# Auckland Regional Council

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## Performance Criteria for Air Pollution Control Equipment

Final

August 2000

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# Contents

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# 1. Introduction

This report was commissioned by the Auckland Regional Council to aid development the air quality chapters for the Regional Plan. It aims to discuss the application of air pollution control equipment to activities that may be subject to rules in this Plan. Current design and performance criteria are presented for the most common control equipment along with suggested activities most suited to their use.

The discussion focuses on the potential to develop rules that promote the use of efficient control technology. Notwithstanding the primary importance of pollution prevention measures and the priority to reduce pollution at source, it is sensible management to encourage operators to employ measures that reduce discharges to air. In this context it is recognised that some activities currently designated discretionary under the transitional provisions of the Resource Management Act (RMA), by virtue of the second schedule to the Clean Air Act, are only such because of their *potential* to discharge contaminants to air, rather than actual discharges. The status of these could be modified provided they employ reliable control technologies.

Air pollution control equipment is confined to a relatively limited range of technologies, which have been used for many years. Most have well understood and proven performance and this provides an opportunity to incorporate suitable performance criteria for rules in the Regional Plan. While it is recognised that possibilities for new and innovative technologies exist, suitable criteria can at least be developed for known technologies without limiting the possibilities for the future.

Compatibility of process and control methodology is a very important part of the selection and performance of any control equipment. The control methods discussed therefore do not have universal applicability. Consequently the potential application of control equipment criteria within the Plan is limited to those applications that are well understood. The activities identified as suitable for this approach fall into the following categories:

- ☐ Combustion processes.
- ☐ Surface coating and printing operations
- ☐ Metallurgical operations
- ☐ Fixed abrasive blasting operations
- ☐ Certain mineral processing and handling (including asphalt plants)
- ☐ Crematoria.
- ☐ Certain animal or plant matter processes (deep fat frying, smoking, roasting and milk drying)

The above is not an exhaustive list. Additional activities could be identified as the plan rules progress. The list was developed after discussions with Council staff and using the format of the second schedule to the Clean Air Act as a basis. Further work may be necessary to establish a more comprehensive list of activities. In fact it is recommended that the Council consider reviewing the structure of the second schedule of the Clean Air Act so activities are categorised by a system designed specifically for the Regional Plan and more appropriate for the requirements of the RMA.

This report is divided into three broad sections as follows:

Section 2 discusses specific air pollution control equipment, principles of operation and recommends some design and performance criteria for their use. Activities considered potentially suitable for particular control equipment types are also discussed.

Section 3 describes how control equipment performance criteria may be applied to rules in a Plan. It addresses the potential to use these rules to encourage pollution control technology and how the discretionary activity status of certain activities may be relaxed by their use. Those activities that could benefit by this approach are identified and a range of potential options discussed.

Finally, Section 5 gives some specific options for conditions that could be used for rules in the Plan.

# 2. Design and Performance Criteria for Control Equipment

The Resource Management Act (RMA) is an effects-based Act. Discharges should therefore be controlled in relation to limiting adverse effects. In general this tends to compel regulators and policy makers towards imposing criteria usually in the form of discharge limits determined by an effects analysis. Unfortunately, there are practical limitations with this approach. Some effects-based criteria are difficult or expensive to measure and some cannot easily be applied to a range of activities and thus may not be suitable for general application in a Regional Plan. Furthermore, there are cases when it is very difficult to determine effects-based criteria, such as those activities discharging very toxic contaminants for which there is no known safe effects-threshold.

For practical purposes therefore it is often necessary to adopt design criteria or performance criteria based on technical specifications for the particular equipment being employed. This is a common approach in overseas air pollution legislation. While there is a danger of this becoming very prescriptive, in some circumstances it may be the most effective approach for developing clear enforceable rules.

The following discussion presents potential performance and design criteria for common control equipment when associated with appropriate activities.

The equipment covered is broadly divided into that which primarily controls gaseous contaminants and that which controls particulate. Gaseous control equipment is discussed first, followed by particulate control equipment.

## 2.1 Incineration of Gaseous Contaminants

Incineration relies on the destruction of air pollutants by thermal oxidation. It is best applied to carbon and hydrogen-containing contaminants because incineration renders them into harmless carbon dioxide and water. There are several different types of incinerator equipment:

- ☐ Thermal
- ☐ Recuperative
- ☐ Catalytic
- ☐ Regenerative
- ☐ Flares

Incineration may be used as a control option for particulate and/or volatile organic materials in a gas stream. In general, it would only be applied where the volatile material is adsorbed onto the particulate matter or is being carried in the gastream.

### 2.1.1 Thermal Incinerators

Thermal incinerators are probably the most common and are often referred to as '*afterburners*' in some industrial applications. These incinerators rely on thermal oxidation by raising the temperature of combustible materials above the auto-ignition point in the presence of oxygen. A straight thermal incinerator is comprised of a combustion chamber and does not include any heat recovery of exhaust air by a heat exchanger.

Contaminant destruction efficiency in thermal incinerators depends upon design criteria (i.e., chamber temperature, residence time, inlet concentration, compound type, and degree of mixing). Typical thermal incinerator design efficiencies range from 98 to 99.99% and above, depending on system requirements and characteristics of the contaminated stream. Typical design conditions needed to meet more than 98% control are: 870 °C combustion temperature, 0.75 second residence time, and flow velocities of at least 6 – 12 metres/second to ensure proper mixing (Buonicore and Davis, 1992). Conditions commonly applied in the Auckland Region to resource consents range from 750 to 850°C with 0.5 second residence time depending on the application and sometimes a minimum oxygen concentration is stipulated. The lower temperatures being suitable for easily combustible odorous compounds, while the higher temperatures are necessary for less reactive pollutants and when very high destruction efficiencies are necessary.

These criteria exclude halogenated streams, which may require significantly more demanding conditions and possibly additional equipment such as acid scrubbing or carbon adsorption due to the potential to generate acidic gases or even dioxins. Similarly, gas streams containing significant quantities of nitrogen or sulphur-containing compounds may need alternative or additional controls to avoid oxides of nitrogen or sulphur dioxide discharges.

For vent streams with low contaminant concentrations (typically below approximately 2000 ppmv for VOCs), reaction rates decrease and maximum destruction efficiency decreases. Relatively high destruction efficiencies may also be difficult to measure with low inlet concentrations due to detection limitations of measurement instruments. Performance criteria may therefore be better expressed as a minimum emission limit, such as outlet concentrations less than 20 ppmv for VOCs.

While VOC and odour control is common with thermal incinerators, they can also be used to control particulate discharges and are commonly used to control smoke and other products of incomplete combustion (PICs). Lower maximum destruction efficiencies should be expected however, when compared to VOCs. As an illustration, in USEPA's 1990 National Inventory, incinerators used as control devices for particulate matter were reported as achieving 25 to 99% control efficiency of $PM_{10}$ compared to VOC efficiencies, which were reported to range up to 99.9% (USEPA, 1998).

### 2.1.2 Recuperative Incinerators

Recuperative incinerator systems are similar to thermal incinerators but employ heat exchangers to preheat the waste gas stream, and if appropriate to recover secondary heat for process heating or to generate steam or hot water. Two general types of heat exchanger are used: shell and tube, and plate heat exchangers. Shell and tube units are more common and have advantages when temperatures exceed 540°C.

Recuperative incinerators have similar destruction efficiencies to thermal incinerators, but this can be limited by the need to limit temperatures in the heat exchanger to prevent damage. Care is needed for applications with gases that are difficult to oxidise or when very high destruction efficiencies are necessary. They are usually more economical to operate than straight thermal incinerators because the can recover 40 to 70% of the waste heat from the exhaust gases, but have higher maintenance costs.

To avoid fouling of heat exchangers excessive particulate in the inlet gases must be avoided.

Suitable design and performance criteria for recuperative incinerators are similar to those for simple thermal incinerators discussed above.

### 2.1.3 Catalytic Incinerators

Catalytic incinerators operate very similar to thermal incinerators, with the primary difference that the gas, after passing through the flame area, passes through a catalyst bed. The catalyst has the effect of increasing the oxidation reaction rate, enabling conversion at lower reaction temperatures than in thermal incinerator units. Catalysts typically used for VOC incineration include platinum and palladium. Other formulations include metal oxides, which are used for gas streams containing chlorinated compounds (USEPA, 1998).

Several different types of catalyst incinerators are available, largely distinguished by the method of contacting the contaminated gas stream with the catalyst. Both fixed-bed and fluid-bed systems are used. Fixed-bed catalytic incinerators may use a monolith catalyst or a packed-bed catalyst. Monolith catalysts are the most widespread. In these systems the catalyst is contained in a porous solid block, containing channels aligned in the direction of gas flow. Packed bed catalysts use a bed of catalyst particles supported in tubes or trays through which the gases pass. They are less common, but are advantageous where large amounts of contaminants like phosphorous or silicon are present. Fluid bed catalysts are characterised by having high mass-transfer and heat-transfer rates, offset by a high overall pressure drop when compared to a monolith. Fluid bed catalysts are generally more tolerable to particulate in the gas stream when compared to fixed bed systems, due to the high level of abrasion which helps remove particulate build-up from catalyst particle surfaces.

Contaminant destruction efficiency is dependent on the composition of the gas, operating temperature, oxygen concentration, catalyst type and space velocity. Temperature and space velocities are particularly important. High temperatures and low space velocities produce increasing destruction efficiencies. For example, 95% destruction of VOCs can be achieved in a catalytic incinerator operating at 450 $^{o}$C, with a catalyst bed volume of 0.029 to 0.12 $m^3$ per standard cubic meter per second of off gas (USEPA CACT, 1998). Destruction efficiencies up to 99% are achievable but this requires larger catalyst volumes and/or higher temperatures.

There are very few examples (if any) of performance or design criteria being applied to catalytic incinerators in New Zealand, partly because they are not common and also because the design of these units are specific to particular applications. In general a minimum temperature of 450$^{o}$C and bed to gas volume ratio of at least 0.12 is expected, but a general design criterion is not recommended. However, performance criteria of 95-99% destruction could be stipulated for inlet gases with high contaminant concentrations, or minimum outlet concentrations specified for treatment of low concentration waste streams.

### 2.1.4 Regenerative Incinerators

Regenerative thermal incinerators are similar in principle to recuperative incinerators, but use direct contact with a high-density media such as a ceramic-packed bed for heat exchange. The bed is heated with exhaust gases before using it to pre-heat and partially oxidise the inlet waste gas. The preheated and partially oxidised gases then enter a combustion chamber where final destruction takes place before the cleaned gases are directed to one or more packed beds cooled by an earlier cycle.

Regenerative incinerators can also employ a catalyst rather than ceramic material in the packed bed. This allows for destruction at a lower oxidation temperature. These units are often called ‘regenerative catalytic incinerators’.

Contaminant destruction efficiencies of thermal regenerative incinerators typically range from 95 to 99%, while catalytic units range from 90 to 99%. Catalytic units however have the advantage of being able to remove carbon monoxide from VOC laden air. Both systems are poor at coping with particulate laded waste streams, and the catalytic system in particular may require removal of any particulate to avoid clogging or blinding problems.

Regenerative incinerators are expensive and difficult to install, have a large size and weight and a high maintenance demand for moving parts. Advantages include low fuel requirements, an ability to operate at higher temperatures than recuperative incinerators and suitability for high flow, low concentration waste streams. These units are rarely used in New Zealand, largely because of their size and complexity, making them suitable for very large sources.

Because they are uncommon in New Zealand, standard design and performance criteria are not recommended for the regenerative incinerators. The are only likely to be applied to very large sources, so it is considered more appropriate to assess these on a site specific basis. However, performance criteria for regenerative thermal incinerators should be similar to straight thermal incinerators, and regenerative catalytic incinerators should be similar to those for catalytic incinerators.

### 2.1.5 Flares

Flares are a specialist category of thermal incinerator. They are primarily safety devices, which deal with flows of short duration (generally an upset condition or an accidental release from a process) rather than a control device that treats a continuous waste stream.

Flares are generally categorized in two ways:

- ☐ by the height of the flare tip *(i.e.*, ground or elevated), and
- ☐ by the method of enhancing mixing at the flare tip *(i.e.*, steam-assisted, air-assisted, pressure-assisted, or non-assisted).

Elevating the flare can prevent potentially dangerous conditions at ground level and this also allows the products of combustion to be dispersed. In most flares, combustion occurs by means of a diffusion flame. A diffusion flame is one in which air diffuses across the boundary of the fuel/combustion product stream toward the center of the fuel flow, forming the envelope of a combustible gas mixture around a core of fuel gas. This mixture, on ignition, establishes a stable flame zone around the gas core above the burner tip. This inner gas core is heated by diffusion of hot combustion products from the flame zone.

Flares can be used to control almost any VOC stream, and can typically handle large fluctuations in concentration, flow rate, and other characteristics. Flares find their primary application in the petroleum and petrochemical industries but are also common for landfill gas treatment. The majority of chemical plants and refineries have flare systems designed to relieve emergency process upsets that require release of large volumes of gas. These large diameter flares are designed to handle emergency releases, but can also be used to control vent streams from various process operations.

### 2.1.6 Suitable Incinerator Applications

Standard thermal incinerators and recuperative incinerators can be used to reduce emissions from almost all sources of VOCs. This includes surface coating operations, ovens, dryers, kilns reactor vents and distillation vents. Both can handle minor fluctuations in flow, but flares are necessary for very large fluctuations. Contaminant concentrations should be well below the lower flammable limit to prevent explosions. A factor 4 is usually employed to give an adequate margin of safety

Catalytic incinerators can also handle a range of VOC sources and are widely used by the surface coating industry. They are most suited to low volume systems when there is little variation in flow and when there is no potential for fouling from particulate, silicone, sulphur, heavy hydrocarbons and metals such as lead.

Regenerative incinerators are more suitable for high flow (above 2.5 $m^3/s$) and low VOC concentrations (below 1000ppmv). They are also suitable for a wide range of sources but cannot handle particulate or condensable material, and catalytic units may be adversely affected by gases containing silicon, phosphorous, arsenic or certain heavy metals.

### 2.1.7 Recommended Performance and Design Criteria for Incinerators

Table 2.1 presents a summary of performance criteria that could be applied to most activities employing incineration as control equipment. These criteria are suitable for use in rules in a Plan or resource consent conditions.

- **Table 2-1 Design and Performance Criteria for Incinerators** [1]

| Incinerator Type | Recommended Design Criteria | Recommended Performance Criteria |
|---|---|---|
| Thermal<br>Recuperative thermal<br>Regenerative thermal | 750 – 850 °C,<br>0.5 – 2s residence time | 98 – 99.99% removal or <20ppm VOCs for low concentration inlets |
| Catalytic | Site specific | 95 – 99% removal or <20ppm VOCs for low concentration inlets |

1. Not appropriate for halogenated waste streams or streams containing dioxins and furans.

A range of conditions are recommended because higher temperatures and residence times are necessary for those contaminants that are difficult to burn, such as particulate and products of incomplete combustion. Lower temperatures and residence times are suitable for flammable VOCs and most odours.

## 2.2 Scrubbing and Adsorption Systems .

Many control systems for the removal of gaseous contaminants are based on absorption (gas scrubbing), adsorption or condensation. The selection of the most appropriate method will depend on the contaminants that must be removed, the characteristics of the gas stream and the efficiency required.

### 2.2.1 Gas scrubbing

Absorption is the removal of a contaminant from the gas stream by contacting the gas with a liquid phase where the contaminant either reacts with the liquid or dissolves in the liquid and is removed.

This type of action may take place in all versions of wet scrubbers, however the most common types for the removal of gaseous contaminants are packed or plate absorbers.

Packed scrubbers are generally in the form of a tower, with the gas inlet at the base and outlet at the top. The scrubbing liquid flows countercurrent to the gas stream. The tower is filled with packing material to increase the surface are where absorption may take place. The packing may be symmetrical in shape such as saddles or rings or random such as coke, plastic scrap, scoria etc.

The scrubbing liquid is commonly water or a solution of a chemical in water to promote a removal mechanism. Other solvents may be used to remove substances having a low solubility in water. The scrubbing liquid should have high gas solubility (or reaction), low volatility, be chemically stable, non-corrosive and preferably have a low toxicity.

Plate scrubbers operate in similar manner to the packed tower and have the same constraints. The scrubbing liquid contacts the gas stream in a series of stages. The liquid enters the top stage, flows across the plate and discharges through holes to the next plate. The gas stream rises through the same holes or openings creating bubbles or froth where removal of the contaminant takes place.

Purpose built scrubbing towers designed for a specific duty may reach efficiencies of 99.99% for certain contaminants. Common efficiencies are in the 90 – 99% range.

Scrubbing systems may also generate external environmental problems due to the need to either dispose of the liquid stream or treat the stream for re-use.

### 2.2.2 Adsorption Systems

The process of concentrating a substance on the surface of porous solids is known as “adsorption”. It may be used for removal of contaminants from an air stream for purification of the discharge or to recover the contaminant for further use. Carbon, zeolite, and polymer adsorbents have each been used to adsorb VOCs and other pollutants from relatively dilute discharge concentrations. Other adsorbents used industrially include alumina, activated clay, silica gel and molecular sieves.

Contaminants are attached or condensed onto the surface of the adsorbent. When the surface has adsorbed nearly as much as it can, the contaminants are desorbed as part of regenerating the adsorbent. When desorbed, the vapors are usually at a higher concentration, after which they are either recovered or destroyed. The principle of adsorption is one of capturing contaminants from a dilute concentration and releasing them in a higher concentration.

The most common adsorption systems used in New Zealand use activated carbon. These range in size and complexity from small systems designed to remove odours from cooking operations to complex solvent recovery systems in the surface coating industry.

Different configurations are available including powder injection and fixed bed systems. In the larger systems it is normal for two fixed bed system to act in parallel, one in adsorption mode the other in regeneration mode. Regeneration methods include thermal systems, vacuum systems, vapour concentration systems, and steam stripping. Steam is the most common method but care is necessary with removal of water-soluble compounds. If recovery is not practical or is undesirable due to the nature of the substances collected, provision must be made for the removal of the material and subsequent disposal by incineration or landfilling.

Well designed adsorption equipment can achieve control efficiencies of 95 to 98% for input VOC concentrations in the range 500 to 2000 ppm. This is independent on the recovery or disposal process. If incineration is used as the regeneration process at 98% efficiency, total removal efficiencies may be 93 to 96% (USEPA CACT, 1998). Lower efficiencies are achieved with less effective regeneration.

### 2.2.3 Suitable Applications for Absorption and Adsorption

Gas scrubbers are used in a very wide range of applications, almost too numerous to list. Notable activities in the context of this report include: electroplating, fertiliser manufacture, general odour control and foundries

Typical uses of adsorption systems are the removal of hydrocarbons from storage vents, odours, solvent recovery units at dry cleaning plants and solvent extraction processes in the food industry.

### 2.2.4 Recommended Performance Criteria for Absorption and Adsorption Equipment

The range of potential scrubber or adsorption equipment types and designs is extremely large and depends on the particular contaminants or group of contaminants of concern. Even for specific applications a range of different options are available. For example, both adsorption and absorption systems are commonly used for odour control. The type of odour control scrubber can vary from a simple spray tower to multiple counter-flow packed towers, and the scrubbing medium could include acid solutions alkaline solutions hypochlorite or catalysed systems.

General design or performance criteria are therefore not possible, and depend very much on both the application and the nature of the contaminants of concern and the location of the process.

## 2.3 Biofilters and Bioreactors

The term 'Biofiltration' is applied to a technology in which vapour-phase organic contaminants are passed through a bed of material and adsorb to the exposed surface where they are degraded by microorganisms in the bed substrate.

Specific strains of bacteria may be introduced into the filter and optimal conditions provided to preferentially degrade specific compounds. The bed material may be soil, bark, compost or any mixture of these components. Synthetic bed materials are also used. The bed material may be contained in a structure or a depression in the ground. The dirty gas or air stream is distributed through pipes placed under the filter bed.

A development of the biofilter is the 'bioreactor'. This operates in a similar manner to the biofilter but uses an inert support media such as plastic rings, scoria or pumice. The support medium used can vary widely depending on the application. The microorganisms are cultured as a biofilm on the surface of support media supported by re-circulating water.

The biofilter provides several advantages over conventional absorbers. First, bio-regeneration keeps the maximum adsorption capacity available constantly; thus, the mass transfer zone remains stationary and relatively short. The filter does not require regeneration, and the required bed length is greatly reduced. These features reduce capital and operating expenses. Additionally, the contaminants are destroyed not just separated, as with activated carbon or similar technologies.

In common with other biological treatment processes, biofiltration is dependent upon the biodegradability of the contaminants. Under proper conditions, biofilters can remove virtually all selected contaminants to harmless products. Biofiltration is used primarily to treat hydrogen sulphide, organo-sulphides, organo-nitrogen compounds and non-halogenated hydrocarbons. Halogenated hydrocarbons also can be treated, but the process may be less effective.

Inlet concentrations of contaminants in the gas stream may range from fractions of a part per million (ppm) up to 1000 ppm or higher. Efficiency of removal is dependent on the system and contaminant. General odour removal (measured by olfactometry) from waste water treatment plants is expected to be at least 90%. Removal efficiencies for hydrogen sulphide and methyl mercaptan are greater than 99% and 95% respectively (Brennam et al, 1996).

Biofilter design centres on ensuring adequate contact or residence time in the filter bed. This is often expressed in terms of the ratio of treated gas volume to bed cross sectional areas. Values of this ratio typically range from 50 to 100 $m^3/m^2/hr$, with bed depths typically 0.8 to 1.2m. The principal disadvantage of biofilters therefore are the large space requirements. However this can be overcome by using stacked systems with synthetic media, or bioreactors, which have less demanding requirements on residence time.

The modern biofilter will operate for extended periods with minimal monitoring, however to maintain maximum efficiency moisture levels must be maintained at higher than 60% and temperature in the 20 –35°C range. Control of pH is less critical but should be within the range 4 – 8. Bed moisture content is very important and humidity of the gas stream should be maintained at near to 100% to prevent drying of the underside of the bed. Overhead watering systems are also common. The filter bed should be maintained in an aerobic condition.

Bioreactors that use an inert bed material normally require the biofilm to be seeded with the most appropriate bacteria and to provide nutrients for food.

### 2.3.1 Suitable Biofilter Applications

Biofilters and bioreactors are suitable for many applications and the variety of processes using them is growing. Presently in New Zealand their use has largely been confined to wastewater treatment, composting, food and animal products industries. They may also be applicable for treatment of VOCs and other contaminants from the surface treatment industry and petrochemical industry. However their success has not been well proven in these areas to date.

### 2.3.2 Recommended Performance and Design Criteria for Biofilters

The following design criteria for conventional biofilters may be suitable for a condition in a rule or resource consent:

- ❑ a maximum ratio of gas volume to bed cross sectional area of $50m^3/m^2/hr$; and
- ❑ a minimum bed depth of 1.0m.

It may also be possible to stipulate an odour destruction efficiency or minimum odour discharge, but such criteria may have practical limitations due to potential odour measurement problems. Olfactometery techniques cannot reliably measure below about 50 odour units per cubic metre ($OU/m^3$), and natural odour from the bark or soil media can interfere, being of the order of 80 to 150 $OU/m^3$ (Rogers, 2000).

## 2.4 Inertial Separators for Particulate

Inertial separators are the most widely used collectors being suitable for medium to large size particles. They fall into two categories:

- ❑ Mechanically aided separators that involve the use of a rotary vane (e.g., radial blade fan) to mechanically impart a centrifugal force on the particles in the gas stream, which causes them to separate from the gas;
- ❑ Cyclonic type separators, which have no moving parts, where the mechanical force is generated by the velocity of the gas stream.

### 2.4.1 Pre-Cleaners and Pre-Collectors

The performance of most particulate control devices can often be improved through pre-treatment of the gas stream. Pre-treatment consists of two categories:

- ❑ Pre-collection
- ❑ Gas conditioning.

Pre-collection devices remove large particles from the gas stream, reducing the loading on the primary control device or preventing dangerous situations, such as hot or burning particles entering fabric filters.

Gas conditioning techniques alter the characteristics of the particles and/or the gas stream to allow the primary control device to function more effectively. Both types of pre-treatment can lead to increased collection efficiency and operating life, while reducing operating costs.

The simplest method of collection of particulate is to reduce the velocity of the gas stream to the point where the falling velocity of the particle exceeds the velocity of the gas stream and it is deposited within a contained area. This is generally known as a void chamber or settling chamber separator. Settling chambers have the advantage of being cheap but require significant space with a low return on efficiency and are only suitable for very large or dense particles.

Elutriators also rely on gravitational settling to collect particles. An elutriator consists of one or more vertical tubes or towers in series, where the gas stream passes upward through the tubes. Larger particles whose terminal settling velocity is greater than the upward gas velocity are collected at the bottom of the tube, while smaller particles are carried out of the top of the tube.

### 2.4.2 Cyclones

Cyclones are also referred to as cyclone collectors, cyclone separators, centrifugal separators, and inertial separators. In applications where many (usually small) cyclones are operating in parallel, the entire system is called a multiple tube cyclone, multiple cyclone, or multicyclone.

Cyclones use inertia to remove particles from a spinning gas stream. Within a cyclone, the gas stream is forced to spin within a parallel-sided chamber adjoining a second lower conical-shaped chamber. Particles in the gas stream are forced toward the cyclone walls by the centrifugal force of the spinning gas, but are opposed by the fluid drag force of the gas travelling through and out of the cyclone. For the larger particles inertial momentum overcomes the fluid drag force so that the particles reach the cyclone wall. For smaller particles, the fluid drag force overwhelms the inertial momentum and causes these particles to leave the cyclone with the exiting gas. Gravity causes the larger particles that reach the cyclone walls to travel down into a hopper located at the bottom of the cyclone body.

Cyclone collectors can be classified into four types, based on how the gas stream is introduced and how the collected dust is discharged:

- ☐ Tangential inlet, axial discharge;
- ☐ Axial inlet, axial discharge;
- ☐ Tangential inlet, peripheral discharge;
- ☐ Axial inlet, peripheral discharge

The first two types are the most commonly used cyclones.

Cyclone collectors can be designed for many applications, and they are typically categorized as high efficiency, conventional (medium efficiency), or high throughput (low efficiency). High efficiency cyclones are likely to have the highest-pressure drops of the three cyclone types, while high throughput cyclones are designed to treat large volumes of gas with a low-pressure drop. Each of these three cyclone types have the same basic design. Different levels of collection efficiency and operation are achieved by varying the standard cyclone dimensions.

The collection efficiency of cyclones varies as a function of particle size, density and cyclone design. Cyclone efficiency will generally increase with increases in:

- ☐ Particle size and/or density;
- ☐ Inlet duct velocity;
- ☐ Cyclone body length;
- ☐ Number of gas revolutions in the cyclone;

- ❑ Ratio of cyclone body diameter to gas exit diameter;
- ❑ Inlet dust loading;
- ❑ Smoothness of the cyclone inner wall.

The cyclone efficiency will decrease with increases in the following parameters:

- ❑ Gas viscosity;
- ❑ Cyclone body diameter
- ❑ Gas exit diameter;
- ❑ Gas inlet duct area;
- ❑ Gas density.
- ❑ Leakage of air into the dust outlet.

The efficiency of a cyclone collector is related to the pressure drop across the collector. This is an indirect measure of the energy required to move the gas through the system. The pressure drop is a function of the inlet velocity and cyclone diameter. In general, 18 meters per second is considered to be the optimum operating inlet velocity.

Common ranges of pressure drops for cyclones are:

- ❑ 0.5 to 1 kilopascals (kPa) for low-efficiency units and high throughput units;
- ❑ 1 to 1.5 kPa for medium-efficiency units;
- ❑ 2 to 2.5 kPa for high-efficiency units.

Control efficiency ranges for single cyclones are often based on three classifications of cyclone. Table 2.2 gives a summary of expected efficiencies for these cyclones.
The collection efficiencies given in Table 2.2 may indicate possible performance criteria for cyclones but should not be applied as conditions of resource consents or rules in a Plan. Particulate removal efficiencies are relatively expensive to measure, consequently discharge limits are a more commonly applied criteria. The performance of the cyclones and other inertial separators is very specific to application however, and general criteria cannot be specified.

- **Table 2-2 Cyclone Control Efficiencies**

| Cyclone Type | Particle Size | Collection Efficiency (%) |
|---|---|---|
| Conventional | Total<br>$PM_{10}$<br>$PM_{2.5}$ | 70<br>30 to 90<br>0 to 40 |
| High Efficiency | Total<br>$PM_{10}$<br>$PM_{2.5}$ | 80 to 90<br>60 to 90<br>20 to 70 |
| High Throughput | > 20µm<br>$PM_{10}$<br>$PM_{2.5}$ | 80 to 99<br>10 to 40<br>0 to 10 |
| Multiple Cyclones | 5µm | 80 to 95 |

### 2.4.3 Suitable Applications for Inertial Collectors

Mechanical and inertial collectors can be used to treat small to large flow rates and to effectively remove larger particulate sizes. They are particularly common as product collection systems.

Typical gas flow rates are 0.5 to 15 $m^3/s$ for single cyclone units, and 50 $m^3/s$ or more for multiple cyclones. Inlet gas temperatures are only limited by the materials of construction of the cyclone, and can be as high as 300°C. Particulate inlet concentrations typically range from 2 to 200 $g/m^3$. Specialised applications may work outside of these parameters with temperatures up to 700°C by using refractory linings, and inlet concentrations can be as high as 16,000 $g/m^3$ and as low as l $g/m^3$.

The majority of dusts are suitable for collection in mechanical and inertial collectors. The only significant exception being sticky dust that can clog systems. This limitation can be overcome by using a “wet cyclone” where the walls of the cyclone are irrigated with water to assist in the removal of the dust stream. Alternatively water may be injected into the inlet gas stream to assist in the collection and removal of the particulate. This should not be confused with a wet cyclone associated with a scrubber and designed to remove the water droplets carried forward.

Most applications for inertial separators are for large particulate where moderate collection efficiencies are required. Timber milling and processing, pneumatic conveying, operations that produce shavings, chips and fibre are generally suitable applications for cyclones. Fossil-fuel and wood-waste fired fuel combustion units are also suitable for multiple cyclones or high efficiency cyclones when moderate collection efficiency is required. However, when high efficiency collection is necessary, wet scrubbers, electrostatic precipitators, or fabric filters are required to collect the remaining fine particulate matter ($PM_{10}$), perhaps with some form or inertial separator as a pre-collector.

### 2.4.4 Recommended Performance Criteria for Inertial Separators

As discussed earlier, the performance of cyclones and other inertial separators are activity-specific. A large range of different designs is possible and performance is also very dependent on particle size and type. Therefore a general performance or design criteria is not recommended. Table 2.2 however, provides a guide to control efficiencies that should be expected for cyclones.

Some general performance criteria could be specified for groups of activities or processes, for example, multiple-cyclones on combustion processes. However, such criteria are as much a function of the process and operational factors than the design of the inertial separator, so it is difficult to set general criteria even for specific industries.

## 2.5 Electrostatic Precipitators

An electrostatic precipitator (ESP) uses electrical forces to remove particles entrained within a gas stream. Particles are given an electrical charge when they pass through a corona (region consisting of charged ions) and then attach to an opposite-charged collector plate. Electrodes are maintained at high voltage. Particulate is cleaned from the plates by knocking or rapping so material slides down into the collection hopper without being re-entrained in the gas stream. This process may be assisted in some ESP's by intermittent or continuous washing with water (wet ESP).

A major factor in the performance of the ESP is the resistivity of the particles. In general higher resistivities are preferred because low resistivity particles are held loosely on collection plates and can re-entrain in the exhaust gas during rapping. Very high resistivity is also a problem however, due to a phenomena known as "back corona". This is caused by an electric field being formed in particulate layer which can build up on the plates. In general, dry ESP's operate most efficiently with dust resistivities between $5 \times 10^3$ and $2 \times 10^{10}$ ohm-cm. Dust resistivity is generally not such a factor for wet ESP's however.

Operating gas temperature and chemical composition of the dust are also key factors and must be carefully considered in the design of an ESP

The various types of precipitator may be configured as:

- ❑ Plate-wire — the gas flows between parallel plates of sheet metal and high voltage electrodes in the form of long wires tensioned by weights. The wires hang between the plates. The plate-wire ESP allows for flow lanes in parallel and can handle large volumes of gas. Rapping to remove the collected material is carried out in sequence through the unit. The units normally operate with three or four wire sections in series (often called stages).
- ❑ Flat-Plate —use flat plates instead of wires for the high voltage electrodes. The plates increase the field that can be used to collect the particles and provide an increased surface for collection of particles. Corona generating electrodes are placed ahead of the plates. Flat plate units have an application for high resistivity dusts. Low flow velocities are required to prevent high rapping losses.
- ❑ Tubular Precipitator — essentially a single stage unit and is unique in having all the gas pass through the electrode. This type of unit is normally used only where special requirements demand eg sticky or wet particulate. The units are usually cleaned with water and have very low re-entrainment losses.
- ❑ Two stage precipitator — these are normally smaller units ($<25$ m$^3$/s) constructed in package form and delivered to the site. The units are two stages with the discharge electrode preceding the collector electrodes.

The particle size distribution impacts on the overall performance of an ESP. In general, the most difficult particles to collect are those with aerodynamic diameters between 0.1 and 1.0 µm. Particles between 0.2 and 0.4 µm usually show the most penetration. This is most likely a result of the transition region between field and diffusion charging.

Typical new equipment design efficiencies are between 99 and 99.9%. Good quality existing equipment have a range of actual operating efficiencies of 90 to 99.9%.

### 2.5.1 Suitable Applications for ESPs

ESPs can be used for the collection of submicron particles such as mists, smoke and fume. Common applications of dry wire-plate ESPs are large solid fuel-fired boilers such as coal-fired power stations or recovery boilers at pulp and paper mills. They are also common in the cement industry and used to some degree in the metallurgical and chemical industries.

Wet ESPs are suitable for the wood products industry to remove blue haze or mist and fume control from sulphonic acid manufacture. In many of these applications using chemical such as sodium hydroxide can enhance the collector washing process. Other applications of wet wire-plate ESPs are similar to dry ESPs and tend to be used when higher control efficiencies are necessary.

ESPs are more common for very large applications. However smaller units are used in the wood processing and chemical industry. Wire-plate ESP's can operate at very high temperatures, up to 700°C.

### 2.5.2 Recommended Performance Criteria for ESPs

Because of the range of design options it is not possible to stipulate general design criteria for ESPs as conditions in a rule in the Plan or in discharge consents.

However, with the above collection efficiencies, particulate discharges of less than 50 $mg/Nm^3$ [1]would be expected in many applications. This could be used as a suitable performance criteria, but should not be treated as a universal limit. For certain applications, such as ESPs used for fume or aerosol capture, site specific criteria are necessary.

## 2.6 Fabric Filtration

Fabric filters are a popular means of separating particles from a gas stream because of their high efficiency and applicability to many situations. Fabric filters can be made of either woven or felted fabrics and may be in the form of sheets, cartridges, or bags, with a number of the individual fabric filter units housed together in a group. Bags are by far the most common type of fabric filter; hence the use of the terms "bag filters" or "bag houses" to describe fabric filters in general.

The major particle collection mechanisms of fabric filters are inertial impaction, diffusion from Brownian motion, and interception. During fabric filtration, dusty gas is drawn through the fabric by forced or induced draft fans. The fabric is responsible for some filtration, but more significantly it acts as a support for the dust layer that accumulates. The layer of dust, known as a cake, is a highly efficient filter, even for sub-micron particles. Woven fabrics rely on the filtration abilities of the dust cake much more than felted fabrics.

Fabric filters possess key advantages over other types of particle collection devices:
- ☐ Very high collection efficiencies;
- ☐ Flexibility to treat many types of dusts;
- ☐ Ability to handle a wide range of volumetric gas flows;
- ☐ Low pressure drops.

The gas-to-cloth ratio is an important design consideration and has a major effect on particle collection mechanisms. This is a ratio of the volumetric flow rate of gas per unit of filtering area and represents the velocity of the gas at the face of the fabric. As the face velocity increases, the efficiency of impaction collection increases and diffusional collection efficiency decreases. High face velocities allow for smaller

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[1] A 'normal cubic metre' ($Nm^3$) is expressed at 0°C, one atmosphere pressure (101.3 kPa) and dry gas basis.

fabric filters, all other things being constant. However, as the face velocity increases, there is increased pressure drop, increased particle penetration, blinding of fabric, more frequent cleaning required, and reduced bag life.

The majority of the dust that penetrates a well designed and maintained filter is a result of dust that is dislodged during the cleaning cycle. This penetrates to the clean side and pass out with the exhaust gas stream. The majority of sub-micron particles that penetrate the fabric ("seepage") pass directly through the pores or are released in the cleaning cycle. Seepage occurs when particles migrate through the filter cake and the fabric by continuous capture and re-entrainment. Seepage is more common with smooth particles and with a lack of significant electrostatic forces.

To operate a fabric filter continuously, the collected dust must be dislodged from the filters and removed from the fabric filter on a regular basis. Fabric filters are frequently classified primarily by their cleaning method and with a secondary classification relating to the type of media. The three major types of fabric filter cleaning mechanisms are mechanical shaker, reverse-air, and pulse-jet. These types are discussed below along with a brief discussion of other less common types of cleaning methods and fabric filter configurations.

### 2.6.1 Shaker Type Bag Filters

As the name implies, a shaking process dislodges collected particulate in shaker-type fabric filters. For small units, shaking can be accomplished manually, while large fabric filters require mechanical shaking.

The tops of the bags are usually attached to a shaker bar. When the bags are cleaned, the bar is moved briskly, which flexes the fabric, causing the dust cake to crack and fall into the hopper. Some amount of filter cake remains on the inside of the filter bag; this is desirable and also necessary to maintain a consistently high collection efficiency. The amount of dust that is removed during cleaning can be controlled by regulating the frequency, amplitude, and duration of the shaking cycles.

The flow of gas through the bags must be stopped during the cleaning cycle to allow the filter cake to release from the fabric and to prevent dust from working through the bag during the shaking. In order to accomplish this, shaker-cleaned fabric filters are often designed with several separate compartments. Each compartment can then be isolated from the gas flow and cleaned while the other compartments continue to filter the stream (off-line cleaning).

Shaker-type fabric filters are very flexible in design, allowing for different types of fabrics, bag arrangements, and filter size, with many applications. The dust must release fairly easily from the fabric, or the fabric will be damaged from over shaking and bag failure will result. Glass fabrics in particular are susceptible to degradation from shaking. The shaker mechanism itself also must be well designed and maintained or it will quickly wear and lose effectiveness.

Typical new equipment design efficiencies are between 99 and 99.9%. Good quality existing equipment has a range of actual operating efficiencies of 95 to 99.9%.

Both shaker baghouses and reverse air baghouses can be assisted by the use of "Sonic horns" to enhance the collection efficiency.

### 2.6.2 Reverse Air Bag Filters

Reverse-air cleaning is a method that has been used extensively in the past and has been improved in recent times. It is more gentle but sometimes less effective cleaning mechanism than mechanical shaking. Most reverse-air fabric filters operate in a manner similar to shaker-cleaned fabric filters. The bags are open on the bottom, closed on top and the gas flows from the inside to the outside of the bags with dust being captured on the inside.

However, some reverse-air designs collect dust on the outside of the bags. In either design, reverse-air cleaning is performed by forcing clean air through the filters in the opposite direction of the dusty gas flow.

The change in direction of the gas flow causes the bag to flex and crack the filter cake. In internal cake collection, the bags are allowed to collapse to some extent during reverse- air cleaning. The bags are usually prevented from collapsing entirely by some kind of support, such as rings that are sewn into the bags. The support enables the dust cake to fall off the bags and into the hopper. Cake release is also aided by the reverse flow of the gas. Because felted fabrics retain dust more than woven fabrics they are more difficult to clean and usually not used in reverse-air systems.

There are several methods of reversing the flow through the filters. As with mechanical shaker-cleaned fabric filters, the most common approach is to have separate compartments within the fabric filter so that each compartment can be isolated and cleaned separately while the other compartments continue to treat the dusty gas.

Reverse-air cleaning alone is used only in cases where the dust releases easily from the fabric. In many instances, reverse-air is used in conjunction with shaking or pulsing. A relatively recent development has been the use of sonic horns to aid cleaning. During cleaning, sonic blasts from horns mounted in the fabric filter assist in the removal of dust from the bags

The gentler cleaning cycle will increased bag life. This is assisted by the fact that reverse air units normally operate on a low gas-to-cloth ratio (velocity of gas through the bag), generally less than 1.2 $m^3$/min of gas per $m^2$ of cloth (m/min)). In comparison pulse-jet units may operate on gas-to-cloth ratios as high as 3.0 m/min.

The efficiency of the units is similar to mechanical and pulse jet systems. The units perform well where the particle density is low, such as collection of fine material in pneumatic conveying air from timber processing industries.

### 2.6.3 Pulse-Jet Bag Filters

Pulse-jet cleaning of fabric filters is relatively new compared to other types of fabric filters. This cleaning mechanism has consistently gained in popularity because it can treat high dust loadings, operate at constant pressure drop, and occupy less space than other types of fabric filters.

During pulse-jet cleaning a short burst of high pressure air is injected into the bags (about 6 bar for 0.03 to 0.1 seconds). The pulse is blown through a venturi nozzle at the top of the bags and this generates a shock wave that continues on to the bottom of the bag. The wave flexes the fabric, pushing it away from the cage, and then snaps it back, thus dislodging the dust cake.

There are several unique attributes of pulse-jet cleaning. Because the cleaning pulse is very brief, the flow of dusty gas does not have to be stopped during cleaning. The other bags continue to filter, taking on extra duty because of the bags being cleaned. In general, there is no change in fabric filter pressure drop or performance as a result of pulse-jet cleaning. This enables the pulse-jet fabric filters to operate on a continuous basis with solenoid valves as the only significant moving parts.

Pulse-jet cleaning is also more intense and occurs with greater frequency than the other fabric filter cleaning methods. This intense cleaning dislodges nearly all of the dust cake each time the bag is pulsed. As a result, pulse-jet filters cannot rely on a dust cake to provide filtration. Felted fabrics are used because they do not require a dust cake to achieve high collection efficiencies. Woven fabrics are not as satisfactory with pulse-jet fabric filters because they leak a great deal of dust after they are cleaned.

A disadvantage of pulse-jet units that use very high gas velocities is that the dust from the cleaned bags can be drawn immediately to the other bags. If this occurs, little of the dust falls into the hopper and the dust layers on the bags becomes too thick. To prevent this, pulse-jet fabric filters can be designed with separate compartments that can be isolated for cleaning.

Typically, pulse-jet filters operate at gas temperatures up to about 260°C, with surges to about 300°C . However higher temperatures are possible with specialist fabrics. The minimum temperature of the pollutant stream must remain above the dew point of any condensable in the stream. The baghouse and associated ductwork should be insulated and possibly heated if potential for condensation exists.

Typical inlet concentrations for baghouses are 1 to 20 g/m$^3$ but in extreme cases, inlet conditions may vary between 0.1 to more than 200 g/m$^3$.

### 2.6.4 Cartridge Collectors

Cartridge collectors have the filter media contained in completed closed containers, or cartridges. These collectors offer high efficiency filtration combined with a significant size reduction in the fabric filter unit. A cartridge filter occupies much less space than filter bags with the same amount of filtration media. In addition, cartridge collectors can operate at higher gas-to-cloth ratios than bag filter systems. Cartridges can be pulse cleaned, and some types can be washed and reused. Cartridge replacement is also much simpler than filter bag replacement. However, this type of fabric filter has been limited to low flow rate and low temperature applications. New filter materials and collector designs are increasing the applications of cartridge filters.

In general, the filter media is pleated to provide a larger surface area to volume flow rate. For this reason, cartridge filters are also referred to as extended media filters. Close pleating, however, can cause bridging at the pleat bottom, effectively reducing the surface area.

There are a wide variety of cartridge designs and dimensions. Typical designs include flat panels, V-shaped packs or cylindrical packs. Commercially available cylindrical packs are approximately 15 to 35 centimetres (cm) in diameter and 40 to 122 cm long. The cartridge is closed at one end with a metal cap. The cartridges may be mounted horizontally or vertically in the filter system.

Cartridge filters in general provide high collection efficiencies on both coarse and fine (submicron) particulate. They are relatively insensitive to fluctuations in particulate loading. Filter outlet air may be sufficiently clean to be re-circulated within the plant in many cases (for energy conservation) but this should not be used when collecting toxic contaminants.

Achievable emission reductions for older existing cartridge collector types are in the range of 99 to 99.9%. Typical new equipment design efficiencies are between 99.99 and 99.999+%. In addition, commercially available designs are able to control submicron particulate with a removal efficiency of 99.999+%.

Standard cartridge collectors are factory-built, off the shelf units. They may handle air flow rates upward of 0.10 $m^3/s$.

The type of filter media and sealants used in the cartridge limits operating temperatures. Standard cartridges utilising paper filter media can accommodate gas temperatures up to about 95°C. Cartridge filters utilising synthetic, nonwoven media such as needle-punched felts fabricated of polyester or Nomex, can withstand temperatures of up to 200°C.

Typical inlet concentrations to paper cartridge collectors are 1 to 20 $g/m^3$. Filters that utilise synthetic, nonwoven media are able to handle inlet concentrations up to 50 $g/m^3$.

### 2.6.5 Static Bag Filters

In a static bag filter the bags are suspended in an enclosure on wires or springs and fixed to the baghouse structure. The filter cake collects on the inside of the bag. Movement of the bag within the air stream and stretching due to the increase in weight periodically contributes to the dust cake detaching from the bag and falling into the hopper.

Removal can be assisted by manually shaking or rapping the outside surface. The bags being accessed from doors on the outside of the structure.

Static baghouse efficiency should be better than 90% if carefully maintained.

The system is only suitable for small applications with relatively low inlet dust burdens and are generally limited to air flows of less than 5 $m^3/s$. They are frequently used to clean air displaced from cement and other powder silos.

### 2.6.6 Fabric and other Media Characteristics

Both the performance and application of fabric filter equipment is very dependant on the type of filter material that is used. Many fibres can be used effectively as filters, with different properties that determine their appropriate applications. In general, fibres can be made into woven or felted fabrics. The cleaning method affects the fibre choice, since some fibres wear quickly and lose their effectiveness as a result of frequent flexing or shaking. The fabric type must also fit the cleaning method, and the stream and particle characteristics. Woven fabrics are preferred for shaker and reverse-air fabric filters. Felted fabrics are recommended for pulse-jet and reverse-jet fabric filters. The use of felt is generally limited to external surface dust collection styles.

Temperature and chemical composition are important characteristics. High temperatures degrade most fabrics. However, among the variety of available fabrics, there is a wide range of maximum operating temperatures that can be matched to the range of temperatures in the different applications. Acids also easily degrade some fabrics, whereas others are highly resistant to acids. Alkalis, oxidizers, and solvents are other types of chemicals that can damage filter materials. New fibres, such as Ryton, Gore-Tex, and Chem-Pro, are continually in development for high temperature and other demanding applications. Ceramic fabrics, Nextel for example, have recently been developed and can function at temperatures up to 550°C. Moreover a range of ceramic filter media is now becoming available whereby the maximum operating temperature of bag filter units can be extended to above 750°C.

Several different finishes and textures have been developed for fabrics to increase their use in filtration. There are also many coatings and chemical treatments available to provide lubrication and other properties to fibres to improve their performance.

Paper and non-woven filters (used principally in cartridge filters) come in two general types: High Efficiency Particle Air (HEPA) Filters and Ultra Low Penetration Air (ULPA) Filters. These filters are used for the removal of submicron particulate that is toxic or hazardous. In general, HEPA filters are defined as achieving 99.97% efficiency for the removal of 0.3 µm diameter or larger particulate matter. ULPA filters achieve 99.9995% efficiency for the removal of 0.12 µm diameter or larger particulate matter.

Some extended media filters are capable of higher efficiencies. Commercially available filters can control particulate with 0.01 µm diameter at efficiencies of 99.99+% and particulate matter with 0.1 µm diameter at efficiencies of 99.9999+%.

### 2.6.7 Suitable Applications for Fabric Filtration

Although fabric filters can be used in many different conditions, there are some factors which limit their application. The characteristics of the dust are one factor. Some particles are too adhesive for fabric filters. While such particles are easily collected, they are too difficult to remove from the bags. Particles from oil combustion are an example of a very sticky dust, most of which is thought to be heavy hydrocarbons.

The potential for explosion is also a concern for certain fabric filters applications. Some fabrics are flammable, and some dusts and stream components may form explosive mixtures. If a fabric filter is chosen to control explosive mixtures, care must be taken when designing and operating the fabric filters to eliminate conditions that could ignite the dust, the stream, and the bags. In addition, the fabric filters should be designed to prevent operator injuries in the event of an explosion.

Temperature and humidity are also limiting factors in the use of fabric filters. Currently, there are few fabric filters in applications where temperatures exceed 300°C for long periods of time. However, ceramic fibres which can operate at temperatures in the 500 – 600°C range are commercially available and in use at some installations in the USA. The high cost of new filter fabrics may discourage the use of fabric filters in very high temperature applications. Excessive humidity can also be a problem when considering fabric filters. Moist particles can be difficult to clean from the bags and can bridge over and clog the hopper. Streams with high humidity can also require baghouses with insulation or heating to maintain temperatures well above the dew point to prevent condensation.

While some fabrics have resistance to acid conditions, the most popular fabrics in New Zealand (Nomex) has poor resistance. Lime injection may be necessary to counteract excessive acidity for some applications using Nomex.

Suitable applications for fabric filters include:

- ☐ Solid fuel-fired combustion processes
- ☐ Metallurgical processes
- ☐ Wood and wood products processing
- ☐ Mineral processing
- ☐ Asphalt plants
- ☐ Grain milling
- ☐ Waste incineration
- ☐ Powder coating

### 2.6.8 Recommended Performance Criteria for Fabric Filtration

Well-designed and maintained fabric filters that are operated correctly should collect greater than 99 percent of particles ranging in size from sub-micron to hundreds of micrometers. Specialist units, such as cartridge filters with non-woven HEPA and ULPA filters can achieve significantly higher efficiencies as discussed above.

In general, for a given combination of filter design and dust, the effluent particle concentration from a fabric filter is nearly constant whereas the overall efficiency of a fabric filter is more likely to vary with particulate loading. For this reason, fabric filters can be considered constant outlet devices rather than constant efficiency devices. This makes fabric filters suitable for general performance criteria based on discharge limits.

Well-designed and operated baghouses have been shown to be capable of reducing overall particulate emissions to less than 50 mgN/m$^3$ and will with careful design and operation achieve levels as low as 1 - 10 mg/Nm$^3$. These levels are near the limit of standard particulate measurement methods. However, measurements at a range of New Zealand fabric filters indicate that a general criterion of 10 mg/Nm$^3$ is capable of being measured.

Site-specific criteria may be necessary for specialist applications where extremely high efficiencies are necessary. Moreover, it may be preferable in many circumstances to impose performance criteria that can be monitored by filter pressure-drop indicators or broken bag detectors. When operating normally, fabric filter systems generally achieve very high control efficiencies and the more important element may be to ensure consistent operation. It is therefore advisable to employ systems that are able to detect equipment faults.

## 2.7 Ceramic Filters

An emerging technology for the cleaning of incineration gases and similar high temperature gas streams is the use of low density ceramic filter elements. The technique was introduced in 1991 and has been developed for a wide range of uses.

A typical ceramic filter is the *Cerafil* unit, typically these have a diameter of 60 mm, length up to 3 metres and a wall thickness of 10 mm. The nominal face velocity is 0.03m/s. A 3 metre long filter will treat about 150 actual cubic metres per hour.

The ceramic filter offers 3 main benefits:
- Refractory composition, fire and spark resistance, high porosity, resistant to thermal shock;
- Inert and resistant to attack from both acid and alkali gas streams;
- Residual dust layer coupled with cake filtration mechanism gives high filtration efficiency.

Ceramic filters accommodate operating temperatures typically to 900°C.

Applications include incineration, secondary metal production, processes with an exhaust temperature above the limitations of conventional filters, dry scrubbing of acid or alkali gas streams. Dry scrubbing of hydrogen chloride and dioxin containing gas streams from incineration processes is also an important application.

## 2.8 Particulate Scrubbers

Wet scrubbers are particulate control devices that rely on direct and irreversible contact of a liquid (usually water) in the form of droplets, foam, or bubbles. The liquid with the collected particulate is then easily collected. Scrubbers can be very specialized and designed in many different configurations. Wet scrubbers are generally classified by the method that is used to induce contact between the liquid and the particulate, e.g. spray, packed-bed, plate. Scrubbers are also often described as low, medium, or high-energy, where energy is often expressed as the pressure drop across the scrubber.

Wet scrubbers have important advantages when compared to other particulate collection devices. They can collect flammable and explosive dusts safely, absorb gaseous contaminants, and collect mists. Scrubbers can also cool hot gas streams and act as flame arresters. There are also some disadvantages associated with wet scrubbers. For example, scrubbers have the potential for corrosion and freezing, can cause water and solid waste pollution problems, and can have a cool, visible discharge plume.

The collection mechanisms of wet scrubbers are highly dependent on particle size. Inertial impaction is the major collection mechanism for particles greater than approximately 0.1 m in diameter. The effectiveness of inertial impaction increases with increasing particle size. Diffusion is generally effective only for particles less than 0.1 m in diameter, with collection efficiency increasing with decreasing particle size.

The combination of these two principal scrubber collection mechanisms contributes to a minimum collection efficiency for particulate approximately 0.1 µm in diameter.

The exact minimum efficiency for a specific scrubber will depend on the type of scrubber, operating conditions, and the particle size distribution in the gas stream.

The design of the scrubber should ensure a closely packed fine dispersion of droplets is generated to act as targets for particle capture. A variety of methods are used to generate the droplets. These include injecting a liquid and pneumatically shearing the liquid into a fine spray with a high velocity gas stream or using a high pressure liquid spray to create the droplets.

The aim is to cause the particle to be lodged inside the collecting droplet and then to remove the large (relatively) collecting droplet from the gas stream. In general, the smaller the liquid droplet the higher the potential will be to remove smaller particles.

The most common scrubber design is the introduction of liquid droplets into a spray chamber, where the liquid is mixed with the gas stream to promote contact with the particulate. In a packed-bed scrubber, layers of liquid are used to coat various shapes of packing material that become impaction surfaces for the particle-laden gas. Scrubber collection can also be achieved by forcing the gas at high velocities though a liquid to form jet streams.

### 2.8.1 Spray Chambers

Spray chambers are very simple, low-energy wet scrubbers. The particulate-laden gas stream is introduced into a chamber where it comes into contact with liquid droplets generated by spray nozzles. The size of the droplets generated by the spray nozzles is controlled to maximize liquid-particle contact and, consequently, scrubber collection efficiency.

The common types of spray chambers are spray towers and cyclonic chambers. Spray towers are cylindrical or rectangular chambers that can be installed vertically or horizontally. In vertical spray towers, the gas stream flows up through the chamber and encounters several sets of spray nozzles producing liquid droplets. A de-mister at the top of the spray tower removes liquid droplets and wetted particulate from the exiting gas stream. Scrubbing liquid and wetted particulate matter also drain from the bottom of the tower in the form of a slurry. Horizontal spray chambers operate in the same manner, except for the fact that the gas flows horizontally through the device.

A cyclonic spray chamber is similar to a spray tower with one major difference. The gas stream is introduced to produce cyclonic motion inside the chamber. This motion contributes to higher gas velocities, more effective particle and droplet separation, and higher collection efficiency.

### 2.8.2 Packed-Bed Scrubbers

Packed-bed scrubbers consist of a chamber containing layers of variously shaped packing material, such as raschig rings, spiral rings, and berl saddles, which provide a large surface area for liquid-particle contact. The packing is held in place by wire mesh retainers and supported by a plate near the bottom of the scrubber. Scrubbing liquid is evenly introduced above the packing and flows down through the bed. The liquid coats the packing and establishes a thin film. In vertical designs, the gas stream flows up the chamber (counter-current to the liquid). Some packed beds are designed horizontally for gas flow across the packing (crosscurrent).

In packed-bed scrubbers, the gas stream is forced to follow a circuitous path through the packing, on which much of the particulate impacts. The liquid on the packing collects the particulate and flows down the chamber towards the drain at the bottom of the tower. A mist eliminator (also called a "de-mister") is typically positioned above/after the packing and scrubbing liquid supply. Any scrubbing liquid and wetted entrained material in the exiting gas stream will be removed by the mist eliminator and returned to drain through the packed bed.

In a packed-bed scrubber, high inlet concentrations can clog the bed; hence, the limitation of these devices to streams with relatively low inlet dust loading or soluble materials. Plugging is a serious problem for packed-bed scrubbers because the packing is more difficult to access and clean than other scrubber designs. In general, packed-bed scrubbers are more suitable for gas scrubbing than particulate scrubbing because of the high maintenance requirements associated with the control of particulate.

### 2.8.3 Impingement Plate Scrubbers

An impingement plate scrubber is a vertical chamber with plates mounted horizontally inside a hollow shell. Impingement plate scrubbers operate as countercurrent collection devices. The scrubbing liquid flows down the tower while the gas stream flows upward. Contact between the liquid and the particle-laden gas occurs on the plates. The plates are equipped with openings that allow the gas to pass through. Some plates are perforated or slotted, while more complex plates have valve-like openings.

The simplest impingement plate is the sieve plate, which has round perforations. In this type of scrubber, the scrubbing liquid flows over the plates and the gas flows up through the holes. The gas velocity prevents the liquid from flowing down through the perforations. Gas- liquid-particle contact is achieved within the froth generated by the gas passing through the liquid layer. Complex plates, such as bubble cap or baffle plates, introduce an additional means of collecting material. The bubble caps and baffles placed above the plate perforations force the gas to turn before escaping the layer of liquid. While the gas turns to avoid the obstacles, most particulate cannot and is collected by impaction on the caps or baffles. Bubble caps and the like also prevent liquid from flowing down the perforations if the gas flow is reduced.

In all types of impingement plate scrubbers, the scrubbing liquid flows across each plate and down the inside of the tower onto the plate below. After the bottom plate, the liquid and collected material flow out of the bottom of the tower. Impingement plate scrubbers are usually designed to provide operator access to each tray, making them relatively easy to clean and maintain. Consequently, impingement plate scrubbers are more suitable for particulate collection than packed-bed scrubbers. Particles greater than 1 µm in diameter can be collected effectively by impingement plate scrubbers, but particles <1 µm tend to penetrate these devices.

### 2.8.4 Mechanically-aided Scrubbers

Mechanically-aided scrubbers (MAS) employ a motor driven fan or impeller to enhance gas-liquid contact. Generally in MAS, the scrubbing liquid is sprayed onto the fan or impeller blades. Fans and impellers are capable of producing very fine liquid droplets with high velocities. These droplets are effective in contacting fine particulate. Once impacted, the droplets are normally removed by cyclonic motion.

Mechanically aided scrubbers are capable of high collection efficiencies, but only with a commensurate high energy consumption.

Because many moving parts are exposed to the gas and scrubbing liquid in a MAS, these scrubbers have high maintenance requirements. Mechanical parts are susceptible to corrosion, material build-up, and wear. Consequently, mechanical scrubbers have limited applications for particulate matter control.

### 2.8.5 Venturi Scrubbers

A venturi, or gas-atomised spray, scrubber accelerates the gas stream to atomise the scrubbing liquid and to improve gas-liquid contact. In a venturi scrubber, a "throat" section is built into the duct that forces the gas stream to accelerate as the duct narrows and then expands. As the gas enters the venturi throat, both gas velocity and turbulence increase. The scrubbing liquid is sprayed into the gas stream just before the gas encounters the venturi throat. The scrubbing liquid is then atomised into small droplets by the turbulence in the throat and droplet-particle interaction is increased. After the throat section, the wetted particulate and excess liquid droplets are separated from the gas stream by cyclonic motion and/or a mist eliminator. Venturi scrubbers have the advantage of being simple in design, easy to install, and with low-maintenance requirements.

The performance of a venturi scrubber is dependent to some extent on the velocity of the gas through the throat. Several venturi scrubbers have been designed to allow velocity control by varying the width of the venturi throat. Because of the high interaction between the particulate and droplets, venturi scrubbers are capable of high collection efficiencies for small particles.

Increasing the venturi scrubber efficiency requires increasing the pressure drop that, in turn, increases the energy consumption. Pressure drops in excess of 25 kpa are not uncommon for this design of scrubber.

### 2.8.6 Orifice Scrubbers

Orifice scrubbers, also known as entrainment or self-induced spray scrubbers, force the particle-laden gas stream to pass over the surface of a pool of scrubbing liquid as it enters an orifice. With the high gas velocities typical of this type of scrubber, the liquid from the pool becomes entrained in the gas stream as droplets. As the gas velocity and turbulence increases with the passing of the gas through the narrow orifice, the interaction between the particulate matter and liquid droplets also increases. Particulate matter and droplets are then removed from the gas stream by impingement on a series of baffles that the gas encounters after the orifice. The collected liquid and particulate drain from the baffles back into the liquid pool below the orifice. Orifice scrubbers can effectively collect particles larger than 2 µm in diameter. Some orifice scrubbers are designed with adjustable orifices to control the velocity of the gas stream.

Orifice scrubbers usually have low liquid demands, since they use the same scrubbing liquid for extended periods of time. They are relatively simple in design and usually have few moving parts, the major maintenance concern is the removal of the sludge which collects at the bottom of the scrubber. Orifice scrubbers rarely drain continually from the bottom because a static pool of scrubbing liquid is needed at all times. Therefore, the sludge is usually removed with a sludge ejector that operates like a conveyor belt. As the sludge settles to the bottom of the scrubber, it lands on the ejector and is conveyed up and out of the scrubber.

### 2.8.7 Condensation Scrubbers

Most conventional scrubbers rely on the mechanisms of impaction and diffusion to achieve contact between the particulate matter and liquid droplets. In a condensation scrubber, particles act as condensation nuclei for the formation of droplets. Generally, condensation scrubbing depends on first establishing saturation conditions in the gas stream. Once saturation is achieved, steam is injected into the gas stream. The steam creates a condition of supersaturation and leads to condensation of water on the fine particulate in the gas stream. Several conventional devices can remove the large condensed droplets.

### 2.8.8 Fibre-Bed Scrubbers

In a fibre-bed scrubber the moisture-laden gas stream passes through mats of packing fibres, such as spun glass, fibreglass, and steel. The fibre mats are often also wetted with the scrubbing liquid. Depending on the scrubber requirements, there may be several fibre mats and an impingement device for particulate removal included in the design. The final fibre mat is typically dry for the removal of any droplets that are still entrained in the stream. Fibre-bed scrubbers are best suited for the collection of soluble particulate material, i.e. material that dissolves in the scrubber liquid, since large amounts of insoluble material will clog the fibre mats with time. For this reason, fibre-bed scrubbers are more often used as mist eliminators, i.e., for the collection of liquids, rather than for particulate control.

### 2.8.9 Suitable Applications for Particulate Scrubbers

Particulate scrubbers can be used in a wide range of applications where waste water or slurry disposal is not a concern.

Venturi scrubbers are suitable for industrial boilers fired with a range of fuels including coal, oil, wood. They can also be applied to control emissions from chemical, mineral products, wood, pulp and paper, rock products, lead, aluminum, iron and steel, and gray iron production industries; and to municipal solid waste incinerators. A particularly common application in New Zealand is hot-mix asphalt plants.

Typically, venturi scrubbers are applied where it is necessary to obtain high collection efficiencies for fine material. Thus, they are applicable to controlling emission sources with high concentrations of submicron particulate.

Spray towers are comparatively uncommon and tend to be used as pre-conditioners for other control equipment or in situations were gas absorption may also be necessary, such as the superphosphate manufacturing industry.

Orifice scrubbers are used in solid fuel combustion processes, food processing (cereal, flour, rice, salt, sugar, etc.); pharmaceutical processing; the manufacture of chemicals, rubber and plastics; ceramics, and fertilizer. Orifice scrubbers can be built as high-energy units, but most devices are designed for low-energy service.

### 2.8.10 Recommended Performance Criteria for Particulate Scrubbers

Collection efficiencies for wet scrubbers are highly variable. Most conventional scrubbers can achieve high collection efficiencies for particles greater than 1.0 µm in diameter, however they are generally ineffective collection devices for sub-micron (<1 µm) particles. Some unconventional scrubbers, such as condensation and charged, are capable of high collection efficiencies, even for sub-micron particles. Collection efficiencies for conventional scrubbers depend on operating factors such as particle size distribution, inlet dust loading, and energy input.

Scrubber collection efficiency is directly proportional to the inlet dust concentration. That is, efficiency will increase with increasing dust loading. This suggests that scrubber removal efficiency is not constant for a given scrubber design, unless, it is referenced to a specific inlet dust loading. In contrast, it has been shown that scrubber outlet dust concentration is a constant, independent of inlet concentration, similar to fabric filters described above.

This feature, along with the large potential variety of design options, means that performance criteria for particulate scrubbers are best expressed in the form of discharge limits. These can vary with application and generalised criteria are not recommended. Site specific discharge criteria are necessary, but it may be possible to develop general criteria for some specific industrial applications. For example, asphalt plants where well managed venturi scrubbers can achieve a discharge less than 100 mg/Nm$^3$, or orifice scrubbers on solid fuel boilers where 100 mg/Nm$^3$ is also achievable.

# 3. Applying Control Equipment Criteria to Rules in the Regional Plan

As discussed in the introduction to this report, the Auckland Regional Council has only began to develop the Regional Plan, so the exact structure of the rules for the air section of the Plan is far from finalised. Moreover, the rule development will be an iterative process, and this will continue through the community consultation period and Council decision making following production of a Proposed Plan.

At this stage however, the Council intends to structure the rules in a broadly similar manner to the second schedule to the Clean Air Act 1972, which currently forms the basis for the regulatory status of activities in the Auckland region under the transitional provisions of the RMA. In general terms, it is understood the Council proposes to reverse the presumption of the RMA and designate all activities as permitted, unless specifically identified as controlled, discretionary or prohibited. Those activities likely to be discretionary or restricted discretionary will be based on Part A and B of the Clean Air Act schedule.

In some respects the second schedule to the Clean Air Act is not fully effects-based. This schedule is activity or process-orientated and it classifies activities by size or complexity - factors that only have an indirect relationship to potential effects. If used unaltered in a Regional Plan, the schedule could lead to inequitable management because some of the larger or more complex activities may employ mitigation technologies that result in minimal discharges to atmosphere. For example, a 20 MW coal-fired boiler (currently discretionary) fitted with high efficiency fabric filtration will have a particulate discharge of similar order to a conventionally controlled boiler less than a twentieth of its size (1 MW).

While this problem can be easily overcome by categorising activities according to the level of control equipment employed, there is a limit to the range of activities suitable for this approach. It is important that rules in a Regional Plan be simple, enforceable and reliably protect against adverse effects. This means they should be conservatively based. It may be necessary to account for the potential effects of equipment malfunction, especially if sophisticated and technically complex equipment is employed, and the potential for poorly designed systems should also be considered. Furthermore, while it may be desirable to structure the rules to accommodate new and innovative technologies, in reality this may not be practicable. Thus it is considered that any control regime identified in the Plan should involve technology with proven performance for the application in question.

With this in mind, and following discussions with Regional Council staff, a preliminary list of suitable activities was developed. Those activities potentially amenable to having their discretionary status relaxed on the basis of employing efficient air pollution control equipment fall into the following general categories:

- Combustion processes.
- Surface coating and printing operations
- Metallurgical operations
- Fixed abrasive blasting operations
- Mineral processing and handling (including asphalt plants)
- Crematoria.

- ❑ Animal or plant matter processes

The following recommendations for control technology relate only to potential conditions for permitted or controlled activity rules in the Regional Plan. They are conservative recommendations, designed for a broad range of circumstances, as discussed above, and should not be used as a basis for forming resource consent conditions. The resource consent process allows individual circumstances to be taken into account and this provides greater flexibility. For those activities that require a resource consent, the individual circumstances may be such that a significantly lower (or higher) level of control is appropriate.

## 3.1 Combustion Processes

The principal contaminants arising from combustion processes are particulate, sulphur dioxide, oxides of nitrogen and carbon monoxide. The mass discharged depends on the type of fuel, the combustion process and the size. For most industrial boilers the discharge of oxides of nitrogen and carbon monoxide are roughly similar for a range of fuels on an energy-input basis. Sulphur dioxide discharges from gas and wood fuels are negligible. For oil and coal they depend on the sulphur content of the fuel. For most Waikato coals (most common coal used in the Auckland region) the sulphur content is a similar order to automotive gas oils on an equivalent energy basis. Thus the management of industrial boilers can, on the most part, be treated the same irrespective of fuel, apart from the discharge of particulate.

Particulate discharges vary considerably with fuel and emission control equipment. For coal, wood and other solid fuels, this contaminant often has the most significance in terms of potential adverse effects. It is therefore necessary to treat these activities differently from burning fuels like oil or natural gas.

Table 3.1 presents a range of particulate emission factors for uncontrolled boilers expressed on an energy-input basis.

**■ Table 3-1 Typical particulate emission factors for uncontrolled industrial boilers (based on USEPA AP-42,1996)**

| Fuel type | Uncontrolled particulate emission factor (g/MJ fuel) |
|---|---|
| Wood waste[2] | 0.4 – 2.7 |
| Coal[3] | 0.2 - 1.5 |
| Heavy fuel oil | 0.03 – 0.10 |
| Light fuel oil | 0.01 – 0.02 |
| Natural gas | 0.0003 –0.002 |

Coal and wood-fired boilers typically operate with mechanical collectors, such as cyclones or multi-cyclones. These units have control efficiencies up to about 80%, so discharges will be significantly less than the uncontrolled factors given in Table 3.1 above. However, even with well operated multiple cyclones, particulate discharges

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[2] Assuming a specific energy (calorific value) of 10.5 MJ/kg

[3] Assuming Waikato coals are used with a specific energy of 23 MJ/kg.

are still at least 3- 5 times more per MJ than heavy oil-fired boilers and remain over ten times more than light oil or gas-fired appliances. This comparison is even less favourable if $PM_{10}$ emissions are considered, because control efficiencies for mechanical collectors are relatively poor for fine particulate.

If fabric filters or electrostatic precipitators were employed however, the particulate discharges from wood and coal combustion reduce to a similar level to those from virgin light oil and gas combustion. On this basis, wood or coal-fired industrial boilers with high efficiency particulate control equipment should be treated the same as light fuel oil and gas, although it may be necessary to take into account that malfunction of particulate control may occur.

A similar comparison can be made between boilers of different sizes. For example a 1 MW coal fired boiler with multi-cyclones (with 80% efficiency) will discharge a similar quantity of particulate to a 20 MW boiler with a fabric filter or ESP (operating at 99% efficiency). Very large coal-fired boilers could therefore be treated in a similar manner to boilers of a size that would normally be considered permitted activities. However, the discharge of other contaminants should be considered. Sulphur dioxide could become an issue for large coal and oil-fired boilers, while oxides of nitrogen may progressively become important for all boilers over a certain size in some locations irrespective of the fuels.

At present it is understood that the Council proposes to designate all boilers with a heat release above 20 MW as discretionary activities.

Sections 2.5 and 2.6 gave potential performance criteria for fabric filters and ESPs when applied to a range of activities. A design criteria is not recommended but a suitable performance criteria for fabric filters is a discharge concentration of 10 to 50 $mg/Nm^3$ [4] irrespective of source. Similar concentrations should be expected for ESPs. For both coal and wood-fired boilers it would therefore be advisable to set a discharge concentration limit on this basis, but with the gas volume corrected to a standard carbon dioxide or oxygen concentration (usually 12% $CO_2$ or 8% $O_2$). This criterion should ensure an over-all particulate collection efficiency of at least 99%.

While a concentration limit is proposed, it may be preferable to consider applying a mass-emission limit since the mass emission is more related to potential effects. In general, mass emission limits are most appropriate for discharge consents, but concentration limits are better applied to a wide range of activities because they are not as dependant on the size and type of process.

It is possible that the Regional Plan could make allowance for the use of fabric filters or ESPs on other combustion systems, such as lignite burning or multiple fuel-fired boilers. However, it is considered that there is not sufficient information on such activities to reliably extend this principle. In some cases there may also be a potential for other contaminants to be discharged. Thus there is too much uncertainty with respect to defining the status within rules of the Regional Plan. Any relaxation of the discretionary status on the basis of employing fabric filtration or ESP should therefore be limited to low-sulphur coal (less than 0.5% say) and untreated wood-fired boilers.

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[4] A ‘normal cubic metre’ ($Nm^3$) is expressed at 0°C, one atmosphere pressure (101.3 kPa) and dry gas basis.

Some care is necessary for wood burners in respect to burning wet wood. Combustion of excessively wet wood can cause a range of problems including discharges of smoke, VOCs and other products of incomplete combustion. It may therefore be preferable to limit this relaxation to woodwaste boilers burning dry fuel or equipped with fuel drying equipment.

## 3.2 Surface Coating and Printing Operations

### 3.2.1 Surface Coating (Spray Painting)

Surface coating operations comprise a large range of different processes, but all involve three general steps: surface preparation, application of coatings and curing.

The principal contaminants of concern are volatile organic compounds (VOCs) and odour, which arise from:
- evaporation during spraying,
- re-evaporation of captured over-spray,
- flash-off, and
- oven curing.

It is possible that the Regional Plan could designate large surface coating operations as discretionary activities, based on some form of a solvent usage threshold, or on a heat input rate for curing ovens.

The potential for VOC and odour discharges depends largely on the type of process and the type of coating that is applied. For example spray painting of automobile bodies with solvent-borne coatings has the potential to generate significant VOC emissions from both the application and curing process, but if the coatings are replaced with electrostatic application of powder coatings, the total mass discharge is reduced by 95 to 99%.

While powder-coating operations are not a significant concern with respect to VOC discharges, they have a potential particulate discharge, which must be considered. Curing or baking ovens can also cause odour from this process. It is anticipated that the Plan will treat powder coating differently to those activities that involve conventional solvent coatings or even water-borne and high solids coatings, but some care is necessary with respect to the oven baking operations.

It is not possible to control all discharges from surface coating operations. As a general rule it is better to employ powder coatings or electro-deposition of high solid coatings than to rely on add-on control equipment for solvent removal. At best the overall reduction in VOC emissions achieved by employing control equipment on spray booth and oven emissions is limited to the range of 50 to 90%. This is because a significant proportion of the total solvents escapes as fugitive emissions (handling of coatings, flash-off areas and imperfect capture from booths and ovens). Furthermore, those booths that employ wet-backs or more sophisticated water scrubbing systems will ultimately produce VOC discharges to air as captured solvents re-evaporate from downstream drains or water treatment systems. While this may not be a concern from the point of view of local impact, total discharges to the general Auckland air-shed should be considered because of the increasing concerns over photochemical smog in the region.

Nevertheless it would represent a very high level of control to employ effective add-on technology to both spray booth and curing oven discharges for typical small to medium-scale surface coating operations in New Zealand. Therefore, if the Regional Plan designates surface coating activities as discretionary based on a solvent usage threshold, it would be possible to relax this status by allowing at least 50% more solvent use if high efficiency solvent control equipment was installed on the booth and oven. Such equipment could include incineration, carbon adsorption or biofiltration, but the preferred option is incineration because this has a proven record in New Zealand for reliable high efficiency. Well-designed carbon adsorption systems work, but these are complex if solvent recovery is employed (usually necessary for medium to large scale surface coating operations). Solvent recovery systems are problematic with high-molecular weight components, mixed solvents or water-miscible solvents common in some printing operations. Biofilters also have potential but to date no system has a satisfactory proven record in New Zealand.

Alternatively, if the focus of the Plan rules were curing ovens alone, as in the curent transitional requirements (second schedule to the Clean Air Act), then it would be possible to relax the threshold even further, because the capture efficiency of discharges from oven exhausts can be comparatively high. The Clean Air Act schedule specifies that any baking or drying processes with a heat release exceeding 500 kW is a ‘Part A’ activity and therefore discretionary under the transitional provisions of the RMA. This threshold could be relaxed considerably if incineration equipment was employed to control the discharge. With 80-90% VOC removal expected, curing ovens of over 2.5 MW will discharge similar quantities of VOC or odour to 500 kW units. Other issues associated with very large curing ovens may need to be considered however, one of which may be the scale of the collective combustion processes.

Some care is required when encouraging the use of afterburners. Thermal afterburners without heat recovery in particular are large energy users and this can have implications with respect to greenhouse gas concerns and energy efficiencies. Alternative technologies may avoid this concern, and recuperative systems should be preferred. It may also be preferable to design control systems into the plant. For example, afterburners that can be used as the principle source of heat for curing ovens.

### 3.2.2 Printing

Printing processes are different to other surface coating operations like automobile coating or appliance coating, because the application process involves rolling or pressing rather than spraying. In some cases this will result in a comparatively lower potential for solvent discharges. Cold-web printing for example (used with newsprint) involves high solid inks with high molecular weights and does not employ curing or drying technology.

Other printing processes can generate significant VOC and odour emissions, such as heatset web offset, flexographic, and gravure printing. These employ driers to cure the inks, and in some cases 40-90% of the total ink-solvents or ‘ink oil’ is evaporated in the driers. In other cases most of the VOC discharge is through fugitive emissions. More VOC discharges arise from cleaning solvents and fountain solutions (watered-down inks). Some of the VOCs discharged from web offset printing have characteristics that can lead to visible plumes of fume due to condensation. Some sheet printing operations use ultraviolet light curing and this has a low VOC potential.

It is considered that the Regional Plan could include heatset web offset, flexographic and gravure printing activities as discretionary activities if they use solvent-based inks and are above a suitable size threshold (measured by drier heat release, solvent or ink usage). While there is a substantial fugitive discharge from many printing operations, control of drier exhausts will reduce VOC discharges, and significantly reduce odour potential. The size threshold for discretionary activities could therefore be relaxed for those printing operations that employ effective incineration to control drier exhaust emissions. The degree to which it is relaxed should be limited by a factor of about 2 however, because of the potential for uncontrolled fugitive discharges. Thus, if printing process where normally considered discretionary by virtue of using a drier with a heat release of 500 kW, this could be extended to a maximum 1,000 kW (1 MW) if incineration was employed to control the drier exhaust.

Suitable criteria for incinerators on surface coating and printing operations could include: a design criteria for thermal units or performance criteria for catalytic units. Thermal incinerators capable of $750^{o}C$ with 0.5 second residence time in the presence of excess oxygen will achieve the required degree of control. For catalytic incinerators, a destruction efficiency of at least 95% is appropriate; or alternatively a VOC discharge of less than 20ppm with inlet concentrations less than about 400 ppm of total VOCs.

## 3.3 Metallurgical Operations

Most metallurgical operations are complex processes with a range of activities that discharge both gaseous and particulate contaminants to air. Many of the discharges can arise as fugitive emissions and some operations are potentially significant sources. For this reason it is anticipated that all medium to large-scale operations, such as foundries, galvanising plants and electroplating plants will be designated discretionary activities in the Regional Plan.

Employing appropriate add-on controls however, can control the majority of discharges from some small-scale metallurgical operations relatively simply.

### 3.3.1 Foundries

Foundries (both ferrous and non-ferrous) discharge gaseous and particulate contaminants from a range of individual operations. The greatest source of emissions are furnaces, pouring operations, shake out fettling and sand handling. Induction and reverberatory furnaces are the least polluting furnace-type generating approximately a tenth of the particulate discharges that arise from electric-arc and cupola furnaces. Table 3.2 lists some emission factors for grey iron foundries.

Control equipment applied to foundry operations usually focus on ventilating the furnace with a portion of fugitive emissions captured by part-ventilation of the working areas. In addition there are often separate controls on sand handling and fettling operations. The discharge removal efficiency is therefore dependant on how effectively the ventilation captures individual source emissions and fugitive discharges. A well-designed system should ensure the large majority of discharges from an induction or reverberatory furnace are captured and, with small foundries at least, it is possible to capture most of the fugitive discharges from general working areas at the same time.

- **Table 3-2 Particulate emission factors for various processes in a grey iron foundry (USEPA AP-42, 1996).**

| Process | Uncontrolled Emission factor (kg/tonne of iron produced) |
|---|---|
| Cupola furnace | 6.9 |
| Electric arc furnace | 6.3 |
| Electric induction furnace | 0.5 |
| Reverberatory furnace | 1.1 |
| Scrap charging and handling | 0.3 |
| Magnesium treatment | 0.9 |
| Refining | 1.5-2.5 |
| Pouring, cooling | 2.1 |
| Shake out | 1.6 |
| Cleaning and finishing (fettling) | 8.5 |
| Sand handling | 1.8 |
| Core making and baking | 0.6 |

The most common control equipment employed in foundries in New Zealand is fabric filtration, often with lime injection to protect against acid attack. Fabric filter systems are capable of removing over 90% (USEPA AP-42, 1996) of furnace particulate and also a portion of general odour. These systems are suitable for controlling furnace emissions, shake out and fettling emissions alike. Water scrubbers are also common, but these are less effective particularly for some of the very fine particulate and fume that some foundries produce. High-efficiency wet scrubbers can also have a high power consumption, mechanical wear and corrosion problems, and there is a need to deal with the contaminated water produced as a result of collecting the air contaminants.

It may be possible to relax a size threshold for those foundries designated as discretionary on the basis of them using fabric filtration equipment. This is particularly the case for small foundries that use induction furnaces (1 to 2 tonnes per hour of melting capacity). However, there may be some difficulty in specifying a suitable criterion for Rules in Plan that ensure efficient capture of fugitive discharges, particularly considering how foundry working areas and systems can vary considerably from site to site. A minimum percentage capture could be specified, but this may be difficult to measure thereby causing potential enforcement problems.

Nevertheless, on the basis that the majority of the total discharges from most small foundries come from the furnace, pouring, sand handling and fettling, it would be possible to relax the size threshold by a factor of 2 (say) if fabric filtration equipment was used to control all of these individual sources. A suitable condition in a Rule could apply a discharge limit for total particulate of 10 mg/Nm$^3$. A higher particulate concentration limit, (up to 50 mg/Nm$^3$) may be more suitable for smaller fabric filters particularly those attached to non-ferrous foundries where very fine particulate is generated.

### 3.3.2 Galvanising

Discharges from hot dip galvanising plants come from a series of open baths with the most significant being the molten zinc bath (galvanising kettle) used for the zinc coating stage. Discharges depend on fluxing methods, the nature of the material being coated and efficiency of cleaning and pickling. Contaminants discharged include particulate, fume and some gaseous components, and they arise as clouds or puffs from large surface area sources. This is essentially a fugitive discharge and it can be reduced by good management practices.

A very high level of control is possible for discharges from zinc baths by effecectively enclosing the baths, installing extraction systems and ventilating the discharge to control equipment. The current configuration of many existing plants in New Zealand may make full enclosure difficult but well-designed extraction systems on new plant should be able to achieve 90-95% emissions capture. Control equipment could include high-efficiency wet scrubbers, ESPs or fabric filters. For zinc bath control, fabric filtration (heated and with lime injection) has been used in recent applications and offers the most efficient system, achieving 90-99% removal of fume and particulate in the ventilation system. This gives an overall efficiency of at least 80% depending on the effectiveness of bath containment and extraction.

Thus, if galvanising operations over a certain size threshold were made discretionary under the Regional Plan, the threshold could be relaxed if they used fabric filtration equipment fitted to appropriate fume containment and ventilation systems. Any criteria should include extraction capture criteria in addition to fabric filter performance specifications. Like foundries however, there will be some difficulty in setting appropriate general criteria to ensure efficient capture of fugitive discharges. The ease at which galvanising baths can be ventilated depends on the particular process employed, but it is possible that the size threshold could be relaxed with fabric filtration used as control equipment. Again, a factor of 2 may be appropriate but larger size thresholds could be allowed, or even all-galvanising operations made controlled or permitted, if a minimum ventilation capture efficiency could be stipulated. Suitable performance criteria could be a particulate limit of 10- 50 mg/Nm$^3$ as commonly applied to fabric filters and other high-efficiency control systems.

Problems associated with galvanising plants will be minimal with fabric filtration equipment is used to control discharges from the zinc baths. Some care is necessary with the potential acid aerosols and hydrochloric acid emissions from pickling baths but this is unlikely to be significant unless sensitive receptors are located in very close proximity to the source.

### 3.3.3 Electroplating

Electroplating operations generate mists and fume caused by the evolution of hydrogen and oxygen gas generated in the plating tanks. As these gas bubbles rise to the surface, they escape into the air and may carry a considerable volume of liquid with them in the form of a fine mist. This is principally chromic acid mist with chrome plating processes, but other heavy metal compounds such as copper, nickel, cyanide, cadmium and lead can be discharged depending on the type of coating applied.

Emissions are also generated from surface preparation steps, such as alkaline cleaning, acid dipping, and degreasing. These emissions are in the form of alkaline and acid mists and solvent vapors. Like galvanizing activities, the discharge is relatively diffuse, coming from large tanks. Control of the discharges however is more effective with scrubbers than fabric filtration due to the emissions primarily consisting of fine mists.

Other techniques used to control emissions are fume suppressant chemicals, foam blankets, or polypropylene balls which float on the surface of the plating baths.

Ventilating the emissions to packed-bed scrubbers can remove at least 90% of total metal and other compounds or particulate over and above that already achieved through fume suppression techniques. Thus, if a size threshold for the discretionary status of electroplating activities is proposed, it could be relaxed on the basis of high efficiency packed scrubbers being employed. It is possible that the status of all electroplating operations could be relaxed, irrespective of size if this technology was used to control all discharges. The scrubber performance should be specified on the basis of minimum aerosol capture efficiency, but specific discharge limits are preferred, for example a chromium compound emissions limit of 0.05 mg/Nm$^3$, expressed as total chromium (USEPA BACT Rules for chromium electroplating).

## 3.4 Abrasive Blasting

Dry abrasive blasting operations are a significant source of particulate, primarily consisting of nuisance dust but there is some potential for toxic materials such as heavy metals (lead) or silica. For those abrasive blasting operations that can be totally enclosed however, it is possible to ventilate the enclosure to control equipment and remove most of this discharge.

Water scrubbers of various types are commonly used, including venturi scrubbers and impingement systems. The most effective control however is with a fabric filter, capable of removing over 99% of the discharge. All fully enclosed abrasive blasting operations could therefore have a reduced status in the Plan on the basis of using either high-efficiency scrubbers or fabric filters. Because different technologies will achieve significant reductions, it makes sense to set a discharge limit as a condition of potential rules. A limit that would represent a high level of control without restricting the use of a particular type of control technology, and 100 mg/m$^3$ would represent a suitable general limit for this activity. It may also be necessary to restrict the type of material being blasted (lead-based paint) and the abrasive material (silica).

This limit is not appropriate for abrasive blasting operations undertaken in the open, which are sometimes at least partially enclosed by using tarpaulins etc. With such enclosures it is not possible to guarantee more than minimla capture of dust discharges.

Obviously not all abrasive-blasting can be undertaken in a full enclosure but it is considered advisable to structure rules that encourage the use of fully enclosed systems as much as is practicable. Other less dusty systems should also be encouraged when it is not possible to enclose the work, such as wet and vacuum blasting systems. A description of different abrasive blasting systems however is beyond the scope of this report.

## 3.5 Mineral Processing

Most mineral processing and handling activities have the potential to generate fugitive discharges of dust. These discharges are controlled by a variety of means, but are clearly not suitable for add-on control equipment. Some activities however, are amenable to treatment by control technology and these include asphalt plants and those processing activities that can be effectively enclosed.

### 3.5.1 Asphalt Plants

Hot-mix asphalt plants discharge a range of contaminants, including particulate, carbon monoxide sulphur dioxide (if oil fuels are used), VOCs and other organic compounds. The most significant contaminants however are particulate or dust and to a lesser extent, odour. While a considerable amount of particulate from hot-mix asphalt manufacture is caused by fugitive dust generating activities such as vehicle movements and stockpiles, dust discharges from the drum mixing process (or dryer) can be controlled effectively. The most common asphalt making process is the parallel dum mix plant, and the most common emission control equipment employed in New Zealand is the venturi water scrubber. Fabric filter systems however, are being increasingly used. High pressure-drop venturi scrubbers can reduce discharges by more than 99% and this is similar performance to a fabric filter. Many plants in New Zealand however, employ medium to low pressure drop systems with emissions ranging from about 50 to over 500 mg/Nm$^3$. A discharge limit commonly applied in the Auckland region is 100 mg/Nm$^3$.

The current status of all asphalt plants is discretionary under the transitional provisions of the RMA. If plants use high pressure-drop scrubbers or fabric filters the discharges will be below 50 mg/m$^3$ (well below 50 in the case of a fabric filter) and this could represent a suitable performance criteria for activities with a relaxed status in the Regional Plan. Account needs to be taken of fugitive discharges however, so the location of the plant should be considered. Sulphur dioxide and other contaminants may need to be considered, depending on the type of fuel used to heat the drum mixer and the mixing process. Furthermore, fabric filtration may be the preferred technology because scrubbers can produce a significant visible steam plume and generate water treatment issues, although scrubbers can also be used to reduce sulphur dioxide discharges if water neutralisation is employed.

A conventional asphalt plant processing 50 tonnes per hour or aggregate will require a 4 to 5 MW burner and therefore generate approximately 2.5 kg/hr of sulphur dioxide if operating on diesel oil. Similarly, a 100 tonne per hour plant will generate about 5 kg/hr of sulphur dioxide. The actual discharge will be probably be less after gases pass through the particulate control equipment, particularly if a scrubber is employed, but these figures are the same order as a medium-sized oil-fired boiler. Therefore it makes sense to treat this discharge at least, in a similar manner to those from boilers. It may be advisable however, to limit the sulphur dioxide discharge or the type of fuel for those asphalt plants classified as controlled or permitted in the Plan.

Odour is also a potential issue. Some asphalt plants will generate a range of volatile hydrocarbons, which can cause odour downwind. This is difficult to predict, but the potential issue is sufficient to ensure that asphalt plants be located in relatively non-sensitive areas.

### 3.5.2 General Mineral Processing

Other mineral processing activities, such as handling, storage, crushing, and screening can be significant sources of nuisance dust but if they are able to be fully enclosed with building air ventilated to control equipment the discharge becomes considerably less significant. Like abrasive blasting operations described above, all fully enclosed mineral processing operations could therefore have a reduced status in the Plan on the basis of using either high-efficiency scrubbers or fabric filters to control ventilation air.

## 3.6 Crematoria

Crematoria are specialist waste incineration facilitates. Potential discharges include particulate, smoke and a ranging of products of incomplete combustion. The most effective way to reduce discharges is to ensure efficient combustion control. Good combustion control is related to the integral design of the cremator and its operation. The key to this is having good control over the primary chamber and having a final combustion chamber that is capable of achieving sufficient temperature and residence time for complete combustion. Consents for crematoria in the Auckland region have included conditions that require a final chamber temperature of at least 850°C for a residence time of 2 seconds in the presence of more than 6% oxygen.

The final combustion chamber acts as an afterburner or fume incinerator. However for a given afterburner design and size it is necessary to carefully manage combustion processes in the primary chamber so that the volume of gaseous products produced do not overload the afterburner. A particular issue with crematoria is when insufficient cooling has been allowed between successive cremation cycles. If a casket is added to the primary chamber when it has not allowed to cool after a previous cremation, there is a high potential for rapid uncontrolled combustion and volatilisation during the initial stage of incineration. This generates volatile-rich combustion gases, which often overloads the secondary chamber causing excessive emissions. To suppress rapid combustion during the initial stage, the air supply is restricted and the primary chamber operates as a controlled-air or pyrolytic incinerator.

It is therefore important that cremator operating proceedures be well managed. While a final chamber temperature and residence time can be stipulated and designed, it is important that these conditions be maintained. If conditions in a rule were to relax the status of crematoria they should at least include general operating conditions that provide for sufficient cooling time between cycles, in addition to afterburner temperature and residence time. It may also be necessary to consider the potential effects of mercury and other contaminants, particularly in certain sensitive locations. There may also be subjective or cultural issues associated with cremator discharges in certain locations.

## 3.7 Animal or Plant Matter Processing

It is very unlikely that certain animal or plant processing activities would have their discretionary status removed despite the use of advanced technology. Animal rendering plants for example, have a significant odour potential and the need for careful management of these processes is such that they will remain discretionary in most circumstances.

However, there are some activities where it may be possible to relax their discretionary status if they were to employ appropriate control equipment, and these are discussed below.

### 3.7.1 Fat and Oil Frying

Most deep fat and oil frying is undertaken on a small scale in restaurants and fast food outlets. These are typically uncontrolled operations, apart from the use of grease traps, but cause few problems by virtue of their small size. The discharge of cooking ventilation air in close proximity to sensitive receptors such as air intake vents or operable windows does cause some complaint however.

The large scale frying operations have a potential to generate significant smoke and odour problems and it is therefore expected that the Plan will designate these as discretionary activities. Currently such processes are listed in Part A and B of the Clean Air Act schedule when more than 5 tonnes per hour and 250 kg per hour of material is processed respectively.

Discharges from deep frying operations can be controlled by effective ventilation with grease and particulate filters followed by carbon adsorption to remove odours. This type of control technology is usually associated with the smaller restaurant–scale operations, where the filters and carbon systems are small enough to be manually cleaned or replaced. Large-scale operations use wet scrubbers or incineration. Wet scrubbers may remove up to 85% of particulate but probably have a limited effect on volatile odorous compounds. Incineration will achieve the highest removal efficiencies of both particulate and odour but this can be expensive due to the high moisture content of exhaust gases.

The 250kg/hr threshold for deep fat frying could be relaxed if incineration equipment was employed. While other equipment may be suitable, caution is advised with these alternatives. It is not easy to impose measurable performance or design criteria for this application. The design of wet scrubbers and carbon systems can vary considerably, and their performance will inevitably rely on good management. A discharge criterion in the form of an odour limit could be developed but it would be necessary to collect a large amount of olfactometry monitoring data before an appropriate limit could be set.

Therefore, incineration (at 750 $^{o}$C for 0.5 seconds) may be the only option for a condition specifying deep fat or oil frying as a controlled or permitted activity in the Plan. Unfortunately, this may be an unrealistic requirement for most deep frying operations, where wet scrubbing is typically employed as the most economic control option. It may therefore be preferable to specify this activity as controlled, in non-sensitive locations when wet scrubbing is employed. It is also considered this activity should remain discretionary if the scale is more than 5 tonnes per hour, due to potential discharges from ancillary activities and consequences if control equipment malfunctioned.

### 3.7.2 Meat and Fish Smoking

Meat and fish smoking operations are similar activities to the fat and oil frying described above. Most smokehouses are small uncontrolled operations and likely to be designated as permitted activities. Again, like oil and fat frying, the Clean Air Act second schedule lists curing by smoking in Part A and B if the processing capacity is greater than 5 tonnes or 250kg/hr respectively.

The design of large smoking operations may include natural or artificial smoke generation, batch processing or continuous processing. Filtration, wet scrubbing, ESPs or incineration can be used to control discharges from large smokehouses and incineration is the most effective option, with particulate, odour and various organic emissions reduced by at least 90%. Combined water scrubbing and ESP is probably the next best option in terms of control efficiency, with a similar level of control for particulate at least.

The 250kg/hr threshold for discretionary activities could also be relaxed for this activity if incineration was employed to control all smokehouse discharges. Like the deep fat and oil frying activities, it would not be advisable to relax the status of very large operations above 5 tonnes per hour.

### 3.7.3 Coffee and Other Bean Roasting

Large-scale coffee roasting involves the handling and cleaning of green beans followed by roasting, product treatment and sometimes chaff incineration in the plant’s boiler or a purpose incinerator. Discharges involve particulate (dust and chaff particles etc.) from the cleaning process and smoke, oils, odour and VOCs from the roasting process itself. Water quenching at the end of roasting generates steam, which may also carry oils and odorous products.

The roaster is the principal source of air discharges and any rules in the Plan are likely to focus on this particular operation. Currently, this activity is in the same category as frying and smoking in the Clean Air Act schedule and listed in Part A and B when the capacity is above 5 tonnes and 250 kg/hr respectively.

Incineration is the most common method for controlling emissions from roasters and these can be incorporated into the design of the roaster to provide the necessary heat. Some coffee roasting activities may require pre-collection of course particulate before ventilating to the incinerator. It may therefore be appropriate to also impose a particulate discharge limit in any rule, to compliment the incinerator design criteria.

The discretionary status of coffee roasting could be relaxed by taking a similar approach to the other animal or plant matter activities described above, with activities above 5 tonnes per hour remaining discretionary. It may also be necessary to take care over potential particulate emissions in this case however.

### 3.7.4 Milk Drying

The term ‘milk drying’ is likely to encompass a range of milk product processing activities, including whole milk and skin milk powder, whey powder, whey protein and lactose powder production. These activities are usually undertaken in spray dryers or fluidised bed dryer systems, which are indirectly heated. They have a potential to discharge particulate, aerosols and odour, but odour is usually a minor discharge. The drying operations also include product coolers and pneumatic conveying systems, which have a similar potential for particulate discharges.

Traditionally, emissions control has relied on high efficiency cyclones. However, fabric filtration is increasingly being used. It may be appropriate to develop a rule in the Plan that provides for a controlled activity status for small milk drying plants with fabric filtration equipment installed on dryers, coolers and pneumatic conveying equipment.

Large milk factories are complex industrial plants involving a number of activities that may discharge contaminants to air. They are large users of energy, so most plants employ thermal plant involving coal, oil or gas combustion activities, which may also be classified as discretionary. It is therefore not considered appropriate to relax the status of milk drying activities with a processing capacity of more than 5 tonnes per hour. In fact, it is likely that a rule for smaller plants may be redundant because there is a trend towards larger milk processing plants in New Zealand.

# 4. Possible Conditions for Rules in the Plan

The following section provides examples of expressions that could be used for conditions in certain Rules in the Regional Plan. With the Plan in its early drafting stage, it is not possible to provide specific rules and, in any case, this is beyond the scope of this report. The emphasis of these expressions is the technical criteria recommended. As such they represent a summary form of the discussion in Section 3. The particular wording or structure can be modified to fit into the Plan if the Council considers it appropriate. Furthermore, other general conditions may be included, such as nuisance odour or minimum chimney heights but they are not part of this discussion.

It was discussed at the beginning of Section 3 that certain discretionary activities could have this status relaxed on the basis of using appropriate control equipment. These 're-classified' activities should be designated either controlled or permitted depending on factors such as location and potential for adverse effects. Once again, it is beyond the scope of this report to determine exactly which activities should be controlled or permitted. However, the following proposed conditions are formed in the light of anticipated activity designations. They should be treated as preliminary recommendations.

Each activity will be discussed in the same order as in Section 3.

## 4.1 Coal and Wood-fired Combustion Processes

The following could be classified as permitted in relatively non-sensitive locations and controlled in sensitive locations, as defined by the zoning systems in the local District Plans:

*Coal-fired boilers with a heat release less than 20 MW, providing:*

*a) The sulphur content of the coal used is less than 0.5% by weight, and*

*b) The boiler is fitted with fabric filter or electrostatic precipitator equipment capable of achieving a total particulate discharge of less than 25 mg/m$^3$ (0$^o$C, 101.3 kPa, dry gas and 8% oxygen or 12% carbon dioxide).*

*Wood and woodwaste-fired boilers with a heat release less than 20 MW, providing:*

*a) No treated or contaminated wood or woodwaste is consumed,*

*b) The fuel has a moisture content maintained below x% by weight (dry basis) and*

c) *The boiler is fitted with fabric filter or electrostatic precipitator equipment capable of achieving a total particulate discharge of less than 25 mg/m$^3$ (0$^o$C, 101.3 kPa, dry gas and 8% oxygen or 12% carbon dioxide).*

It may be possible to define the term "treated wood" in the above condition by listing those treatments that are considered unacceptable to burn. This should at least include copper-chrome-arsenic treatments and possibly some modern insecticide and fungicide treatments. Borate treated woods however, are acceptable to burn providing the appliance refractory is designed for the purpose and excessive clinkering does not occur.

## 4.2 Spray Painting Operations

As discussed in Section 3, it is anticipated that the Plan may designate spray-painting activities as discretionary on the basis of the quantity of solvents used on site or the heat rating of the curing oven. The former option is considered a better indication of VOC discharge potential but it is not known what the threshold may be. The figure therefore is omitted from the proposed wording.

The following could be permitted in relatively non-sensitive locations and controlled in sensitive locations. Some caution should be exercised however, since there is a significant fugitive discharge potential and odour nuisance potential may remain even in industrial locations.

> *Spray painting and curing operations using less than X kilograms per year (or 24 hour day) of total solvents, provided the spray booth and curing oven are fitted with effective fume capture equipment and either:*
>
> *a) A thermal incinerator capable of achieving at least 750°C with a residence time of at least 0.5 seconds in the presence of oxygen, or*
>
> b) *A catalytic incinerator capable of destroying at least 95% of the total volatile organic compound (VOC) discharges, or less than 20 ppm total VOC in the incinerator exhaust if the inlet concentration is less than 400 ppm.*

> *Drying or curing of surface coatings in an oven with a heat release less than 2.5 MW provided the oven discharge is fitted with either:*
>
> *a) A thermal incinerator capable of achieving at least 750°C with a residence time of at least 0.5 seconds in the presence of oxygen, or*
>
> b) *A catalytic incinerator capable of destroying at least 95% of the total volatile organic compound (VOC) discharges or less than 20 ppm total VOC in the incinerator exhaust if the inlet concentration is less than 400 ppm*

Similar conditions could be applied to certain printing processes but possibly with different size thresholds, for example 1 MW for the total curing heat release.

## 4.3 Foundries

Because there is a significant fugitive discharge potential of a range of contaminants from associated processes (fettling etc.) it may not be advisable to make the metal melting operations permitted, unless there was certainty that all discharges were effectively captured to control equipment. The following could therefore be classified as controlled in non-sensitive locations.

> *The melting of any metal or metal alloys where the total melting capacity is less than 2 tonnes per hour, provided:*
>
> *a) Metal or alloys are melted in induction or reverberatory furnaces only, and*
>
> *b) At least 90% of discharges from the process can be captured by extraction and ventilation systems*
>
> *c) The captured discharge is ventilated to fabric filtration equipment capable of achieving a total particulate discharge of less than 10 mg/m$^3$ (0°C, 101.3 kPa, dry gas) and,*
>
> *d) the process is located in Business Zones 5 and 6 as defined by the relevant District Plan.*

## 4.4 Hot Dip Galvanising

As with foundry operations, galvanising processes have a significant fugitive discharge potential. It may not be advisable to make the galvanising operations permitted, unless there was certainty that all significant discharges were effectively captured to control equipment. The following could therefore be controlled in non-sensitive locations

> *Hot dip galvanising operations, provided:*
> *a) At least 90% of discharges from the zinc baths can be captured by extraction and ventilation systems,*
> *b) The captured discharge is ventilated to fabric filtration equipment capable of achieving a total particulate discharge of less than 10 mg/m$^3$ ($0^oC$, 101.3 kPa, dry gas)*
> *c) The process is located in Business Zones 5 and 6 as defined by the relevant District Plan*

Note that no size threshold is proposed in this example. Most galvanising operations are relatively small but it may be advisable to limit the size threshold to which the above conditions apply, perhaps the size of the baths could be used, or the quantity of zinc consumed.

The potential effects of discharges from pickling baths should also be considered, possibly by using a general no-nuisance condition, minimum building design requirements or restricting the location of these units.

## 4.5 Electroplating

Electroplating operations could be treated in a similar manner to small foundries and galvanising plants as above. Therefore, controlled activities could be:

> *Electroplating operations, provided:*
> *a) At least 90% of discharges from the process can be captured by extraction and ventilation systems,*
> *b) The captured discharge is ventilated to high efficiency packed tower scrubber capable of removing at least 90% of entrained electrolyte aerosols, and*
> c) *The process is located in Business Zones 5 and 6 as defined by the relevant District Plan*

It is preferable to express condition (b) above in terms of discharges of specific compounds. Unfortunately it is difficult to provide a general discharge limit that covers the range of different electroplating activities. However, specific discharge limits could be considered for chromium, copper, cyanide, cadmium, lead and nickel compounds, depending on the type of process.

## 4.6 Abrasive Blasting

The following could be permitted in insensitive locations and controlled in sensitive locations:

*Abrasive blasting operations, providing:*

*a) All blasting is undertaken in a permanent fully enclosed structure, and*

*b) The enclosure is effectively ventilated to fabric filter equipment capable of achieving a total particulate discharge of less than 10 mg/m$^3$ (0$^o$C, 101.3 kPa, dry gas).*

A similar condition could be applied to enclosed mineral processing operations.

## 4.7 Hot Mix Asphalt Plants

Some asphalt plants are located within quarries where significant fugitive dust potential exists. In these circumstances the asphalt plant discharges may not be significant compared to the other dust sources. It could therefore be possible make the following at least controlled or even permitted activities when located in such areas. If plants are located in more sensitive areas however, it may better to designate them discretionary irrespective of the level of add-on equipment.

*Processes for making hot-mix asphalt paving mixes, providing*

a) *Discharges from the drum mixer are ventilated to fabric filter equipment capable of achieving a total particulate discharge of less than 25 mg/m$^3$ (0$^o$C, 101.3 kPa, dry gas),*

b) *The sulphur dioxide discharge is less than 5 kg/hr, and*

c) *The process is located in Business Zones 5 and 6 as defined by the relevant District Plan.*

Some care is necessary, due to the potential for fugitive dust and odour discharges. An appropriate chimney height condition will also be necessary.

## 4.8 Crematoria

The following could be controlled or permitted in non-sensitive locations:

*Human and pet cremators, provided*

*a) Final chamber combustion conditions are such that a temperature of at least 850$^o$C is maintained for at least 2 seconds in the presence of at least 6% oxygen, and*

*b) Sufficient time is allowed between cremation cycles to allow the primary combustion chamber to cool to prevent rapid combustion and loss of the next charge or loss of control of primary chamber combustion.*

All cremators may need to be discretionary in sensitive locations due to cultural or subjective issues.

## 4.9 Animal or plant matter processing

### 4.9.1 Fat and Oil Frying, Smoking and Roasting

It may be appropriate to combine frying, smoking and roasting activities into one rule (similar to the second schedule of the Clean Air Act), and small to medium sized operations could be classified as permitted in non-sensitive locations or controlled in sensitive locations, as follows:

*Deep fat or oil frying of animal or plant matter, curing or flavouring by smoking and roasting of beans, berries or grains, provided*

*a) The raw material capacity is less than 5 tonnes per hour,*

*b) At least 90% of discharges from the process can be captured by extraction and ventilation systems,*

*c) The captured discharge is controlled in a thermal incinerator capable of achieving at least 750$^o$C with a residence time of at least 0.5 seconds in the presence of excess oxygen, or a catalytic incinerator capable of destroying at least 95% of the total volatile organic compound (VOC) discharges or less than 20 ppm total VOC in the incinerator exhaust if the inlet concentration is less than 400 ppm, and*

*d) The particulate discharge is less than 50 mg/Nm$^3$.*

Alternatively, deep fat and oil frying could be treated separately and be designated a controlled activity in non-sensitive areas as follows:

*Deep fat and oil frying, providing*

*a) The raw material capacity is less than 5 tonnes per hour,*

*b) At least 90% of discharges from the process can be captured by extraction and ventilation systems,*

*c) The captured discharge is controlled in an effective water scrubber,*

*d) The particulate discharge is less than 100 mg/Nm$^3$ and*

e) *The process is located in Business Zones 5 and 6 as defined by the relevant District Plan.*

### 4.9.2 Milk Drying

Milk drying processes could be classified as permitted in non-sensitive locations and controlled in sensitive locations as follows:

*Drying of milk powder, lactose or whey, provided*

*f) The raw material capacity is less than 5 tonnes per hour, and*

*g) Discharges from the dryer and product cooler are ventilated to fabric filter equipment capable of achieving a total particulate discharge of less than 10 mg/m$^3$ (0$^o$C, 101.3 kPa, dry gas).*

# References

Brenman B. M., Donlan M. and Bolton E., 1996, *Peat Biofiltraion as an Odour Control Technology for Sulphur Based Compounds* J.CIMEM, June 1996.

Buonicore A. J. and Davis W. T., 1992, *Air Pollution Engineering Manual* AWMA, Van Nostrand Rienhold, New York.

USEPA, 1996, *Compilation of Air Pollutant Emission Factors* AP-42 Fith Edition, Volume 1: Stationary and Point Sources. http//www.epa.gov/ttn/chief/

USEPA, 1998. U.S. EPA, Office of Air Quality Planning and Standards, *Stationary Source Control Techniques Document for Fine Particulate Matter*, EPA-452/R-97-001, Research Triangle Park, NC., October.

USEPA, CACT, 1998 Clean Air Technology Centre, Technology Fact Sheets. http//www.epa.gov/ttn/catc/

Rogers P, Watercare Services Ltd., personal communication June 2000).