe. Due to the high cost of replacing existing single core gas pipework there had been little change in the extent of use of these coaxial pipe systems since 2002.

34 A number of sites had improved the extent of enclosure of processes since 2002, usually via the purchase of new equipment. For example, several sites had installed automated, enclosed and extracted wet processing machines to replace manually operated wet benches where control of exposure was much more dependent on the adequacy of the LEV.

35 Toxic gas detection was universal, although the number and position of test points varied. The automated alarm systems appeared sensitive and alarm set points were either equivalent to, or less than, relevant workplace exposure limits.

36 Many tools had automatic purge cycles to clear pipework of gas or residues. Despite this, one of the highest perceived risks by maintenance staff was when breaking into hazardous gas piping systems to change components, eg mass flow controllers, or supply bottles. While the working practices for this work varied slightly from site to site, they all offered a good standard of protection from exposure provided the correct safe system of work was followed. Due to the infrequency of the activity and the reliance on the system of work, a written permit to work system was used at many sites. Companies were aware of the relevant guidance on handling gases published by the British Compressed Gases Association (BCGA).

**Control - Local exhaust ventilation (LEV)**

37 All companies placed a heavy reliance on LEV systems as a primary control method. The LEV systems were often very sophisticated and well controlled, in some cases by computer, where key parameters were continuously checked and recorded. The use of visual airflow indicators and gauges on LEV systems was widespread. Most were fitted with a visual indication of acceptable range and many were fitted with auto-alarms and automatic shutdown features. In this aspect, the semiconductor industry demonstrated good practice.

38 There were a few examples of LEV branch ducts that appeared to have been connected into the LEV ductwork in an ad hoc manner, usually for non-production work. In one case, the resulting ‘add-on’ LEV was totally ineffective, although the actual risk of harm was low.
39 Some of the ventilation and extraction systems, particularly those fitted to partially enclosed machinery, had a dual role; helping prevent product contamination and controlling or preventing exposure of workers to hazardous substances. The inspection teams found a few examples where key staff failed to fully appreciate this dual function and the importance of carefully maintaining the balance of the airflows.

Control – safe systems of work
40 Written safe systems of work were common and the relevant safety measures were usually integrated into production work procedures. Written procedures were comprehensive and understandable and usually presented in a suitable manner.

41 However, there were a few examples where risks and control methods were not sufficiently covered by the safe system of work. Examples included the risk of spread of surface contamination from parts contaminated by arsenic deposits, and insufficient consideration of the possible consequences of a spillage of liquid nitrogen inside a room. In the former case, the failing was significant enough to result in the issue of an enforcement notice.

42 Formal permit to work systems were operated by many companies where the likelihood or consequences of exposure were relatively high and the effectiveness of exposure control systems were highly reliant on safe working practices.

Control – personal protective equipment (PPE)
43 In line with the CA, companies supplied a wide range of personal protective equipment. Where supplied, the PPE was invariably to the appropriate standard. It was usually clean and well maintained, and there were suitable systems in place to allow for replacement.

44 Respiratory protective equipment (RPE) was usually only specified for work by maintenance staff or others undertaking non-production work, including emergency control. Procedures were generally in place to carry out the necessary training of users, including face fit testing, and maintenance, inspection and testing of the equipment.

45 Protective gloves were a common control measure where hazardous substances were handled. The majority of companies had selected and supplied appropriate gloves and replacement gloves were available on request. All companies had in-house replacement procedures. Although there were a few instances where the incorrect glove or soiled gloves were used, employees generally had a good awareness of the purpose of the gloves, the need for correct selection, storage and maintenance. However, in most cases the integrity testing method for gloves may not have been sensitive enough to identify small ‘pin’ holes.

Use of control measures (including methods of work)

COSHH requires employers to take all reasonable steps to ensure control and that measures provided are properly used or applied; employees are required to make full and proper use of the controls.

46 Many of the control measures to prevent or adequately control exposure to hazardous substances during production were ‘built in’ to the production facilities, eg automatic clean and purge cycles. For many production operations, there was no option but to use the control measures. There was no evidence of attempts to circumvent such controls. However, exposure control for some production processes, eg manual wet benches and many maintenance and servicing activities, relied on a combination of LEV, safe systems of work and use of appropriate PPE.
47 While some employees were seen to be using very good techniques to remove potentially contaminated gloves, others were less good, highlighting a need for suitable instruction and regular refresher training.

48 When cleaning up spills etc suitable protective gloves were invariably used. However for maintenance tasks, some employees and contractors were observed wearing normal ‘fab’ gloves when additional protective gloves were necessary. Occasionally two pairs of ‘fab’ gloves were misguidedly worn for ‘added protection’. This appeared to be a particular issue where the loss of dexterity from using the protective gloves was perceived to be a problem.

49 Although written permit to work systems were available in many companies, for example for non-routine maintenance, their use was relatively infrequent and few were seen in use during the visits, although some were demonstrated. Those that were seen operated satisfactorily. However, some concerns were raised relating to the arrangements for ensuring that the person signing off the forms fully understood what they were authorising; whether they had a sound understanding of the safe working procedures; and whether they had undertaken the appropriate checks to confirm safety. Similarly there was concern that technicians signing off each others permits did so on trust, rather than on confirmed action.

**Maintenance, examination and testing of controls**

*COSHH requires that all control measures are properly maintained, that engineering controls are subject to periodical thorough examination and testing, PPE is appropriately stored, checked, kept clean and replaced.*

**Maintenance**

50 Planned preventive maintenance was the norm for production tools and equipment, including the H&S controls. LEV was extensively used as a control measure. To help ensure the LEV was maintained to a suitable standard most companies carried out regular face velocity checks and had visual airflow indicators to show the performance of the LEV on tools and enclosures. Many showed acceptable limits of performance (indicator needles or red/green zones), some of which were connected to automatic alarms. The use of visual limit indicators and alarmed indicators were examples of good practice.

51 The inspection teams found several examples of airflow indicators where the lower limit needle had been set to zero. It was clear that this was not a policy, as at any particular site not all the gauges were the same. It is likely that certain gauges had been adjusted down to prevent triggering low level alarms or automatic purge and shut down of the tool.

52 A few companies demonstrated good practice through the use of other visual indicators of LEV performance, for example using ‘dry ice’ or smoke to visually confirm that contaminants were effectively controlled. Many of these techniques are well established in specific semiconductor industry guidance as appropriate dustless methods of demonstrating that contaminants are being adequately controlled.

* ‘fab’ gloves are worn by anyone entering semiconductor fabrication areas to prevent contamination of the product. They are not designed to provide protection from hazardous substances for the wearer.*
Thorough examination and test

53 Most companies had their LEV systems thoroughly examined and tested by a competent person on an annual (14 monthly) basis. In most cases, the competent person was a contractor - either an insurance company engineer or a specialist ventilation company. In a few cases, the thorough examination and test was carried out in-house by a suitable trained person who was independent from the employees responsible for day-to-day maintenance.

54 A few companies did not have current records of examination and testing for their LEV, and could not demonstrate the continued adequacy of LEV performance via other means. This resulted in enforcement action for failure to comply with COSHH regulation 9. However, despite these non-compliances, HSE assessment of the performance of the LEV systems in those companies did not identify any significant problems.

55 A few companies had chosen not to carry out annual thorough examination and testing of some LEV plant. Instead, they relied on records of real-time air pressure and airflow monitoring, combined with periodic smoke and face velocity testing, to demonstrate that the system remained capable of controlling contaminants. The use of continuous monitoring and other records in place of an annual test is extremely uncommon and may even be unique to these companies. It complies with the intention of COSHH, but not with wording of the law which requires that a suitable annual examination and test is made and record kept. HSE did not identify any situations where the LEV was failing to control exposure to hazardous substances at the companies concerned but the issue was identified as a matter requiring further attention (see Appendix 1).

Exposure monitoring

COSHH requires that, where necessary, exposure of employees to hazardous substances should be monitored.

56 Most companies had carried out monitoring for hazardous substances by environmental/personal sampling to assess how much airborne contamination was being generated under certain conditions, and the resulting personal exposure. The results for normal production work were invariably below the relevant workplace exposure limit, and in the vast majority of cases significantly below. However no company had set an internal exposure standard that was based on the exposures that had been historically shown to be achievable.

57 Of those companies using arsenic, or arsenic compounds, several carried out routine biological monitoring. Others had carried out such tests in the past but had ceased, usually as the results consistently showed little or no work-related exposure. One company that had stopped carrying out routine biological monitoring, due to a consistent return of zero results, undertook a one-off survey which showed apparently significant exposures to arsenic in the test subjects during maintenance work. Investigations had not been completed at the time of the HSE visit, however, and it may be that procedures had changed or the safe systems of work for maintenance had deteriorated over time, allowing higher exposure during a procedure which had previously been tightly controlled.

58 Personal exposure monitoring specifically carried out during maintenance and cleaning operations was limited. There was often an assumption that because such activities were done by competent staff, covered by safe systems of work (including permit to work in some cases) using PPE and often RPE, risks were minimal. Some, but not all, companies carried out surface swab tests to detect the possible spread of arsenic contamination, following relevant maintenance and cleaning.
59 At two different sites where biological monitoring was carried out for arsenic exposure, high results were initially blamed on foods or laboratory error. Initial investigations looking for possible work-related causes were not as robust as they should be and were started after all other causes were discounted. A time delay in initiating an investigation made it less likely that the investigation would return conclusive results.

60 Where biological monitoring was carried out, it was sometimes on a regular periodic basis, and not always performed when the work gave rise to the greatest risk of exposure eg after potentially contaminated items had been handled.

**Health surveillance**

*COSH* requires that, where appropriate for health protection, employees exposed to a hazardous substance should be under suitable health surveillance.

61 Many semiconductor companies bought in an Occupational Health (OH) service from an external contractor. However, the health surveillance and health monitoring part of the contracts was relatively small. The majority of the work of the OH contractor concentrated on ‘well being’ and sickness absence. In-house OH departments usually had a similar split of work. Often the OH was generic and not sufficiently risk based.

62 In most cases, the specific conditions of COSHH regulation 11 that trigger a legal requirement for health surveillance were not reached. However, often the OH services had not been involved in decisions about the provision of other health surveillance that is not a legal requirement, but which could provide a useful contribution to the overall control of risk from hazardous substances.

**Information, instruction and training**

*COSH* requires that employees liable to be exposed to substances hazardous to health should be provided with suitable and sufficient information, instruction and training.

63 Most companies demonstrated, through their training records, extensive training associated with hazardous substances and COSHH assessments. Work procedures invariably contained good levels of information and instruction. The overall knowledge of employees concerning the risks from the substances to which they were liable to be exposed, and the control measures, appeared adequate.

64 However, it was common to find that the production workers or other employees working with extracted work benches did not understand the purpose and readings of the visual indicators of LEV performance (e.g., magnahelic gauges). They often assumed it was something the tool technicians or maintenance staff used, and that they had no need to take notice of it.

**Arrangements to deal with incidents and emergencies**

*COSH* requires that arrangements are in place to protect employees from any accident, incident or emergency relating to a hazardous substance.

65 Semiconductor companies universally had systems in place to deal with likely emergencies arising from hazardous substances. For example, continuously monitored toxic gas sensors, linked to alarms, were strategically sited throughout the ‘fab’ areas, and emergency drench showers were available in wet process areas.
where strong acids were used. All sites had emergency response teams that were appropriately trained and provided with suitable emergency equipment, including full self-contained breathing apparatus. Periodical practice drills were commonplace, and at some sites toxic gas alarms occurred periodically, although almost entirely due to sensor faults (and not gas escape).

Health and safety management

The Management of Health and Safety at Work Regulations 1999 (as amended) is the most relevant legislation relating to the necessary managerial arrangements. The following section follows the layout of the guidance in HSG65 - Successful health and safety management.

Policy

66 All companies had a current H&S policy statement, signed by the most senior person on site. In most companies, there appeared to be a strong desire and commitment from the top to effectively manage H&S - they accepted their responsibilities and had documented supporting organisation and arrangements. In many cases, there was a good alignment between H&S policies and human resource management policies, particularly in promoting well-being of employees.

67 Most companies had H&S policies which included a combination of achieving legal compliance and desire for continuous improvement. There were examples where companies were exceeding legal compliance and exhibiting good or best practice, providing opportunities for them to be seen as an H&S leader or exemplar, and which could be included within their H&S policy aspirations.

68 Some companies had developed a specific and separate occupational health policy. Although there is no requirement to have a separate policy document for health issues, the presence of a separate policy helped to raise the awareness of, and focus attention on, occupational health hazards.

Organisation

69 All companies had organisational arrangements intended to achieve the key four elements of control, co-operation, communication and competence.

Control

Control arises from the combination of formal and informal systems and culture exhibited through communications, co-operation and commitment.

70 There were clear management structures, with line management having the day to day responsibility for H&S management. In many cases clear leadership was being displayed by senior managers through their active interest, their visibility, setting of H&S goals and H&S related questioning within production areas. However, in some companies there was limited evidence of visible accountability among the senior and middle management.
71. There was some use of H&S related personal performance targets but not many companies had mapped out a strategy that included establishing personal ‘SMART’ H&S objectives for managers and other key staff.

72. H&S advisers had been appointed at all sites and most sites had H&S committees in place. Committee meetings were attended and usually chaired by the senior manager on site, and had an appropriate level of workforce representation. These committees provided an opportunity for discussion and debate and were capable of overseeing the effectiveness of the management arrangements.

73. Most companies had different managerial reporting lines for H&S advisers and for OH advisers (who were often contract staff). The latter usually reported through the human resources manager, which reflected a key component of their activity concerned with managing sickness absence. This separation of reporting often meant that the managerial lines only converged at top management level and the role and input of OH advisers to managing H&S was often very small. This was seen as a significant issue by the HSE teams at many sites where the contribution of the OH adviser to managing hazardous substances was poor, limited or negligible. It was commonplace for the OH advisers not to have any contribution to the COSHH Assessment process. In one case, the OH adviser was not aware of the hazardous substances present on site and had not visited the production areas where they were used.

74. Management arrangements for engagement and control of contractors (excluding occupational health contractors) was universally formalised and seemed to work well. Despite many contractors having been working at the site for years and the consequent familiarity, companies observed the usual management controls such as requiring them to sign in, provide method statements and risk assessments. Many companies required all work of contractors to be carried out under a permit to work system.

**Co-operation**

Co-operation supports risk control by encouraging involvement and ownership in H&S management and development of a positive culture.

75. The level of co-operation between management and workforce on H&S was generally good. The level of workforce involvement in H&S management was variable across the companies but at most sites there was active engagement of worker representatives and a well developed and positive safety culture, particularly where there were long standing groups and safety committees. However, in a few cases, formal systems had been tried but there had been a lack of worker interest and the systems collapsed. Some safety representatives reported that they had time to complete their role, while others felt that although they could leave their work for meetings they did not get time to attend to other issues.

76. Contractors with a frequent or permanent site presence were often fully integrated into the company information and communication systems leading to an appropriate level of involvement in the safety management system and high levels of co-operation. This integration was seen as a positive advantage in maintaining good safety performance.

*SMART – specific, measurable, achievable, relevant, time-bound*
77. As indicated above, the OH provider usually reported to the HR department. Although this is not unusual across industry, it places a great importance on the communication and co-operation between the HR and H&S departments. This was thought to be particularly important during the initial stages of setting up a contract when the H&S department may have more knowledge of the statutory needs and what management information was required to track health performance. Continued cooperation was required for the success of the overall health risk management, and particularly when health records and other information were returned to the company via the HR department.

Communication

Effective communication is essential to ensure appropriate H&S messages flow through the organisation.

78 Most companies operated both formal and informal methods of communicating H&S information. Some good examples were seen of information boards and information centres where recent H&S performance, including results of monitoring activities, were displayed. The level and effectiveness of the informal communications usually reflected the levels of worker involvement and cooperation.

79 In a few cases, there were misunderstandings about the difference between health records (required to be kept by the company), group anonymised data (needed for statistical analysis), and medical records (confidential medical records usually held by the OH provider). This led to an unnecessary restriction in communication of useful information. The limited information in anonymised health data was sometimes not shared with line managers and H&S departments restricting their ability to identify trends, clusters and other potential health risks in the workplace.

Competence

H&S competence for all employees and contractors is essential for effective risk control.

80 The level of formal training in H&S for operational and maintenance staff was mostly good. Many companies were able to demonstrate a thorough approach to the training through computerised training records, including arrangements for refresher training. In many cases, this also included records of training and refresher training for contractor staff. While senior managers generally appeared knowledgeable or well briefed on their roles and responsibilities, there was limited evidence of formal H&S Management training. Several directors and senior managers had committed to attending a ‘Managing Safely’ course, but a few appeared to be having difficulty finding the time to do so.

81 The in-house H&S Advisers generally appeared competent to provide the health and safety assistance necessary, and recognise where expert assistance was necessary. In some cases, for example, a qualified Occupational Hygienist was brought in to assist in conducting airborne monitoring. At a few sites, there had been an appreciation of the need to improve in-house competence in managing LEV systems, following the publication of HSG258 - Controlling airborne contaminants at work® and selected individuals had been trained to the new British Occupational Hygiene Society, P601 proficiency module®.

82 In addition to training and experience, awareness and access to relevant guidance is key to maintaining competence. It was therefore surprising that some companies did not appear aware of the existence of relevant industry specific H&S
guidance documents developed by the wider semiconductor industry eg guidance published by SEMI\(^\text{6}\) and BCGA\(^\text{10}\).

83 There were examples of suitable and sufficient CAs produced without OH involvement, where other persons contributing to the assessment had adequate knowledge of OH issues. However, many companies were not making best use of the OH expertise available to ensure CAs were suitable and sufficient. The HSE teams concluded that using the knowledge and expertise of both OH and Occupational Hygiene specialists could enhance the risk assessment process, the identification of suitable exposure control measures, and also provide a degree of independent assurance that they are effective and efficient.

84 Many contractors undertaking high hazard work on-site were ex-employees or had many years experience working in semiconductor plants, and their general competence was considered to be good. It was not possible to judge the competence of off-site contractors involved in work on equipment contaminated, or potentially contaminated, with hazardous substances.

85 OH providers were frequently also contractors but the checks on the competence of these companies, and the staff they routinely provided, was far less robust and often taken for granted. At some sites, HSE teams expressed concerns over the level of competence of the OH nurse/doctor for the role they were expected to undertake.

**Planning and implementing**

*Planning is essential for the translation and implementation of the H&S policies and organisational arrangements into effective activity and management.*

86 Planning the control systems for hazardous substances was firmly linked to established COSHH assessment processes in all companies. There were procedures to identify applicable substances, assess them and identify suitable and sensible controls. Many companies had suitable procedures to check implementation and confirm the long term effectiveness of those controls. Each one of these parts was vital to the success of the overall management system and the prevention or limitation of exposures. Most assessments were centred on the substance rather than process or activity where the substance would be encountered.

87 Many companies had the laudable aim of continuous improvement as part of their H&S policy and most companies had headline safety targets, for example ‘zero accidents’, and they were often required to report on progress toward these targets at corporate or group level. In most companies, however, there appeared to be little visible evidence of a strategy or a clear and specific plan to show how they were going to achieve it. In many cases it was evident that a series of smaller steps and objectives would be required to turn aspiration into reality.

88 Most companies rated exposure to hazardous substances as one of the key hazards on their sites, however a large majority of them had no ‘ill health’ related targets, other than for acute health effects such as burns from contact with corrosive substances. Most companies relied on setting targets for reduction in accidents and near misses, and most were able to demonstrate improved performance against these measures. A few companies had subdivided H&S issues and measured progress against these individual components, for example highlighting that stress and manual handling were the most common H&S issues.
89 In some cases, the basic health and safety assessments and controls had been overlooked, examples include the lack of workstation assessment for people using microscopes and use of appropriate noise control measures; the latter resulted in enforcement action.

Monitoring

90 All companies had procedures in place to monitor their H&S performance. A range of statistical information including accidents, sickness absence, and in some cases near misses, was presented to management and relevant H&S committees. In most cases, the company set great store by their improvement in accident rates, and used this as an indicator of overall H&S performance.

91 Reporting systems were mainly used for safety issues, there was less evidence of reports relating to unintentional spills, leaks or escapes of hazardous substances. There was little evidence of near miss reports relating to a “dangerous situation”, where a spill or leak was narrowly averted.

92 However, there was a general absence of suitable indicators of performance on ill health. Most companies were seemingly buoyed by an absence of cases of ill health, but where health effects take extended periods of time to develop, there is little or no benefit in collating statistics based solely on diagnosed ill health cases.

93 Many companies carried out environmental and personal exposure monitoring for key hazardous substances, and in some cases, surface wipe monitoring. Monitoring tended to concentrate on exposure during normal production processing and there was less, or sometimes no information to confirm control of exposure during maintenance and cleaning. Sometimes this was because it was assumed the combination of infrequent exposure and use of suitable PPE (including RPE) would be adequate. Often, there was no consideration of risks to others arising from the maintenance and cleaning, for example from spread of contamination.

94 Health and safety ‘compliance monitoring’ (the positive confirmation that controls and safety systems actually perform as expected) was generally not done well, although this is not unusual compared to other industries. Several companies were poor at positively inspecting or otherwise monitoring maintenance operations, including those done by contractors.

95 There were some good examples of integrating H&S monitoring into monitoring systems for production management or quality systems. These systems were largely based on production operators and technicians monitoring process parameters, equipment condition and the more simple maintenance procedures throughout their working shifts. Sometimes, a baseline position and any deviations were recorded on a visible board and checked daily.

Audit and review

96 The use of safety auditing amongst the companies was variable, a few companies had good systems in place. Others were doing little or no auditing at all. A few were externally audited either via other companies within the same group, or independently through OHSAS 18001.

97 The level and quality of H&S system auditing and review was lower than expected, especially given the high level of auditing carried out to ensure product quality. In most cases, a good internal audit and review methodology would have identified many of the issues that the HSE inspection teams found, and would have enabled companies to make improvements before the visits.
Contractors reported that audits and safety inspections of their work were either not done or were very informal, often consisting of someone looking in on them. The expectation was that if the company person saw something wrong they would comment on it. It was surprising that apart from one or two reports of PPE infractions, contractors and companies could not recall any reports of unintentional spills, leaks or escapes of hazardous substances or any reports of dangerous situations where a spill or leak was narrowly averted.

Similarly, the OH services, whether they were contracted out or in-house, were also not routinely audited to establish if they are providing the correct services or a suitable level of service.

One company had a formal system to review documents specifically looking for old, outdated documentation, which helped to focus attention on the key risks. Although this question was not raised at all visits, the example highlighted good practice.

Cross-industry recommendations

The industry should pay greater and more explicit attention to the hazardous substance exposure risks arising during maintenance and cleaning to both those carrying out the work and the effects of that work on others. Arrangements should be in place to provide proportionate and effective monitoring of non-production activities both by observation of work practices and procedures, and by monitoring of personal exposure and surface contamination. Deviations from expected performance should be promptly and effectively followed up. This recommendation is particularly important, and a legal requirement, where there is risk of exposure to a carcinogenic substance.

The Microelectronics Joint Working Group (MJWG) should consider developing guidance on appropriate techniques, frequencies and regimes for compliance monitoring, and standards for implementation. This could include, for example, checks on maintenance activities, checks of LEV systems, exposure monitoring and surface contamination monitoring. There may be scope for the MJWG to identify suitable visual indicators of LEV performance, such as the use of dry ice (seen in use at one company), and document them so other companies have access to the techniques.

The MJWG should identify a suite of appropriate leading and lagging indicators, both high level ones and more basic ones, utilising systems that companies routinely have or can easily implement. Accidents and other safety related statistics are only part of the H&S profile, and suitable indicators applicable to ill health control are essential. As well as being useful to demonstrate individual company performance and allowing benchmarking, the indicators could be used to demonstrate the overall industry performance in terms of prevention of ill health and accident reduction.

The industry should consider its ability, and if appropriate take steps to influence the H&S performance of the contract companies undertaking work on plant contaminated with hazardous substances that is removed from the semiconductor manufacturing site. Particular attention should be given to contractors who are small and medium sized enterprises (SMEs). Part of the contract letting process should include consideration of the H&S performance of the contract company and the health and safety precautions the contractor uses. In the construction industry this approach is very common. Given the often highly specialised nature of the work and the value of the contracts, semiconductor
companies have a significant buying power, and a common expectation will help
provide and/or maintain a level playing field for contractors. It should be relatively
easy to use this to influence safety and health performance in the supply chain.

105 In view of the heavy reliance of the semiconductor industry on LEV to control
exposure to hazardous substances, and its relative complexity, every company
should ensure they have access to competent advice from someone suitably
trained in design and maintenance of LEV systems. This person could be a suitably
trained ‘facilities’ or ‘tool’ technician or an external consultant. They should be
involved in decisions relating to new plant, modifications or significant maintenance
of all LEV systems.

106 Companies (or the semiconductor industry) should consider setting in-house (or
industry) standards for airborne exposure to hazardous substances based on levels
that have historically been shown to be achievable. If they do so, it would make any
deviation in control effectiveness easier to spot and correct before there was loss of
adequate control, and enable demonstration of compliance with COSHH Regulation
7(7)(c). This concept of monitoring against an internal standard and setting ‘action
levels’ was familiar to most companies for control of product quality.

107 The MJWG should consider developing guidelines to assist semiconductor
companies to become ‘intelligent customers’ when contracting in OH provision. The
guidelines could include:

- establishing their actual occupational health requirements;
- distinguishing these from other services, such as sickness absence and ‘well
  being’ services;
- identifying the relevant competencies for the OH provider; and
- providing examples of effective integration of OH services into the management
  arrangements for hazardous substances.

Improvements in this area would help companies improve the service received from
OH contractors and possibly provide better value for money.

108 The MJWG should consider the systems and methods currently used
by companies to carry out audits and reviews, explore good practice in other
industries, and establish and promote good industry practice for the semiconductor
industry. With a robust and flexible audit system most or all of the points raised by
the inspection teams could have been identified internally without the need for HSE
intervention.

109 The MJWG should consider the other issues identified during the inspections
(see Appendix 1) and how it can assist the industry to improve performance.
Appendix 1  Other issues identified during the inspections

1  Methods for testing gloves for ‘pinholes’ (para 45)
2  Guidance and refresher training for operators on safe removal of gloves (para 47)
3  Arrangements for ‘signing off’ permits to work (para 49)
4  Clarity on compliance with requirements for thorough examination and test of exhaust ventilation systems (paras 54/55)
5  Workers’ understanding of exhaust ventilation airflow indicators and the actions of these workers to an ‘out of specification’ reading (para 64)
6  Disclosability of aggregated ill health data (para 79)
7  Management H&S Awareness training (para 80)
8  Knowledge of existing industry guidance (para 82)
9  Setting H&S targets and interim objectives (paras 87/88)
Appendix 2  List of companies visited

Midlands
Dynex Semiconductor Ltd, Lincoln
Oclaro Ltd, Towcester, (formerly Bookham Technology)
Druck Ltd, Groby, Leicestershire

East South East
Bourns Ltd, Bedford

North East
RFMD Ltd, County Durham

Scotland
National Semiconductor UK Ltd, Greenock
Intense Ltd, Blantyre, Glasgow
Semefab (Scotland) Ltd, Glenrothes
Shin-Etsu Handotai Europe Ltd, Livingston
Raytheon Systems Ltd, Glenrothes

Wales and South West
International Rectifier Company (Great Britain) Ltd, Newport
IQE (Europe) Ltd, Cardiff
IQE Silicon Ltd, Cardiff
X-Fab UK Ltd, Roborough, Plymouth
Westcode Semiconductors Ltd, Chippenham, Wiltshire

North West
Diodes Zetex plc, Chadderton, Oldham
NXP Semiconductors Ltd, Bramhall, Stockport
Appendix 3 Details of enforcement notices issued

The following formal enforcement action was carried as a result of the visits. Details of the notices are available to the public via the HSE public register of enforcement notices (http://www.hse.gov.uk/notices/). They are as follows:

**Intense Co Ltd, 3 improvement notices, requiring:**


2. Implement a programme of measures to control noise exposure at the bead blaster. Issued under Control of Noise at Work Regulations, regulation 6(2) – Compliance date 25/09/2009 (subsequently extended to 20/11/2009)

3. Make improvements to the control of Gallium Arsenide dust during wafer lapping. Issued under COSHH Regulation 7(7)(a) – Compliance date 09/10/2009 (subsequently extended to 20/11/2009)

**IQE Europe Ltd, 1 improvement notice, requiring:**

1. A suitable and sufficient assessment of hazardous substances specifically those used for research and development. COSHH Regulation 6(1) – Compliance date 11/9/2009

**Dynex Ltd, 2 improvement notices, requiring:**

1. Thorough examination and test of exhaust ventilation systems. Issued under COSHH Regulation 9(1) and 9(2) – Compliance date 26/03/2010

2. Improvement to the overall H&S management system. Issued under Management of Health & Safety at Work Regulations, Regulation 5(1) and 5(2) – Compliance date 26/03/2010

**Bourns Ltd, 1 improvement notice, requiring:**

1. Thorough examination and test of the local exhaust ventilation systems. COSHH Regulation 9(2) – Compliance date 06/11/2009
Appendix 4  Leading and lagging indicators

Accident statistics, near miss reporting and to some extent ‘potential substance exposure’ reporting are all reactive measures. They record things that have already happened ie past performance and are sometime referred to as ‘lagging indicators’. For accidents, provided there are enough records to analyse, the performance and trend is useful management information.

However, some health effects take extended periods of time to develop, so the benefit of using statistics based on diagnosed ill health cases as an indicator of current H&S performance is limited, or could be misleading. In some cases ill health statistics will reflect company performance as it was many years ago. It is therefore appropriate to use leading indicators (eg the percentage of planned weekly LEV tests completed) and appropriate lagging indicators (eg number of chemical spills) when considering measurement of health performance.

For an effective indication of overall company H&S performance a ‘balanced scorecard’ of leading and lagging measures should be utilised. Leading and Lagging indicators are referred to in HSG654 where they are referred to as ‘active’ and ‘reactive’ measures. Specific guidance on leading and lagging indicators is given in HSG 254 – ‘Developing process safety indicators: A step-by-step guide for chemical and major hazard industries’12. Although this guidance is aimed at high hazard, chemical production facilities the concepts are equally applicable to other industries.
Appendix 5  Inspection methodology, site and topic selection

The targeted inspection method used for this project is a relatively common approach within HSE. It is particularly appropriate where the sites have complex processes and well developed management systems. The inspection teams targeted the management control for hazardous substances, referencing it against the management framework found in HSG65 - Successful Health and Safety Management and the COSHH regulations.

Targeting specific H&S topics and processes of interest allows for a more in-depth assessment and makes best use of the time spent on site. This approach allowed the inspection teams to reduce the onsite time from three days, as seen in HSE’s previous inspection series in 2002, to a maximum of two days.

Sites were selected using the most current information available to HSE, the National Microelectronics Institute and MJWG were consulted before it was finalised. Using a similar approach to that taken in the 2002 inspection series, companies primarily producing semiconductors for research and development purposes were excluded. Appendix 2 contains a list of the 17 sites visited.

Companies were notified, in writing, of the intended date of the visit approximately one month in advance. The letter asked companies to provide HSE with defined information in advance of the visit to help the inspection team target areas of interest and reduce the on-site time.

In order to test how the companies managed contractors, particularly those contractors doing work with hazardous substances, the initial letter to the company requested that they identify suitable contractors that they use. HSE selected a contractor based on the information provided and asked companies to make arrangements for the contractor to be available during the visit period. The letter also asked companies to make arrangements for any OH service providers they use to attend site during the visit period.

Although the main focus of the visits was control of hazardous substances, inspectors were expected to deal with any other matters of high concern that were either observed during visits or brought to their attention by the workforce or their representatives. This practice follows HSE standard operating procedures.

A pilot visit was undertaken at one company at the end of March 2009 to confirm that the inspection procedure and methodology was effective, and enable any changes to be made before the inspection of the remaining companies commenced. Feedback from the company visited was integrated into the procedure used for all the further visits. The remaining inspections were carried out between May and Sept 2009.

The HSE inspection teams were usually made up of four people: the inspector responsible for the site, an occupational hygiene specialist, and occupational health specialist, and an inspector from the Manufacturing Sector. One of two Sector inspectors took part in all the visits to help ensure a consistent approach.

Although many of the companies were known to carry out broadly similar processes, it was anticipated there would be significant differences in detail and levels of risk. To aid consistency, a guideline question set was developed for the inspecting teams, but the teams were encouraged to adapt the inspection and the questions asked to the specific site conditions found.
Tailoring the inspection to each site ensured the inspection findings and feedback to the company was relevant to that site and therefore more useful to the company concerned. However, it made it more difficult to compare the findings at one site to the findings at others. Consequently, no attempt has been made to use quantitative methods to present the findings.
References


2 Inspections by the Health and Safety Executive in 2002 of manufacturers of semiconductors in GB. HSE, 2002.


5 A further study of cancer among the current and former employees of National Semiconductor (UK) Ltd., Greenock. HSE/ Institute of Occupational Medicine, 2010.


11 BS OHSAS 18001 - Occupational health and safety management systems - requirements. BSI Group, 2007

Further information

HSE priced and free publications can be viewed online or ordered from www.hse.gov.uk or contact HSE Books, PO Box 1999, Sudbury, Suffolk CO10 2WA Tel: 01787 881165 Fax: 01787 313995. HSE priced publications are also available from bookshops.

For information about health and safety ring HSE’s Infoline Tel: 0845 345 0055 Fax: 0845 408 9566 Textphone: 0845 408 9577 e-mail: hse.infoline@natbrit.com or write to HSE Information Services, Caerphilly Business Park, Caerphilly CF83 3GG.

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