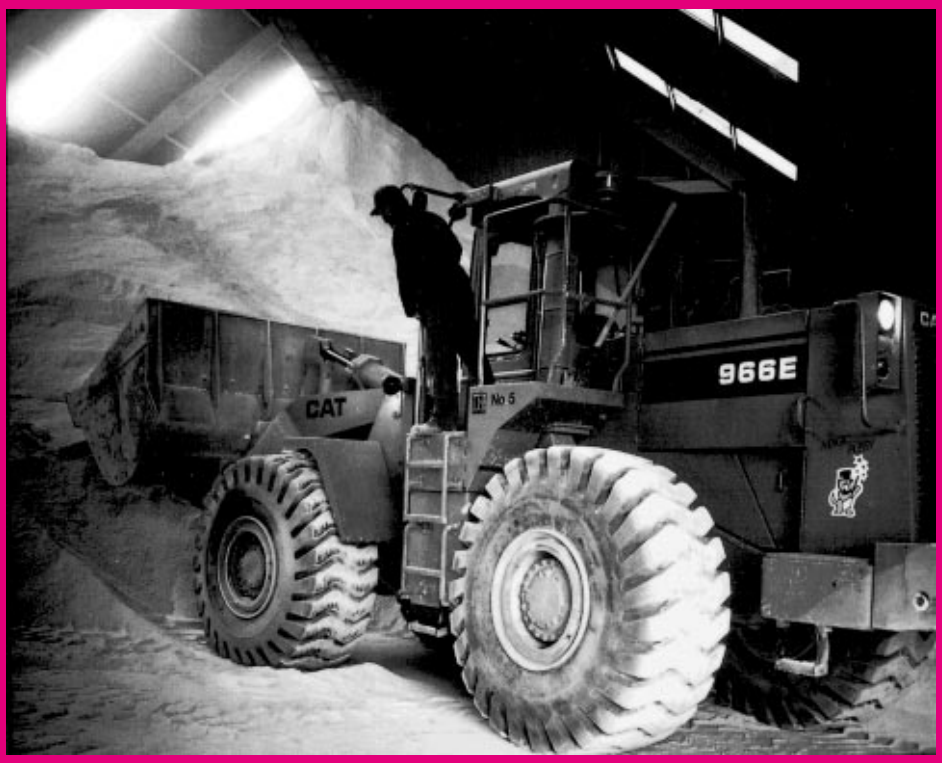
HEALTH AND SAFETY IN EMPLOYMENT ACT 1992

## APPROVED CODE OF PRACTICE FOR THE

# PREVENTION OF SULPHUR FIRES AND EXPLOSIONS




OCCUPATIONAL SAFETY & HEALTH SERVICE

DEPARTMENT OF LABOUR
TE TARI MAHI

ISSUED AND APPROVED BY THE MINISTER OF LABOUR JUNE 1993

Published by the Occupational Safety and Health Service
Department of Labour
Wellington
New Zealand

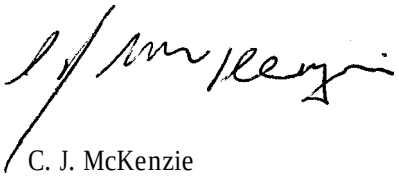
September 1993

ISBN 0-477-03466-7
$10 (incl. GST)

# Contents

# NOTICE OF ISSUE

I have issued this *Approved Code of Practice for the Prevention of Sulphur Fires and Explosions*, being a statement of preferred work practices or arrangements, for the purpose of ensuring the health and safety of persons to which this code applies and persons who may be affected by the activities covered by the code.

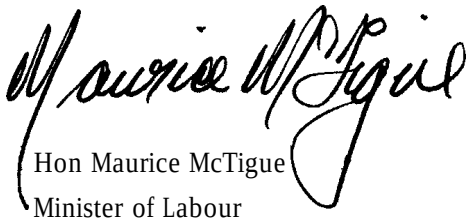


C. J. McKenzie
Secretary of Labour
June 1993

# FOREWORD

I have approved this statement of preferred work practices, which is an approved code of practice for the prevention of sulphur fires and explosions under section 20 of the Health and Safety in Employment Act 1992.

When a code is approved a court may have regard to it in relation to compliance with the relevant sections of the Health and Safety in Employment Act. This means that if an employer in an industry, or using a process to which an approved code applies, can show compliance with that code in all matters it covers, a court may consider this to be compliance with the provisions of the Act to which the code relates.



Hon Maurice McTigue
Minister of Labour
June 1993

# A SUMMARY OF THE HEALTH AND SAFETY IN EMPLOYMENT ACT 1992

The principal object of the Health and Safety in Employment Act 1992 is to prevent harm to employees at work. To do this it imposes duties on, and promotes excellent health and safety management by, employers. It also provides for the making of regulations and codes of practice.

## APPROVED CODES OF PRACTICE

The Act provides for the development and approval of statements of preferred work practice or arrangements, that may be approved as "approved codes of practice". These are recommended means of compliance with provisions of the Act, and may include procedures which could be taken into account when deciding on the practicable steps to be taken. Compliance with codes of practice will not be mandatory. However, they may be used as evidence of good practice in court.

## EMPLOYERS' DUTIES

Employers have the most duties to perform to ensure the health and safety of employees.

If you are an employer then you have a general duty to take all practicable steps to ensure the safety of employees while at work. (This is set out in section 6.) In particular, you are required to take all practicable steps to:

- Provide and maintain a safe working environment;
- Provide and maintain facilities for the safety and health of employees at work;
- Ensure that machinery and equipment in the place of work is designed, made, set up, and maintained to be safe for employees;
- Ensure that employees are not exposed to hazards in the course of their work; and
- Develop procedures for dealing with emergencies that may arise while employees are at work.

## HAZARD MANAGEMENT

Employers must identify hazards in the place of work (previously existing, new and potential) and regularly review them to determine whether they are significant hazards and require further action. Where there occurs any accident or harm in respect of which an employer is required to record particulars, section 7 (2) of the Act requires the employer to take all practicable steps to ensure that the occurrence is so investigated as to determine whether it was caused by or arose from a significant hazard.

"*Significant hazard*" means a hazard that is an actual or potential cause or source of:

(a) Serious harm; or

(b) Harm (being more than trivial) the severity of whose effects on any person depend (entirely or among other things) on the extent or frequency of the person's exposure to the hazard; or

(c) Harm that does not usually occur, or usually is not easily detectable, until a significant time after exposure to the hazard.

### *WHERE THE HAZARD IS SIGNIFICANT*

The Act sets out the steps an employer must take:

- Where practicable, the hazard must be *eliminated*.
- If elimination is not practicable, the hazard must be isolated.
- If it is impracticable to eliminate or isolate the hazard completely, then the employer must *minimise* the hazard to employees.

In addition the employer must, where appropriate:

- Ensure that protective clothing and equipment is provided, accessible and used;
- Monitor employees' exposure to the hazard;
- Seek the consent of employees to monitor their health; and
- With informed consent, monitor employees' health.

## INFORMATION FOR EMPLOYEES

Before an employee begins work their employer must inform them of:

- Emergency procedures;
- Hazards the employee may be exposed to while at work;
- Hazards the employee may create while at work which could harm other people;
- How to minimise the likelihood of these hazards becoming a source of harm to others; and
- The location of safety equipment.

The employer is also required to inform employees of:

- The results of any health and safety monitoring. In doing so, the privacy of individual employees must be protected.

## EMPLOYERS TO INVOLVE EMPLOYEES IN THE DEVELOPMENT OF HEALTH AND SAFETY PROCEDURES

Employers need to ensure that all employees have the opportunity to be fully involved in the development of procedures for the purpose of identifying hazards and dealing significant hazards or dealing with or reacting to emergencies and imminent dangers (section 14).

## TRAINING OF EMPLOYEES AND THE SAFETY OF OTHERS

The employer must ensure employees are either sufficiently experienced to do their work safely or supervised by an experienced person. In addition, the employee must be adequately trained in the safe use of equipment in the place of work, including protective clothing and equipment (section 13).

An employer is also responsible for the health and safety of people who are not employees. An employer must take all practicable steps to ensure that an employee does not harm any other person while at work, including members of the public or visitors to the place of work (section 15).

## EMPLOYEES' DUTIES

If you are an employee, the Act gives you responsibility for your own safety and health while at work. You must also ensure that your actions do not harm anyone else.

## ACCIDENTS AND SERIOUS HARM (RECORDS AND NOTIFICATION)

In the Act:

"Accident" means an event that—
(a) Causes any person to be harmed; or
(b) In different circumstances, might have caused any person to be harmed:

This means that "accident" includes both near misses and accidents that result in harm to a person, or might have caused any person to be harmed.

Every employer is required to maintain a register of accidents and serious harm; and record particulars relating to:

(a) Every accident that harmed (or, as the case may be, might have harmed):-

(i) Any employee at work; or
(ii) Any person in a place of work controlled by the employer; and

(b) Every occurrence of serious harm to an employee at work, or as a result of any hazard to which the employee was exposed while at work, in the employment of the employer.

Where there occurs any serious harm or accident an employer must:-

(a) As soon as possible after its occurrence, notify the Secretary of the occurrence, and

(b) Within 7 days of the occurrence, give the Secretary written notice, in the prescribed form, of the circumstances of the occurrence.

The notification to the Secretary applies to:

(a) Every occurrence of serious harm to an employee at work, or the occurrence of serious harm as a result of any hazard to which the employee was exposed while at work, in the employment of the employer; and

(b) Accidents of a kind or description required by regulations.

**Note: Regulations had not been promulgated at the time of printing**.

# 1. INTRODUCTION

**1.1** The purpose of the this code of practice is to establish reasonable safety and health protection requirements to eliminate or reduce the hazards of explosion and fire inherent in the processing and handling of sulphur, and mixtures containing sulphur, thereby protecting the safety of employees involved.

**1.2** The code is primarily concerned with the hazards arising from the processing of solid sulphur, but also considers the major risks associated with handling sulphur in liquid form.

# 2. INTERPRETATION

**2.1** Regulations make provision for the precautions to be taken with respect to explosive or flammable materials. By complying with this code, employers will be deemed to have taken "all reasonable precautions" to fulfil their obligations.

**2.2** The code has been written with special reference to the fertiliser industry, but also applies to other factories where sulphur is handled or processed as an ancillary operation to the main industry.

**2.3** The code does not endeavour to cover the mechanical safety of plant and equipment, but all machinery must comply with the requirements of the regulations.

# 3. DEFINITIONS

**Act** Means the Health and Safety in Employment Act 1992.

**BEI** Biological Exposure Indices as described in the WES booklet (see below).

**Combustible dust** A dust which can be burnt and presents an explosion hazard when dispersed in air.

**Commercially screened sulphur** This product shall have a typical sieve analysis as follows:

*TABLE 1: SIEVE ANALYSIS OF COMMERCIALLY SCREENED SULPHUR*

| *Passing BS sieve* | *Max. particle size (microns)* | *%* |
|---|---|---|
| 10 | 1674 | 91.9 |
| 18 | 852 | 67.4 |
| 30 | 500 | 42.0 |
| 60 | 251 | 20.0 |
| 100 | 152 | 8.3 |

In addition, not more than 25% of any batch of commercially screened sulphur shall pass a 60 BS sieve (25l microns).

**Department** The Occupational Safety and Health Service of the Department of Labour.

**Dust** All particles with maximum dimensions not exceeding 1400 microns (12 BS sieve).

**Fine sulphur dust** All sulphur particles with maximum dimensions not exceeding 500 microns (or "fines") (30 BS sieve).

**Hazardous area** Any area or vessel within a factory where there is present combustible dust of such a character and to such an extent as to be liable to give rise to an explosion or explode on ignition.

**Inspector** Unless specified means an inspector appointed under the Act.

**MSDS** Material Safety Data Sheet.

**STEL** Short Term Exposure Level as described in the WES Booklet.

**TLV** Threshold Limited Value as described in the WES Booklet.

**TWA** Time Weighted Average as described in the WES Booklet.

**WES** Workplace Exposure Standards. The WES booklet is a guideline for assessing the adequacy of the measures taken to limit exposure to airborne substances in the workplace. The WES booklet is updated and published regularly. Copies are obtainable from branch offices of the Occupational Safety and Health Service.

# 4. DUST EXPLOSIONS

## 4.1 DUST EXPLOSION DESCRIBED

**4.1.1** A dust explosion occurs when a fine dust in suspension in air is ignited, resulting in a very rapid burning, and the release of large quantities of gaseous products. This in turn creates a subsequent pressure rise of explosive force capable of damaging plant and buildings and injuring people. It is generally considered that a dust explosion can only be initiated by dust particles less than 500 microns diameter, but that once initiated larger particles up to 1400 microns diameter will contribute to the propagation of an explosion.

## 4.2 PRIMARY AND SECONDARY EXPLOSIONS

**4.2.1** Usually the initial or primary explosion takes place in a confined space such as plant or machinery, and can be of sufficient force to damage or rupture the plant. If the shock wave from the primary explosion enters the surrounding area, it will disturb any settled dust layers, forming a second dust cloud, and often initiate a much larger secondary explosion. All large-scale explosions have resulted from chain reactions of this type.

## 4.3 CONDITIONS FOR A DUST EXPLOSION

**4.3.1** Certain conditions are necessary before a dust explosion can take place. They are:

(a) The dust must be combustible.

(b) The dust cloud must be of explosive concentration, i.e. between the lower and upper explosion limits for the dusts.

(c) There must be sufficient oxygen in the atmosphere to support and sustain combustion.

(d) A source of ignition must be present.

(e) The dust must be fine enough to support an explosion.

## 4.4 FACTORS AFFECTING DUST EXPLOSIBILITY

**4.4.1** The following factors can have a marked effect on the explosibility of a given dust, including sulphur:

(a) *Particle size*: As the particle size of the dust decreases, the available surface area increases, making it much easier for the dust to burn rapidly (explode). Thus, the explosibility of a dust increases as the particle size decreases, and the smaller the particles, the less energy that is required to ignite the dust cloud. A fine dust will also form suspensions in air more readily and remain suspended longer than coarser particles.
Although dust generally needs to be less than 250 microns in diameter in order to explode, research has shown that particles up to 500 microns diameter will explode under the right conditions. The presence of larger particles helps to reduce the explosion hazard. However, once an explosion is under way, even relatively coarse particles can burn and add energy to the explosion.

(b) *Moisture content*: The presence of moisture has the effect of making the dust particles more cohesive so that they produce agglomerates which are more difficult to disperse and ignite. However, it is considered that for many dusts the moisture content has to be as high as 30% to avoid the risk of an explosion.

(c) *Inerting*: When a combustible dust is mixed with an inert diluent, the resultant mixture can be less explosive than the pure substance. However, for many combustible dusts, including sulphur, the mixture may still explode if it is possible for approximately 10% or more fines to separate out from the mixture. Inerting can also be achieved by replacing or reducing the oxygen level in the air with an inert gas such as nitrogen, carbon dioxide or steam. For many dusts, an atmosphere containing 8% or less oxygen will not support an explosion (see also section 6.8).

# 5. HAZARD RATING OF SULPHUR

## 5.1 EXPLOSION RISK

**5.1.1** Sulphur is a flammable substance in both the solid and liquid states. The dust is characterised by a very low ignition point of 190°C compared to other combustible dusts, and dust clouds are readily ignited by weak frictional sparks. Dusts containing 25% or more elemental sulphur may be almost as explosive as pure sulphur.

## 5.2 INCOMPATIBLE CHEMICALS

**5.2.1** Explosive mixtures may be formed if sulphur is contaminated with chlorates, nitrates or other oxidising agents (see also section 6.5.7).

## 5.3 STATIC ELECTRICITY

**5.3.1** Sulphur has excellent electrical insulation properties and under the right conditions will readily pick up static electricity which if discharged can result in ignition (see also section 6.8.4).

## 5.4 OTHER HAZARDS

### *5.4.1 FIRE*

**5.4.1.1** Solid and liquid sulphur will burn to produce sulphur dioxide gas, which is extremely irritating and toxic (refer to appendix 2). The effects of the fire hazard itself are slight.

### *5.4.2 HYDROGEN SULPHIDE*

**5.4.2.1** Much of the world's sulphur is now produced from the treatment of sour gases found in refinery and natural gas installations. As a result, when this sulphur is remelted, it may release small quantities of hydrogen sulphide gas, which is both flammable and toxic. The specific precautions required are considered in detail in sections 8.2.2-5.

# 6. DUST EXPLOSION PREVENTION AND PROTECTION

## 6.1 GENERAL

**6.1.1** There are two basic approaches available for handling combustible dust safely:

(a) *Explosion Prevention*: Dust explosions can be prevented by ensuring that the following conditions are met:

- Suspensions of sulphur dust in air are avoided; and
- All sources of ignition are excluded.

(b) *Explosion Protection*: If an explosion is initiated, its harmful effects can be avoided by:

- Containment of the shock wave generated in a vessel capable of withstanding the maximum pressure produced (about 700 kPa for sulphur) without bursting.
- Venting the vessel using a bursting disc or similar device so that the pressure rise initiated by the explosion is relieved by the opening of the vent.
- Suppression of the explosion by detection of the embryonic shock wave, followed by the discharge of usually a halon gas which both inerts and suppresses the explosion. Such a system is capable of being fully activated within 10-30 milliseconds, whereas a typical explosion may require 100-200 milliseconds to develop its full force.
- Plant separation: this relies on physically isolating the hazardous process from other plant operations by the use of “chokes” or by distance.

**6.1.2** In this code of practice, explosion prevention methods are favoured wherever practical as the primary means of providing a safe working environment.

## 6.2 MINIMISATION OF DUST

**6.2.1** To prevent dust formation during the storage and handling of sulphur, enclosures should be constructed with a minimum number of horizontal surfaces where dust can accumulate.

**6.2.2** Scattering of dust where solid sulphur is transferred from one point to another should be avoided. Where feasible, dust-tight housings or extraction hoods should be provided.

**6.2.3** Where vacuum cleaners are used for dust control and removal, they shall be suitable for the hazardous area in which they are to be used. Refer to section 6.5.5 for electrical requirements.

**6.2.4** Bulk accumulations of fine sulphur may also be removed using soft push brooms, having natural bristles and non-sparking scoops or shovels before vacuum cleaning equipment is used.

**6.2.5** The use of compressed air to remove dust from any surface, vigorous sweeping or any other method of cleaning which may raise a dust cloud is prohibited.

**6.2.6** Long sulphur drops from overhead gantries into the store should be avoided by discharging near the top of the existing sulphur pile. Alternatively, dust formation can be reduced using a telescoping spout, preferably made from aluminium. Where this is not possible or practical, the sulphur shall be dampened (see section 6.2.7) to minimise dust cloud formation.

**6.2.7** Where dust formation is a problem within a factory, a water sprinkler system shall be available to damp down the sulphur to approximately 3% moisture content prior to loading it into the bulk store.

## 6.3 CONSTRUCTION OF BUILDINGS

**6.3.1** In addition to complying with the building requirements of the territorial authority, the following points shall also apply where practicable:

(a) All buildings used to store solid sulphur shall be constructed of fire-resistant materials.

(b) Aluminium is the best all-round material for fabricating bins containing sulphur, because it is non-sparking and resistant to corrosion.

(c) In the case of buildings, a steel frame construction with light non load-bearing exterior walls and a light roof is preferred.

(d) Buildings used to store sulphur should be cool and must provide good natural or mechanical ventilation. The use of any form of heater or heating system is not permitted.

(e) Where interior structures have horizontal surfaces on which sulphur dust may collect, these should be roofed with steeply sloping upper surfaces of at least 60°.

## 6.4 FIRE CONTROL

**6.4.1** Automatic sprinkler systems which comply with NZS 4541 and provide a fine spray or mist are recommended as the most satisfactory extinguishing system for bulk stores. Fire hoses and extinguishers must be fitted with fine spray nozzles to ensure that sulphur dust clouds are not raised, as these can explode on contact with the fire.

**6.4.2** Incipient fires in storage piles may be smothered by gently shovelling sulphur onto them.

**6.4.3** At least two sets of self-contained breathing apparatus shall be available for use in case of sulphur fires on premises where bulk sulphur, fine or granular, is stored. The term "bulk sulphur" shall not apply to sulphur supplied in multi-wall bags, or similar packaging. All respiratory equipment shall comply with and shall be selected, used and maintained in accordance with AS 1715 and AS 1716. These standards have been adopted by Standards New Zealand.

**6.4.4** Factory fire crews shall be available on premises where bulk sulphur is stored, and be provided with safety belts and lifelines, with one worker standing by in case of accidents.

**6.4.5** In addition to the above provisions, employers should liaise with the local commander of the New Zealand Fire Service and follow his or her recommendations with regard to the size and training of factory fire crews and other related matters, including rescue and evacuation procedures.

## 6.5 ELIMINATION OF IGNITION SOURCES

### *6.5.1 SMOKING*

**6.5.1.1** Smoking and the use of matches shall be prohibited in all areas where sulphur dust is likely to be present. Prominent NO SMOKING signs shall be placed around such areas.

### *6.5.2 NAKED FLAMES OR LIGHTS*

**6.5.2.1** Naked flames or lights and the use of gas cutting or welding equipment is prohibited during the normal operation of the plant. Repairs involving the use of flames, heat, or hand or power tools in areas where sulphur may be present shall be made only after all sulphur-handling machinery and operations are shut down, and a hot work permit of the type illustrated in appendix 3 completed. Where practical, all sulphur shall be removed. Where this is not possible the sulphur shall be wetted down, and workers provided with an assured supply of fresh air and a hose line with spray nozzle to extinguish fires.

### *6.5.3 HOT SURFACES*

**6.5.3.1** Dust layers or dust clouds of sulphur are very easily ignited by hot surfaces (see appendix 1). The result of this can be a small fire which may then become an ignition source for any suspended dust in the vicinity.

**6.5.3.2** Overheated bearings, poorly ventilated electric motors and electric lighting are all examples of hot surfaces that can cause fires and dust explosions.

**6.5.3.3** To prevent excessive heat build-up, all equipment shall be properly and securely installed to ensure correct alignment of rotating shafts, belt tensions, etc. This must be backed up by a valid maintenance programme of inspection, lubrication and repair. Sealed bearings are recommended for all heavy duty equipment in areas subject to dust production.

**6.5.3.4** The surface temperature of the plant or machinery should not exceed 2/3 of the ignition temperature of sulphur dust, i.e. 127°C. However, consideration should also be given to the melting point of sulphur (110 - 121°C) in the selection of heat-producing electrical equipment.
In the case of electrical equipment used in hazardous areas, international standards define a temperature classification of "Tl - T6" to designate the maximum permissible temperature rise, referenced to a 40° C ambient temperature.
Hence, suitable electrical equipment for use in a sulphur hazardous area shall have a "T rating" of T5 or T6, i.e. a maximum surface temperature of 100°C.

## 6.5.4 STATIC ELECTRICITY

**6.5.4.1** Solid sulphur is a poor conductor of electricity, and when in motion under conditions of low humidity can easily develop a sufficient static charge to cause sparking and ignition. For this reason, fine, dry sulphur dust must not be allowed to fall freely in air. For further information on static electricity control, refer to AS 1020: *The control of undesirable static electricity*.

**6.5.4.2** Every care must be taken to prevent static electricity accumulation in areas where solid sulphur is handled. All machinery, hoppers, bins, chutes, conveyors, and metal buildings must be continuously bonded and earthed in accordance with AS 1020. The electrical resistance between any point in the system and earth should not exceed $10^6$ ohms. The equipment needs to be checked, to ensure that bonding and earthing is adequate every 6 months and whenever plant repairs are carried out.

**6.5.4.3** Dressing of belts with resins or gums generally tends to increase the generation of static electricity and is not recommended. Where possible, such transmission systems should be replaced by direct drive types. If this is not practical, belts shall be of a conducting type and pulleys must be earthed.

**6.5.4.4** If the relative humidity of the air can be maintained above 60%, the possibility of static build-up is reduced.

## 6.5.5 ELECTRICAL REQUIREMENTS

**6.5.5.1** Both electrical wiring and equipment can constitute a source of ignition for a dust explosion and precautions must be taken to eliminate this hazard.

**6.5.5.2** The first requirement is to define the extent of the hazardous area in which sulphur dust may be continuously present as a dust layer or suspended in air either continuously, intermittently or periodically under normal

operating conditions in quantities sufficient to produce an explosive concentration.

**6.5.5.3** The classification of the hazardous area is the responsibility of a health and safety inspector and should be made with reference to NZS 6101 part 2 *Classification of hazardous areas — combustible dusts.* These classifications are used in NZS 6105 to set the electrical equipment and wiring requirements for that area.

**6.5.5.4** The employer is responsible for installing electrical equipment appropriate to the hazardous area designation and complying with the Electrical Wiring Regulations and associated codes of practice. The occupier shall also take into account the recommendations set out in section 6.5.3.4 concerning the working surface temperature of the electrical equipment.

**6.5.5.5** A health and safety inspector may require that the completed installation be checked for compliance with the Electricity Act by an authorised electrical inspector.

### *6.5.6 FRICTION OR IMPACT SPARKS*

**6.5.6.1** Many explosions and fires have been caused by impact or friction sparks as the result of foreign materials entering the intake conveyor.

**6.5.6.2** Precautions must be taken using grids and magnets to remove all foreign material at the sulphur receiving facilities (see also section 7).

### *6.5.7 EXPLOSIVE MIXTURES*

**6.5.7.1** Solid sulphur is capable of forming explosive mixtures when mixed with chlorates, nitrates or other oxidising agents. Where practical, it is recommended that nitrates or other oxidising materials are stored in completely separate buildings from sulphur with their own loading facilities. If this is not possible, bins for these products need to be separated from the sulphur by at least 30 metres.

**6.5.7.2** In situations where nitrates and sulphur presently use the same loading elevators, great care must be taken to ensure no cross contamination occurs. All shutes, hoppers and conveying equipment must be thoroughly cleaned between deliveries of sulphur and nitrates. In addition to these precautions, deliveries of sulphur and nitrates shall not be sequential, but interspersed with a delivery of an inert substance such as phosphate rock to further reduce the risk of cross-contamination.

## 6.6 EXPLOSION RELIEF VENTING

### *6.6.1 GENERAL*

**6.6.1.1** Any enclosed plant in which dust can accumulate to the extent that it is liable to give rise to an explosive concentration must have explosion protection devices fitted. For most operations the cheapest and most

practical of these is known as explosion venting, in which the pressure rise from an explosion is reduced by the installation of explosion reliefs such as vents, bursting panels or explosion doors. The relief must be capable of operating almost instantaneously, as often there is only a very small safety factor between the operation of the vent and the bursting pressure of the plant. In this way the products of the explosion are discharged, hence keeping the explosion pressure at a lower level than the design strength of the vessel and so protecting it from the worst effects of an explosion. Care must be taken to site such explosion reliefs so that the products of an explosion are vented to a safe place in the open air.

## 6.6.2 SIZING OF EXPLOSION RELIEFS

**6.6.2.1** The actual size of the explosion relief depends on:

(a) The rate of pressure rise of the flammable material i.e. sulphur;

(b) The strength of the vessel;

(c) The volume of the vessel;

(d) The potential strength of the ignition source; and

(e) The vent release pressure.

**6.6.2.2** The Occupational Safety and Health Service uses various methods for determining vent sizes depending on individual circumstances. The usual method is based on the design criteria set out in NFPA 68 *Venting of deflagrations*. This information is presented as a series of nomographs so that the determination of the vent area is a straightforward technical exercise. Further details can be obtained from OSH branch offices.

## 6.6.3 EXPLOSION RELIEF VENTS

### 6.6.3.1 General

**6.6.3.1.1** Explosion reliefs must be dust-tight and have sufficient mechanical strength to resist the wear to which they are subjected. They should be located as close as possible to potential sources of ignition. An open vent is the most effective but is usually impractical because of the need to protect the product against contamination, the weather, and to stop the dust contaminating the atmosphere. Hence a variety of closures are used.

### 6.6.3.2 Bursting Discs

**6.6.3.2.1** These can be made of waterproofed paper, varnished cloth, polythene sheeting, cellophane, thin metal foil, rubber or other suitable materials. They must be capable of bursting at a much lower pressure than that which will rupture the enclosure. Cutters or knives placed at the centre or on the periphery of the disc can hasten the pressure relief.

### 6.6.3.3 Explosion Doors

**6.6.3.3.1** These may be made of light metal or other non-combustible material. The hinges need to be regularly maintained and lubricated. This type of

explosion relief has been found to be nearly as effective as open reliefs for relieving the pressure generated by explosions which do not have a very high rate of pressure rise.

**6.6.3.3.2** The door must not weigh more than 25 kg and preferably not more than 10 kg per square metre of door area.

**6.6.3.3.3** Felt or other suitable material may be used to provide a dust-tight fitting.

**6.6.3.3.4** Other explosion doors can consist of light rigid covers held in place by springs, spring clips, gravity, magnets, friction or thin metal tongues.

**6.6.3.3.5** The doors need to be securely attached so that they do not become dangerous missiles when they operate.

### *6.6.4 SAFE VENTING*

**6.6.4.1** The most effective way of obtaining safe venting is to locate the plant in the open air, or beneath a light waterproof structure so that the flames, hot gases and burning dust are vented harmlessly away.

**6.6.4.2** If this is not possible then the explosion relief must be linked to the outside via ducting. The ducting must be strong enough to withstand the maximum pressure to which it is likely to be subjected, and should be as short and straight as possible.

**6.6.4.3** Any duct will decrease the effectiveness of the vent in proportion to its length because the explosion pressure increases with ducting length.

**6.6.4.4** To overcome this problem the vent duct should be no longer than 3 metres. If this is not possible, either the vent area must be enlarged or the vessel strengthened to withstand a higher pressure.

**6.6.4.5** The duct must not be longer than 6 metres.

**6.6.4.6** The following table sets out the requirements for calculating the vent area for different lengths of ducting.

*TABLE 2: VENT AREA FOR DIFFERENT LENGTHS OF DUCTING*

| *Length of duct* | *Area of vent/pressure vessel can withstand* |
|---|---|
| Up to 3.0m | Multiply by 1.0 |
| 3.0m to 4.5m | Multiply by 1.5 |
| 4.5m to 6.0m | Multiply by 2.0 |

**6.6.4.7** Further information on safe venting designs and requirements may be obtained from registered engineers or any OSH branch.

## 6.7 EXPLOSION DETECTION AND SUPPRESSION

**6.7.1** Where venting is not practicable as an explosion protection method, an explosion suppression system can be used as an alternative.

**6.7.2** The incipient explosion is monitored by an explosion detector, usually by the detection of a pressure rise. This information is relayed to a control unit which causes the suppressant to flow, and then kill the impending

explosion. The plant will be shut down automatically at this stage by the control unit. Suppressants usually consist of vaporising liquids such as the halogenated hydrocarbons (halons). To use a suppression system the plant needs to be able to withstand a pressure rise of about 20 kPa. Where such systems are installed care is required owing to the toxic nature of some of the suppressants.

## 6.8 INERTING

**6.8.1** In many plants and processes where the dust is confined within an enclosure, explosions may be prevented by the replacement of the normal atmosphere with an inert gas.

**6.8.2** In such a system, oxygen is excluded, or the oxygen content in the plant atmosphere is reduced to a level at which combustion cannot be sustained. The use of an inert gas ensures that if a dust cloud does form, it will not be able to explode. Additionally, the inert gas may extinguish sources of ignition.

**6.8.3** The reactivity of the dust and the strength and duration of any ignition source must be taken into consideration when choosing the inerting gas. In the case of sulphur, using carbon dioxide as the inerting gas, the oxygen concentration must be reduced to 12% to prevent ignition of dust clouds.

**6.8.4** To ensure the integrity of the inerting system the plant must be operated under positive pressure.

## 6.9 PROTECTION OF PLANT BY STRENGTH

**6.9.1** Strengthening the plant, so that it can withstand the effects of an explosion intact, can be used as a method of explosion protection. In this method the plant is designed to withstand an internal pressure of 700 kPa without bursting. The system is most suitable for small plant items but is not usually used in large plants because of the cost involved.

# 7. SPECIFIC HAZARDS RELATING TO SULPHUR HANDLING

## 7.1 INTAKE STORE

### *7.1.1 LOADING OPERATION*

**7.1.1.1** Whenever sulphur is discharged into the bulk store a certain amount of dust will be generated, even though the precautions provided for in sections 6.2.6 and 6.2.7 are followed. For this reason only essential workers shall be present during the loading operation, and no other work shall be permitted in the store until all airborne dust has settled.

### *7.1.2 CONTROL OF SLIDES*

**7.1.2.1** Slides can be a hazard to employees working on bulk piles or in bins of bulk sulphur, and reasonable safety precautions must be observed to avoid overhangs and slides. For example, undercutting of sulphur piles must be avoided. Manual undercutting is particularly dangerous as the angle of repose of loose bulk sulphur is 35°. Where a worker needs to work in a bin that is in danger of sliding, a safety belt with a lifeline fastened securely at the top of the bin must be worn and the worker observed by another employee similarly equipped.

### *7.1.3 FRONT-END LOADERS*

**7.1.3.1** Unmodified front-end loaders powered by diesel or other fossil fuels are a source of ignition. They must be equipped with spark arrestors and protected muffler and exhaust systems, when used in areas where the sulphur contains 10% or more fines. The temperature rating of the engine, and exhaust system shall be T5, which allows for a maximum surface temperature of 100°C.

**7.1.3.2** The buckets of front-end loaders are generally manufactured from hardened alloy steels, which in contact with concrete can produce incendiary sparks and ignition of sulphur. There is no firm evidence, however, that the so called “non sparking” metals such as bronzes are any safer in this respect, as these can also generate sparks in contact with concrete which are hotter than those produced by steel. (The non-sparking metals generally do not spark in contact with steel but there are also exceptions, e.g. when the steel is rusty.) This means that when working

with front-end loaders care must be exercised to avoid raising dust clouds as far as possible and to prevent the bucket from scraping along the concrete.

## 7.2 ELEVATORS AND CONVEYORS

### *7.2.1 SCREW CONVEYORS AND BUCKET ELEVATORS*

**7.2.1.1** All elevators and conveyors which agitate the sulphur being transported, such as bucket elevators, shall be enclosed in dust-tight casings and provided with explosion venting.

**7.2.1.2** Where bucket elevators are constructed from ferrous casings, the buckets or bucket conveyor shall be non-ferrous.

**7.2.1.3** Where used, screw conveyors must be modified to act as chokes so that the spread of an explosion is prevented. This can be achieved in the case of upward tilting conveyors by removing either the end or one of the central flights of the screw. With horizontal screw conveyors the central flight shall be removed and a baffle plate inserted in its place to ensure the screw always retains a plug of sulphur.

### *7.2.2 BELT CONVEYORS*

**7.2.2.1** All belts are to be protected against the build-up of static electricity, as set out in AS 1020 and BS 3289.

**7.2.2.2** Where shutes deliver the powdered sulphur to a conveyor belt, or whenever cross-over conveyors are used, the sulphur shall be constrained from spilling by the use of a hopper provided with rubber seals in contact with the conveyor.

## 7.3 SIEVING

**7.3.1** In some locations crude sulphur is sieved to produce fine grades for special purposes. This operation must be carried out in properly designed and constructed plant, consisting of a controlled feed of crude sulphur to the sieve and enclosed dust-handling equipment. Where practical the whole plant must be protected against the effects of a possible explosion using one of the methods listed in sections 6.6, 6.7, 6.8 or 6.9.

**7.3.2** The preferred location for sieving plant is in an open area which shall be surrounded by an isolation distance of 30 m from any other building, operation or fence.

**7.3.3** Where the provisions set out in section 7.3.1-2 are not practical the operation may be carried out within a building provided the additional precautions set out in sections 7.6.2.3 - 7.6.2.7 are followed.

## 7.4 HOPPERS

**7.4.1** Where sulphur is loaded into open hoppers no explosion relief venting will be required provided these are located in large open areas, and the formation of dust clouds is not a problem in the opinion of the inspector. In all new plants or when existing plant is modified, consideration shall be given to relocating all such hoppers outside. In situations where dust formation is a problem, this must be controlled either by damping down the sulphur, (section 6.2.7) or by providing dust extraction equipment, (section 7.6.3). In all situations where sulphur is loaded into hoppers within buildings breathing apparatus must be readily available as required by section 6.4.

## 7.5 RESTRICTED ACCESS

**7.5.1** Because a degree of hazard exists wherever sulphur dust is handled or is present, in spite of precautions taken, no unauthorised person shall be permitted entry into the following areas:

(a) The bulk store during filling; or

(b) The intake conveyor enclosure while the conveyor is moving sulphur.

## 7.6 CRUSHING AND PULVERISING

### *7.6.1 GENERAL*

**7.6.1.1** The need for crushing and pulverising equipment to produce finely ground sulphur has considerably diminished since nearly pure pelletised sulphur became available on world markets from the treatment of sour gases generated in oil refineries and natural gas installations.

**7.6.1.2** However, where used this equipment generates large quantities of fine dust, making it a high-risk operation. Hence, more stringent precautions against the possibility of explosions are required than in most other parts of the plant.

### *7.6.2 EXPLOSION PROTECTION*

**7.6.2.1** Explosion protection shall be provided on all pulverising equipment using one of the methods described in sections 6.6, 6.7, 6.8 or 6.9.

**7.6.2.2** Where crushing and pulverising plant is located in the open it must be provided with a surrounding isolation distance of 30m from any other building, operation or fence.

**7.6.2.3** All buildings and enclosures containing crushing and/or pulverising equipment shall be constructed of non-combustible materials of as light a type as possible, so that minimum resistance is provided, should an explosion take place. The floors shall be of solid material such as concrete.

**7.6.2.4** Such buildings and enclosures do not require explosion protection provided there is a separation distance of 30m from any other building, operation or fence.

**7.6.2.5** Where it is not possible to provide a separation distance of 30m, all buildings and enclosures must be explosion vented using the Vent Ratio Method for structures capable of withstanding pressures of 14 kPa or less. Further details of the method can be obtained from any OSH branch office.

**7.6.2.6** The enclosure or semi-enclosed space in which the crushing or pulverising machinery is located shall be used for no other purpose during the periods when size reduction of sulphur is in progress.

**7.6.2.7** The number of persons in such buildings or enclosures shall be kept to a minimum consistent with the efficient operation of the plant.

### 7.6.3 DUST COLLECTION SYSTEMS

**7.6.3.1** Dust collectors shall be constructed from non-combustible materials and vented in accordance with the requirements set out in section 6.6. They may be located in any of the following areas:

(a) On the roof.

(b) Outside and isolated by 30 m from all buildings, operations and boundaries except the crushing and pulverising enclosure.

(c) In separate rooms or buildings which meet the requirements of section 7.6.2.5.

### 7.6.4 PREVENTION OF IGNITION

**7.6.4.1** Either permanent magnetic or electromagnetic separators shall be installed ahead of the crusher or pulveriser.

**7.6.4.2** All machinery shall be installed and maintained to minimise the possibility of frictional sparks.

**7.6.4.3** Interlocking controls shall be installed to stop the dust feed if the pulveriser stops or if the fans or blowers stop for any reason.

### 7.6.5 OTHER PRECAUTIONS

**7.6.5.1** Where appropriate the precautions set out in section 6 shall also apply to crushing and pulverising.

# 8. LIQUID SULPHUR

## 8.1 GENERAL

**8.1.1** Solid sulphur is usually melted in a brick-lined tank by means of steam heated radiators, and, after filtering, stored in insulated iron or aluminium tanks. The liquid sulphur is generally used for either the production of sulphuric acid or it may be incorporated directly into phosphate fertilisers during manufacture. The properties of liquid sulphur are given in appendix 1.

## 8.2 EXPLOSION RISKS

**8.2.1** To avoid the possibility of an explosive concentration of sulphur vapour occurring, the temperature of the liquid sulphur shall not exceed 154°C. The temperature should, however, be maintained above 114°C to prevent the accumulation of solid sulphur on internal tank surfaces exposed to air. Any sulphur deposits are corrosive to steel in the presence of moisture.

**8.2.2** Solid sulphur often contains impurities of mainly hydrogen sulphide but also traces of organic solvents. When melted the sulphur may liberate gases and solvent vapours in explosive or toxic quantities.

**8.2.3** Tanks used to store liquid sulphur shall be fitted with vents to prevent the accumulation of explosive quantities of hydrogen sulphide. These pipes shall be so designed using steam tracing or other means, to ensure plugging with sublimed sulphur cannot occur.

**8.2.4** The buildings housing liquid sulphur tanks shall be provided with good natural or mechanical ventilation to disperse flammable gases and vapour and maintain the atmosphere below the WES-TWA for hydrogen sulphide.

**8.2.5** The concentration of flammable gases which may accumulate above molten sulphur shall not exceed 35% of the lower explosive limits under any circumstances. These concentrations shall be checked periodically with an explosimeter and after each new consignment of sulphur. If hazardous gas levels are recorded, operations shall be discontinued until the gas concentration registers 15% of the LEL. Additional ventilation may be required.

**8.2.6** Because liquid sulphur is capable of building up a significant electrostatic charge, especially when pumped at high speeds, tanks shall be filled from the bottom or through discharge pipes that extend to the bottom. However, in situations where molten sulphur is flowing at rates not exceeding 2m/sec, as will normally be the case with gravity feed systems, bottom filling of tanks, while recommended, is not mandatory.

**8.2.7** All pipe work, metal parts of tanks and buildings must be bonded and earthed in accordance with AS 1020. Where appropriate grounding connectors shall be provided for the bonding of liquid sulphur tanks and tank cars being loaded and unloaded.

## 8.3 FIRE CONTROL

**8.3.1** Liquid sulphur burns but does not explode. Apart from the fire hazard itself, the sulphur dioxide gas produced is highly irritating and toxic in very small amounts. (See also appendix 2.)

**8.3.2** The factory fire crew shall be provided with safety belts and lifelines with one worker standing by in case of accidents.

**8.3.3** If the fire occurs in a closed tank it can be smothered by closing all vents. However, the tank may become very hot before the fire goes out, and must be allowed to cool before the vents can be opened again. It is recommended that a properly engineered fixed steam flooding system be provided for extinguishing any fires in liquid sulphur tanks.
**Note: A solid stream of water hitting hot sulphur in a closed tank may cause a steam explosion.**

**8.3.4** At least two sets of self-contained breathing apparatus shall be available for use in case of sulphur fires, unless fire protection is provided by an automatic or remotely operated steam quenching system. All respiratory equipment shall comply with and shall be selected, used and maintained in accordance with AS 1715.

**8.3.5** In addition to the above provisions, occupiers are required to establish a liaison with the area commander of the New Zealand Fire Service and follow his or her recommendations with regard to the size and training of factory fire crews and other related matters, including rescue and evacuation procedures.

## 8.4 BURNS AND FIRST AID

**8.4.1** First-degree burns can result from splashes of liquid sulphur on skin and clothing. The sulphur will rapidly solidify. Do not attempt to remove it. Immerse affected area in cold water, treat the patient for shock and obtain medical attention.

**8.4.2** If larger amounts of liquid sulphur are in contact with the body, e.g. when someone gets a boot full of sulphur, deep third-degree burns will result. Immerse the burned area in cold water for at least 20 minutes. Do not attempt to remove affected clothing. Hospital treatment is essential.

## 8.5 PERSONAL PROTECTIVE EQUIPMENT

**8.5.1** Details of the protective equipment to be worn are contained in section 10.4.

**8.5.2** The routine handling of liquid sulphur in well-ventilated premises does not require respiratory protective equipment. Emergency situations are covered in section 8.3.4.

## 8.6 ELECTRICAL EQUIPMENT

**8.6.1** The hazardous area where liquid sulphur is present or handled shall be classified according to current standards for dust layers which may prevent the safe dissipation of heat. All electrical equipment used within the hazardous area shall comply with the requirements of NZS 6105 (see also recommendation in section 6.5.3.4).

# 9. FERTILISERS CONTAINING SULPHUR

## 9.1 BACKGROUND

### *9.1.1 ADDITION OF COMMERCIALLY SCREENED SULPHUR*

**9.1.1.1** The Civil Aviation Authority of New Zealand has previously permitted the addition of elemental sulphur to certain fertilisers, at rates of up to 23% by weight, for application by aerial top dressing to agricultural pasture. Under these conditions the sulphur is made non-explosive by the presence of an inert diluent such as superphosphate or calcium sulphate. Other diluents such as limestone are less effective. Care is required in the manufacture of these fertilisers, to ensure that the particles of sulphur and superphosphate are of similar size, so that during handling there is no tendency for the mixture to separate out — which could lead to the formation of higher and, therefore, explosive concentrations of sulphur.

### *9.1.2 ADDITIONS OF MOLTEN SULPHUR*

**9.1.2.1** Since 1965 phosphate fertilisers have been predominantly produced in pelletised form to reduce the formation of dust during handling. When required, elemental sulphur has been incorporated into superphosphate fertiliser by injecting molten sulphur into the hot wet mix at a temperature of approximately 120°C. This ensures the sulphur is uniformly dispersed and bound to the superphosphate particles within the pellet. The same technique has also been applied to the production of high phosphate-sulphur fertilisers in which the basic phosphate rock is reacted with phosphoric instead of sulphuric acid.

### *9.1.3 MANUFACTURE OF WATER DEGRADABLE PELLETS OR SULPHUR PRILLS*

**9.1.3.1** One method of manufacture consists of mixing liquid sulphur at a temperature not exceeding 154°C with 10% bentonite clay and other trace chemicals. The prills are formed by cooling droplets of the molten mix in a light oil followed by filtration and drying. In the absence of water the prills are hard and resistant to abrasion, but when moistened they break down into finely divided and potentially explosive powder. The prills are a fire hazard.

### 9.1.4 SCIENTIFIC STUDIES

**9.1.4.1** Dr H P Rothbaum and others at the Chemistry Division, DSIR, carried out extensive investigations between 1961 and 1985 into the explosibility of all types of sulphur-containing fertilisers. This has included abrasion tests on a range of sulphur-containing wet mix superphosphate pellets as well as sulphur prills, and determining the explosion risk of the dusts produced.

**9.1.4.2** These recommendations have been accepted by the Civil Aviation Authority of New Zealand and form the basis for the precautions required in section 9.2 of the code.

## 9.2 MIXTURES OF LESS THAN 30% BY WEIGHT OF ELEMENTAL SULPHUR

### 9.2.1 DRY MIX

**9.2.1.1** Commercially screened sulphur may be mixed with either superphosphate or calcium sulphate of an equivalent particle size using an enclosed mixer or blender. Precautions against the possibility of an explosion shall be taken on the sulphur feed but are not required for the mixed product.

### 9.2.2 WET MIX

**9.2.2.1** Molten sulphur may be added to the superphosphate in the mixer, provided the temperature of the sulphur is within the range 120°- 154°C and the den temperature at the point of injection not less than 60°C. If these conditions are not met, the resultant product shall be regarded as potentially explosive and precautions must be taken.

## 9.3 MIXTURES OF 30% OR MORE BY WEIGHT OF ELEMENTAL SULPHUR

**9.3.1** The conditions set out in sections 9.2.1 or 9.2.2 shall apply but, in addition, not more than 20% of the mixture shall pass a 60 BS sieve (251 microns) and the bulk resistivity shall not exceed $10^{11}$ohm-cm at 50% relative humidity.

**9.3.2** It should be noted that although the sulphur mixtures described in section 9.3.1 are non-explosive, they can be ignited. However, the flame is only self-propagating in mixtures containing over 50% sulphur by weight.

## 9.4 WATER DEGRADABLE PRILLS

**9.4.1** Prills containing up to 90% sulphur can be handled without taking precautions for explosion protection provided the following conditions are met:

(a) The prills contain less than 1% dust which will pass a 60 BS sieve (25l microns).

(b) The bulk resistivity must not exceed $10^{11}$ohm-cm at 50% relative humidity.

(c) They are stored in waterproof bags.

## 9.5 PRECAUTIONS REQUIRED FOR OTHER MIXTURES

### *9.5.1 CONTAINING UP TO 10% SULPHUR*

**9.5.1.1** Where sulphur dusts are mixed with other non-combustible, non-oxidising diluents of comparable particle size and density, the handling of such mixtures will not require precautions against the risk of an explosion, provided the sulphur content does not exceed 10% by weight.

**9.5.1.2** Sulphur may also be added to granular wet-mix formulations other than superphosphate at rates up to 10% by weight, without taking precautions against the risk of an explosion, provided the additions take place in a den at the temperatures specified in section 9.2.2.1. In all cases the diluent must be non-combustible and non-oxidising.

### *9.5.2 CONTAINING 10% OR MORE SULPHUR*

**9.5.2.1** Because there have been no specific recommendations into the abrasion resistance and explosibility of other mixtures containing sulphur, all such mixtures shall be considered to be potentially explosive and precautions taken against the risk of an explosion, unless independent tests prove the mixtures to be safe to the satisfaction of the Department of Labour.

**9.5.2.2** The presence of oxidising substances in sulphur fertiliser mixtures is not permitted.

### *9.5.3 CONTAINING SULPHUR PRILLS*

Sulphur prills may be blended with other fertilisers provided the mixtures comply with the requirements set out in either section 9.5.1 or 9.5.2.

# 10. PERSONAL PROTECTIVE EQUIPMENT AND TRAINING

## 10.1 GENERAL

**10.1.1** Employees working with bulk liquid or solid sulphur shall be provided with personal protective equipment and are required to wear it.

## 10.2 HEALTH HAZARDS

**10.2.1** Sulphur dust or fumes can cause irritation to the eyes and mucous membranes. There is no evidence, however, that contact with sulphur causes systemic poisoning. In some individuals sulphur dust has an irritant action on the skin which may be aggravated by perspiration or moisture.

## 10.3 SOLID SULPHUR

### *10.3.1 EYE PROTECTION*

**10.3.1.1** Dust-tight safety goggles shall be available to workers.

### *10.3.2 RESPIRATORY PROTECTION*

**10.3.2.1** Although sulphur is essentially non toxic, dust respirators should be worn for greater employee comfort. Breathing apparatus suitable for use in atmospheres containing sulphur dioxide shall be available for emergency use, in case of sulphur fires (see 6.4.3). All respiratory equipment shall comply with and shall be selected, used and maintained in accordance with the recommendations of AS 1715.

### *10.3.3 BODY PROTECTION*

**10.3.3.1** The use of fire-retardant overalls is recommended. As the ignition of sulphur impregnated clothing could result in serious burns, overalls should be kept as free of dust as possible. Impregnated clothing must not be worn. Workers whose skin may be sensitive to sulphur dust should wear PVC or rubber gloves.

## 10.4 LIQUID SULPHUR

### *10.4.1 EYE PROTECTION*

**10.4.1.1** Safety glasses with side shields or a full-face shield shall be worn.

### *10.4.2 RESPIRATORY PROTECTION*

**10.4.2.1** For routine handling of liquid sulphur no respiratory protection is required provided the premises are well-ventilated.

**10.4.2.2** Breathing apparatus suitable for use in atmospheres containing sulphur dioxide shall be available for emergency use unless fire protection is provided by an automatic or remotely operated steam quenching system.

### *10.4.3 BODY PROTECTION*

**10.4.3.1** Workers shall wear hats, full-length heavy duty overalls, fabric or heat-resistant gloves, and safety shoes. Open-top boots, sandals, sneakers or jandals are not suitable.

## 10.5 TRAINING

**10.5.1** It is the employer's responsibility to provide a comprehensive training programme for employees. Workers must receive initial training prior to commencing work with sulphur and be adequately supervised until they are trained. The instruction shall include:

- The fire and explosion hazards of finely divided sulphur and the importance of good work practices to avoid the formation of dust clouds.
- The avoidance of sources of ignition with special emphasis on the care required to operate front end loaders.
- The danger of sulphur slides in the bulk store.
- The necessity for keeping sulphur free from contamination by nitrate fertilisers and other oxidising substances.
- The wearing of suitable protective clothing.
- The correct procedure to be followed in the event of fires, including the danger of sulphur dioxide gas and the correct use and care of respirators.
- First aid procedures especially for inhalation of sulphur dioxide and burns caused by contact with molten sulphur.

# APPENDIX 1: PROPERTIES OF SULPHUR

**Physical state** Yellow crystalline solid or liquid

**Melting point** 110° - 121°C depending on its crystalline form

**Auto-ignition temperature** 190°C dust clouds

221°C dust layers

248° - 261° liquid sulphur

**Flash point** 168° -188°C

**Vapour pressure** Less than 0.0001 m, Hg (20°C)

**Explosive limits of dust in air** LEL about 35 $g/m^3$

UEL about 1400 $g/m^3$

**Solubility** Insoluble in water

**Specific gravity** 1.92 - 2.07 depending on its crystalline form

**Corrosivity** Dry - none

Wet - slow generation of sulphuric acid

**Reactivity** Burns to form sulphur dioxide
May form explosive mixtures with powerful oxidising chemicals such as chlorates and nitrates

**Toxicity** Virtually non-toxic

# APPENDIX 2: HEALTH HAZARDS OF SULPHUR DIOXIDE

## TOXICITY

When sulphur burns in the atmosphere it forms sulphur dioxide gas. Sulphur dioxide is irritating to the eyes, nose, throat and lungs in concentrations greater than 6-20 parts per million (ppm). At 150 ppm irritation is extreme. Concentrations in excess of 400-500 ppm may result in suffocation. The workplace exposure standard, eight-hour time-weighted average (WES-TWA-[1992]) is 2 ppm. Exposure to sulphur dioxide has no permanent systemic effect.

## FIRST AID

Move workers suffering from over-exposure due to inhalation of sulphur dioxide into fresh air. Keep them warm and still. Full recovery is fairly rapid for most people. Irrigate eyes with warm water for 15 minutes. Obtain medical attention if lung or eye irritation persists.

# APPENDIX 3: HOT WORK PERMIT

**HOT WORK PERMIT**

TO BE DISPLAYED ON THE WELDING OR CUTTING APPARATUS AND RETURNED TO THE RESPONSIBLE OFFICER ON COMPLETION OF THE WORK

Permission granted to:

To use (Type of equipment)

In (Location)

On (Date)

From (Time)

To (Time completed)

1. All combustible materials removed or made safe ☐
2. No flammable liquids, vapours gases or dusts present ☐
3. Extinguishers/hoses provided on site ☐
4. Operator knows how to use fire equipment ☐
5. Operator knows location of telephone/fire alarm ☐
6. Site inspected after completion of work ☐

Permit issued by (Responsible officer)

***On the left is an*** *example of a hot work permit which can be printed on a card and attached to a welding trolley.*

*Below is an example of the hot work permit advocated in NZS 4781.*

**HOT WORK PERMIT**

..... is hereby authorised to carry out: cutting, burning, welding
(Name) (Cross out where not applicable)

other work on ..... as from .....
(Plant or equipment) (Date: time)

Signed .....
Factory manager

I have inspected the work. The permit has been withdrawn as from .....
(Date: time)

Signed .....
Factory manager (or nominee)

# REFERENCES


1. National Fire Protection Association, NFPA 655:1988 *Standard for Prevention of Sulphur Fires and Explosions.*

2. Field, P. *Dust Explosions.* Elsevier Scientific Publishing Company, 1982.

3. National Safety Council Data Sheet 1-612. *Handling and Storage of Solid Sulphur*. rev 1984, USA.

4. National Safety Council Data Sheet 1-592-78. *Handling Liquid Sulphur*. rev 1978, USA.

5. Fire Prevention Association. *Information Sheet on Hazardous Materials, H 14 Sulphur,* UK.

6. Miscellaneous Publication, *Electrical Wiring in Hazardous Locations.* Standards New Zealand.

7. NZS 6101:1990 *Classification of hazardous areas, part 2, combustible dusts.*

8. AS 1020: 1984. *The Control of Undesirable Static Electricity.*

9. Department of Labour. *Guidelines for the Control of Static Electricity in Industry*. 1981.

10. BS 3289: 1982. *Conveyor belting primarily for use underground (including fire performance).*

11. Civil Aviation Information Circular, GEN A80/86. *Flammable Materials: Aerial Application*. Ministry of Transport, New Zealand.

12. Rothbaum, HP. *Safety Requirements for the Aerial Distribution of Sulphur.* New Zealand Fertiliser Manufacturers' Research Association 20th Technical Conference Proceedings.

14. Massey University Occasional Report No. 4. *Proceedings of the Technical Workshop on Sulphur in New Zealand Agriculture,* 23 and 24 May 1983. ISSN 0111-3313.


## *OTHER LEGISLATION*

Dangerous Goods Order 1983: Fine grain sulphur is listed as a class 4.1(c) flammable solid.

Safety in Employment (Machinery) Regulations 1993: Detail requirements for mechanical safety of plant and equipment.

Electrical Wiring Regulations 1976.