HEALTH AND SAFETY IN EMPLOYMENT ACT 1992

APPROVED CODE OF PRACTICE FOR THE PREVENTION, DETECTION AND CONTROL OF FIRE AND EXPLOSION IN

NEW ZEALAND DAIRY INDUSTRY SPRAY DRYING PLANT

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

October 1993

ISBN 0-477-03470-5
$10 (incl. GST)

Contents

NOTICE OF ISSUE

I have issued this *Approved Code of Practice for the Prevention, Detection and Control of Fire and Explosion in New Zealand Dairy Industry Spray Drying Plant*, being a statement of preferred work practices or arrangements, for the purpose of ensuring the health and safety of people to which this code applies and those 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, Detection and Control of Fire and Explosion in New Zealand Dairy Industry Spray Drying Plant, 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 1992. 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

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, approved codes may be used in court as evidence of good practice.

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 of the Act.) 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 or not they are significant hazards requiring further action. Where there occurs any accident or harm in respect of which an employer is required to record particulars, section 7 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

(a) 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.

(b) 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 with 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)

The Act offers the following definition:

“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 Labour the occurrence; and

b) Within 7 days of the occurrence, give the Secretary of Labour (OSH) 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 have yet to be promulgated.

1. INTRODUCTION

1.1 PREAMBLE

1.1.1 This code of practice has been developed to provide practical guidance for the dairy industry on the design, operation and maintenance of spray drying plant and ancillary plant for the avoidance of fire and explosion, and minimising the effects of fire and explosion.

1.1.1 Casein and other non-spray-dried dairy powders will be covered in a subsequent code of practice.

1.2 BACKGROUND

1.2.1 The inherent hazard involving plant and processes using or generating dust or powders of such a character likely to give rise to an explosion or fire has been known for some time. Following a dust explosion in a Masterton plastics factory in 1965, in which four people died, the Factories Act 1946 was amended to ensure factory occupiers took practicable steps to prevent such explosions. These provisions have been retained in the present legislation. There have been a number of dust explosions and associated fires reported overseas and in New Zealand. Incidents have occurred frequently enough to warrant the development of this code. Attention has been focused on existing standards of explosion protection and the potential for devastation of plant and buildings.

1.3 APPLICATION OF CODE

1.3.1 SCOPE

1.3.1.1 This code is intended for designers, manufacturers and users of food spray drying plant and equipment used in the dairy industry. It applies to all new and existing:

- Spray drying plant including two-stage dryers with integrated fluidised beds and “Filtermat” dryers;
- Fluidised bed dryers and other powder handling equipment;
- Dust collection equipment;
- Bulk storage facilities including silos and bins used to hold dry powder;
- Ducting; and
- Bag sealing and shrink wrapping equipment.

1.3.1.2 This code sets standards for the design, installation and the operation of the above plant and equipment and the training of operators.

1.3.2 GUIDELINES TO IMPLEMENTATION

1.3.2.1 All new plant and equipment including spray dryers, fluidised beds, cyclones, ducting, bag filters, dust collection equipment, bulk storage facilities, silos, bins, heat sealers, and shrink wrappers, if not specifically exempted under section 1.3.3 of this code, shall be expected to comply in full with the code's requirements from the date of approval of this code.

1.3.2.2 All existing plant and equipment (as listed in section 1.3.1), if not specifically exempted under section 1.3.3 of this code, shall be expected to comply in full with the code's requirements from the date of approval of this code within the following time scale.

1.3.2.3 All existing spray dryers with an expected life-span exceeding 7 years shall be expected to comply with the explosion protection requirements of this code within 7 years of the date of approval of this code.

1.3.2.4 All other existing plant and equipment (i.e. bag filters, silos, bins, etc.) shall be expected to comply within 2 years of the date of approval of this code.

1.3.2.5 All other requirements of this code (i..e. all matters not covered elsewhere and including sections 2 and 4 of this code) shall be expected to be complied with in full.

1.3.2.6 Where it is considered to be impractical, or where problems arise in the application of the requirements of the code to any new or existing plant or equipment the matter must be fully discussed with OSH as soon as possible. This will allow an alternative safety standard, that adequately safeguards the safety and health of all persons engaged, employed or legally on the premises, and members of the general public, to be put in place.

1.3.2.7 It is recommended that this code be reviewed at least every 5 years by a working party representing interested parties.

1.3.3 SPECIFIC EXEMPTIONS

1.3.3.1 The requirements of section 4 of the code, Explosion protection, only, shall not apply to the following types of existing plant or equipment.

1.3.3.2 Spray dryers

(i) All existing spray dryers due for replacement within 7 years from the date of approval of this code are exempt from the code's provisions, but attention is drawn to section 1.3.4.

(ii) The following existing types of spray dryers not due to be replaced within 7 years from the date of approval of this code (excluding associated bag filters) will be considered for exemption from the code on application to OSH:

- Flat bottom dryers; or
- Box dryers.

All new spray dryers falling within these categories installed and operated after the date of approval of this code shall comply in full with the provisions of the code.

1.3.3.3 Fluidised beds and cyclones

(i) All existing fluidised beds and cyclones are exempt from the provisions of this code on the condition and providing that all openings (manholes) and removable inspection panels are firmly secured; flexi-couplings shall have deflectors fitted; and the immediate area in the vicinity of the fluidised bed or cyclone (flexicouplings, inspection panels, openings, or other pressure relief openings) must be treated as a "no go", or "restricted access" areas. In the event of extensive alteration, modification, repair or maintenance being carried out on any fluidised bed or cyclone, full explosion protection must be considered and any problem in carrying this out must be fully discussed with OSH.

(ii) All new fluidised beds and cyclones (see 1.3.2) installed and operated after the date of approval of this code must be provided with explosion protection in accordance with the requirements of the code. Where it is considered that it is impractical to comply, or where problems arise, the matter must be fully discussed with OSH at the planning and design stage and prior to installation and operation. This will enable alternative safety measures to be considered.

1.3.4 GENERAL INFORMATION

1.3.4.1 The above guidelines on the application and implementation of this code are designed to assist industry in meeting the requirements of the code in a planned and cost-effective manner.

1.3.4.2 It does not relieve the industry or individual occupiers, owners or employers from their duties and responsibilities under the Act and OSH will not accept any responsibility should fire or explosion occur involving plant or equipment or work procedure not complying with the Act or this code.

1.3.4.3 The onus to comply rests with the industry, occupier, owner, employer, or employee, and OSH reserves the right to require full compliance in the event of an immediate and serious hazard being identified or brought to its attention. In the event of an injury accident occurring involving any plant, equipment or work procedure, OSH will be obliged to consider and instigate court proceedings for non compliance. Therefore, it is recommended that the industry or individual undertaking take all practical steps to comply, in full, with the requirements of this code in respect of all new and existing plant, equipment and work procedures, as soon as possible after approval of the code. This code may also be useful in the production of other food products or products falling into the same dust explosion class. However, it should be noted that any exemption under the code or the guidelines given for implementation would not apply, and it is recommended that full discussions with OSH be held before applying the provisions of the code to such plant and equipment.

1.3.4.4 Although this code may be applied to both class St 1 and 2 products, its main application will be to class St 1 products. Most food products fall into this class, e.g. dried milk powder, sugar fines, coffee, and maize starch. A few food products exhibit the more severe characteristics of class St 2, the most common being corn starch.

1.3.4.5 Dusts may be grouped into four classes based on their K_{st} value.

TABLE 1: DUST EXPLOSION CLASSES

Dust explosion	*K_{st} (MPa m/s)*
St 0	0
St 1	0-20
St 2	20.1-30
St 3	30 +

Dust explosion classes are discussed in more detail in the standards.

1.4 DEFINITIONS

In this code, unless inconsistent with the context, the following definitions apply:

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

Approving authority: The Occupational Safety and Health Service of the Department of Labour.

Bulk storage: Hoppers or silos in which dry products may be stored.

Drying system (plant): The complete spray drying apparatus; including air heating, atomisation, powder collection, secondary drying, powder cooling, powder sifting and conveying equipment (including ducting) but excluding bulk storage, packaging and warehousing.

Dust: Small solid particles that may be suspended in air for some time, which may settle out under the influence of gravity.

Fast acting temperature sensor: A temperature sensor with a first order time constant of less than 20 seconds under conditions of use.

Hazardous area: A delineated area in which all electrical installations and equipment used must be of a type approved by the electrical authority for installation and use in the area.

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

K_{st}: Constant of the equation – (dP/dt)max. $V^{0.333} = K_{st}$ where (dP/dt) max is the maximum rate of pressure rise in a closed vessel of volume, V. K_{st} is normally determined from measurements of maximum rate of pressure rise in a 1 m^3 or 20 litre test apparatus with a 10 kJ ignition source.

Minimum ignition temperature: The lowest temperature at which flame propagation occurs in a dust suspension.

No-go area: An area that personnel shall be prohibited from entering when the plant is operating.

OSH: The Occupational Safety and Health Service of the Department of Labour.

P_{red}: Reduced pressure. Maximum explosion pressure in a vented vessel.

P_{stat}: The static pressure at which the vent cover opens or bursts.

Restricted access area: An area that all personnel are prohibited from entering during plant operation, with the exception of authorised personnel, who may enter the area for short periods to carry out process inspections and checks, sampling of product, and during emergency procedures. Routine maintenance work shall not be carried out in restricted access areas during operation of the plant.

Standard: Means the current standard published by Standards New Zealand or an equivalent overseas organisation. A list of the relevant standards current at the time of publication is appendixed. However, as they are regularly updated, their current status should be checked.

Thermodisc: Thermally-operated switch; used to detect excess temperatures.

2. HAZARDS AND HAZARD PREVENTION

2.1 FIRE AND EXPLOSION: GENERAL

2.1.1 Dairy-based powders are flammable and, in suspension as a dust cloud, explosive. Milk powder is used as a typical example for the purpose of this code.

2.1.2 Hazard assessment or hazard and operability studies should be carried out at the design, development and construction stages of all new construction, or modification to existing construction in “at risk” areas of plant, as described under sections 3.1 and 3.2 of this code, including pipes, ducting and ancillary plant.

2.2 FIRES

2.2.1 Milk powder may burn without causing an explosion. Accumulations of powder may be subject to self-ignition if it adheres to surfaces in the hot zone of the drier.

2.2.2 It is important to note that self-ignition of a powder layer does not occur at any one particular temperature, see table 2. It will depend mainly on he thickness of the layer that builds up, ie the thicker the layer, the lower the temperature at which self-ignition can occur.

2.2.3 Beever (table 2) has summarised the critical thickness for self-ignition of a layer of powder for two ambient temperatures: 200°C, representing a typical temperature likely to be met in the top of the spray drier, and 100°C, which approximates to the surface temperature found lower in the drier.

2.2.4 Typically, there is a factor of 10 difference between the critical thicknesses at 100°C and 200°C.

2.2.5 The moisture content of the powder and the time the layer is allowed to remain, also affect the self ignition temperature.

2.2.6 Excessive quantities of oversized particles appearing in the tailings from the sifter may be associated with a potential fire resulting from the accretion of product on hot surfaces. Sometimes these particles are black or discoloured, clearly indicating problems, but sometimes they are white on the surface and charred inside.

2.2.7 Powder that has not been cooled and is then held in bulk storage may be subject to self-heating if left undisturbed for a period of time.

2.2.8 In summary, it should be assumed that at the temperatures at which conventional spray dryers operate, i.e. between 250°C at the inlet and 80°C at the outlet, if powder deposits can form, then self ignition is possible. The critical points in the dryer are at the top (where the highest temperatures occur), at the base, and on any ledges where thick deposits may build up.

Table 2: Critical Thicknesses for Self-Ignition of Milk Powders

Products	*Minimum thickness for self-ignition of layer at 200° C (mm)*	*Minimum thickness for self-ignition of layer at 100° C (mm)*
Skim milk	17	170
Skim milk	11	150
Skim milk	9	120
Coconut oil - filled milk	13	130
Coconut oil - filled milk	14	140
Tallow-filled milk -30%	11	200
Tallow-filled milk -30%	15	150
Whole milk	10	170
Whole milk	17	100
Buttermilk	9	130
Buttermilk	8	100
Fillled milk (formulation unknown)	14	140
Whey	13	320

Source: Beever (1985)

2.3 EXPLOSIONS

2.3.1 GENERAL

2.3.1.1 A dust explosion may occur when milk powder is dispersed in air and exposed to a source of ignition. Certain overriding conditions must prevail before an explosion can occur:

- The concentration of the dust suspension must be within its explosive range (see table 3);
- The ignition source must be of sufficient energy to initiate combustion (see table 3); and
- There must be sufficient oxygen to support combustion.

2.3.1.2 Data on the explosion characteristics of food materials can be found in published literature (refer to bibliography). Care must be taken in using published data because the explosion characteristics are influenced by:

- Particle size;
- Moisture content;
- Composition;
- Temperature; and
- Test method.

2.3.1.3 The values given in table 3 are typical values and specific test work may be necessary to establish the behaviour of a particular dust (see appendix 1). The samples used for the test work must represent the worst case conditions, particularly in terms of dryness and particle size. Interpretation of the data should only be undertaken by those experienced in the field of explosion protection.

Table 3: Explosive Characteristics of Milk Powder

Dust	*Minimum ignition temperature (°C)*	*Minimum explosive concentration (g/m³)*	*Minimum ignition energy (J)*	*Maximum explosion pressure (MPa)*	*Maximum rate of pressure rise (MPa/s)*
Milk powder	440	60	-	0.58	2.8
Skim milk powder*	490	50	0.05	0.66-0.68	11.0-15.9
Skim milk powder†	500	60	-	0.90	9.9

* Data obtained from small scale tests
† Data obtained from large scale tests

Sources: Field (1984) Jacobsen et al (1961) Anon (1980)

2.3.2 PRIMARY EXPLOSIONS

2.3.2.1 A primary explosion is one that takes place within the confines of a component of the drying system. A primary explosion will cause a rapid rise in pressure within the component (typically 800-1000 kPa). The component will be affected as follows:

(a) If of sufficient strength it will retain the pressure and confine the explosion;

(b) It may fail and rupture;

(c) It may allow the release of pressure through purpose built vents that open at low pressure, typically in the range of 3-10 kPa.

2.3.2.2 In a spray drying plant the vulnerable areas for primary explosions are:

(a) In the lower part of the main chamber;

(b) In the cyclones and filter bag houses;

(c) Above the fluidised beds;

(d) In an "empty" powder storage silo; and

(e) In pipe work and ducting that carries product and air.

2.3.2.3 At all of these points both powder and air are present; the missing component for an explosion is a source of ignition. If a source of ignition is introduced, the propagation of the flame front through the dust suspension causes a rapid increase in temperature and pressure which gives rise to explosive effects.

2.3.2.4 It is important to recognise that an explosion in one component may set off an explosion in other interconnected components, due to the transportation of burning material or when the flame front travels from one vessel to another.

2.3.3 SECONDARY EXPLOSIONS

2.3.3.1 If a component ruptures or a vent opens during an explosion, a pressure wave will emerge, followed by a cloud of as yet unburned powder. The expansion effect and consequent turbulence to the surrounding atmosphere will cause any dust that may have settled and accumulated to be dispersed into a dust cloud. This dust cloud may then be ignited by the combustion products of the primary explosion, usually resulting in a more severe explosion than the primary explosion.

2.3.3.2 To minimise the risk of a secondary explosion, good housekeeping is essential.

2.3.3.3 A secondary explosion may be retained within the confines of the building. Alternatively, if the magnitude of the explosion relative to the size and strength of the building is sufficiently high, the pressure may rise to the point where wall panels, ceiling/roof panels and windows are blown out or, in extreme cases, more serious structural damage results.

2.4 SOURCES OF IGNITION

Explosions develop initially from a fire or from other sources of ignition. The possibility of explosions and fires occurring can be reduced by removing known sources of ignition.

2.4.1 FLAMES

2.4.1.1 Sources of naked flames include:

- Cigarettes;
- Flames used to sterilise laboratory sampling equipment;
- Hand-held gas torches; and
- Direct-fired air heaters.

These sources of ignition must be prevented from coming into contact with any powder.

2.4.2 CHARRED PARTICLES

2.4.2.1 Charred particles are the result of combustion and are another possible source of ignition. Usually they are too small to cause ignition, but they can provide an early warning that a hazardous situation is developing.

2.4.2.2 It is possible that particles passing through a direct fired heater may become incandescent. Gibson and Schofield (1977) have shown that incandescent particles would need to be at least 3-5 mm in diameter, at temperatures of 600°C, to cause ignition.

2.4.3 HOT SURFACES AND SELF-IGNITION

2.4.3.1 Hot surfaces are inherent in the operation of a spray dryer and occur in the hot air inlet sections, on the surface of air heating units and on mechanical equipment that malfunctions.

2.4.3.2 Minimum ignition temperatures of milk powder clouds vary between about 440°C and 500°C depending on the characteristics of the product (see table 3). Such temperatures do not occur during normal operation.

2.4.3.3 Component parts of the structure of spray dryers, in direct contact with primary drying air, can heat up to temperatures in excess of 200°C. Such temperatures are more than sufficient to initiate accelerated oxidation and self-heating, leading to ignition of accumulations of product adhering to internal surfaces or components of a dryer. This is of particular concern in cases where inlet temperatures of 250°C or more are used. These accumulations can become a source of ignition elsewhere in the system when particles of incandescent material become detached and travel on the air stream to high risk areas where the product is dry and in suspension with air.

2.4.3.4 In addition, where a system for returning fines to the atomising zone in the dryer is in use, the fines could be ignited by incandescent material adhering to the top of the dryer.

2.4.3.5 Other hot surfaces which are potential ignition sources include exposed electrical heating elements (e.g. hand drying units, heat sealers associated with packaging equipment), and improperly located incandescent filament light bulbs.

2.4.4 MECHANICAL FRICTION

2.4.4.1 Frictional heating will occur whenever two contacting surfaces move relative to each other. It is important to recognise that this phenomenon is not limited to faults arising from two surfaces meeting unintentionally but can also occur in lubricated items such as gearboxes and bearings. Rotary atomisers, because of their rotational speed and high stress, are a high risk area.

2.4.5 IMPACT SPARKS

2.4.5.1 Impact sparks are one of the more common sources of ignition. They may be created when metal drying system components fall into the chamber or ducts. Most commonly, impact sparks have been caused by the atomiser wheel parting from the shaft and hitting the chamber walls. A lower risk area is the outlet fan for the drier. Dust present in the exhaust air may impinge on the impeller, resulting in product build-up. This may cause dynamic imbalance and excessive vibration resulting in premature failure of the bearings. Whilst the bearings for these units are normally mounted externally to the fan casing, failure may cause the impeller of the fan to touch the casing and create a hazard.

2.4.6 ELECTRICAL SPARKS

2.4.6.1 Electrical energy may be a source of ignition, with sparks containing energy substantially in excess of that required to ignite dusts. Sparks produced during the normal working of switches, contact breakers, fuses, motor brushes, etc. can readily ignite dusts unless precautions are taken. Portable appliances such as electric vacuum cleaners (see section 3.1.15), drills, grinding and welding equipment, should be considered as potential sources of electrical sparks.

2.4.7 ELECTROSTATIC DISCHARGE SPARKS

2.4.7.1 Electrostatic discharge sparks are generally of low energy, often below the 50 mJ minimum for ignition of milk powders. However, variations in this energy and the flammability of the powder can occur. Electrostatic discharge, therefore, needs to be taken into account as a potential source of ignition.

2.4.8 HOT WORK

2.4.8.1 Welding and cutting produces sparks and localised heating of plant. Similar hazards arise from operations such as soldering, burning and the use of power tools.

2.4.8.2 Flammable material left in the vicinity of welding operations (e.g. wooden structures, tarpaulins) can be ignited and remain smouldering for several hours (see section 3.2.7).

3. RECOMMENDATIONS AND REQUIREMENTS

3.1 PROCESSING EQUIPMENT

Figures 1a and 1b illustrate areas where particular attention should be paid in the design, operation and maintenance of the two most common configurations of spray dryers.

3.1.1 AIR HEATERS

High temperatures occur on the surface of air heating units. Filter units must be provided prior to each air heat exchanger either by a "filter room" concept or by individually filtering each air heater supply inlet.

3.1.1.1 Indirect oil or gas-fired air heaters

Indirect air heating units employing a flame or using hot oil should be situated in a separate compartment. The structure of the compartment shall have a fire resistance rating of two hours in respect of load bearing capacity, insulation and integrity as determined by the relevant standards.

Doors shall have a fire resistance rating of two hours or be a type C door in compliance with the standard.

Glazing should be avoided on any side of the compartment facing the process.

Methods to minimise the ingress of dust into the compartment should be adopted, e.g:

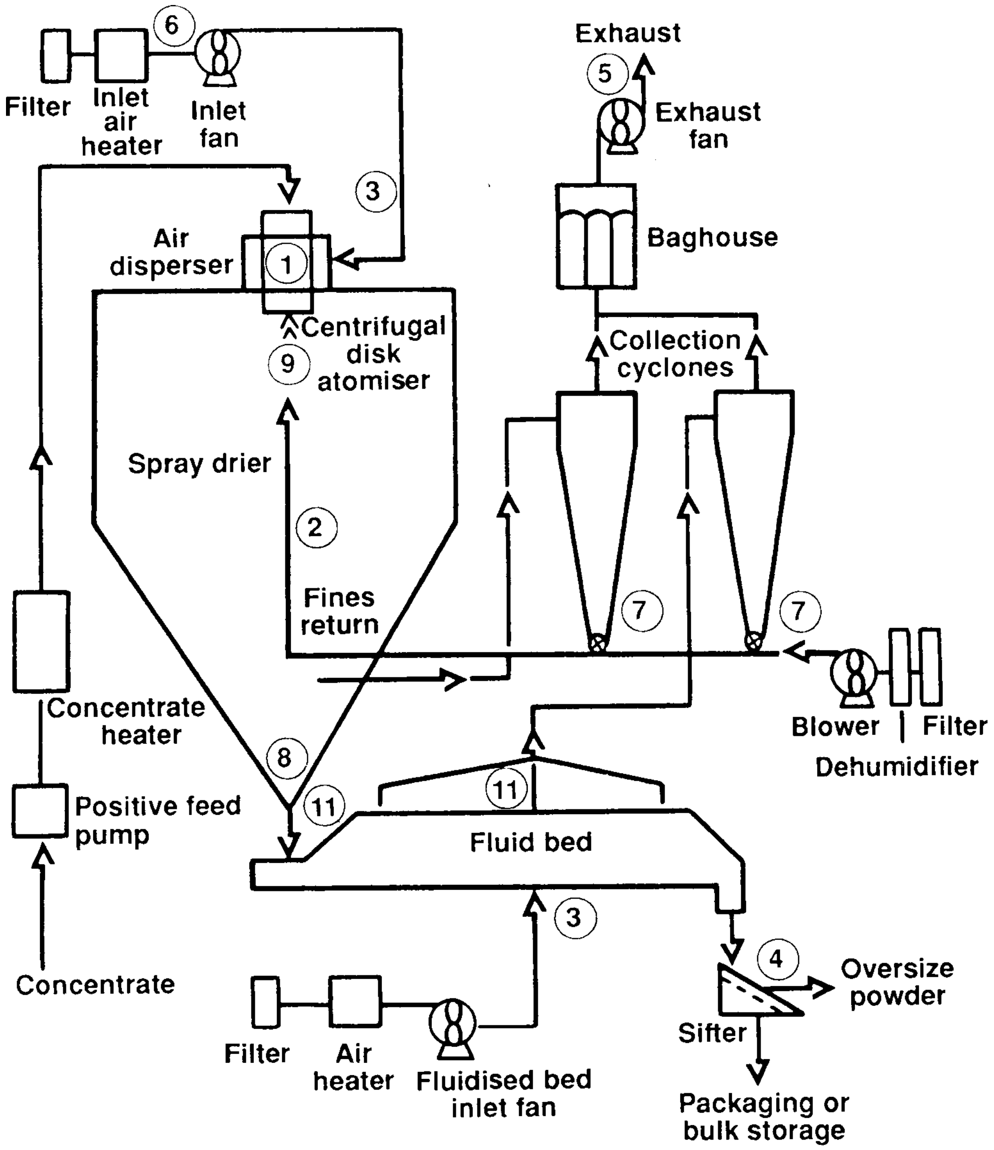
- Pressurising of the room;
- Air locks; or
- Isolation of the air heating compartment from the processing area.

3.1.1.2 Direct fired air heaters

Air heating units employing a flame shall have a separate combustion chamber and should be situated to keep flames well away from flammable dust. It is possible that incandescent particles could enter the dryer through the air supply. This can be prevented by:

- Locating the air intake in a clean area;
- The provision of a suitable filter on the air intake (e.g. standard MAF filter);
- Keeping the inside of the heating systems clean and dust free.
- Installing a mesh screen downstream of the burner with a maximum grid space of 3 mm (Institution of Chemical Engineers, 1977). The mesh filters should be inspected and cleaned regularly.

Figure 1a: Typical atomiser spray drier — areas requiring particular attention in design, operation and maintenance.



Key points

1) Centrifugal disk atomiser

Design:

Wheel attachment
Vibration monitor
Lubricant status (Flow temperature, pressure)

Operation:

Correct assembly by competent personnel
Use approved lubricants

2) Fines return

Pressure switch on conveying line
Position tube accurately in dryer
Fines discharge nozzle unobstructed

3) Inlet air ducts

Freedom from powder deposits

4) Sifter

Check oversize (tailings) for signs of charring

5) Exhaust fan

Provision for cleaning of impeller

6) Air heater

All types:

Intake located away from dusty areas
Filtration of incoming air

Direct fired:

Check carbon deposits on burners
Mesh screen after burners

7) Cyclones

Check for powder blockages
Care when clearing blockages into fines return system

8) Wall deposits

Minimise using wall sweeps, powder scrapers,
vibrators, knocking hammers: ensure effective maintenance

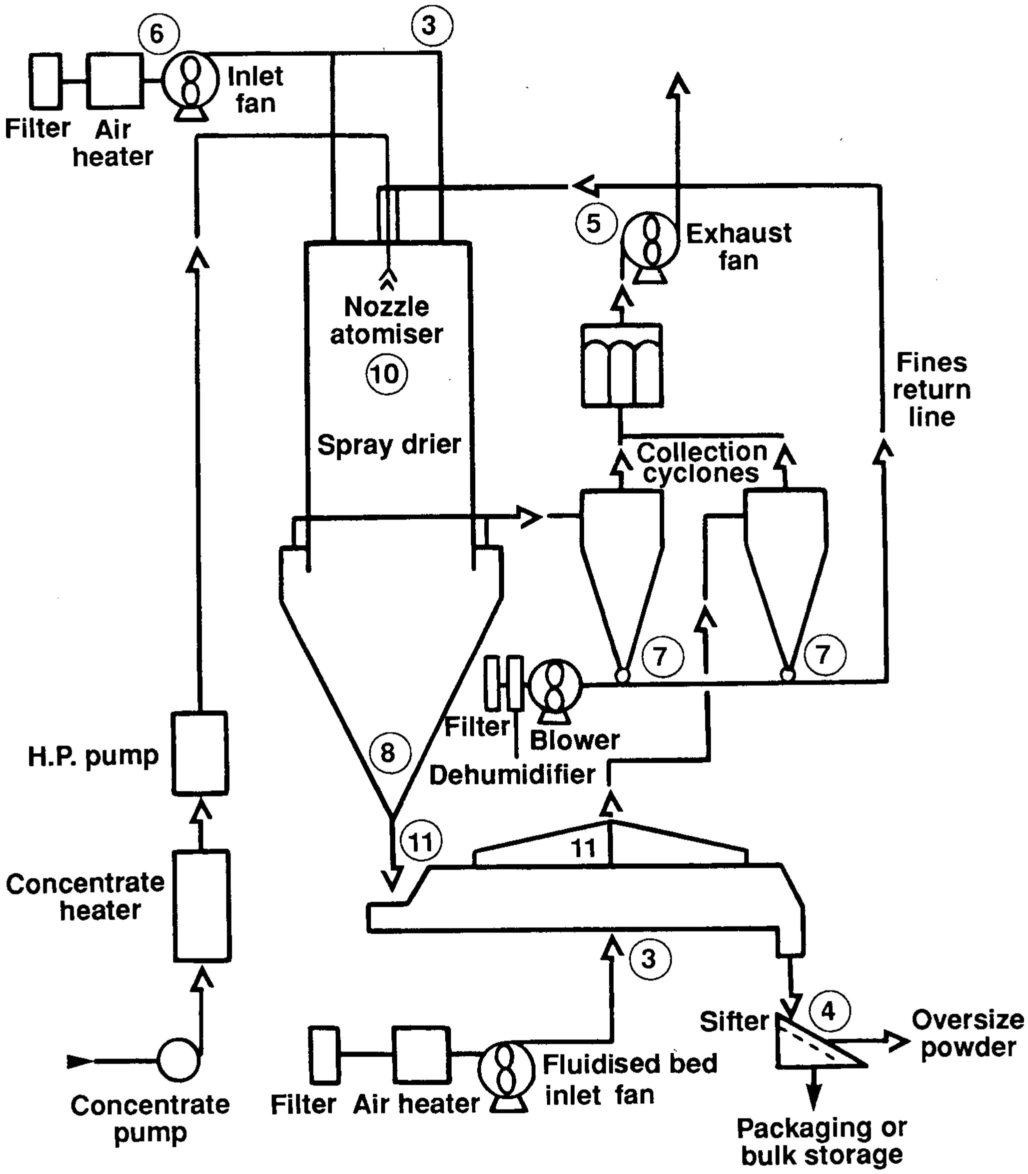
9) Air disperser

Ensure freedom from deposits (inspect)
Adjustment by competent people only
Check operation of cooling systems at neck/roof of drier

11) Blast deflection

In position, correctly mounted

Figure 1b: Typical nozzle atomiser spray drier — areas requiring particular attention in design, operation and maintenance.



Key points

3) Inlet air ducts
   Freedom from powder deposits
4) Sifter
   Check oversize (tailings) for signs of charring
5) Exhaust fan
   Provision for cleaning of impeller
6) Air heater

All types:
   Intake located away from dusty areas
   Filtration of incoming air

Direct fired:
   Check carbon deposits on burners
   Mesh screen after burners

7) Cyclones
   Check for powder blockages
8) Wall deposits
   Minimise using wall sweeps, powder scrapers, vibrators, knocking hammers:
   ensure effective maintenance
10) Pressure nozzle atomiser
   Correct assembly by competent personnnel
   Replace worn/damaged components
   (gaskets, orifices, internal parts)
   Monitor leaks
   Concentrate pipe must be able to sustain the pressure
11) Blast deflection
   Positioned by flexible connections and correctly mounted

Direct fired burners should be operated in such a way as to ensure complete combustion. Erratic burning and flame blow out shall be investigated and remedied immediately. Detailed advice for the installation of gas burners is available in the standards.

3.1.2 AIR DISPERSER

3.1.2.1 Excessive temperatures are most likely to occur in the area of the dryer where the inlet air enters the drying chamber. By employing insulation and cooling techniques, the design of this area should ensure that the temperature of this risk area is:

- Low enough to prevent ignition or browning of any product deposits which might accumulate; and
- High enough to prevent moisture condensation which would cause accumulation of powder deposits.

3.1.3 ATOMISATION

3.1.3.1 Centrifugal disk

The feed line to the atomiser should be fitted with a duplex filler. Blockages of the filter can be monitored using a differential pressure measuring device.

The design of the atomiser wheel assembly must ensure that a properly assembled wheel will not come apart from the shaft.

The atomiser assembly shall be fitted with vibration monitoring instrumentation which will allow the generation of alarms; (see section 5.4.2).

Oil temperature and oil pressure monitoring equipment should be an integral feature of atomiser protection, and alarms should be generated as appropriate.

3.1.3.2 Pressure nozzle

All components of a pressure nozzle atomisation system including the high pressure pump, feed line, flexible couplings, valves, nozzles and other fittings shall be constructed of appropriate materials with adequate strength to withstand the pressures necessary for effective atomisation.

Care must be exercised when selecting combinations and positioning nozzle assemblies in the dryer to ensure that concentrate does not impinge directly on hot surfaces because of inappropriate spray trajectories.

3.1.4 FINES RETURN

3.1.4.1 Because of the risk of partial blockage of the fines return conveying line which could cause the powder to penetrate the atomisation zone and impinge on the air disperser, the fines return conveying line shall be monitored by a pressure-operated switch. This switch shall interrupt the powder flow into the fines return system when pressures exceed predetermined safe limits. Where fines are introduced from above (pointing downwards into the dryer), it will assist in eliminating the risk of getting powder into the hot air stream from the air dispenser (see section 3.2.3).

3.1.5 FANS

3.1.5.1 All fans carrying powder laden air shall be designed to allow periodic cleaning of the impeller and casing.

3.1.5.2 Consideration should be given to the provision of vibration monitoring equipment on any fans handling powder laden air. Alarms should be generated as appropriate (see section 5.4.2).

3.1.6 TEMPERATURE CONTROL SYSTEM

3.1.6.1 Abnormally high temperatures can be caused in the dryer if the feed is interrupted with the danger of powder deposits in the dryer subsequently igniting.
To minimise this danger the dryer shall be fitted with a temperature activated alarm and fire control system as described in section 5.4.5.1.

3.1.7 EQUIPMENT CONTAINING POWDER

3.1.7.1 Surfaces such as the dryer cone, walls and transfer duct-work must be designed so that the angle of any surface will discourage a build-up of powder. Precautions such as air scouring, mechanical sweeping or knocking devices should be employed wherever a build-up is likely.

3.1.8 REMOVABLE INSPECTION PANELS

3.1.8.1 Removable inspection panels may be provided in order to examine whether build-up of powder is taking place under operating conditions. The panels shall be designed such that they maintain the strength of the parent vessel. The panels may be provided in every closed vessel, such as cyclones, fluidised beds and filter casings, and at each otherwise inaccessible location. When the dryer is commissioned, these areas shall be examined frequently and modifications made to the plant to remove any detected problems. Under normal running conditions, less frequent, but regular (e.g. monthly) inspections should take place.

3.1.8.2 All removable inspection panels must be secured in such a manner so as to prevent them becoming missiles in the event of an explosion.

3.1.9 ELECTRICAL EQUIPMENT

3.1.9.1 As a general precaution the installation of electrical equipment should be avoided where an explosive dust is likely to be present. For example, switch-gear may be installed in a room separated from the main working area. Where this precaution cannot be taken and the equipment must be used in the presence of combustible dust suitable electrical wiring and fittings shall be provided.

3.1.9.2 A T classification

A T classification (or any subsequent modification to this classification) shall be given to all electrical equipment in the spray dryer process stream, or any other designated hazardous area. Temperature ratings shall follow the temperature profile of the process with a 50°C margin over and above that of the process temperature.

Note: The classification of the hazardous area is made with reference to the standard by an inspector.

Electrical equipment suitable for such areas is determined by the Energy Resource Division of the Ministry of Commerce according to the standards.

3.1.9.3 Process and plant lighting

All lighting for process inspection and plant environs shall be enclosed, suitable for the hazard involved and must take account of the dangers of overheating of enclosures and transparent panels on which powder deposits may accumulate.

3.1.9.4 Insect killers

Insect killers utilising electricity are not permitted in any area where explosive concentrations of dusts may be present.

3.1.9.5 Heat sealers

All heat sealers are to be soundly constructed and properly maintained at all times. Heat sealers shall not be sited within 2 metres of any bag filling equipment and extraction systems shall be provided between the bag filling equipment and the heat sealer to remove airborne concentrations of powder. The heating element must be interlocked to "fail safe" with the extraction system to ensure it is switched off in the event of the extraction system failing or not being operated.

3.1.9.6 Hot air hand dryers

Hot air hand dryers are not permitted in any area where explosive concentrations of dusts may be present.

3.1.9.7 Shrink wrappers

All shrink wrapping machines shall be soundly constructed and properly maintained at all times.

"No go" areas shall be established and fenced off to ensure that no worker can accidentally or inadvertently come into contact with any moving parts. All shrink wrapped products shall be inspected before removal to any storage area for scorched or burning areas. The correct sized wrap shall be used for the size of package being covered at all times. A suitable fire extinguisher shall be provided and sited at the shrink wrapping machine.

3.1.10 EARTHING

3.1.10.1 Electrostatic sparks may be of sufficient energy to ignite milk powder. The most common danger is the retention of charge on a conductor. The accepted method of avoiding the hazard is to connect all components to each other and to earth by low resistance electrical paths which permit the dissipation of charge. A resistance of 10 ohms is generally suitable for wholly metallic systems but may not be appropriate for systems involving non-metallic components.

3.1.10.2 All plant and equipment shall be earthed and a regular monitoring system shall be established. All earthing devices shall be inspected visually on a regular basis. In addition, measurements of earthing resistance should be made before the plant is brought into use, at each scheduled maintenance and after any other modification or maintenance, and a log kept in order to indicate any changes.

3.1.11 LIGHTNING PROTECTION

3.1.11.1 The building must be protected against lightning strike.

3.1.12 FLEXIBLE CONNECTIONS

3.1.12.1 Flexible connections or couplings in areas where people are likely to be exposed to a hazard shall be adequately protected (see section 4.7.40.

3.1.13 PROCESS ISOLATION

3.1.13.1 Individual plant items should be protected against the effect of explosion and fire and should be isolated from each other by means of baffles, chokes, quick acting valves, etc. (see section 4.3).

3.1.14 MACHINERY

3.1.14.1 All machinery, shall be soundly constructed, properly maintained and safely operated at all times. All prime movers, transmission machinery and dangerous parts of machines shall be provided with and operated with suitable guards fitted.

3.1.14.2 All operators of machinery shall be trained or supervised.

3.1.15 HOUSEKEEPING

3.1.15.1 A housekeeping programme shall be put in place to ensure a safe and good working environment. The programme shall ensure:

- That all refuse is removed on a regular basis, daily or weekly as necessary.
- That all powder accumulations wherever lodged are removed safely on a regular basis.
- That all powder spills are dealt with safely as soon as possible or at least daily.
- That all facilities provided for persons engaged or employed and work areas are cleaned regularly on a daily or weekly basis as necessary to ensure a clean and healthy environment.

- That all equipment, stores and materials of any kind are stored, used and kept so as to ensure a safe and accident free environment in both working and facility areas.

There are available in New Zealand, pneumatically powered vacuum cleaners suitable for collecting explosive dusts. Electric powered vacuum cleaners can be a potential source of ignition unless they are designed for use in hazardous areas (see section 2.4.6).

3.1.16 NOISE

3.1.16.1 All practicable steps shall be taken to:

(a) Control at source the noise arising from any machinery, process or activity carried on; or by

(b) Isolation or insulation of any machinery, process or activity;

to ensure that no person engaged or employed is exposed to any noise that would be likely to impair their hearing.

3.1.16.2 Where, during the interim period, steps are being taken to control at source, isolate or insulate such noise, or where it is shown to be impractical or technically not feasible to do so, all workers exposed to the noise shall be provided with a suitable individual hearing protection device. Workers shall be required to wear such devices at all times while exposed to the noise.

3.1.17 PROTECTIVE CLOTHING AND EQUIPMENT

3.1.17.1 All workers shall be provided with such protective clothing and equipment as necessary to safeguard their safety and health. All workers have a duty to wear or use any protective clothing and equipment provided whenever the circumstances for which it is provided prevail.

3.1.17.2 No person shall interfere with or misuse any protective clothing and equipment provided for their safety and health or the safety of the plant and equipment. No person shall do anything likely to endanger themselves or any other person.

3.2 MANAGEMENT RESPONSIBILITIES

3.2.1 GENERAL

3.2.1.1 To ensure compliance with the legal requirements and to reduce the possibility of a fire or explosion developing it is necessary for a contribution to be made by everyone concerned with the operation.

3.2.1.2 Management shall clearly define levels of authority with regard to operational duties, cleaning and maintenance. Emergency procedures shall be established. All these matters should be in writing and should form part of an operator's manual, and the company safety policy.

3.2.1.3 An example of inspection procedures for operators is given in appendix 2. This may be used as a checklist amended as necessary to suit local conditions.

3.2.1.4 The operation and maintenance of the plant should be in accordance with the plant manufacturers' instructions and this code of practice, and personnel involved in these operations must be adequately trained and made aware of the provisions of the code (see section 3.2.6).

3.2.1.5 It would be beneficial if a planned preventative maintenance schedule was incorporated within the engineering and maintenance department to ensure all electrical, mechanical and pneumatic plant and machinery is maintained to design specification.

3.2.1.6 Records should be maintained of inspections conducted and include details of date of inspection, defects identified, action taken and identification of the person conducting the inspection.

3.2.2 ATOMISERS

3.2.2.1 Centrifugal disk

The dismantling and assembly of the wheel must be carried out by a competent, trained person, using correct tools, procedures and spare parts.

Care must be taken to avoid damaging critical rotating components such as the atomiser wheel during assembly and disassembly and the use of a protective rubber mat is recommended.

Approved lubricants of a grade no lower than that recommended by the manufacturer shall be used.

Modifications to, or departures from, the manufacturer's settings, specifications or procedures relating to the operation and maintenance of the atomiser shall not be permitted.

3.2.2.2 Pressure nozzle

Nozzles must be correctly assembled by trained and competent personnel. Correct tools and spare parts must be provided for this purpose.

If frequent changes of product type occur, (with an associated need to use a variety of nozzle sizes), it is important to ensure that the proper nozzle parts are installed.

Damaged or worn nozzle parts should be removed from the area in which the maintenance is conducted.

3.2.3 CONTROL OF DEPOSITS

3.2.3.1 It has been stated previously (section 2.2) that self ignition of powder deposits is possible and steps must be taken during operation to reduce the chance of this occurring. Powder deposits can be formed in several ways:

- Air currents can cause material to build up near the top of the dryer. This is more likely to be a problem in dryers fitted with centrifugal disk atomisers and it is important that the air flow and the atomiser speed are correctly adjusted to minimise this problem.
  In multipurpose dryers air disperser vanes may also require adjustment. Fires have occurred within 30 minutes of improper adjustment of the air disperser vanes. Only suitably qualified persons should perform any adjustment.
- All powder accumulations should be removed during wet washing of the plant. Any remaining deposits will provide sites for further deposit formation. A visual inspection of the internal surfaces should be carried out to ensure no powder deposits remain.
- The correct start-up procedure shall be used. Failure to do so may result in wetting of the chamber wall which will provide sites for the formation of deposits.
- If separate fractions of fat and skim milk concentrate are atomised, fat deposits will accumulate on the wall of the dryer. Fat-containing concentrates must therefore be well mixed.
- If fines are returned directly below the atomiser disk, care must be taken that the return tube is centred accurately otherwise powder may be blown on to the hot surfaces at the top of the dryer. If the fines return tube outlet is partially blocked, the increased discharge velocity may cause powder to be projected through the atomiser cloud on to hot surfaces (see section 3.1.4).
  Overloading of the fines return system, which may result from the clearance of cyclone blockages, must be avoided.
- Explosion panels/doors shall be checked regularly to ensure that they are operating correctly and are free from powder accumulations.

3.2.3.2 In many cases, air sweeps, powder scrapers, vibrators and knocking hammers are provided to prevent powder accumulating on the chamber walls during operation. It is important to ensure that these are maintained correctly.

3.2.3.3 The inner surfaces of the chamber around the hot air inlet(s) must be inspected (using a battery operated hand torch) after each run and before any cleaning of the chamber. If any powder deposits in this area appear charred, the cooling arrangements must be checked.

3.2.3.4 Should any of the operating conditions change significantly, then more frequent inspection should be established.

3.2.4 CONTROL OF BLOCKAGES

Operators must undertake process checks on a routine basis to ensure that blockages do not occur. If powder begins to accumulate in the base of the chamber, the dryer should be shut down. Unless this is done, the temperature of product in the dryer will begin to rise and ignition may occur. Stopping the operation may also reduce the amount of material in the dryer that may become involved in any subsequent fire or explosion.

3.2.5 START-UP AND SHUTDOWN PROCEDURE

3.2.5.1 At each start-up, stable drying conditions should be established on water before switching to product feed.

3.2.5.2 At each shutdown, the plant should be run on water for a period long enough for airborne powder residues to be substantially removed from the dryer. This method of operation should preclude powder flowing back into the air disperser and heating section as a result of the "chimney" effect. See shutdown procedures, section 5.4.5.

3.2.6 TRAINING AND EDUCATION OF OPERATORS

3.2.6.1 In addition to instruction provided to facilitate normal operation of the plant, operators must receive training enabling them to:

- Appreciate the importance of carrying out the checks detailed in appendix 2;
- Be aware of the characteristic smell of burnt powder; and
- Detect charred particles in powder and in oversized product (tailings) from the sifter, and must know the appropriate action to take if these are found. Sampling points must be provided to enable the operator to perform this task (see also section 3.1.16, 3.1.17, and 5.2).

3.2.6.2 All personnel receiving operator training shall be instructed in basic fire prevention and fire fighting including:

- Triangle of fire (temperature, fuel, oxygen);
- Causes of ignition;
- Dust explosion hazards;
- Dangers of fire fighting where dust is present; and
- Vital actions in the event of fire.

3.2.7 PERMIT-TO-WORK

3.2.7.1 To ensure compliance with the statutory requirements summarised at the beginning of this code, management should develop and introduce a written permit-to-work system into the workplace. Examples of permit-to-work systems are given in appendix 3. A permit-to-work system should predetermine a safe procedure and be a clear record that all foreseeable hazards have been considered and taken in correct sequence. It does not, in itself, make the work safe, but is dependent for its effectiveness on the persons concerned carrying it out conscientiously.

3.2.7.2 Special care should be taken to ensure that contractors who may be engaged to carry out specific tasks are included in any permit-to-work system that may be operating. Contractors, employees or representatives may be completely unaware of the nature of any special risks inherent in the process plant, be inexperienced in the use of safety equipment, and be unaware of safety or rescue procedures.

3.2.7.3 Hot work must not be carried out unless the plant has been shut down, emptied and cleared of dust or the dust rendered non-explosive (see section 2.4.8).

3.2.8 WORK IN CONFINED SPACES

3.2.8.1 Work that must be carried out in confined spaces is also extremely hazardous. Hazards can arise not only from the risk of fire or explosion but also from toxic fumes or the lack of oxygen. Such conditions may be present within the confined space or generated by the work carried out. An "entry permit" and "lock-out" system must be introduced (examples are given in appendix 3) which may also incorporate a "hot work" permit-to-work.

3.2.9 DEVELOPMENT OF PERMIT-TO-WORK SYSTEMS.

3.2.9.1 Further advice on the development of a "permit-to-work" system and the precautions to be taken can be obtained from OSH branch offices.

4. EXPLOSION PROTECTION

4.1 GENERAL

4.1.1 The options available to the designer to minimise the impact of a dust explosion are:

(a) Explosion venting;

(b) Process isolation;

(c) Use of pressure vessels;

(d) Explosion suppression; or

(e) Drying in an inert atmosphere.

4.1.2 The designer must consider the total plant in order to achieve an integrated protection system. Several options may be used in one plant to achieve the most effective protection system.

4.2 EXPLOSION VENTING

4.2.1 BACKGROUND

4.2.1.1 The basic principle of venting provides for the rapid opening of a vent of sufficient area to allow unburned dust and explosion products to escape, thus limiting the pressure rise to an acceptable level. The acceptable pressure rise is determined by the requirement that the vessel should not rupture and, in some cases, that it should not deform.

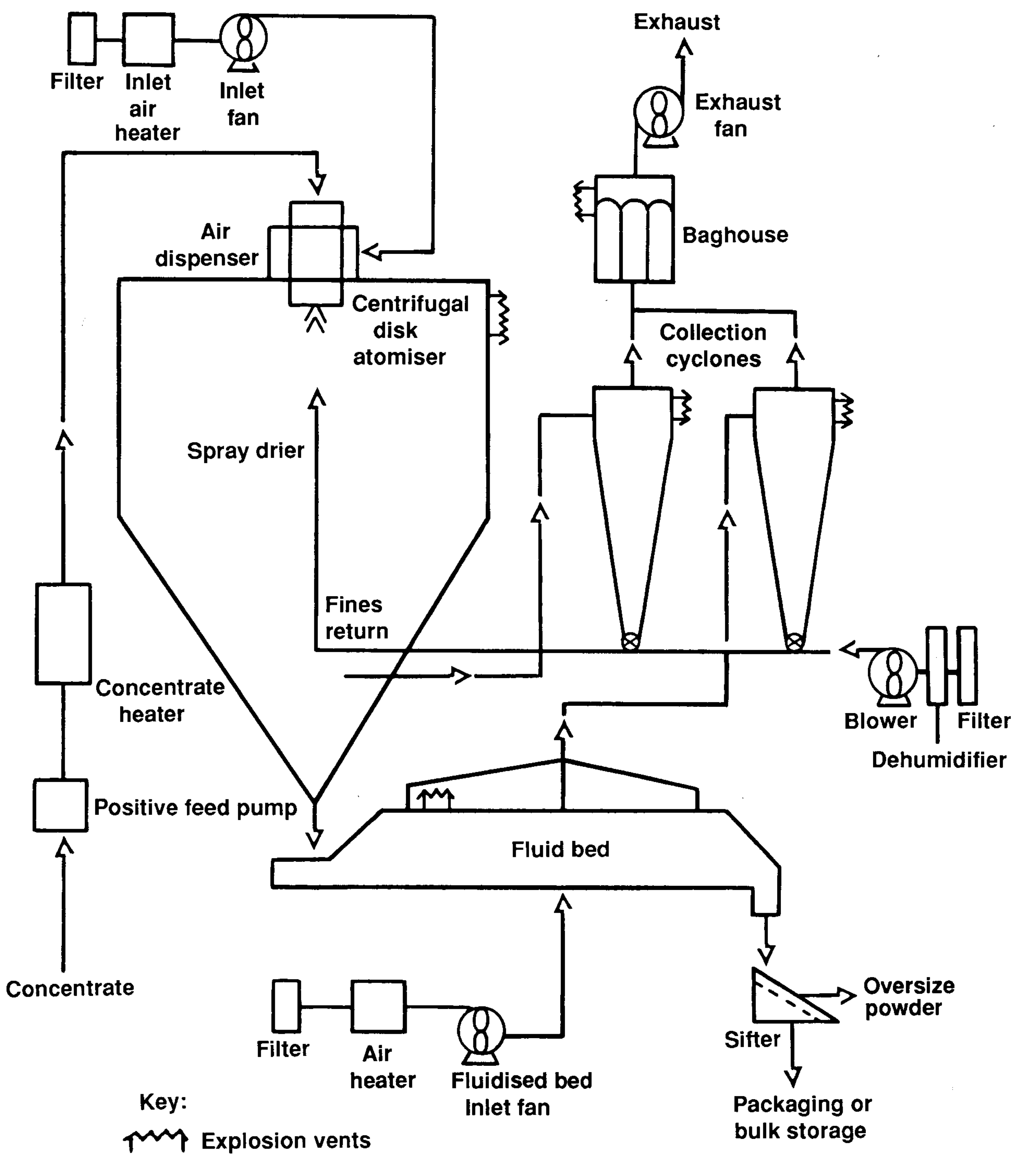
4.2.1.2 The maximum explosion pressure in a vented vessel is called the "reduced explosion pressure", or P_{red}. This is usually designed to be approximately two-thirds of the pressure required to rupture the vessel.

4.2.1.3 In a given vessel the "reduced explosion pressure" will depend upon the size, number and location of the vents, the opening pressure and inertia of the vent cover, the presence of ducts from the vent, the presence of obstructions inside the vessel and the state of the dust cloud. The explosive characteristics of the dust will also have a bearing on the vent area.

4.2.1.1 On most existing equipment the size of vents is based on an estimate of the full volume. Industry experience has shown that in the case of a spray dryer only one third of the volume needs to be considered to calculate the explosion relief vent area. However, for all other plant in which powder is present the full volume must be used to determine the area of the explosion relief vents. The general subject of explosion protection, including identification of the key points and their relevance to class St 1 materials, is detailed by Lunn (1992). With care, this information may also be used to evaluate options for handling class St 2 materials.

4.2.1.1 Possible vent locations are shown in figure 2.

Figure 2: Typical spray drying plant — possible vent locations



4.2.2 SIZING OF VENTS: VENT RATIO METHOD

4.2.2.1 This is the traditional method and for class St 1 materials and if applied, the following vent areas are required.

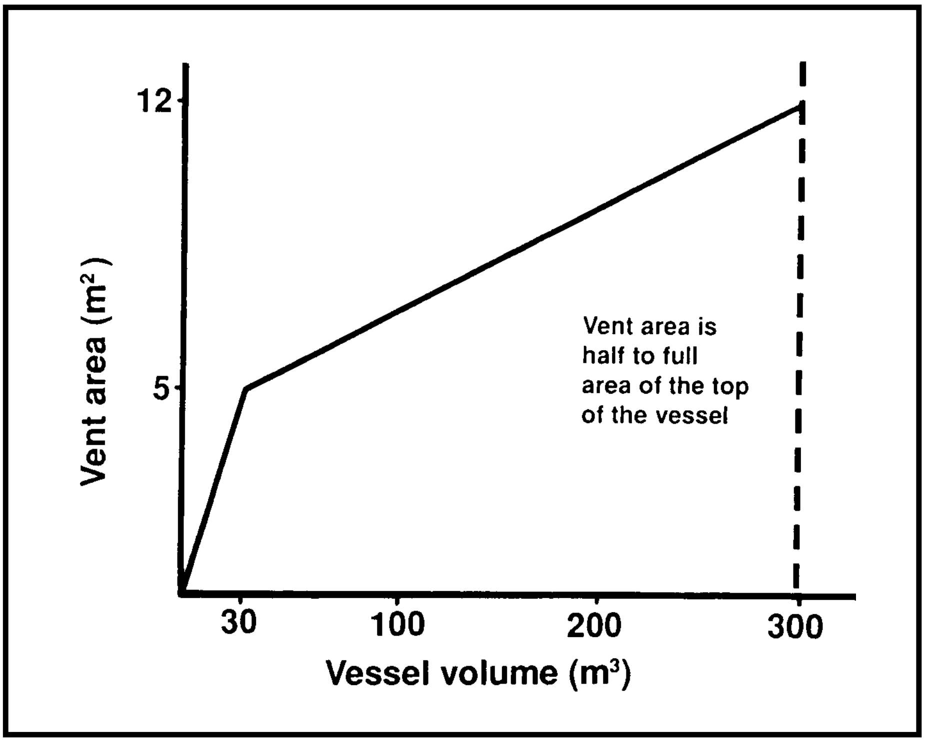
TABLE 4: REQUIRED VENT AREAS ACCORDING TO THE VENT RATIO METHOD

Vessel size	*Vent area*
up to $30m^3$	$1m^2$ for each $6m^3$
$30m^3$- $300m^3$	Ratio reduces linearly from $1m^2$ for each $6.1m^3$ to $1m^2$ for each $25m^3$
Over $300m^3$ (silos)	Half to full area of the top of the vessel

4.2.2.2 A graphical representation of these values is presented in figure 3. The vent ratio method is based on a maximum reduced explosion pressure (P_{red}) of 14 kPa and allows for a high degree of turbulence and flame front fragmentation. To apply the vent ratio method the designer must meet the following two criteria:

- The vent opening pressure will not exceed 3 kPa and the vent cover will not weigh more than 25 kg/m^2.
- Vent ducts, if incorporated, are less than 3 m long (vent ducts are not recommended for very weak vessels).

Figure 3: Graphical representation of the vent area against vessel size, calculated by the vent ratio method



4.2.3 SIZING OF VENTS: NOMOGRAPH OR CUBIC LAW METHOD

4.2.3.1 This method is considered to be a more precise calculation technique and may result in smaller vent areas on larger vessels. The standards detail the procedure.

4.2.3.2 The vent area appropriate to a particular vessel volume is read from a nomograph, an example of which is given in figure 4. A family of nomographs has been produced covering a range of values of P_{stat} the opening pressure of the vent, and P_{red} the reduced explosion pressure.

4.2.3.3 Families of curves are available for classes St 1, St 2 and St 3. Further families of curves are available for different K_{st} values within the 0-20 MPa m/s range covered by class St 1 materials.

4.2.3.4 The calculation technique also allows the effect of duct design on P_{red} to be estimated.

4.2.3.5 The specific areas of application of the nomograph method and the necessary conditions may be summarised as follows:

(a) K_{st} determination: the minimum enclosed volume of the test sphere shall be 20 litres.
The test methods are detailed in appendix 1.

(b) The turbulence in the vessel to be protected must not exceed that encountered in the dust explosion test method.

(c) The vessel should have a length-to-diameter ratio of less than 5:1 (less than 3:1 for class St 2 dusts).

(d) The vessel volume used when applying the nomograph method shall be the total free volume of the vessel except in the case of spray dryers where only one third of the volume shall be considered.

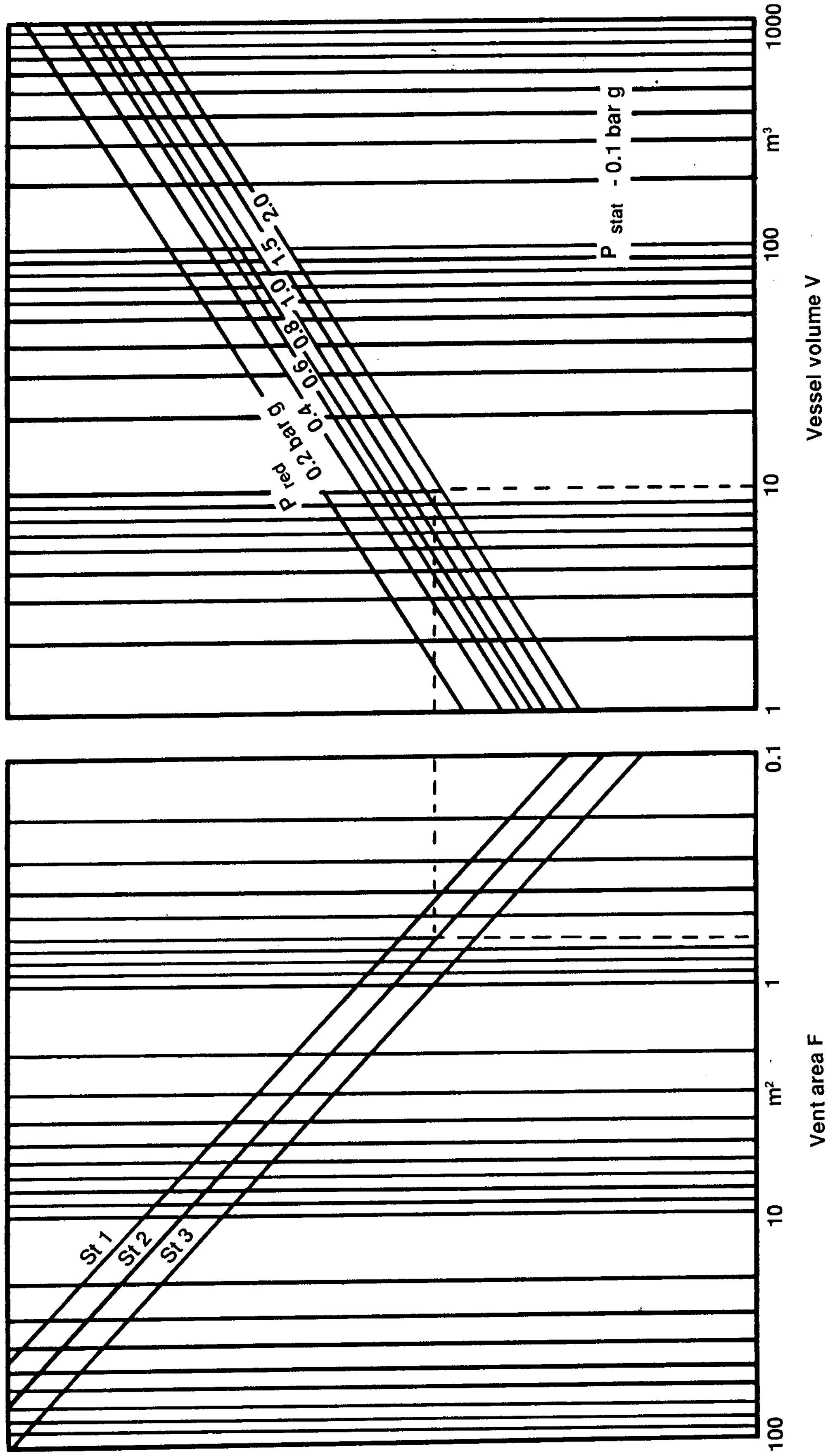
(e) Advice should be sought from OSH for vessels over 1,000 m^3.

(f) Calculations of relief vent size using the nomograph method are not normally permitted for P_{red} less than 20 kPa (see section 4.2.4).

(g) The vent cover inertia should be low; the weight of the cover should be less than 10 kg per square metre of vent cover area (see section 4.2.3).

(h) The basic method does not take account of vent ducts. Separate graphs allow the duct effect to be estimated. An example is given in figure 5.

Figure 4: Example of a nomograph



4.2.4 VENT AREAS FOR WEAK VESSELS

4.2.4.1 The nomograph method described in section 4.2.3 has been extended by Lunn (1988) for the British Materials Handling Board (BMHB), to include special provision for venting explosions occurring in weak vessels (see bibliography). The advantages of the BMHB refinements over the other standards are:

- Calculation of relief vent sizing is possible for reduced explosion pressures, P_{red} as low as 5 kPa. This allows the bursting strengths of vessels to be as low as 7.5 kPa, i.e. 50% above P_{red} for all K_{st} values in the range 10600 bar m sec^{-1}.
- As a precondition for the above the vent release pressure, P_{stat} must be as low as possible and in no case exceed half the reduced explosion pressure, P_{red}.
- The ability to assess the effect on P_{red} of long vent ducts. The ducts may be either straight, or contain a single bend at either 45° or 90°.

4.2.4.2 When the area of the explosion doors used to vent the spray dryer is calculated by the BMHB method, the weight of the doors may be increased up to a maximum of 30 kg/m^2 provided the width of each door from the hinge does not exceed 1.0 m.

4.2.5 VENT DUCTS

4.2.5.1 Explosion vents must discharge to a safe location. This is normally achieved on new plant by ducting vents to the outside of the building or locating plant externally. Venting of the building may be necessary in certain instances and especially in the case of existing plant where venting to the outside may be impractical or not possible.

4.2.5.2 A frame building with lightweight cladding is preferred for buildings handling explosive dusts in order to prevent severe damage or collapse from secondary explosions.

4.2.5.3 Where plant, including the ducting, is allowed to vent into a building, as may occur on some existing equipment, full consideration must be given to:

- The risk of secondary explosion; and
- The building design and its ability to withstand pressure rise from the primary and secondary explosions.

4.2.5.4 Where it is necessary for vents to discharge within buildings:

(a) Suitable deflectors shall be provided at potential discharge points to protect staff in the event of an incident (see section 4.7);

(b) Suitable barriers shall be provided to fence off or otherwise delineate “no go” areas; such barriers shall be effective when the plant is in operation and shall be interlocked to the alarm system to initiate a class I (defect) alarm (see section 5.4.2.1) if the barriers are not in place.

4.2.5.5 Large vessels shall not be allowed to vent into a room unless the room is designated as having “restricted access”. OSH shall be consulted if venting into a room is being considered at the design stage and prior to installation.

4.2.5.6 Duct design affects the maximum pressure reached in a vessel (P_{red}). The guidelines for duct designs can be summarised as follows:

(a) Vent ducts should be as short as possible and less than 3 m in length. For vent ducts in excess of 3 m advice must be sought. Such advice may be obtained from OSH.

(b) The cross-sectional area of the duct shall be the same as, or up to 10% greater than, the vent panel size. An increase in cross-sectional area in the direction of flow is desirable.

(c) The vent cross section can be round, square or rectangular. Circular ducts are often preferred because of their greater strength for the same gauge of metal.

(d) There shall not be a change of shape of the vent duct along its length that could impede the flow of combustion products or the movement of vent covers.

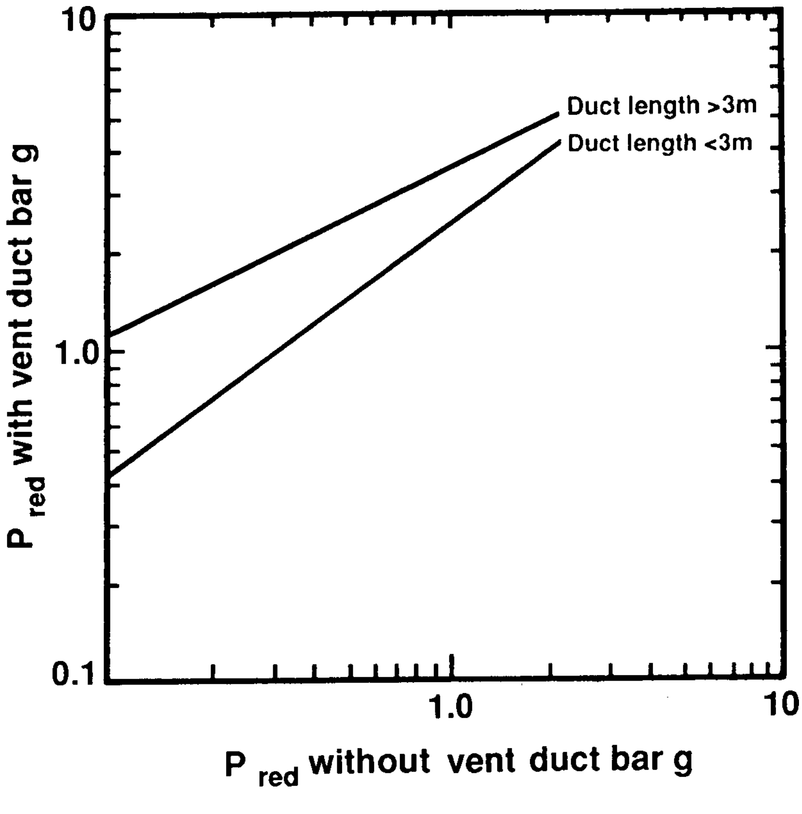
(e) Vent ducts should be straight because of the unpredictable effects of bends. Bends may be acceptable to divert the discharge. Advice should be sought from OSH.

(f) The vent duct shall be constructed to a standard equivalent to or in excess of the pressure-shock resistance of the vessel being protected.

4.2.5.7 The effect of the duct on the reduced explosion pressure in the vessel depends on its length to diameter ratio, (L/D) and is illustrated in figure 5. It can be seen that the increase in pressure may be large especially with ducts at high L/D ratios, and could cause the vessel to rupture.

4.2.5.8 A full treatment on this subject is given by Lunn in *Guide to dust explosion protection, Part 1-Venting*, which should be consulted.

Figure 5: The effect of vent ducts on the pressure in a vented vessel. Source: VDI 3673: 1979



4.3 PROCESS ISOLATION

4.3.1 GENERAL CONSIDERATIONS

4.3.1.2 An effective method of explosion protection is to isolate the particular piece of plant in question by placing it in a separate room that must be constructed with sufficient strength to withstand the effects of an explosion or that has its own explosion relief vents sited in the wall or the roof. Doors and windows to such an isolated room must be capable of withstanding the effects of an explosion. Where a building itself is to be explosion protected OSH must be consulted. The room must be treated as a "no-go" area or have restricted access to plant personnel during operation.

4.3.1.3 Individual plant items should be protected against the effect of explosion and should be isolated from each other in order to:

- Control the transfer of burning and smouldering material;
- Allow the protection system to be matched to a specific volume of plant; and
- Avoid an explosion in the first vessel causing re-compression, increased turbulence and a subsequent increase in the rate of pressure rise in the second vessel.

4.3.1.4 Full account must be taken of the handling problems and essential hygiene requirements associated with food products when isolating sections of the plant. The risk of vessel collapse must be considered when isolation of sections of plant exposes a vessel to increased pressure differences.

4.3.1.4 Lunn (1992) discusses process isolation techniques. Rotary valves and screw conveyors can be used. Where under normal operation it is preferable to maintain an uninterrupted process flow, quick-acting slide valves, baffles, chokes or suppressant barriers can be built in.

4.3.2 ISOLATION OF FINES MATERIAL

4.3.2.1 In spray drying plant that have a fines return there must be a means of preventing burning or charring particles from being "recycled" back into the spray dryer. Isolation can be achieved by interlocking the rotary valve and/or the fines return air flow system with the fire protection system. To ensure full protection of the spray dryer it is recommended that a divert valve, interlocked to the fire protection system, be placed as close as possible to the spray dryer and any diverted material be returned to the external fluid beds, or into an area free from dust and designated as a "no go" area.

4.4 USE OF PRESSURE VESSELS

4.4.1 BACKGROUND

4.4.1.1 For a given material and configuration of equipment, the maximum explosion pressure may be predicted from small scale test data.

4.4.1.2 Where the equipment is relatively small, or hygiene constraints limit applicability of other systems, it may be preferable to design the vessel to withstand the pressure, rather than use other protection systems.

4.4.1.3 This technique is often applied to cylindrical components such as duct-work.

4.4.2 DESIGN CONSIDERATIONS

4.4.2.1 Vessel design can be based on either pressure resistant vessels or pressure-shock resistant vessels.
In both design cases, the pressure rating of the vessel must be able to withstand the maximum pressure rise for the dust concerned.

4.4.2.2 Pressure resistant vessels
These vessels are designed to contain an explosion without rupture or deformation.

4.4.2.3 Pressure-shock resistant vessels
These vessels are designed to withstand the maximum explosion pressure without rupture but would be liable to permanent deformation. This approach reduces capital cost but accepts that following an explosion the vessel might need substantial repair or replacement.

4.5 EXPLOSION SUPPRESSION

4.5.1 Explosion suppression systems exploit the time (typically 30-100 ms) that it takes for an explosion to generate a destructive pressure in a containing vessel. The method is usually restricted to vessels less than 100 cubic metres. These sophisticated systems require a high standard of regular maintenance. The principles of explosion suppression are discussed in appendix 4.

4.6 DRYING IN AN INERT GAS ATMOSPHERE

4.6.1 Prevention of fires and explosions may be achieved by reducing the oxygen concentration in the drying gases to less than that required to support combustion. The technique is generally neither suited to nor applied to large food manufacturing plants. The principles of drying in an inert gas atmosphere are discussed in appendix 5.

4.7 SPECIFIC REQUIREMENTS FOR EXPLOSION PROTECTION

4.7.1 The spray dryer and dust collector must be explosion protected. Other spray drying plant such as cyclones and the bulk storage silos or bins must be explosion protected wherever practical.

4.7.2 Connecting ducting must be explosion protected where necessary and practical. For removable inspection panels see 3.1.8.

4.7.3 It is recognised that it is difficult to explosion-protect existing fluidised beds, so only minimum precautions have been included in this code (see 1.3.3 (b), 3.1.8 and 4.2.5.4. (a) (b)). Further protection can be achieved in many existing fluidised beds by converting existing hatches to vents and allowing the explosion to vent into the building. In this way the reduced explosion pressure can be kept below 50 kPa. However, many of the newer types of fluidised beds are weak vessels which will rupture at their ends, at pressures below 10 kPa.

In general, these vessels should be strengthened to withstand at least 20 kPa without bursting and explosion relief obtained either by allowing one end of the vessel to act as a vent or allowing the explosion products to rupture the flexi-couplings. In all cases due regard must be given to the additional requirements set out in section 4.2.5.

These improvements should be considered during any maintenance work carried out to the existing fluidised beds, and when undertaken, further advice can be obtained from OSH.

Future designs may well enable further improvements to be made to protect fluidised beds from the effects of explosions.

4.7.4 Flexible connections are particularly vulnerable to rupture when pressure builds up. Protection may be accomplished using any of the following methods:

- Fitting of blast deflectors which are strong enough to withstand the force of an explosion, thereby protecting people. In practice it is often impractical to consider blast deflectors for the flexi-couplings unless the pressure produced by the explosion is 50 kPa or less.
- Strengthen or replace the existing flexicoupling material using fabrics which will withstand fire and explosion pressures up to at least 50 kPa.
- Delineate areas as "no go" areas where people are likely to be exposed to a hazard as a result of a flexible connection rupturing.

4.7.5 Where explosion vents are fitted, they must be inspected at 6-monthly intervals (or more frequently) to ensure correct assembly and safe operation. With sticky food products more frequent inspections are recommended.

Assessing the explosion protection requirements of a plant is a complex process. Further advice should be obtained from OSH.

4.8 PLANS AND DESIGNS

5.8.1 All drawings, plans or designs of any structure, buildings, plant or equipment shall be prepared by a suitably qualified person and be certified with that person's qualification. All related calculations and workings shall be similarly certified.

5.8.2 All vessels (including spray dryers, cyclones, fluidised beds, bag filters, bins, silos and similar powder holding plant) and buildings used to isolate plant in respect of explosion protection shall have the internal pressure they can withstand without rupturing determined and certified as described above.

5.8.3 All the above drawings, designs, plans and calculations shall be made available to OSH on request.

5. FIRE CONTROL AND PROTECTION

5.1 GENERAL

5.1.1 Fires are likely to occur:

- Within the drying system;
- Within the dryer building; or
- In plant or buildings adjacent to the dryer(s) and the dryer building.

Such fires are potential sources of ignition for:

- Explosions within the drying system;
- Explosions within the confines of the drying building where there may be a dust-laden atmosphere.

5.1.2 Fire fighting in general should be left to the Fire Service but it is acknowledged that immediate fire fighting by staff may prevent the development of a major incident.

5.1.3 Water is the best extinguishing agent, although extensive uncontrolled use of water can result in unnecessary product damage. Where used, water should be in the form of a spray rather than a solid jet to enable it to deal more effectively with the nature of dust fires.

5.1.4 Additional information in planning fire control and emergency procedures may be obtained from:

- The local area commander, New Zealand Fire Service;
- Fire protection companies, installers and manufacturers; and
- The Insurance Council of New Zealand Inc.

5.2 GENERAL RECOMMENDATIONS

5.2.1 Training in relevant aspects of fire control and the use of fire fighting appliances shall be provided for all personnel (see section 3.2.6).

5.2.2 Specific responsibilities for emergency duties shall be allocated to appropriate personnel.

5.2.3 There shall be a regular and documented procedure for checking and maintenance of escape routes, route marking, emergency lighting. Escape routes shall remain free from obstruction at all times.

5.2.4 An operator shall be stationed within the control room or the immediate vicinity at all times during processing ready to respond in the event of an emergency and to initiate the shut down of the plant if this can be carried out safely.

5.2.5 It is recommended that all buildings be fitted with automatic fire sprinkler systems in accordance with the standard, whether or not these are required by the territorial authority.

5.2.6 The spray drying equipment nominated in section 1.3.1 shall be protected in accordance with the requirements of this code, which shall take precedence over the standard.

5.2.7 Process water storage tanks are a good source of fire fighting water. These should be adapted to enable connection to fire brigade equipment.

5.3 GENERAL REQUIREMENTS

5.3.1 Emergency plans shall be developed and shall include the provision of:

- Written instructions for personnel evacuation; procedures and assembly points shall be displayed in a prominent place;
- Fire fighting and evacuation drills on a regular basis;
- Practical trials and discussions with the fire brigade including tests to ensure that fire-fighting equipment is adequate;
- A telephone in the control room which may be used to raise an alarm in the event of an emergency; and
- A fire alarm system complying with the standard and connected to the brigade.

5.3.2 A manually operated fire alarm call point connected to the fire alarm system should be located in the control room. Activation of the manual call points in the spray dryer zone shall also activate extinguishing systems as required by clauses 5.4.3.2 and 5.4.4.

5.3.3 Specific instructions on fire fighting should include the following statements:

Do not attempt to fight a fire unless you have ensured that:

- *The alarm is activated;*
- *The Fire Service has been called; and*
- *You have a safe line of retreat from the fire area to a safe place.*

Do not open doors, hatches or vents to dryers, cyclones or any other closed vessel until you are quite satisfied that the fire has been extinguished.

Note: This system only applies to process plant and equipment.

5.4 SPECIFIC REQUIREMENTS

5.4.1 DETECTION

5.4.1.1 Temperature sensors for drying air
Fast-acting temperature sensors or “thermodisc” sensors shall be fitted to measure the temperature of the incoming heated air to the dryer except for steam radiators and hot water heaters on fluidised beds.

5.4.1.2 Temperature sensors for powder-laden air

Fast-acting temperature sensors shall be fitted in the main exhaust flow, the cyclone exhaust manifold, in any exhaust air filters and in any device, such as sound attenuators, where it is possible for powder to accumulate and receive burning particles. Where an external fluidised bed is provided, this shall be fitted with temperature sensors in the outlet air system.

5.4.1.3 Spark detection

Infra-red or similar spark detection equipment of a type approved by the Insurance Council of New Zealand Inc. and the New Zealand Dairy Research Institute shall be installed with sensors located at appropriate positions throughout the plant. This equipment must be properly maintained and inspected regularly. Records of such inspections must be kept and made available to the inspector on request, together with the appropriate documentation.

5.4.1.4 Sensor integrity

All sensors shall be scanned/polled automatically at specific intervals to prove that they are operational.

5.4.2 CLASSIFICATION OF ALARMS

There shall be two classes of alarm.

5.4.2.1 Class I (Defect)

Shall be automatically activated when:

- Abnormally high but safe temperatures are detected by thermodiscs, or over-temperature sensors (see sections 5.4.1.1 and 5.4.1.2);
- Abnormally high but safe levels of vibration associated with a centrifugal disk atomiser are detected;
- Automatic fire protection equipment is disabled, under test or otherwise inoperative;
- Infra-red radiation (sparks) is detected (see section 5.4.1.3); and
- Mechanical interlocks, safety switches (eg fitted to explosion vents, “no-go” access barriers, etc.) indicate an unsafe plant condition.

5.4.2.2 Class II (Fire)

Shall be automatically activated when:

- Abnormally high and unsafe temperatures are detected by thermodiscs, or over temperature sensors (see sections 5.4.1.1 and 5.4.1.2); and
- Manual fire alarm switches associated with the spray drying plant are operated.

5.4.3 RESPONSE TO ALARMS

5.4.3.1 Class I (Defect)

A class I alarm condition, (see section 5.4.2.1), shall immediately and automatically:

- Alert operators by activating prominent visible warning lights and audible alarms which are distinctive and identifiable from any others in the premises.

- Activate an orderly shutdown of the plant, with the objective of minimising the risk of damage to the plant or product within. It is not required that fire extinguishing equipment be activated or that general fire alarms be activated (see section 5.4.2.1).

5.4.3.2 Class II (Fire)

A class II alarm condition, (see section 5.4.2.2), shall immediately and automatically:

- Activate general fire alarms;
- Actuate appropriate fire extinguishing equipment;
- Initiate emergency shutdown of the affected plant as described in section 5.4.5.2. In addition:
- A fire call shall be transmitted to the nearest fire brigade; and
- Procedures for the protection of personnel shall be invoked.

5.4.4 EXTINGUISHING SYSTEMS

5.4.4.1 General

Water supplies to the dryer sprinkler/CIP system and the fluidised bed sprinkler system shall be available at the required pressure close to the point of demand.
Water supplies may be controlled by solenoid valve devices as a part of the automatic suppression system.
Water supplies shall be manually operable by the plant operator. A control switch to activate the water supply shall be clearly identified and shall be located in an accessible position within the control room.
Manual shutdown of fire-fighting facilities by the person or persons responsible for fire control is permitted.

5.4.4.2 Dryer

A sprinkler system shall be installed in the dryer to provide a water spray, with a minimum density of 10 mm/min. The pressure measured under duty at the nozzles shall be not less than 100 kPa. The sprinkler nozzles shall be kept dust free by suitable means such as seals or low pressure warm air flow.
A CIP system exceeding the basic requirements shall be regarded as a sprinkler system for this code. The sprinkler/CIP system shall be automatically activated as described in section 5.4.3.2 in response to a class II (fire) alarm condition.

5.4.4.3 Fluidised bed dryer and/or cooler

A sprinkler system shall be installed in the fluidised bed to provide a water spray, with a minimum density of 5 mm/min. The pressure measured under duty at the nozzles shall be not less than 100 kPa. The sprinkler nozzles shall be kept dust free by suitable means such as seals or low pressure warm air flow. The sprinkler system shall be automatically activated as described in section 5.4.3.2, in response to a class II (fire) alarm condition.

5.4.4.4 Filter bag houses

The filter bag house (if installed) shall be protected by either:

(a) A fire sprinkler installation providing a nominal 5 mm/min density and fitted with link type sprinklers rated at the maximum operating temperature of the bag house, plus 30°C; or

(b) Installation of a sprinkler system to provide a water spray, with a minimum density of 5 mm/min. The pressure measured under duty at the nozzles shall be not less than 100 kPa. The sprinkler nozzles shall be kept dust free by suitable means such as seals or low pressure warm air flow. The sprinkler system shall be automatically activated as described in section 5.4.3.2 in response to a class II (fire) alarm condition.

5.4.5 SHUTDOWN PROCEDURES

There shall be two shutdown procedures:

5.4.5.1 Controlled shutdown

Initiated by a class I (defect) alarm condition signalling impending, but not immediate danger of an “event”. The plant should be closed down promptly and in an orderly fashion. The following actions should be incorporated into the shutdown sequence:

- Feed atomiser with water (nozzle or disk);
- Shutdown air heaters; and
- When temperatures are low enough, shut-off feed, airflow, powder transport, sifter.

Note: In other words, a normal shutdown procedure with no unnecessary delays in the sequence. The plant shall not be restarted until the condition which caused the defect alarm has been investigated and rectified. No operator intervention, which might delay or circumvent the shutdown procedure, shall be permitted.

Note: False alarms due to faulty equipment, poor design or improper operating procedures must be rectified at the source, not by suppression of the automatic actions.

5.4.5.2 Emergency shutdown

Initiated by either a class II (fire) alarm condition or a manually activated emergency shutdown when there is significant risk of propagation of fire to other parts of the plant or danger to life resulting from continued operation of the plant.
The following actions shall be immediate and simultaneous:

- Activate fire extinguishing equipment;
- Switch off fans;
- Shut-down air heating;
- Shut-down atomiser;
- Stop rotary valves;
- Stop feeding dryer with concentrate;
- Isolate (bypass) bag house(s);
- Shut-down product transport system and sifter.

5.5 TESTING AND MAINTENANCE

5.5.1 Equipment must be regularly tested to ensure fitness for use. The testing procedures applied must be appropriate for this purpose but should take into account the conditions of use and the recommendations of the equipment manufacturer, supplier and installer.

5.5.2 Excess temperature sensors shall be cleaned at appropriate intervals. Sprinkler/CIP systems shall be tested by activating the over-temperature sensors at not more than 12-monthly intervals.

5.5.3 All testing and servicing of fire extinguishers shall be carried out by competent, trained personnel as per the standard.

APPENDIX 1: EXPLOSION TEST METHODS

In New Zealand, dusts are tested qualitatively for their explosibility in the Vertical Tube test. Dusts which ignite and propagate a flame in the Vertical Tube test are considered explosible and dusts which do not propagate flame are considered non-explosible.

The Vertical Tube test, which is described in detail by Field (1983), is accepted by OSH for the purposes of classification.

OSH can arrange for dust to be tested in a spherical dust bomb in Australia if quantitative results, such as K_{st} or lower explosive limit values, are required. Quantitative testing is expensive and is normally only carried out when it is believed necessary to obtain such specific values. Therefore, OSH may seek cost recovery where a company requested such a test to be carried out. Alternatively, the company could approach any recognised testing laboratory and make its own arrangements for such testing.

Lunn (1992) lists a number of laboratories in the United Kingdom which are able to carry out quantitative dust explosion testing. These are listed below.

Building Research Establishment
Fire Research Station
Borehamwood WD6 2BL
Hertfordshire

Fenwal International
Lyons House
2A Station Road
Frimley
Camberley GU16 SMF
Surrey

Imperial Chemical Industries Ltd
Hazards and Process Studies Group
Organics Division
PO Box 42
Hexagon House
Blackley
Manchester M9 3DA

Graviner Ltd
Poyle Road
Colnbrook Slough SL3 OHB
Buckinghamshire

Wolfson Applied Electrostatics Ltd
University of Southhampton
Highfield
Southhampton S09 5NH
Hampshire

In Australia the following laboratory can carry out quantitative dust explosion testing:

The Londonderry Occupational Safety Centre
132 Londonderry Road
Londonderry
NSW 2753

APPENDIX 2: OPERATOR'S CHECKLIST

Operator's checklists are a useful means of ensuring that essential activities are carried out and that responsibility for actions is clearly and unambiguously defined.

The following activities should be incorporated into an operator's checklist which should be part of routine process control procedures normally in place in dairy plants.

Frequency	Activity
Hourly (or more often):	Inspect nozzle lances (where feasible) from inspection portholes to ensure that no leaks develop. Check disk atomiser (where applicable) vibration levels, and lubricant status. Check all items of plant through which powder passes for blockages. Examine sifter tailings, lumps, pebbles for unusual features which might indicate developing problems.
Daily:	Inspect the inside surfaces of the dryer and associated plant, including the air disperser, to ensure that there are no deposits of powder. Check hammers, scrapers or other devices intended to prevent accumulation of powder, to ensure that they function correctly. Examine air filters, to ensure that they are clean and in good condition. Check the disk atomiser (where applicable) to ensure that it is clean and undamaged, the liquid distributor is clean and correctly mounted, the lubricating oil level is correct and that the drive belt (where appropriate) is in good condition and is correctly adjusted. N.B. The atomiser wheel must be assembled and checked by competent and authorised personnel.
Daily:	Check nozzle atomisers (where applicable) to ensure that the correct nozzle size(s), configuration and orientation is used. Worn or damaged parts and gaskets should not be used. N.B. Assembly and testing of pressure spray systems must be carried out by competent and authorised personnel. Ensure that fines return tubes and discharge nozzles are clean and correctly positioned within the drier. Check general cleanliness of plant and building — remove accumulations of dust from floors, pipe-work etc. Check access ways and emergency exits are unobstructed. Ensure that blast deflectors are correctly mounted.
Weekly:	All alarm devices, excess temperature sensors, spark detection equipment and other monitoring equipment is operational. Check air heater internal surfaces are clean,. e.g. carbon deposits on profile plates of direct gas-fired air heaters must be removed; mesh filters, installed to collect incandescent carbonaceous particles, should be examined.
Monthly:	Check earth continuity of the chamber, powder ducts, cyclones and silos. Check for deposits around inspection panels; explosion vents correctly assembled and operable.

APPENDIX 3: EXAMPLES OF PERMIT TO WORK SYSTEMS

CONFINED SPACE ENTRY PERMIT

____

____

____

THIS PERMIT IS ISSUED ONLY FOR WORK DESCRIBED
DESCRIPTION OF WORK AND LOCATION ____

____

SAFETY CHECK

State Yes. No or Not Applicable (NA) - All spaces must be completed

	YES NO N/A COMMENTS
	____
1. Has steam, air, gas coils etc. been depressurised?	____
2. Are valves locked and tagged?	____
3. Are pipelines disconnected or blanked?	____
4. Are electrical switches locked and tagged?	____
5. Is all machinery isolated - disconnected - tagged?	____
6. Has confined space been purged?	____
7. Is space ventilated— Naturally? Mechanically?	____
8. Is continuous forced ventilation in effect?	____
9. Has space been steamed and why?	____
10. Has space been flushed with water and why?	____
11. Have sewers, drains, trenches within 15 m of work been sealed?	____
12. Is there a fire hazard in or around the space?	____
13. Is adequate fire protection close to work?	
14. Is fire and emergency alarm close to work?	____
15. Is each person entering space equipped with safety harness?	____
16. Is rope securely fastened to person entering space?	____
17. Is rope attended by competent person outside acting as an observer?	____
18. Does outside attendant know how to get immediate assistant?	____
19. Are sufficient standby personnel detailed? — Inside — Outside	____
20. Is resuscitation equipment with attendants?	____
21. Does attendant know how to use resuscitation equipment?	____
22. Is self-contained breathing equipment required, convenient?	____
23. Is self-contained breathing equipment suitable or is other life support available?	____
24. Are non-metallic or non-sparking tools used where scraping activities are carried out?	____

25. Are atmospheric tests required - to be repeated during work? ______________________________

YES NO N/A COMMENTS

26. If tests to be repeated - at what intervals? ______________________________

27. Is atmosphere temperature safe? ______________________________

28. Is entry to be made for a specified period? ______________________________

29. If so, how long is period - has person entering been told? ______________________________

30. Is confined space safe for entering? ______________________________

31. With or without breathing apparatus? ______________________________

32. Are all persons involved trained in use of all equipment and work? ______________________________

33. Is mechanical lifting equipment necessary in the event of an emergency? ______________________________

34. If so, is it at work site? ______________________________

EXCAVATIONS

(a) Sides safely shored? ____________________

(b) Barriers erected? ____________________

PROTECTIVE EQUIPMENT REQUIRED

	YES	NO	COMMENT		YES	NO	COMMENT
NONE				ACID CLOTHING			
GOGGLES				MASKS - INDICATE TYPE			
PVC GLOVES				LIFELINE			
HELMET				SAFETY HARNESS			

SUITABLE ACCESS AND EGRESS PROVIDED YES ______ NO ______ COMMENT __________________

CONFINED SPACE AIR TEST

	COMBUSTIBLE	TOXICITY	OXYGEN %	TESTER'S SIGNATURE
Time	Hrs/Date			
Repeat tests Time	Hrs			
Time	Hrs			

Others on separate sheet

SPECIAL INSTRUCTIONS ____

ELECTRICAL ISOLATION BY ___________ CERTIFIED BY ______________ DESIGNATION __________________

I HAVE PERSONALLY CHECKED THE SITE AND CONDITIONS. PERMISSION IS GRANTED FOR ENTRY TO BE MADE

SIGNATURE ____________________________

DESIGNATION ____________________________

THIS PERMIT MUST BE DISPLAYED AT THE WORK SITE. COPIES TO BE HELD BY MANAGER, SUPERVISOR, FOREPERSON, SAFETY OFFICER.

PROVIDE SKETCH OF WORK LOCATION ON REVERSE IF CONSIDERED NECESSARY

SHOULD ANY CONDITION CHANGE ALL WORK MUST STOP IMMEDIATELY AND ALL APPROVERS CONSULTED - WORK WILL NOT RESUME UNTIL THE "DISPLAY AT JOB" COPY HAS BEEN APPROVED IN FULL

WORK COMPLETED AT ___________________ ON _________________ SIGNATURE ____________________

DESIGNATION____________________

PERMIT FOR CUTTING AND WELDING WITH PORTABLE GAS OR ARC EQUIPMENT (FRONT)

Date ________________

Building ____

Dept ________________________ Floor________________________

Work to be done ____

____

Is fire watch required?____

The location where this work is to be done has been examined, necessary precautions taken, and permission is granted for this work. (See other side)

Permit expires ___________________

Signed __________________________

(Individual responsible for authorising welding and cutting)

Time started ____________________________ Completed_____________________

____

FINAL CHECK-UP

Work area and all adjacent areas to which sparks and heat might have spread (including floors above and below and on opposite sides of walls) were inspected 30 minutes after the work was completed and were found safe.

Signed __________________________

(Supervisor or Fire Watcher)

CHECK LIST (BACK)

Before approving any cutting and welding work the fire safety supervisor or his appointee shall inspect the work area and confirm that precautions have been taken to prevent fire in accordance with the standard.

PRECAUTIONS

- ☐ Sprinklers in service
- ☐ Cutting and welding equipment in good repair

WITHIN 10 METRES OF WORK

- ☐ Floors swept clean of combustibles
- ☐ Combustible floors wet down, covered with damp sand, metal or other shields
- ☐ No combustible material or flammable liquids
- ☐ Combustibles protected with covers, guards or metal shields
- ☐ All wall and floor openings covered
- ☐ Covers suspended beneath work to collect sparks

WORK ON WALLS AND CEILINGS

- ☐ Construction non-combustible and without combustible covering
- ☐ Combustibles moved away from opposite side of wall

WORK ON ENCLOSED EQUIPMENT
(Tanks, containers, ducts, dust collectors, etc.)

- ☐ Equipment cleaned of all combustibles
- ☐ Containers purged of flammable vapours

FIRE WATCH

- ☐ To be provided during and 30 minutes after operation
- ☐ Supplied with extinguisher, bucket pumps and small hose
- ☐ Trained in use of equipment and in sounding fire alarm

FINAL CHECK-UP

- ☐ To be made 30 minutes after completion of any operation

ENTRY PERMIT

Location of work site* ______________________________

Description of work ______________________________

SAFETY CHECK

STATE YES, NO OR NOT APPLICABLE (N/A) — ALL SPACES MUST BE COMPLETED

1. Has equipment been completely:		3. (a) Sewers, drains and trenches within 15m of worksite sealed?	☐
(a) Depressurised?	☐	(b) Combustible material cleared?	☐
(b) Drained?	☐	(c) Fire protection sited?	☐
(c) Isolated by: Blanking?	☐	(d) Suitable access and egress provided?	☐
Disconnecting?	☐	(e) Standby personnel detailed?	☐
Valving?	☐	(f) Lifebelts, ropes and breathing apparatus?	☐
(d) Steamed?	☐		
(e) Water flushed?	☐	4. Are repeat gas tests required?	☐
(f) Ventilated: Naturally?	☐		
Mechanically?	☐	5. Excavations:	
		(a) Sides safely shored?	☐
2. Electrical equipment disconnected and tagged?	☐	(b) Barriers erected?	☐

	OXYGEN TEST			COMBUSTIBLE GAS TEST			TOXIC GAS TEST			PROTECTIVE EQUIPMENT REQD, INDICATE BY "X"			
READING										NONE		ACID CLOTHING	
TIME										GOGGLES		CANISTER MASK	
SIGNATURE										PVC GLOVES		FRESH AIR MASK	
												LIFELINE	

Special instructions: ______________________________

Electrical isolation by: ____________ Certified by: ____________ Designation: ____________

I have personally checked the site and conditions, permission is granted for entry to be made.

Signature: ____________________ Superintendent

This permit must be held at the worksite, a duplicate (where required) is to be displayed in the service's supervisor's office. Completion and acceptance will be recorded on the third copy which will be held by the superintendent.

* Provide sketch of work location on reverse if considered necessary.

Work completed at ____________ on ____________

Signature ______________________

I/C work ______________________

Work accepted at ____________ on ____________

Signature ______________________

Superintendent ______________________

HOT WORK PERMIT

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

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) ☐

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)

APPENDIX 4: EXPLOSION SUPPRESSION

BACKGROUND

Explosion suppression is a technique by which a developing explosion in a confined volume is detected and arrested during its incipient stage. In order to prevent or minimise damage, sufficient chemical suppressant has to be discharged into the growing fireball in the vessel at a fast enough rate to extinguish all flames before a destructive over-pressure develops. Explosion suppression is often used where it is not possible to vent the contents of the vessel to a safe place or the hygienic considerations make the design of venting systems difficult. However, suppression may introduce additional hygiene problems.

PRINCIPLE OF OPERATION

An explosion suppression system may consist of explosion detectors, explosion suppressors and a central control unit. For a given explosion hazard in a vessel the reduced explosion pressure for a suppressed explosion depends on:

- The type of detector (pressure or radiation);
- The threshold level of detection at which the explosion is recognised;
- The suppression efficiency of the suppressant;
- The number of suppressors fitted;
- The mass of suppressant; and
- The throw and dispersion of the suppressant.

The pressure created at an early stage of an explosion within an enclosure spreads itself evenly at the speed of sound in all directions.

The explosion detector is required to recognise the existence of an explosion immediately after ignition. Pressure sensors are well suited for the detection of incipient explosions in explosion suppression systems.

The control system detects changes in the explosion sensor output, activates the suppressors in a very short period of time and automatically shuts down the plant in a safe manner, e.g. cutting off the supply of fresh product into the protected vessel and the fans supplying air. The control system must prevent the plant restarting unless the suppression system is rearmed.

The hardware used to store the suppressant comes in various forms depending on the manufacturer, but when discharged must:

(a) Give a high mass discharge rate;

(b) Have high suppressant discharge velocity to give effective throw; and

(c) Give good angular dispersion of suppressant.

Discharging a spray of liquid or powder into a growing fireball results in a number of complex effects, the most important for dust explosions being quenching (heat abstraction from the combustion zone by energy transfer).

DESIGN CONSIDERATIONS

Unlike venting, the design methods for suppression are based on proprietary information. The systems have to be specified and designed in conjunction with the suppliers.

Specification of the system will require:

- Dust explosive characteristics (maximum explosion pressure and the maximum rate of pressure rise);
- Plant shape and layout;
- Plant component shock resistance (the maximum pressure that the component is designed to withstand);
- Processing parameters, such as pressure and temperature;
- Processing conditions (in particular, the level of turbulence).

Particular care must be taken if systems are to be specified for plant with any of the following characteristics:

(a) Vessel aspect ratio is greater than 2:1;

(b) Partially vented vessels;

(c) Vessel is fitted with fixed or mobile apparatus which could impede the distribution of suppressant;

(d) Operating pressures and temperatures are substantially higher or lower than normal atmospheric conditions;

(e) High level of turbulence and/or product throughput;

(f) Vessel volumes are substantially greater or lower than those used in the efficacy test.

APPENDIX 5: DRYING IN AN INERT GAS ATMOSPHERE

BACKGROUND

The application of inert gas atmosphere drying in food industry spray dryers is rare. The technique is applied occasionally on ancillary equipment such as conveying systems, hoppers, filters, silos and mills.

The technique involves the partial or complete substitution of the air in which the dust is mixed with an inert gas. Typically nitrogen, carbon dioxide or flue gases are used.

For a given dust and assuming ignition with an electric spark, carbon dioxide tends to be more effective than nitrogen because of its greater molar heat capacity. With carbon dioxide containing slightly higher oxygen levels than nitrogen, ignition is still prevented.

The design of the system requires data on the lower explosive limit of the product with the specified inert gas. Test methods are discussed in Field (1983).

As a general guide the levels of oxygen required to prevent ignition and explosion of most dusts are in the ranges 8-15% with carbon dioxide and 6-13% with nitrogen.

The plant normally operates at positive pressure to avoid the uncontrolled ingress of oxygen which would defeat the inert gas atmosphere system.

DESIGN CONSIDERATIONS

Inert gas systems are sophisticated and specification and design is normally handled by specialists. The design would consider the following:

(a) Effective and efficient gas supply and control systems to produce and maintain the inert atmosphere;

(b) Oxygen monitoring at key points coupled with automatic shutdown and alarm systems;

(c) The need to maintain minimum leakage to avoid oxygen entry, to avoid risk to operators from a build-up of the inert gas in the operating area and to minimise operating costs;

(d) Start-up and shutdown sequences to ensure that the plant is protected through all phases of operation;

(e) That operating at elevated temperatures above 100°C requires careful interpretation and extrapolation of the test data from which target oxygen levels are established;

(f) The need for back-up systems in the event of a failure of the inert gas atmosphere system.

RELATED DOCUMENTS

Warning: The following information has been updated at the time of publication, however it is subject to change without notice at any time.

NEW ZEALAND LEGISLATION

Building Act 1991

Building Regulations 1992

Dairy Industry Act 1952

Dairy Industry Regulations 1990

Electrical Wiring Regulations 1976

Food Hygiene Regulations 1974

Health Act 1956

Health and Safety in Employment Act 1992

Local Government Amendment Act (No 2) 1981

Resource Management Act 1991

NEW ZEALAND STANDARDS AND ASSOCIATED DOCUMENTS

COP section	*Reference No*	*Subject*
1.3.4 / 4.2.3	NFPA, No 68-1988	*Explosion venting guide*
1.3.4 / 4.2.3	VDI 3673: 1979	*Guidelines on venting dust explosions*
3	NZS/AS 1020: 1984	*The control of undesirable static electricity*
3	NZS/AS 1768: 1991	*Lightning protection*
3	NZS 4232: 1988	*Performance criteria for fire resisting enclosures*
3	NZS 5261: 1990	*Code of practice for the installation of gas appliances and equipment*
3	NZS 6101: 1990 Pt.2	*Classification of hazardous areas - combustible dusts*
3	AS 1530: 1990 Pt.4	*Fire-resistance tests of elements of construction methods for fire tests on building materials, components and structure*
3	AS 2381: 1981	*Electrical equipment for explosive atmospheres selection, installation and maintenance — Pt.10, Equipment for combustible dust (class 11) areas*

3	AS 3000: 1991	*Section 9, Wiring in hazardous areas*
3	BS 476: 1972 Pt.8	*Test methods and criteria for the fire resistance of elements of building construction*
3	ISO 834: 1975	*Fire-resistance tests - Elements of building construction*
5.2	NZS 4541: 1987	*Automatic fire sprinkler systems*
5.3	NZS 4561: 1973	*Fire alarms systems manual*
5.5	NZS 4503: 1974	*Code of practice for the distribution, installation and maintenance of hand operated fire fighting equipment for use in buildings*
——	NZS 1900: 1988	*Chapter 5. Fire resisting construction and means of egress*
——	NZS 4504: 1981	*Fire hose reels*
——	NFPA, No 78-1975	*Lightning protection code*
Appendix 3	NZS 4781: 1973	*Code of practice for safety in welding and cutting*

BIBLIOGRAPHY

1. *Forschungsbereicht staubexplosionen brenn und explosions kengrosen von staben schriftenreihe des hauptverbandes der gerwerblichen berufsgenosschaften e.v.* Bonn, FRG, 1980.

2. Beever, P.F. “Fire and explosion hazards in the spray drying of milk”. *Journal of Food Technology*, 20, 637-645, 1985.

3. Field, P. *Explosibility assessment of industrial powders and dusts.* Building Research Establishment Report, Fire Research Station, Dept. of Environment, HMSO, 1983.

4. Field, P. *Explosibility of industrial powders and dusts.* Building Establishment Report K6, HMSO, 1984.

5. Gibson, N. and Schofield S. *Fire and explosion hazards in spray dryers.* Institution of Chemical Engineers Symposium Series No. 49,1984.

6. Institution of Chemical Engineers. *User guide to fire and explosion hazards in the drying of particulate materials.* Institution of Chemical Engineers, Rugby, 1977

7. Jacobson, M., Nagy, J., Cooper, A.R. and Ball, F.J. *Explosibility of agricultural dusts.* Report of Investigations 5373, U.S. Dept of the Interior, Bureau of Mines, Washington, USA, 1961.

8. Lunn, G.A. *Guide to dust explosion and protection. Part 3 Venting of weak explosions and the effect of vent ducts.* Institution of Chemical Engineers and British Materials Handling Board, Rugby, 1988.

9. Lunn, GA. *Guide to dust explosion prevention and protection. Part 1 - Venting.* Institution of Chemical Engineers, Rugby, 1992.

Note: The above information has been updated at the time of publication, however, it is subject to change without notice at any time.