

MAXIMUM EXPOSURE LIMIT FOR VANADIUM PENTOXIDE REGULATORY IMPACT ASSESSMENT

PURPOSE AND INTENDED EFFECT

Issue and objective

1. The Advisory Committee on Toxic Substances' Working Group for the Assessment of Toxic Chemicals (WATCH) considered the risk assessment on vanadium pentoxide in January 1999. The lead health effects for vanadium pentoxide are mutagenicity and respiratory tract toxicity. It is estimated that around 1,100 employees are exposed to vanadium pentoxide. WATCH concluded that the criteria for an occupational exposure standard could not be met and it was recommended that vanadium pentoxide should be considered for a Maximum Exposure Limit (MEL). In addition, WATCH concluded that a respirable vanadium limit was not justified and that a MEL for total inhalable vanadium would be appropriate. A Chemical Hazard Alert Notice (CHAN) on vanadium pentoxide, providing interim advice, was issued in March 1999.

2. The objective of setting a MEL for vanadium pentoxide is to reduce occupational exposure and thereby reduce the risk of adverse health effects. This RIA informed the Advisory Committee on Toxic Substances (ACTS) of the costs to industry and the possible health benefits resulting from setting a MEL for vanadium pentoxide. The costs quoted in the document are (unless otherwise stated) those that were current at the time this RIA was written (2000).

RISK ASSESSMENT

3. The key health effects of concern for vanadium pentoxide are mutagenicity and respiratory tract toxicity. Vanadium pentoxide is an *in vivo* mutagen, and its effects appear to be mediated by an aneugenic mechanism, i.e. a mechanism which involves effects on the mitotic spindle rather than direct interaction with DNA. This mechanism can lead to changes in chromosome numbers in affected cells.

4. Aneugenicity is, in principle, a form of mutation for which a threshold mechanism is involved. However, from the data available, it is not possible to identify the threshold level of exposure, by any exposure route of relevance to humans, below which the mutagenic effects of vanadium pentoxide would not occur.

5. There are no carcinogenicity studies, either in animals or humans, with vanadium pentoxide, so no firm conclusions can be drawn regarding the risk of cancer in occupationally exposed workers. However, the mutagenic properties of vanadium pentoxide do raise concerns for the potential to cause cancer.

6. Overall, in relation to the mutagenic effects of vanadium pentoxide, it is not possible to describe the exposure-response relationships for these effects nor to identify a threshold, hence no conclusions can be drawn regarding the risk at any proposed value for a MEL. Given the potential for both inhalation and oral absorption of vanadium pentoxide, any MEL which is established should apply to the total inhalable fraction.

7. In relation to respiratory tract toxicity, a single eight-hour exposure to 0.1 mg.m⁻³ respirable vanadium pentoxide (0.06 mg.m⁻³ vanadium) led to mucus production and cough after twenty-four hours, with effects resolving within four days. Exposures to higher concentrations produced more prominent effects with a more rapid time of onset. Repeated exposure to the dust and fume of vanadium pentoxide causes irritation of the eyes, nose and throat, and impaired pulmonary function, but there are insufficient data to describe the exposure-response relationship for these effects. Repeated inhalation studies in rats and mice show no changes to the lungs at 1 mg.m⁻³, but this same concentration produced respiratory distress in monkeys when exposed for 2 days/week; such effects did not occur on the remaining 3 days/week when exposures were ten fold lower. However, the human evidence suggests that delayed effects occur at this concentration. Therefore, from the animal and human data, a reliable no-effect level for the respiratory effects of vanadium pentoxide cannot be identified.

8. The risk assessment considered by WATCH showed that the greatest occupational exposure occurs during cleaning heavy oil fired boilers and furnaces. Personal vanadium occupational exposure results for a variety of industries are summarised in Table 1. The data were obtained between 1995 and 1999.

Table 1: Summary of total inhalable vanadium results

Industry	Task	Number of samples	Range (mg.m ⁻³ , as V)	% of samples above 0.05 mg.m ⁻³	% of samples above 0.1 mg.m ⁻³	% of samples above 0.5 mg.m ⁻³	Control measures
boiler/furnace cleaning and furnace demolition	various	27	0.01 to 19	70	59	26	RPE
catalyst refurbishment	catalyst removal	2	0.04 & 0.4	50	50	0	RPE □
	catalyst sieving	2	0.04 & 0.08	50	0	0	
	reloading bed	3	0.02 to 0.06	^a	0	0	
alloy manufacture	various	4	All results <0.01 ^b	0	0	0	LEV & RPE
pigment manufacture	weighing and "tray filling"	20	0.01 to 0.05 ^c	0	0	0	LEV & RPE

^ainformation not available. ^bThis 1999 data was not available when the risk assessment was produced. ^cThe range of the data used in the risk assessment was 0.04 to 0.17. This represented exposure during a simulated worst-case scenario. This 1999 data was obtained during normal production.

9. The patterns of exposure and control in the various industries are summarised below:

a) Boiler/furnace cleaning and furnace demolition. Heavy fuel oil can contain up to 600 ppm vanadium which is converted to vanadium pentoxide during burning in

boilers and furnaces. The solid residues include fly ash, soot and boiler scale which contain between 1 and 60% vanadium. It is not practical to use local exhaust ventilation (LEV) to control exposure during cleaning and demolition.

10. Heating boilers are typically cleaned once per year by specialist contractors. The operation involves removing fly ash from the boiler tubes and inside the boiler doors. Deposits are normally removed from the tube using a rotating nut on the end of a motor-driven rod. Boiler doors are normally cleaned using a wire brush. Cleaning usually involves shovelling or vacuuming loose fly ash and wire brushing pipes.

11. There is only one oil powered generation boiler in Great Britain. This is operated as a standby generator and the patterns of exposure during cleaning are similar to cleaning heating boilers.

12. Process heating furnaces are generally very large and exposure occurs mainly during cleaning and demolition. Specialist contractors are usually employed for these jobs. Working methods during furnace cleaning are similar to those used during boiler cleaning. Furnace demolition is a less frequent operation during which contractors are usually employed for that specific job. Exposure during demolition is typically less than exposure during boiler/furnace cleaning.

13. Disposable filtering face piece respirators and half mask respirators are used by most contractors in all of the above processes. Powered respirators with full face masks are provided by some organisations and occasionally compressed airline breathing apparatus (CABA) is used. A contractor estimated that around 20% of contractors use powered respirators and less than 10% use CABA. A variety of overalls and gloves are also used. Vanadium exposure is lower when vacuum systems of cleaning are used. However, these methods are used in a minority of cases.

14. **b) Catalyst refurbishment.** Catalyst refurbishment is carried out approximately once every two years by specialist contractors. Exposure may occur during removal of the spent catalyst, sieving the spent catalyst and reloading the catalyst bed. The personal protective equipment (PPE) used on site by the contractors typically is disposable hooded overalls, powered respirators with full face masks and P3 filters (assigned protection factor 40) and PVC gloves. Joints between the PPE and gloves are often sealed with tape. In addition, vacuum cleaners used during the refurbishments are fitted with HEPA filters. It is impractical to use LEV to control exposure.

15. **c) Alloy manufacture.** Additions of vanadium-aluminium alloy ingots, containing 10 to 60% vanadium, are used to control the viscosity of molten titanium-boron-aluminium (TiBAI) alloy during its production. The alloy is added to the molten TiBAI in kilogram quantities approximately six times per shift. Details of another TiBAI production method were withheld for reasons of commercial confidentiality. The duration of exposure is of the order of a few minutes per shift and LEV is used to control exposure. One manufacturer also supplies people working at the task with full face mask powered respirators with P2 filters (assigned protection factor 20).

16. **d) Pigment manufacture.** Personal exposure to vanadium pentoxide only occurs during the first two steps of the pigment manufacture process. Vanadium pentoxide is manually tipped from 25 kg bags into a hopper. Other powders are added and the final concentration of vanadium pentoxide in the mix is around 15%. After mixing in a fully enclosed, high speed disperser, the powder is manually dosed, in 15 kg portions, into a tray (known as a saggar). The mix is then calcined for eight hours at 900 °C, after which vanadium is no longer present as the pentoxide. The duration of exposure during weighing and saggar filling does not exceed one hour per shift and LEV is used during both processes. Single-use disposable filtering half mask respirators (P2 standard, assigned protection factor 10) and gloves are used during weighing. Respiratory protective equipment (RPE) is not used during saggar filling. The floor around the weighing and saggar filling operations is typically cleaned twice per shift using either a vacuum cleaner fitted with a HEPA filter or a “wet and dry” vacuum cleaner.

OPTIONS

17. Vanadium pentoxide currently has 8-hour time weighted average (TWA) occupational exposure standards (OESs) of 0.5 mg.m⁻³ for total inhalable dust and 0.04 mg.m⁻³ for fume and respirable dust. Both are measured and expressed as vanadium.

18. WATCH concluded that a MEL for total inhalable vanadium was appropriate and that there was no basis for setting a limit for respirable vanadium. Consequently, the current numerical value of 0.5 mg.m⁻³ (as V) will be considered as one option. It would be inappropriate to have other options higher than the current limit because adverse health effects have been observed in volunteers at exposures below this level. Human studies have shown that a single 8-hour exposure to 0.1 mg.m⁻³ vanadium pentoxide dust (98% of particles less than 5 µm) produces respiratory tract irritation. This is equivalent to 0.06 mg.m⁻³ vanadium and so 0.05 mg.m⁻³ will be another option. A further option of 0.1 mg.m⁻³ will be used for comparison.

BENEFITS

19. The most important health effect for vanadium pentoxide is mutagenicity. There is in-vivo evidence of mutagenicity which raises a presumption of carcinogenicity, although there is actually no evidence in either animals or humans to confirm this. There is no identified threshold for this effect. In addition, there are insufficient data to determine the dose-response relationship for the respiratory effects of vanadium pentoxide. However, a reduction in exposure is likely to reduce the risk of any mutagenic or respiratory effects.

20. There is no available information on cases affected and workdays lost due to respiratory illness from exposure to vanadium pentoxide. It is likely that very few, if any, workers have to change job or leave the labour market because of respiratory illness due to vanadium pentoxide exposure. The majority of cases are likely to be fairly mild and the affected population is small.

21. Although we can assume that reducing exposure reduces the risk of any mutagenic effects (from an unknown level), we do not know by how much. In the absence of any such knowledge we have assumed that the risk is halved (see below). In order to apply a monetary value to this reduction in risk we assume that an individual might equate an unknown, but probably small, risk of contracting a potentially fatal disease some time in the future with having a less serious disease now for certain. We estimate that a non-permanently incapacitating illness resulting in at least seven days off work (i.e. a less serious illness) involves a welfare cost of around £1,900 (1999/00 prices) per person¹. This figure is used as the basis for costing the 'benefits' of introducing the MEL.

22. We then double this welfare cost to take account of the evidence that indicates people have a particular dread of cancer and therefore would place a higher value on avoiding the possibility of a cancer death compared to most other types of death. Doubling is used in the absence of specific data to indicate how much people might be willing to pay to avoid this possibility. The welfare cost per person is taken as £3,800.

23. It is estimated that around 1,100 employees are exposed to vanadium pentoxide. However, the limited exposure data means that it is unclear how many of these employees might be exposed above the proposed MEL. This RIA assumes (see below, section on costs) that most firms need to take action to control exposure. About 190, 370 and 570 employees² are assumed to potentially benefit from these actions depending on whether the MEL is set at 0.5 mg.m⁻³, 0.1 mg.m⁻³ or 0.05 mg.m⁻³, respectively.

24. Grossing up £3,800 over the estimated 190, 370 and 570 workers yields estimates of £722,000, £1,406,000 and £2,166,000 for each of the MEL options. These would be the benefits if the risk to exposed employees were completely removed by the MEL. This is, however, unlikely. Assuming that the risk is halved, it is appropriate to halve the benefits to £361,000, £703,000, and £1,083,000 depending on whether the MEL is set at 0.5 mg.m⁻³, 0.1 mg.m⁻³ or 0.05 mg.m⁻³, respectively.

25. It should be stressed that these benefit estimates are only intended to be illustrative and to permit comparison with the cost.

26. Anecdotal evidence obtained from the business sectors affected included:

¹See 'The costs to Britain of workplace accidents and work-related ill health in 1995/96', HSE Books, 1999, ISBN 0-7176-1709-2 for an explanation of how this welfare cost is derived.

²The number of employees who may benefit from reduced exposure is estimated on the basis of the information provided and assumptions made in the following section on compliance costs. 1) Boiler/furnace cleaning and furnace demolition: there are 180, 360 and 540 people upgrading their RPE with a MEL of 0.5 mg.m⁻³, 0.1 mg.m⁻³ and 0.05 mg.m⁻³ respectively. 2) Catalyst refurbishments: improvements in engineering control are required in 20% of contractors, for each of the MEL options; there are 50 employees intermittently exposed in this sector, so we assume that 10 employees may benefit. 3) Alloy manufacture: no employees benefit from the MEL. 4) Pigment manufacture: no employees benefit from a MEL of 0.5 mg.m⁻³ and 0.1 mg.m⁻³, whereas about 20 employees potentially exposed during the production process may benefit from a MEL set at 0.05 mg.m⁻³.

a) Twelve to fifteen years ago, everyone on a boiler-cleaning job had a black tongue. Fewer had flu-like symptoms.

b) Five years ago, 50% of specialist contractors carrying out a catalyst refurbishment job had flu-like symptoms and a greenish black tongue. Today, because of improved controls and work practices, adverse health effects are not observed.

c) There are no reports of ill health from the use of vanadium pentoxide in pigment manufacture.

COMPLIANCE COSTS FOR BUSINESS, CHARITIES AND VOLUNTARY ORGANISATIONS

Business sectors affected

27. During the risk assessment, four types of activities were identified where employees are exposed to vanadium. These activities will be used to define the business sectors affected. They are:

a) Boiler/furnace cleaning and furnace demolition. There are an estimated 100,000 boilers in Great Britain. Many boiler servicing organisations employ only one or two people and it is estimated that around 400 employees spend less than 20% of their time cleaning oil fired boilers. Furnace cleaning and demolition are also carried out by contractors and approximately 500 people are exposed on an occasional basis. Exposure results included in Table 1 for boiler cleaning were between 0.02 and 0.35 mg.m⁻³. The range of recent exposure results during furnace cleaning was 0.01 to 19 mg.m⁻³. Exposure results obtained during furnace demolition in the early 1990s (not included in Table 1) were between less than 0.01 and 0.08 mg.m⁻³. Boiler/furnace cleaning and furnace demolition were treated as a single business sector because industry were unable to provide sufficient information to estimate the costs of complying with a MEL for each industry individually.

b) Catalyst refurbishment. A number of gas-phase oxidations are catalysed by vanadium pentoxide. Examples include the oxidation of sulphur dioxide and nitrogen oxides. The most frequently used catalyst consists of a silica base containing 4 to 6% vanadium. The activity of the catalyst gradually deteriorates during use and eventually the catalyst bed needs to be refurbished. The maximum personal exposure results reported to HSE during catalyst removal, sieving and reloading were 0.4, 0.08 and 0.06 mg.m⁻³ respectively. This work is usually carried out by specialist contractors and it is likely that around 50 employees are intermittently exposed.

c) Alloy manufacture. There are two manufacturers of TiBAI rod in Great Britain. It is estimated that less than 100 employees are exposed to vanadium during its production. The results of a recent personal vanadium exposure monitoring exercise carried out by one of the manufacturers were all less than the limit of detection (less than 0.01 mg.m⁻³).

d) Pigment manufacture. Pigments and inks containing up to about 15% vanadium pentoxide are used in the ceramics industry. There is only one producer

of pigments containing vanadium in Great Britain. Up to 20 people are potentially exposed during the production process. The range of recent 8-hour TWA total inhalable vanadium results was 0.01 to 0.05 mg.m⁻³ (mean = 0.02 mg.m⁻³).

28. Small quantities of vanadium pentoxide are used in the manufacture of speciality glass. The process starts with adding an unopened bag of vanadium pentoxide (around 2 kg) to around 1 tonne of flat glass raw materials in a mixer. The operation is infrequent (approximately once every 5 years) and the vanadium pentoxide exposures are understood to be well below 0.05 mg.m⁻³. It is assumed that complying with the MEL will not incur any costs for this business sector and so it is not discussed further in this RIA.

29. As far as we are able to determine, charities and voluntary organisations will not be affected by adopting a MEL for vanadium pentoxide.

Compliance costs to industry

30. The purpose of this section is to present the costs of implementing a MEL of either 0.5, 0.1 or 0.05 mg.m⁻³ in the business sectors affected. Information on the costing of RPE was obtained from HSE guidance note HSG53 (The selection use and maintenance of RPE, 1998), HSE Specialist Inspector's Report number 50 (Costing a RPE programme, 1996) and a manufacturer of RPE. The cost of employing a consultant occupational hygienist was obtained from the 1996/97 directory of occupational hygiene consultants, published by the British Institute of Occupational Hygienists. Laboratory analysis costs were taken from a 1997 list of prices charged by contract laboratories. LEV prices were obtained from a 1997 HSE report (Costings of LEV systems) by J R Cain. The costs in this report were obtained from industry in 1996. The cost of hiring industrial vacuum cleaners was provided in 2000 by an industrial plant hire company. All costs are calculated in 1999/2000 prices over a ten-year period³. The base year for appraisal is year 1999/2000. Details of the actual costings are described below.

a) Boiler/furnace cleaning and furnace demolition

31. The number of heavy fuel fired boilers and furnaces has reduced significantly during recent years. According to the Oil Firing Technical Association for the Petroleum Industry ("OFTEC"), heavy fuel oil burning has decreased by 75% since 1990. Heavy fuel oils have largely been replaced by gas and OFTEC predict that heavy fuel oil use will cease completely within a couple of years. Heavy fuel oil sales in the UK fell from 8.9 million tonnes in 1994 to 2.9 million tonnes in 1998.

32. The Control of Substances Hazardous to Health (COSHH) Regulations 2002 place a duty on contractors to adequately control vanadium pentoxide exposure and the general COSHH Approved Code of Practice (ACOP) describes a hierarchy of exposure control measures, with engineering methods placed near the top and RPE at the bottom. However, most contractors who will be required to further control

³In arriving at ten year cost figures, two adjustments are made. Firstly, earnings are assumed to rise by 1.8% per year in real terms - the observed increase for the whole economy over the past twenty-five years or so. Secondly, costs are discounted to present value using the Treasury recommended 6% discount rate.

exposure when a MEL is adopted will choose RPE as their primary control method. The costs of control methods based on either engineering control (vacuumation) or RPE will be presented in order to inform ACTS of their relative costs.

Control strategy based on engineering control

Vanadium pentoxide monitoring costs

33. Following discussions with industry it has been estimated that between 20 and 150 companies carry out 1,000 jobs with associated vanadium pentoxide exposure each year. Monitoring costs have been estimated on the frequency of measurements carried out by companies. It is assumed that insufficient monitoring is currently carried out by all contractors and boiler/furnace owners.

34. We have made the assumption that all of the monitoring costs due to setting a MEL will be incurred by contractors. The daily cost of employing a consultant occupational hygienist is between £310 and £730 per day. Sample analysis consists of an acid digestion prior to vanadium determination by inductively coupled plasma atomic emission spectroscopy. The costs of analysing batches of two, five and ten samples are £40 to £110, £95 to £255 and £190 to £510 respectively.

35. We assume that all companies will monitor the first five jobs after the MEL is set in order to validate their control strategy. This monitoring frequency is independent of the numerical value of the MEL. It is also assumed that a consultant occupational hygienist is hired for one and a half days (one day on site work and a half day report writing) and that two samples per job are taken. Therefore, the initial, one-off cost would be between $((1.5 \times £310) + £40) \times 5 \times 20 = £51k$ and $((1.5 \times £730) + £110) \times 5 \times 150 = £904k$.

36. After a control strategy has been implemented, the monitoring frequency will depend on the MEL. European standard EN 689:1995 (Workplace atmospheres - guidance for the assessment of exposure by inhalation to chemical agents for comparison with limit values and measurement strategy) lists the following maximum time intervals between periodic measurements:

a) Sixty-four weeks if the occupational exposure concentration does not exceed one quarter of the limit value. However, the general COSHH ACOP specifies that monitoring should be carried out at least once every twelve months.

b) Thirty-two weeks if the occupational exposure concentration exceeds one quarter of the limit value but does not exceed one half of the limit value.

c) Sixteen weeks if the occupational exposure concentration exceeds one half of the limit value but does not exceed the limit value.

37. Using these time intervals as a guide, we assume that engineering control methods will reduce exposure to a level where, after initial monitoring, repeat monitoring for MELs of 0.5, 0.1 and 0.05 mg.m⁻³ will be required every twenty, ten and five jobs respectively.

38. For a MEL of 0.5 mg.m⁻³, repeat monitoring will be required at $1000/20=50$ jobs annually. The recurring cost is therefore between $((1.5 \times £310) + £40) \times 50 = £25k$ and $((1.5 \times £730) + £110) \times 50 = £60k$.

39. For a MEL of 0.1 mg.m^{-3} , the annual frequency of repeat monitoring is $1000/10 = 100$ jobs. The recurring cost is therefore between $((1.5 \times \text{£}310) + \text{£}40) \times 100 = \text{£}51\text{k}$ and $((1.5 \times \text{£}730) + \text{£}110) \times 100 = \text{£}121\text{k}$.

40. For a MEL of 0.05 mg.m^{-3} , after initial monitoring, monitoring will again be needed at $1000/5 = 200$ jobs annually. The recurring cost is between $((1.5 \times \text{£}310) + \text{£}40) \times 200 = \text{£}101\text{k}$ and $((1.5 \times \text{£}730) + \text{£}110) \times 200 = \text{£}241\text{k}$.

41. Because the use of heavy fuel oils in furnaces and boilers is expected to stop within a couple of years, recurring annual costs will recur for the first two years only.

Control costs

42. As with monitoring annual costs, because the use of heavy fuel oils in furnaces and boilers is expected to stop within a couple of years it is assumed that contract cleaners will hire (rather than buy) industrial vacuum cleaners, and that these costs will recur for only two years. Industry sources quoted costs of between $\text{£}90$ and $\text{£}250$ per week for hiring 50 to 200 litre capacity machines. These are likely to be suitable for all except the very large furnaces and boilers. Industry was unable to quote costs for appropriate equipment for these jobs.

43. A contractor estimated that 10% of contractors possessed vacuumation plant. The recurring, annual costs of hiring industrial vacuum cleaners depends on the number of jobs carried out. Following discussions with industry it has been estimated that, on an annual basis, 1,000 jobs with associated vanadium pentoxide exposure are carried out. Assuming that 90% of these are carried out by contractors not possessing vacuumation plant, the number of jobs carried out per year, by contractors without vacuumation plant is therefore 900. For a control strategy based on engineering control, it is assumed that all jobs are carried out with vacuumation, irrespective of the MEL. Assuming one vacuum cleaner hire per job, the recurring annual costs are between $900 \times \text{£}90 = \text{£}81\text{k}$ and $900 \times \text{£}250 = \text{£}225\text{k}$ for each of the MEL options. It is assumed that the current level of RPE is maintained, and that there are no additional RPE costs, after the MEL is adopted.

Control strategy based on respiratory protective equipment

Vanadium pentoxide monitoring costs

44. In the previous Section on costs for an engineering based-control strategy, it was assumed that companies will monitor the first five jobs after the MEL is set in order to validate their control strategy and that this monitoring frequency is independent of the numerical value of the MEL. The same is true for a control strategy based on RPE. The initial, one-off costs are therefore also between $\text{£}51\text{k}$ and $\text{£}904\text{k}$.

45. After an RPE based-control strategy has been implemented, monitoring will be required more frequently than would be the case for a control strategy based on engineering control. Using engineering control methods, it was assumed that repeat monitoring for MELs of 0.5, 0.1 and 0.05 mg.m^{-3} will be required every twenty, ten

and five jobs respectively. For an RPE based control strategy it is assumed that repeat monitoring for MELs of 0.5, 0.1 and 0.05 mg.m⁻³ will be required every ten, five and two jobs respectively.

46. For a MEL of 0.5 mg.m⁻³, repeat monitoring will be required at 1000/10 = 100 jobs annually. The recurring cost is therefore between ((1.5 x £310) + £40) x 100 = £51k and ((1.5 x £730) + £110) x 100 = £121k.

47. For a MEL of 0.1 mg.m⁻³, repeat monitoring will be required at 1000/5 = 200 jobs annually. The recurring cost is therefore between ((1.5 x £310) + £40) x 200 = £101k and ((1.5 x £730) + £110) x 200 = £241k.

48. For a MEL of 0.05 mg.m⁻³, repeat monitoring will be required at 1000/2 = 500 jobs annually. The recurring cost is therefore between ((1.5 x £310) + £40) x 500 = £253 and ((1.5 x £730) + £110) x 500 = £603k.

49. As with monitoring annual costs under an engineering-based control strategy, because the use of heavy fuel oils in furnaces and boilers is expected to stop within a couple of years, annual costs will recur for the first two years only.

Control costs

50. The extent of the RPE upgrade is difficult to quantify, but it is assumed that, for a MEL of 0.5 mg.m⁻³, the proportion of contractors currently using powered respirators (assumed to be 20%) would double. Assuming that there are 900 people working in boiler/furnace cleaning and furnace demolition, the number currently using powered respirators is 900 x 20% = 180. Doubling the number using powered respirators is 900 x 20% x 2 = 360. Therefore, the extra costs are for 360 - 180 = 180 people.

51. The initial, one off cost of a power assisted respirator package is between £290 and £365. The cost for one hundred and eighty people will be between 180 x £290 = £52.2k and 180 x £365 = £65.7k.

52. The recurring annual costs are:

a) Filters. These cost between £10 to £25 and are assumed to last for five days. A work year is assumed to comprise two hundred and forty days and contractors are assumed to spend 15% of their time boiler/furnace cleaning and furnace demolition. Therefore, the number of days spent doing the job is 240 days x 15% = 36 days. The number of filters required annually is therefore 36 days ÷ 5 days per filter = 7.2 filters. This will cost between 7.2 x £10 = £72 and 7.2 x £25 = £180. For one hundred and eighty people, the cost will be between 180 x £72 = £13.0k and 180 x £180 = £33.8k.

b) RPE cleaning. RPE cleaning is assumed to take around twenty minutes per shift. The total amount of time spent RPE cleaning is therefore, 20 minutes x 36 days = 12 hours. At £8.85 per hour this costs £106. For one hundred and eighty people, the cost will be 180 x £106 = £19.1k

c) Servicing/inspection. This is assumed to take twelve hours per year in a full working year. Because only 36 days are spent boiler/furnace cleaning and furnace demolition. The amount of time spent servicing/inspecting the RPE is therefore (36

days ÷ 240 days) x 12 hours = 1.8 hours. At £8.85 per hour this costs £16 and for one hundred and eighty people the cost is 180 x £16 = £2.9k.

d) Training. This is assumed to take place every year and to cost £60 per person. The course plus travelling time is assumed to take 8 hours and at £8.85 per hour⁴ this costs £71. The total per person is, therefore, £131. For one hundred and eighty people the cost is £23.6k.

The total of these annual recurring costs is between £58.4k and £77.9k.

53. For a MEL of 0.1 mg.m⁻³, we have assumed that the proportion of people upgrading their RPE to a powered respirator would increase from the current level of 20% to 60%. The number of people upgrading is therefore (900 x 60%) - (900 x 20%) = 360. This is double the number used to calculate the control costs for a MEL set at 0.5 mg.m⁻³. For 360 people, the initial cost is therefore between £104.4k and £131.4k and the recurring annual cost is between £116.9k and £155.8k.

54. For a MEL of 0.05 mg.m⁻³, it is assumed that there will be a further increase in the number upgrading their PPE. Again, this is difficult to quantify, but we have assumed that the proportion of people using a powered respirator as their primary control method at this MEL would be 80%. The number of people on which to base calculations on is (900 x 80%) - (900 x 20%) = 540. This is three times the number used to calculate the control costs for a MEL set at 0.5 mg.m⁻³. For 540 people, the initial cost is therefore between £156.6k and £197.1k, and the recurring annual cost is between £175.3k and £233.7k.

55. As with control annual costs under an engineering-based control strategy, because the use of heavy fuel oils in furnaces and boilers is expected to stop within a couple of years, annual costs will recur for the first two years only.

Overall costs

56. The estimated costs associated with complying with different MELs for specialist contractors adopting either an engineering-based or an RPE-based control strategy are summarised in Table 2.

⁴The 1998 New Earnings Survey gives the average hourly wage (excluding overtime) of an employee in an industrial cleaning company as £6.53. Uprating to 1999/2000 prices and adding a 30% allowance for non wage costs, suggests that £8.85 is a reasonable estimate. It is thereafter assumed that earnings rise by 1.8% per year in real terms.

Table 2: Total, initial and recurring annual costs for specialist contractors involved in boiler and furnace cleaning to comply with a variety of MELs using different control strategies (Costs given in 000's of pounds, except for the total ten year costs which have been rounded and given in millions. Initial costs are given in Roman, running costs are italicised, in brackets)

Operation □	Control strategy based on engineering control			Control strategy based on respiratory protective equipment		
	Cost for a MEL of 0.5 mg.m ⁻³ (£k)	Cost for a MEL of 0.1 mg.m ⁻³ (£k)	Cost for a MEL of 0.05 mg.m ⁻³ (£k)	Cost for a MEL of 0.5 mg.m ⁻³ (£k)	Cost for a MEL of 0.1 mg.m ⁻³ (£k)	Cost for a MEL of 0.05 mg.m ⁻³ (£k)
Monitoring	51-904 <i>(25-60)</i>	51-904 <i>(51-121)</i>	51-904 <i>(101-241)</i>	51-904 <i>(51-121)</i>	51-904 <i>(101-241)</i>	51-904 <i>(253-603)</i>
Control	0 <i>(81-225)</i>	0 <i>(81-225)</i>	0 <i>(81-225)</i>	52.2-65.7 <i>(58.4-77.9)</i>	104.4-131.4 <i>(116.9-155.8)</i>	156.6-197.1 <i>(175.3-233.7)</i>
Ten year costs* (present value, £ million, rounded)	£0.3-1.5m	£0.3-1.6m	£0.4-1.8m	£0.3-1.4m	£0.6-1.8m	£1.1-2.7m

* Note that the recurring annual costs only recur for the first 2 years.

57. The recurring annual costs for monitoring and control shown in table 2 do not take the decreasing use of heavy fuel oil into account. However, decreasing use will reduce the recurring costs and, therefore, we have taken this into account in the 10 year costs, by assuming that monitoring and control costs of both control strategies cease to exist after 2 years. Also, by the time the MEL comes into effect, heavy fuel oil use should have declined substantially and this should reduce the initial costs.

b) Catalyst refurbishment

58. Chemicals producers predict that the number of catalyst beds containing vanadium pentoxide currently operating in Great Britain is between fifty and one hundred. The total is gradually declining but the rate is not known.

Vanadium pentoxide monitoring costs

59. Monitoring for exposure is carried out by chemical manufacturers using their own staff and is not conducted by the specialist contractors. Monitoring is carried out during every refurbishment and therefore there would be no extra monitoring in

order to comply with the MEL.

Control costs

60. Discussions with specialist contractors and chemicals manufacturers suggested that control standards sufficient to reduce exposure below 0.05 mg.m^{-3} are currently met by around 80% of contractors. Consequently, we believe that attaining the same level of control by the remaining 20% of contractors is reasonably practicable. The total number of companies involved in catalyst refurbishment is difficult to estimate. However, a contractor estimated that the total would not be much more than six. Therefore, it is assumed that improvements in engineering control are required at $(100\% - 80\%) \times 6 \approx 1$ company. We also assume that the control measures used by this company are not currently sufficient to reduce exposure as far below MELs of 0.1 and 0.5 mg.m^{-3} as is reasonably practicable.

61. For all the MEL options, vacuumation plant such as a lorry mounted self contained vacuum machine would be required. A contractor estimated that this cost around £90.0k in 1999 with annual running costs of around £9.0k thereafter.

Overall Costs

62. The estimated costs associated with complying with different MELs for specialist contractors are summarised in Table 3.

Table 3: Total, initial and recurring annual costs to comply with a variety of MELs for specialist contractors involved in vanadium pentoxide catalyst refurbishment (Costs given in 000's of pounds, except for the total ten year costs which have been rounded and given in millions. Initial costs are given in Roman, running costs are italicised, in brackets)

Operation	Cost for a MEL of 0.5 mg.m^{-3} (£k)	Cost for a MEL of 0.1 mg.m^{-3} (£k)	Cost for a MEL of 0.05 mg.m^{-3} (£k)
Monitoring	0	0	0
Control	90.0 <i>(9.0)</i>	90.0 <i>(9.0)</i>	90.0 <i>(9.0)</i>
Ten year costs (present value, £ million, rounded)	£0.16m	£0.16m	£0.16m

c) Alloy manufacture

63. A manufacturer of TiBAI alloy recently found that personal vanadium monitoring results were less than the limit of detection (0.01 mg.m^{-3}) during alloy production. The two UK alloy producers believe that there will be no extra costs to this industry in order to comply with a proposed MEL. We agree with this.

d) Pigment manufacture

64. It is understood that there is only one manufacturer in Great Britain producing pigments and inks containing vanadium pentoxide. The estimated costs are detailed below.

Vanadium pentoxide monitoring costs

65. Monitoring for occupational exposure to toxic metals, including vanadium, is carried out in-house by the pigment manufacturer. We believe that the current monitoring frequency of around once per month is easily sufficient to check compliance with all of the proposed MELs. This means that there should be no additional monitoring costs.

Control costs

66. For MELs of 0.5 and 0.1 mg.m⁻³, the exposure data in Table 1 suggest that there should be no additional control costs to this business sector.

67. For a MEL of 0.05 mg.m⁻³, we have assumed that LEV at weighing and saggar filling operations would be upgraded. Incorporating a bag capture unit at the weighing station and improving the enclosure and extraction at saggar filling would cost between £11.3k and £16.9k. The annual running costs will be £2250.

Overall Costs

68. The estimated costs associated with complying with different MELs for one manufacturer producing pigments and inks containing vanadium pentoxide are summarised in Table 4.

Table 4: Total, initial and recurring annual costs for a pigment manufacturer to comply with a variety of MELs (Costs given in 000's of pounds, except for the total ten year costs which have been rounded and given in millions. Initial costs are given in Roman, running costs are italicised, in brackets)

Operation	Cost for a MEL of 0.5 mg.m⁻³ (£k)	Cost for a MEL of 0.1 mg.m⁻³ (£k)	Cost for a MEL of 0.05 mg.m⁻³ (£k)
Monitoring	0	0	0
Control	0	0	11.3-16.9 (2.3)
Ten year costs (present value, £ million, rounded)	0	0	£0.028-0.0344m

69. Using different assumptions, the pigment manufacturer estimated that, in order to comply with a MEL of 0.1 mg.m⁻³, the initial one-off cost would be £15k with recurring annual costs of £1.5k. A MEL of 0.05 mg.m⁻³ was not costed by the pigment manufacturer because it believed that this would be prohibitively expensive. We do not believe that industry's costs for a MEL of 0.1 mg.m⁻³ would be incurred because the exposure data in Table 1 show that the maximum vanadium concentration is 0.05 mg.m⁻³ and eighty five per cent of these results are less than 0.05 mg.m⁻³. We believe that this exposure information suggests compliance with the COSHH Regulations for a MEL of 0.1 mg.m⁻³.

70. The total costs for all the affected business sectors are summarised in Table 5.

Table 5: Summary of costs to comply with a variety of MELs, present values over ten years (£m).

Business sector		Cost for a MEL of 0.5 mg.m ⁻³ (£m)	Cost for a MEL of 0.1 mg.m ⁻³ (£m)	Cost for a MEL of 0.05 mg.m ⁻³ (£m)
Boiler/furnace cleaning and furnace demolition	Engineering control strategy	£0.3-1.5m	£0.3-1.6m	£0.4-1.8m
	RPE control strategy	£0.3-1.4m	£0.6-1.8m	£1.1-2.7m
Catalyst refurbishment		£0.2m	£0.2m	£0.2m
Alloy manufacture		0	0	0
Pigment manufacture		0	0	£0.03m
Total present value (ten years, £m)	Engineering control strategy for boiler/furnace work	£0.4-1.6m	£0.5-1.7m	£0.6-2.0m
	RPE control strategy for boiler/furnace work	£0.5-1.5m	£0.8-2.0m	£1.2-2.9m

IMPACT ON SMALL BUSINESSES, CHARITIES AND VOLUNTARY ORGANISATIONS

71. The majority of costs associated with implementing a MEL for vanadium pentoxide will affect boiler/furnace cleaning and furnace demolition businesses, which are mainly small operations.

72. The view of boiler/furnace cleaners and boiler/furnace owners was that occupational vanadium exposure will diminish in line with decreasing use of heavy fuel oil. Consequently, the recurring annual costs to boiler/furnace cleaners are likely to be significantly less than the costs presented in this RIA (note, however, that we have taken this into account in calculating the ten years costs).

73. Catalyst refurbishment is also carried out by small firms of specialist contractors. The frequency of contractor exposure in this industry is also likely to decline due to increasing importation of sulphuric acid, increasing robustness of catalysts and adoption of alternative methods of sulphuric acid manufacture. Therefore, annual recurring costs are also likely to decrease in this business sector. Generally, occupational exposure in this industry is better controlled than in boiler/furnace cleaning and furnace demolition and the costs associated with complying with a MEL will be relatively less.

COSTS TO HSE

74. It is likely that the workload of HSE inspectors will increase slightly because of the proposed change to a MEL. The actual cost is difficult to estimate.

TOTAL COSTS TO SOCIETY

75. The vast majority of the societal cost is borne by industry. This is detailed above.

ENVIRONMENTAL IMPACTS

76. The waste from boiler/furnace cleaning and furnace demolition and catalyst refurbishment goes to landfill. The quantity of waste from boiler/furnace work is unknown. Approximately 100 tonnes of catalyst waste per year goes to landfill. It is thought that the quantity of waste that goes to landfill will not change following the setting of a MEL. As far as we are able to determine, therefore, there are no environmental impacts other than the health effects already discussed.

BALANCE OF COSTS AND BENEFITS

77. When an engineering-based control strategy takes place in the boiler/furnace cleaning sector, the total cost estimates in table 5 show little difference between costs for a MEL of 0.5 mg.m^{-3} (£0.4-1.6m) and a MEL of 0.1 mg.m^{-3} (£0.5-1.7m). Costs from a MEL of 0.05 mg.m^{-3} (£0.6-2.0m) are higher, mostly at the top end of the range considered.

78. For an RPE-based control strategy in the boiler/furnace work sector, total costs are higher than the engineering-based control strategy under every MEL but 0.5 mg.m^{-3} , which involves similar costs. Costs for a MEL of 0.05 mg.m^{-3} (£1.2-2.9m), are twice as large as the costs for a MEL of 0.5 mg.m^{-3} (£0.5-1.5m). Costs for a MEL of 0.1 mg.m^{-3} are equal to £0.8-2.0m.

79. Benefits are equal to £361,000, £703,000, and £1,083,000 depending on whether the MEL is set at 0.5 mg.m^{-3} , 0.1 mg.m^{-3} and 0.05 mg.m^{-3} , respectively. On this basis, benefits either balance out or are larger than the lower end of the range of costs faced by industry when adopting an engineering-based strategy under each MEL. Benefits almost balance out the costs at the lower end of the range under each of the MEL options if employers follow an RPE strategy. Costs at the top end of the range are, instead, higher than the benefits under each of the MEL in both

strategies, and the ratio between costs and benefits tends to be smaller with a MEL of 0.1 mg.m^{-3} and 0.05 mg.m^{-3} , than with an 0.5 mg.m^{-3} MEL.

80. However, the benefits are subject to substantial uncertainties. Since the uncertainty lies mainly in the number of employees who will benefit from the MEL, it is useful to consider what the costs per worker exposed are from setting this MEL, and how these costs compare with past MELs. The table below shows the cost to employers per worker exposed (rounded figures) of approved MELs for substances that were labelled with the risk phrase R45 'may cause cancer'.

81. Table 6 shows that if employers follow a RPE-based control strategy, the cost per employee exposed with setting a MEL at 0.1 mg.m^{-3} and 0.05 mg.m^{-3} is likely to be much higher than the costs per employee exposed when a MEL was set for other substances whose principal health concern was that they could produce cancer in humans. If employers follow an engineering-based control strategy, the costs per worker exposed, under each of the MEL options, are not too far off the costs for the other substances.

Table 6:

Substance	Cost per worker exposed (£, 1999/2000 prices)
Dimethyl sulfate and diethyl sulphate	410-550
Hydrazine	390-1,330
Vanadium pentoxide	
<i>MEL 0.5 mg.m⁻³</i> Engineering control strategy	390-1,480
RPE control strategy	440-1,390
<i>MEL 0.1 mg.m⁻³</i> Engineering control strategy	430-1,590
RPE control strategy	680-1,800
<i>MEL 0.05 mg.m⁻³</i> Engineering control strategy	550-1,830
RPE control strategy	1130-2,670

82. On the basis of the above, the balance appears to be that costs are more likely to exceed benefits than benefits exceed costs. However, benefits are very uncertain. If deaths were avoided by the MEL, benefits would be much larger.

Uncertainties

83. Uncertainties in the assumptions made on costs are reflected in the use of range rather than point estimates.

84. The benefits are subject to substantial uncertainties. Because there is no information on dose-effect, it is not possible to make a direct estimate of benefits and an alternative approach has been adopted.

SUMMARY AND RECOMMENDATIONS

85. The costs for contractors working in boiler cleaning, furnace cleaning and furnace demolition to comply with the MEL options are expensive and gradually increase (see Table 5) as the numerical value of the options (0.5 mg.m^{-3} , 0.1 mg.m^{-3} and 0.05 mg.m^{-3}) decrease. The costs using a strategy based on engineering control are less than the costs using a strategy based on RPE, particularly at 0.05 mg.m^{-3} if an RPE control strategy is used. The costs (£0.2m, total present value) of complying with a MEL of 0.05 mg.m^{-3} are only likely to be incurred by one out of the six catalyst refurbishment contractors. The range of the recently reported vanadium occupational exposure results during pigment manufacture is 0.01 to 0.05 mg.m^{-3} . Fifteen per cent are exactly 0.05 mg.m^{-3} and the remainder are below 0.05 mg.m^{-3} . The initial costs to this industry for complying with a MEL of 0.05 mg.m^{-3} are estimated at £11.3k to £16.9k. The recurring annual costs are £2.3k. We do not believe this to be prohibitively high. There will be no extra costs for alloy producers complying with any of the MEL options.

86. The costs to the boiler cleaning, furnace cleaning and furnace demolition industry for a MEL of 0.1 mg.m^{-3} are also expensive and it is likely that some will not be able to meet the additional costs. We have not been able to estimate the number. The costs for catalyst refurbishing contractors complying with a MEL of 0.1 mg.m^{-3} are the same as those for complying with a MEL of 0.05 mg.m^{-3} . There are no costs for the pigment manufacturer complying with 0.1 mg.m^{-3} .

87. For a MEL of 0.5 mg.m^{-3} , the costs to the boiler cleaning, furnace cleaning and furnace demolition industry are slightly less than those for complying with 0.1 mg.m^{-3} . The costs for catalyst refurbishers and a pigment manufacturer complying with a MEL of 0.5 mg.m^{-3} are the same as those for complying with a MEL of 0.1 mg.m^{-3} .

88. Bearing in mind the strong uncertainties in the estimation of the benefits, and the comparison made with the costs per worker exposed in other MELs set for substances that may cause cancer, the total costs from setting a MEL for vanadium pentoxide are likely to be somewhat higher than the benefits under each option. A comparison of total costs and benefits, however, shows more favourable cost-benefit ratios the lower the proposed MEL, in particular with a strategy based on engineering control. In view of this, and of the above analysis of the costs, we recommend setting a MEL at either 0.1 mg.m^{-3} or 0.05 mg.m^{-3} . On the one hand, if employers choose a strategy based on engineering control, with a MEL of 0.05 mg.m^{-3} we would have slightly higher costs than with a MEL of 0.1 mg.m^{-3} , but a better cost-benefit ratio (i.e. benefits are likely to almost balance out the costs). A 0.05 mg.m^{-3} MEL would also be preferable in view of human studies which show that a single 8-hour exposure to 0.06 mg.m^{-3} vanadium produces respiratory tract irritation. On the other hand, with a MEL of 0.1 mg.m^{-3} , even though the benefits are less likely to balance out the costs, total compliance costs would be lower.

RESULTS OF CONSULTATIONS

89. Questionnaires designed to determine the costs and benefits associated with replacing the OESs for vanadium pentoxide with a single MEL were sent to the following industry associations:

Aluminium Federation;
Combustion Engineering Association;
Employers Engineering Federation;
British Ceramic Research Ltd;
Oil Firing Technical Association for the Petroleum Industry and
National Sulphuric Acid Association.

90. The questionnaire was also sent to a chemicals producer, a pigment manufacturer and two specialist industrial cleaners. The Combustion Engineering Association sent the questionnaire to six of its member companies.

91. The number of companies contacted in the business sectors affected was as follows:

- a) Boiler/furnace cleaning and furnace demolition - 8
- b) Catalyst refurbishment - 5
- c) Alloy manufacture - 2
- d) Ceramics industry – 1.

92. Public consultation on the proposal took place between May and August 2000. On the basis of the comments received HSE recommended to ACTS that a limit of 0.05 mg.m^{-3} be established for vanadium pentoxide. A MEL set at this level came into force in April 2001.

ENFORCEMENT, SANCTIONS, MONITORING AND REVIEW

93. The MEL is enforced at workplaces by HSE. Assigning a MEL requires an increase in the emphasis inspectors attach to vanadium exposure. This has resulted in a slightly increased workload for inspectors during inspection and any resulting enforcement action. The MEL will be revised if significant new information becomes available, which places doubt on the current assessment of the health risks.

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