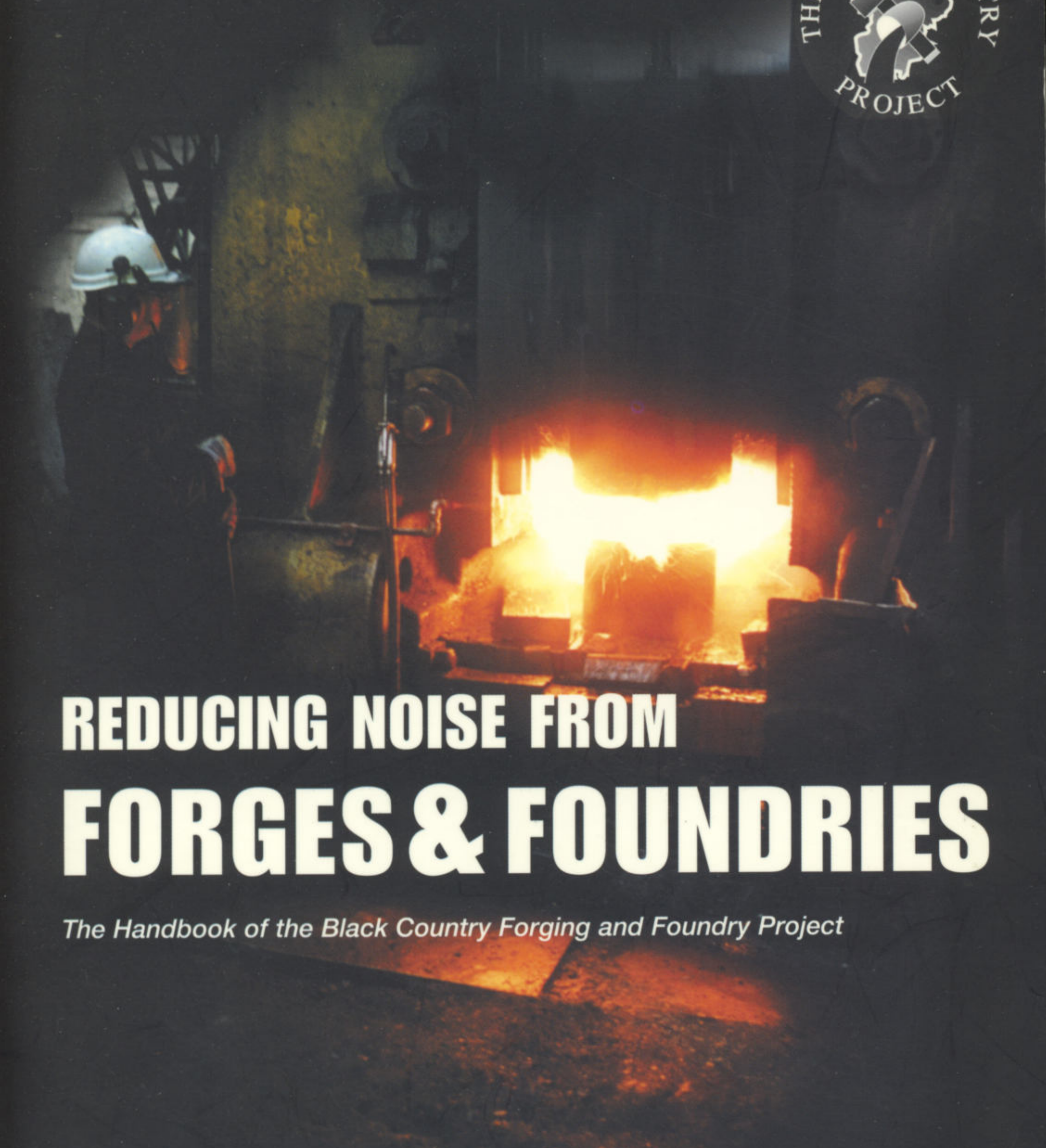
THE BLACK COUNTRY PROJECT



REDUCING NOISE FROM FORGES & FOUNDRIES

The Handbook of the Black Country Forging and Foundry Project

Supported by the European Regional Development Fund

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Contents Page

About this handbook

This handbook has been prepared as part of an EU-funded project centred on forges and foundries in the Black Country area of the UK West Midlands. The Black Country is a traditional centre for metalworking industries, and in many cases forges and foundries are situated close to housing. These industries are inherently noisy, and in recent years problems of noise affecting neighbours have become more frequent. In some cases, this has meant that foundries and forges have had to restrict their operations to such an extent that their viability has been threatened. The Black Country Project was designed to find out the main causes of noise problems from these industries and to identify and demonstrate practical solutions.

There is further information about the Project in Annex 1.

How this handbook can help

It gives practical advice on how to avoid or resolve noise and vibration problems affecting people living near forges and foundries. Although some of the information relates specifically to these industries, the same principles apply to most other industries. It is directed towards forge and foundry owners and managers, although it may also be useful to Environmental Health Officers, to others involved in noise assessment and control, and to residents who are bothered by noise from a forge or foundry. The Project, and this handbook, concentrate on community noise - noise escaping from industrial sites and affecting neighbours – rather than noise in the workplace, although often these go hand-in-hand.

This handbook gives basic explanations about noise and vibration – causes, methods of measurement and assessment, and principles of reduction. The emphasis is on practical methods of reducing noise. A number of noise control projects in forges and foundries are illustrated with information on costs and effectiveness. Noise and noise control can be complex mathematical and engineering subjects. This handbook can provide only general guidance.

Sources of further information and support are listed in Annex 3.

1 Noise and Vibration – basic questions and answers

1.1 *What is noise? How is it measured?*

Noise is unwanted sound. Sound is a form of energy which is transmitted through the air and is detected by the ear as rapid changes in pressure. The air is set into motion by the source of the sound, which is most often a vibrating surface or a turbulent flow of air. The loudness and character of a steady sound are determined by its **frequency** (measured in Hertz or Hz) and its **level (**measured in decibels or dB). In this handbook, noise levels will be stated in dB(A) – this is the noise level measured by a meter which simulates the response of the human ear to sounds of different frequencies. Noise levels in dB(A) are almost universally used for the assessment of noise in the community and in the workplace.

1.2 *How does noise affect people?*

Depending on the level of noise and the duration of exposure, noise can cause varying degrees of annoyance or difficulties in communication. It can disturb relaxation or sleep, or can have adverse health effects including damage to the hearing. This handbook is about noise affecting people living near industry. In this situation, the noise levels experienced are such that the worst adverse effects of noise are annoyance and sleep disturbance. Some noise may cause only minor and temporary irritation, but in other cases noise can cause such a strong reaction that an individual's ability to relax or concentrate is severely affected.

Peoples' response to noise, particularly to noise from outside their own home, is highly variable. Some people are far more or less tolerant than others, for a variety of reasons, many of them psychological. There are obvious factors such as 'lifestyle' – a person who is at work during the day is obviously less likely to complain about daytime noise than is the shift-worker next door who has to sleep during the day. However, an important factor is the attitude of the individual towards the source of noise – people are far less tolerant of noise if they think that the noise-maker is inconsiderate or unreasonable.

1.3 *What about vibration?*

Noise and vibration are inseparable – noise is generated by a vibrating surface or body of air or gas. However, vibration itself is a potential cause of problems. Some heavy engineering processes, particularly the operation of forging hammers, can result in significant energy being transmitted to the ground through machine foundations. This can be transmitted to nearby houses and can sometimes be felt as actual motion, because the human body is a very sensitive vibration detector.

1.4 *How does vibration affect people?*

High levels of vibration can cause physical personal injury or damage to buildings. However, vibration from industry affecting nearby houses is never so intense that there is any conceivable risk of any health effects, and building damage from any source of ground-borne vibration is extremely rare. However, vibration can be annoying and disturbing.

Apart from causing detectable (although in fact very slight) motion in nearby houses, ground-borne vibration from industry can also cause noise problems in these houses. This is because the internal surfaces of houses (walls, floors and ceilings) can be caused to vibrate by vibrations transmitted from the ground through the foundations and building structure. These surfaces can then radiate low-frequency noise ('thumps' and 'rumbles') rather in the manner of large loudspeakers. People living near factories containing equipment such as forging hammers, large presses or guilllotines can sometimes hear the resulting 'thumps' inside their houses, although the vibration itself – the actual motion of the structure – is too slight to be felt. Ground-borne vibration can also be detected in other ways – objects such as slightly loose central heating radiators, and glasses or china in light contact, may squeak or rattle.

Residents who can feel vibration, or hear the 'thumps' and 'rattles' it sometimes causes, are often more concerned about the possibility of damage to their houses (which is most unlikely to be caused) than they are annoyed by the actual disturbance to themselves.

Problems arising from ground-borne vibration are relatively rare, although drop-hammers can cause detectable ground vibration up to around 100 metres away, and sometimes at greater distances in some ground conditions. This handbook concentrates on the far more widespread situation where houses near forges and foundries are affected by airborne noise. However, the possibility of a 'noise' problem being a 'vibration' problem should be borne in mind - noises caused by ground-borne vibration must be distinguished from the effects of noise which is transmitted through the air (airborne noise) since different control methods are required and incorrect diagnosis can lead to costly wasted work. Further information about noise and vibration will be found in Annex 2.

1.5 *How much noise is acceptable?*

This section explains briefly the Standards and Regulations which apply to noise from industry in England. There may be minor differences and exceptions in Wales, Scotland and Northern Ireland. Different standards and Regulations will apply elsewhere.

From a new site or building...

Where planning consent is required for a new site, new buildings or a change of use, this consent often includes conditions to limit noise emission. These conditions might include restrictions on hours of use or methods of working, or they may specify maximum noise levels which are not to be exceeded at specified times of the day or night. These Conditions are enforced by the Local Authority. A breach of a planning condition can lead to an Enforcement Notice and prosecution. If noise affecting other premises amounts to a nuisance, a Local Authority can also use its powers under the Environmental Protection Act (the 'EPA' - see below) to abate the nuisance.

If there is an established use....

Many industrial sites do not have a formal planning consent, because a current use which has been carried on for more thanten years can be considered lawful. Many forges and foundries fall into this category. In these cases, if noise causes a nuisance to neighbours a Local Authority would use its powers under Section 80 of the EPA. If the Local Authority is satisfied that noise amounts to a nuisance, it has to serve an Abatement Notice. The company can appeal against a Notice within a specified period. Non-compliance with a Notice can lead to prosecution. If a company can show that it has applied the best practicable means of reducing noise (often termed 'Best Available Techniques' or 'BAT') this can provide a ground for an Appeal against the Notice or for defence against prosecution.

Where noise is causing a nuisance, private individuals can take action against an industrial site under Section 82 of the EPA, or under common law, even when the Local Authority choose not to do so. Such actions are rare, however.

When is noise a nuisance?

Noise is a nuisance when it materially affects people's amenity. There are no fixed limits for industrial noise affecting houses – what is or is not considered acceptable or a nuisance depends on local circumstances. However, the following table illustrates the general range of unacceptable and acceptable noise levels from industry in a 'typical' built-up environment of mixed residential and industrial areas.

	Acceptable	*Complaints Expected*	*Unacceptable*
Day (7 am – 7 pm)	50 – 55	55-60	60+
Evening (7 – 11 pm)	45 – 50	50-55	55+
Night (11 pm - 7 am)	40 – 45	45-50	50+

Table 1: Range of noise levels in dB(A) from industry – as measured outside nearby houses. Levels are average (L_{eq}) levels – see Annex 2.

These are 'broad brush' values and must not be taken as specific guidance for any particular site or situation. Higher noise levels might be acceptable in areas exposed to high levels of road traffic noise from trunk roads or motorways. Lower noise levels might be needed in quieter areas. An important factor is the character of the industrial noise. Noise which contains bangs and crashes is far more annoying and disturbing than steady noise of the same average level. The regular 'banging' caused by forging hammers is a particularly distinctive and potentially disturbing noise. For these types of noise, the noise levels in the Table should be reduced by at least 5 dB(A).

1.7 A widely-used British Standard

There is a British Standard (BS4142 - reference 1) which sets out a method of predicting whether noise from an industrial site is likely to provoke complaints. This standard is based on comparing the noise (measured or predicted) from the premises, as received at any house, with the background noise level at the same position when the industrial operation is stopped. The method includes a means of allowing for the 'character' of the noise, by penalising noise which contains bangs, crashes, whines or hums.

Evidence based on the use of BS4142 is generally accepted in the Courts to demonstrate (or to dispute) the existence of a noise nuisance. Noise limits in Planning Conditions are usually based on consideration of BS4142. The Standard is widely used (and often misused) and will inevitably be quoted whenever an industrial noise problem arises. However, proper application of the Standard requires expertise and judgement and a good understanding of its limitations.

1.8 Other Controls – Current and Future

Some companies operate voluntary environmental policies and procedures which include the assessment of noise emitted to their locality. These procedures might include, for example, regular noise monitoring at key locations and a method of assessing the extent of any change in noise emission likely to result from changes in plant or operating methods. Some companies formally accredit these policies under ISO 14001 (ref 2). In some sectors of industry, ISO 14001 accreditation is a customer requirement.

The introduction of Integrated Pollution Prevention and Control (IPPC) is likely to have a significant impact on the way noise from foundries and forges is controlled. IPPC will broaden the scope of exsisting pollution controls , which currently apply to certain industrial processes (including ferrous foundries and but excluding forges) to include noise and vibration. One objective of IPPC will be to encourage good practice (BAT).

1.9 Workplace noise

This handbook is not concerned directly with noise in the workplace, although reducing noise 'at source' by quietening a process or operation can often result in benefits both in the workplace and in the neighbouring area.

Noise levels in the workplace are covered in the UK by the Noise at Work Regulations 1989 (ref 3). An HSE document (ref.4) explains the Regulations and gives further guidance. New regulations on noise at work will appear in a revised EU Physical Agents Directive, currently being discussed. These changes will work through into UK regulations.

Summary - Standards and Regulations

Regulations and enforcement procedures relating to environmental matters, including management of noise, are constantly changing. As far as possible, keep up to date by extracting information from trade journals and government circulars. Trade Associations are a major source of such information.

2 Noise from forges and foundries

2 Noise from forges and foundries

2.1 *What makes noise?*

Noise (or sound) is generated in two ways:

By the vibration of solid surfaces which then act as noise 'radiators'. The vibration may be caused by an impact (such as the strike of a forging hammer or a casting being dropped on to a hard surface) or because of the action of rotating machinery.

By unsteady flows of air or gas. Examples are the flow of air over the blades of a fan, the turbulence within furnaces burning gas or oil, and the discharge of high-pressure compressed air.

2.2 *What are the main causes of noise from forges and foundries?*

Most industrial processes involve the use of machinery, the movement of materials, and the movement of air for ventilation, heating and cooling. All of these generate noise which can affect neighbours. The following lists show the sources most likely to cause people living near forges and foundries to complain about noise and vibration:

Forges

- Impact noise from hammers and presses
- Air exhaust noise from air-driven hammers
- Combustion roar from gas and oil furnaces
- Bar cropping
- Compressor houses, particularly if reciprocating compressors are used.
- Ground vibration from hammers

Foundries

- Fans on ventilation and dust collection systems.
- Fettling and grinding to remove flash and sprue from castings.
- Loading furnaces (particularly cupolas) - impact of material on feed hopper
- Deliveries of sand and clay (usually using blowers mounted on delivery vehicle)
- Shakeouts

Sources common to both industries

- Outside operations, particularly truck movements in stockyards.
- Movement and tipping of materials and scrap – impacts of castings and forgings in stillages, bins and hoppers
- Alarms, Tannoy systems, vehicle reversing buzzers
- General activity noise – from yards, car parks and open doorways. Shouting, door slamming and music noise can be a particular problem at night, from any industrial premises.

These noises can be grouped under three headings:

- **Breakout of process and machinery noise from buildings**, through the building fabric or through openings, including doorways and holes providing ventilation.

- **Noise from ancillary equipment** installed externally or in perimeter plant rooms - air compressors, cooling towers and heat exchangers, dust extraction and sand reclaim plants etc.

- **Noise from external activities**, particularly movement of materials by forklift truck and the associated impact noise.

3 Reducing Noise - the principles

There is no 'standard' method of reducing noise from forges and foundries. Each site and its surroundings is different, and each will have different 'main' noise sources. This handbook offers examples of noise reduction solutions which have worked on some sites, and also explains the basic principles which lead to these solutions. The basic principles first.......

3.1 How does sound travel?

Noise travels through the air as a pressure disturbance. Moving further away from the source, the noise level generally decreases because the sound energy is distributed over a larger area. In a simple case, the sound level reduces by 6 dB each time the distance from the source is doubled (the 'inverse square law'). This rule does not always apply: for example, close to a large noise source such as the wall of a factory the noise level does not start to fall off with distance until you are some way from the wall.

This means that if a factory produces a noise level of 55 dB(A) at a house 200 metres away, the noise from the factory will be reduced to about 49 dB(A) at 400 metres. This is not a very dramatic reduction, even over quite a large distance. Relocating equipment or operations on a site to move them further away from houses (unless they are then screened by an intermediate building) may not be a very effective measure.

3.2 Can noise be contained?

If a source of sound is enclosed within a solid 'box', the sound energy emitted is reduced because a solid material has the property of sound insulation – only part of the noise energy striking one side is radiated from the other side. The heavier the material, the greater the sound insulation. Materials made up in the form of multiple layers (an example is double glazing) provide more sound insulation than a single layer of the same total mass. Values of sound insulation, like sound levels, are stated in dB or dB(A). Typical values of sound insulation are shown on Table 1 (overleaf).

Note that because decibels are logarithmic units (see Annex 2) the normal arithmetic rules of addition and subtraction do not apply. A noise reduction of 10 dB means that the original sound energy has been reduced by a factor of 10, a reduction of 20 dB means a reduction in sound energy by a factor of 100, 30 dB means a reduction by a factor of 1000 (that is to 0.1% of the original energy).

Single Panels	Weight kg/m^2	Sound Insulation*
10mm plywood / chipboard	5	15 dB
12mm plasterboard / 1.2mm steel / 4mm glass	10	20 dB
3mm lead	35	35 dB
100mm lightweight concrete	100	40 dB
115mm brick	200	45 dB
200mm concrete	400	50 dB
Double Skin Panels		
0.9 + 0.55mm steel, 150mm spacing, mineral wool infill	20	35 dB
Double glazed window, 6mm glass, 100mm airspace	30	40 dB

**figures are approximate average values for sound at mid-frequencies (250 - 1000Hz)*

Table 1: Typical values of sound insulation - different materials

An enclosure can only provide good sound insulation if it is reasonably airtight. Noise will escape through any direct air path. An enclosure with holes amounting to 10% of its surface area will provide only 10 dB of sound insulation, however heavy the material the solid parts are made of To provide 30 dB sound insulation, as well as being built of a suitably heavy material the total area of air gaps in an enclosure has to be less than 0.1% of the total area – a tall order.

3.3 Does sound travel in straight lines?

Sound is reflected from hard surfaces such as walls and roadways in much the same way as rays of light are reflected from a mirror. Some materials and surfaces – grassland and undergrowth, porous materials such as glass fibre blankets – absorb some sound and reflect only some of the sound striking them, as a dark surface reflects only some of the incident light. However, it can be misleading to compare the behaviour of sound with that of light. One significant difference is that sound is refracted round obstacles such as fences and buildings – it 'travels round corners'. It is a common observation that things (voices, cars etc) can be clearly heard even when they are not visible. There is some 'noise shadow' effect when a source of noise is hidden from view, but it is a limited effect. This is why attempts to reduce noise by building a wall or fence to hide a source of noise often produce disappointing results. For the same reason, noise radiated from the roof of a factory cannot be ignored even if the roof cannot be seen from a particular nearby house. Roofs are usually the largest part of a building, in terms of surface area, and are often the weakest in terms of sound insulation because the sheeting is light in weight and usually has openings for ventilation.

3.4 *What levels of noise are we dealing with?*

Noise levels in casting and finishing areas in mechanised foundries are generally around 85 – 90 dB(A). Shakeout machines (unless enclosed) can give higher levels, depending on the sizes of castings and core boxes.

Levels in forges where hammers are used are generally 95 – 100 dB(A). Because of the highly impulsive nature of hammer noise, this is the major problem facing forge operators.

How do these noise levels relate to levels outside the foundry or forge?
Table 2 shows what noise levels might be expected at different distances from a typical building (with a floor area of 1000 m^2) with average internal noise levels of 85 or 95 dB(A). The building is assumed to provide 15 dB(A) sound insulation – this is a typical figure for a building with lightweight single-skin cladding and open doorways and ventilators.

Noise level inside	*Noise level at distance outside*			
	100	*200*	*400 metres*	
85 dB(A)	52	46	40	dB(A)
95 dB(A)	62	56	50	dB(A)

Table 2: Noise radiated from a lightweight building.

If these numbers are compared with the rough 'guideline' values on Table 1, it is clear that forges in particular present a major difficulty. Even 400 metres away, a forge in a lightweight building will give rise to a noise level 10 dB(A) above what might be judged reasonable in the early morning or late evening, and at distances of 100 metres or less is likely to produce unacceptable levels of noise during the day. Larger buildings will produce rather higher levels.

Noise levels in the range 50 – 65 dB(A) are commonplace in residential areas close to working foundries and forges.

4 Noise Reduction in Practice

4.1 *Reducing noise at Source*

The most effective way of reducing noise is usually to avoid making noise in the first place - to use a quieter machine or process. Unfortunately this is often not practicable. For example it would, in theory, be possible to design a 'quieter' forging hammer. Forging presses are less noisy than hammers (although by no means quiet). However, most forges and foundries will be using existing machinery and processes for the foreseeable future.

However, there is some scope for noise reduction at source, even in an existing forge or foundry. When new ancillary equipment such as an air compressors or a ventilation system is installed, there is often a choice between noisy and quiet equipment to do the same job. It is not unusual for a company to buy new equipment without consideration of noise levels and create a 'new' noise problem.

Always obtain information on noise levels when buying new machinery or tools. This is particularly important for equipment to be located outside or in a plant room which is directly ventilated to outside through louvres, such as dust collectors, heat exchangers or compressors. Suppliers are legally obliged to provide such information. You may need to take specialist advice to interpret the information, and on whether you should specify a maximum noise limit for new machines, and what this limit should be. A visit to see and hear the same machine working on another site is often a good way to assess the likely noise levels.

Equipment is usually noisier if it is defective. Worn fan motor bearings, or a badly-maintained clutch on a drop hammer, can produce distinctive noise which might not seem like a problem on the working site, but might be very annoying to neighbours.

Reducing Impact Noises

Many noises in forges and foundries arise from hard metal-to-metal impacts. The main problem is the noise caused by small forgings or castings falling into hoppers, on to chutes and tables, or into bins ('stillages'). The resulting 'crashes' are frequent causes of complaint from neighbours.

These noises can often be reduced by low-cost methods. For example:

Reducing the number of transfer operations. In most forges and foundries, pieces are tipped from stillage to hopper or bin and returned to stillage several times between production and the end of finishing operations. A review of working methods and re-design of fixtures can often reduce these operations.

Reducing the height from which pieces fall on to hard surfaces. Sometimes this is difficult to control - a crane driver moving scrap metal using a magnetic crane has considerable freedom. However, some measures are effective: for example, raising stillages at fettling stations or at the discharge of shot-blast machines, using a simple fixture to reduce the drop distance, can be effective.

The main problem with steel stillages, hoppers, chutes and benches is that they 'ring' when struck by a metal object. This 'ringing' can be reduced by reducing the impact force using a resilient surface covering, by 'deadening' or 'damping' the response of the structure being hit, or by making it a less efficient radiator of noise. Examples of these techniques are illustrated in the case studies in Section 5.

There is no great problem in producing a 'quiet' stillage, which does not 'ring' when metal pieces are thrown or tipped into it. However, there are thousands of stillages in use, which circulate between final customers, forges and foundries, heat treatment and machining companies. The universal introduction of quiet stillages (which would invariably cost more than the standard steel stillage) is therefore an unrealistic aim. However, a company might find it practicable to have a number of 'quiet' stillages dedicated to a particular task or area, to resolve a particular problem For example, it might be possible to use a small number of 'quiet' stillages to take scrap from an external stockyard to the furnaces.

Summary - Reducing Noise at Source

Always be on the lookout for ways to reduce noise.

Never buy a new machine or tool without considering its likely noise levels.

Noise reduction should be a key element in process engineering - quieter methods can often be introduced in conjunction with changes designed to improve efficiency or quality.

Where you have houses near your site, especially if noise has caused problems in the past, make a regular 'patrol' of the site boundary to identify new noises and possible defective equipment.

Identify operations where there are frequent metal-to-metal impacts. Eliminate unnecessary material transfers. Reduce impact forces by reducing drop heights, 'cushion ' impacts using resilient linings, make stillages, chutes, and tables less effective noise radiators.

4.2 'Boxing In' the noise - Enclosures

Noise emitted from machines and operations can be reduced by enclosing them. Enclosures present some problems - they may obstruct access, they take up floor space, and if personnel have to work inside they may present a hazard. However, sometimes enclosures are effective solutions to noise problems. To be effective, enclosures intended to reduce noise must have good sound insulation properties. To provide a high degree of sound insulation, as explained in para. 3.2, enclosures must be reasonably heavy and well-sealed to eliminate direct air paths. However, lightweight enclosures, with some openings, often provide useful attenuation. For example, an enclosure made from overlapping PVC strip curtains can provide a noise reduction of around 10 dB(A). Such enclosures have been used with some success around foundry shake-out stations, to control dust as well as noise. They have the advantages of providing ready access and reasonable vision, although they are not very durable and obviously cannot withstand contact with hot castings.

For noise reductions greater than about 10 dB(A), careful design is needed to deal with features such as access doors and openings for materials. There are numerous specialist suppliers of 'acoustic' enclosures. Proprietary enclosures are built up using modular sheet steel panels with an internal lining of mineral wool faced with perforated steel sheet. This sound absorbent lining reduces noise reflections within the enclosure, which would otherwise lead to a 'build-up' of noise inside and resulting inferior performance. Effective enclosures can also be built (at a lower cost) using brick or concrete blocks, timber, plasterboard or materials such as wood-wool cement slabs, although without specialist advice results may be disappointing.

Forges and foundries can be tough environments. Enclosures round machines need to be well-engineered and robust to withstand assault from fork lift trucks, for example. If buying an enclosure from a specialist supplier, find a supplier with specific experience in these industries.

Examples of acoustic enclosures fitted to shot-blast machines are described in the case studies in Section 5.

Summary - Enclosing noise sources

Enclosing individual machines or processes to reduce noise can be effective, but the drawbacks (access, space, creation of workplace hazards) should be carefully considered.

The effectiveness of an enclosure in reducing noise depends on the detailed design. Seek specialist advice.

Enclosures in forges and foundries must be robust. A badly-engineered enclosure of unsuitable materials will require regular repair during a limited life.

4.3 Building Treatments

The buildings which house a forge or foundry can be thought of as a large acoustic enclosure - the sound insulation provided by the building determines how much noise escapes to annoy neighbours. Most forge buildings are of lightweight construction, with many openings for ventilation. The noise reduction afforded by such a building is poor, usually no better than 10 - 15 dB(A). (Foundry buildings tend to be rather better than forges in this respect, because more stringent environmental controls have led to the widespread introduction of mechanical ventilation, with cleaning systems to remove dust and fumes. There is therefore less reliance on natural ventilation and fewer openings in the buildings to provide escape paths for noise).

Inside an enclosed space with solid surfaces the level of noise builds up because of the repeated reflections of sound from the walls, floor and roof - this effect is termed 'reverberation'. Treating the internal surfaces with sound-absorbent (less reflective) materials will reduce the reverberant noise. Reducing the noise level inside a building reduces the level outside by the same amount. However, the installation of internal sound-absorbent treatment does not have a dramatic effect - a reduction of around 5 dB(A) in average noise levels might be achieved by lining the inside of the roof. The most widely used material is semi-rigid boards of mineral wool, 50mm thick, which can have a woven cloth or very thin plastic facing to resist dust contamination. For new buildings (or re-sheeting) some proprietary double-skin steel sheeting systems have a perforated inner skin which exposes the mineral wool between the skins and provides sound absorption, although the actual sound insulation of these systems (the resistance to sound passing through) is inferior to that of two solid skins.

The obvious way of reducing noise from a building which contains numerous noise sources (for example, a forge with a number of drop hammers) is to improve the sound insulation of the building itself, to keep the noise in. This is rarely a simple task. Improving the sound insulation of the actual cladding of the building (often single-skin metal sheeting) means adding considerable weight, which may not be possible without strengthening the structure. More fundamental is the need to limit the escape of noise through openings, which have to be closed off or greatly reduced in area. This immediately presents a problem with ventilation: high air change rates are needed to maintain reasonable working temperatures, particularly during hot weather. Access to and from the building is required, and an open doorway will provide a large noise escape path. Doors must therefore be kept open for a minimum time, and when closed must provide sound insulation to match that of the rest of the building. At an existing forge or foundry it is unlikely to be possible to suspend operations whilst major building works are carried out, which further limits the scope of practicable works.

It is tempting to believe that treating only part of a building, perhaps just the wall facing nearby houses - will reduce noise significantly. As explained in 3.3, noise 'goes round corners'. The noise which reaches neighbours is coming from all parts of the building, including the parts which cannot be seen. The roof of a building is usually of much greater total area than the walls, and is often of lighter construction. Improving the sound insulation of the walls of a building, without treating the roof, is almost always ineffective. An acoustics specialist with experience of industrial buildings can identify the contribution of each part of the building to the noise level at any point outside, and design a suitable 'balanced' package of insulation works.

One of the pilot projects involved extensive modifications to a forge building, involving the installation of a second external 'skin', easily-operated acoustic doors, and a system of mechanical ventilation which allowed other ventilation openings to be closed off. Adding a second skin outside the existing sheeting has several advantages - the building can be made more weatherproof, appearance can be improved, and the work can often be carried out without disrupting production. This project is described in para. 5.2.

Summary - Building Treatments

If a building contains many sources of noise, improving the sound insulation of the building could to be the only practicable means of reducing noise escaping to outside.

It will usually be necessary to treat large areas of the building - at least 3 walls and the roof - to achieve a significant noise reduction.

Holes and openings must usually be closed off, and a mechanical ventilation system installed.

Assistance from an acoustics specialist, structural engineer and heating/ventilating engineer is generally essential. Planning consent may be required.

Building modifications are expensive. However, a scheme has been demonstrated in the course of this project which has proved to be effective and practicable, and was installed without disrupting normal production to any appreciable degree.

4.4 Screens and Barriers

It is often assumed that hiding a source of noise from view will reduce or eliminate the noise. Because sound goes round corners (unlike light) the effect of placing a physical barrier (a wall or fence) between a source of noise and a listener is quite limited. This is particularly true for low-frequency noise (such as a dull rumble) which passes round a barrier very readily, whereas high-frequency noise (such a high-pitched whistle) behaves more like light and can be screened more effectively.

Screens can be effective in reducing noise from a small source (such as a cooling tower or an open doorway, for example) escaping in a particular direction. A screen is most effective if placed near the source or the receiver (see diagram), because the noise reduction is higher if the angle ‘a’ is greater. For the same reason, a large screen is more effective than a small one, even though both may hide the noise source from view.

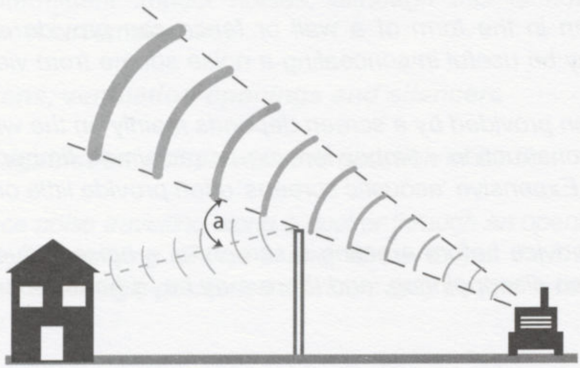


Fig 1: Acoustic barrier - (close to source or receiver and as high as possible to increase angle 'a' for more noise reduction.)

Because the noise reduction provided by a screen is limited by the noise which passes over the top and round the edges, the screen does not need to provide very high resistance to noise passing through it. As a screen, a close-boarded fence will provide the same noise reduction as a brick wall or earth mound of the same height and width. However, on a factory premises a robust form of screen is needed. Timber sleepers slotted into vertical steel columns can serve as a useful and durable screen, and can also form (for example) material bays in a foundry stockyard.

In practice, a screen is unlikely to provide a noise reduction of more than 5 - 10 dB(A). A screen may have a psychological benefit as well as an acoustic one: for example, a screen which conceals a lighted doorway at night, or which prevents local residents observing truck movements in a factory yard, may satisfy complaints even though the actual noise reduction is quite modest.

Screens can be expensive and are rarely a cost-effective solution to a noise problem. Proprietary 'acoustic screens', primarily intended to be used as noise barriers alongside trunk roads and motorways, are widely promoted by the manufacturers for more general use but in many applications are no more effective than a simple close-boarded timber fence (although they are constructed to a higher specification and would be more durable). Specialist advice should always be obtained before erecting a screen in an attempt to reduce noise - there is often a better way of achieving the same effect.

Summary - Screens and barriers

A barrier or screen in the form of a wall or fence can provide a modest noise reduction, and may be useful in concealing a noise source from view.

The noise reduction provided by a screen depends mainly on the width and height. Cheap forms of construction - timber fencing or reclaimed timber sleepers - are usually adequate. Expensive 'acoustic screens' offen provide little or no advantage.

Obtain specialist advice before erecting a screen as a noise reduction measure - the results are often disappointing, and there may be a better solution.

4.5 Air-moving systems

Ventilation and dust-extraction equipment are regular causes of noise problems. The main noise source is the fan powering the system. Ventilation openings such as louvres to compressor houses can also transmit noise to outside. Any passage, duct or opening which permits the flow of air will also transmit noise. Note that the transmission of noise along an air passage or duct is not affected by the direction of air flow - it is a common misconception that noise travels 'with the flow', so that no noise escapes from an air inlet opening such as a fan intake. The reason is simple - sound travels at about 330 metres per second in air, and it is hardly impeded by the flow of air in a ventilation duct which would rarely exceed 20 m/s.

Noise emitted from fan intakes or exhausts, or from exhaust stacks and louvres, can be reduced using silencers. These are of various types, but they generally contain passages lined with porous sound-absorbent material, which 'take out' noise whilst permitting air to flow through. Silencers almost always restrict the airflow and may reduce the performance of a system - this has to be taken into account.

The positioning of a silencer can also be important. A silencer too close to a fan can disturb the air flow and make the fan noisier. A silencer too far from a fan, connected by a duct, may allow noise to 'break out' through the duct before it reaches the silencer. Selection of silencers, and choosing where to put them, is a specialist job.

Beware of making fans and equipment containing fans (such as cooling towers) too quiet. A continuously running fan, as long as the noise it makes is 'smooth' in character, may actually be useful in masking intermittent noises from other sources. There have been many cases where factories have spent a great deal of money and effort in reducing noise from fans and have provoked more complaints because bangs and crashes, previously masked by fan noise, became audible. (Some neighbourhood noise problems have actually been solved by introducing continuous noise - and hence actually **raising** average noise levels - to conceal intermittent impact noises, although this is not a recommended approach in most circumstances).

Summary - Fans, ventilation openings and silencers

*Noise travels **against** as well as **with** the direction of air flow*

Silencers reduce noise travelling along a duct or through an opening whilst permitting the flow of air. Specifying silencers and where to put them is a specialist job. Incorrectly sized or wrongly-positioned silencers may be ineffective and can seriously reduce air flow.

*Before reducing noise from a fan, make sure that it is not doing a useful job by masking other more intrusive noises - noise **control** does not always mean noise **reduction**.*

4.6 Site Layout and Management

Some industrial sites are laid out in a way which almost invites complaints from neighbours, with the noisiest (and most visually intrusive) areas and buildings close to a boundary shared with a residential area. This is often historical ("the factory was here before the houses...") and major reorganisation of a site is not often feasible. When designing a new site, the major sources of noise and visual impact can be identified and located away from a sensitive boundary, perhaps using 'quieter' buildings such as a warehouse or office block as a 'buffer'. This is usually a matter of common sense, not acoustics.

Even on existing sites, some changes in layout may be possible. One Black Country foundry had a long-standing problem caused by noise from the stockyard which faced houses across a residential road. Deliveries of scrap iron and coke, and movements of the crane and trucks in the yard, were regular causes of complaint. As part of a programme of general improvements to the site the stockyard was relocated to land previously used as the employees' car park, further from the houses, and screened from view with a barrier of timber sleepers. This has successfully reduced the problem of stockyard noise.

Even without a change in processes or site layout, noise problems can sometimes be resolved by relatively minor changes in the way an industrial site is operated and managed. Such 'non technical' measures might include:

- Relocating doorways to face away from houses.
- Shutting off 'Tannoy' systems and muting alarms during unsocial hours.
- Relocating tanker discharge points.
- Providing additional internal storage areas to limit the need for outside truck movements, especially at night.
- Resurfacing external areas. Fork lift trucks are notoriously noisy on uneven surfaces, especially when unloaded or carrying an empty steel stillage.

The need for such measures can only be established by carrying out regular assessments of noise from the site, as experienced by neighbours. Some problems do not need the services of an acoustics specialist to find a solution - an employee with a good knowledge of the site operations can sometimes define the problem and identify the solution better than the 'expert'.

People living close to forges and foundries in the Black Country are generally extremely tolerant of noise from these premises, at least during reasonable daytime working hours. Residents are most likely to complain if they experience some noise which they believe to be unnecessary - a door to a noisy shop left open, shouting and revving of a truck engine in the yard, or a radio being played loudly. These problems can be avoided by adequate management control and the development of greater 'noise awareness' amongst employees.

Last, but by no means least, any company should have a proper method of dealing with complaints from local residents. Experience shows that if a company deals with complaints in a courteous and organised way and makes efforts to reduce 'avoidable' noise, then residents are far more tolerant of other noise (for example, from drop hammers) which they appreciate is difficult for the company to reduce whilst staying in business.

Summary - Noise Management............

On many sites with noise problems, some benefit could be obtained by relatively minor changes to the layout of the site. Such changes should always be considered before embarking on 'acoustic' remedies.

Consider how noise can be reduced by management measures. Avoid unnecessary noise, make employees 'noise aware'.

Develop good relationships with neighbours. Respond quickly to complaints.

4.7 Noise Reduction – Overall Strategy

Noise from an industrial site often arises from a number of separate sources. There are many ways of controlling noise, but each noise problem is different. Many attempts at reducing noise from industrial sites have failed because the problem was not properly identified, and inappropriate control measures were carried out. Before attempting to reduce noise affecting neighbours, it is essential to develop a strategy to address the following key points:

Establish the target for noise reduction.

What are the noise levels at the houses affected? What noise levels would be acceptable?

Identify the noise sources

What are the noise sources which contribute to the problem?
Sometimes this is obvious. However, often it is necessary to make detailed measurements, perhaps with equipment operated individually or in groups, to find out how much each source contributes to the overall noise. Remember that noise measurements do not tell the whole story – some noises cause far more annoyance than might be expected from the actual measured noise levels they produce. A visit to a complainant's house to listen to the noise from your site can be most instructive, and sometimes reveals an obvious solution to a problem.

Set a reduction target for each source

Some sources of noise will be more important than others – they will not all need the same degree of reduction. However, the difficulty and cost of reducing noise from each source must also be considered. As an extreme example, if there are ten equal sources of noise, a reduction of 10 dB(A) could be achieved by reducing the noise of each source by 10 dB(A). Alternatively, you could reduce the level of nine of the sources by 30 dB(A) and leave the 'difficult' source unchanged, to achieve the same effect. The objective is to develop the most effective and economical package of works to achieve the overall result.

Take advice, but retain control

Solving noise and vibration problems often needs specialist assistance, from a consultant or noise control equipment supplier. Trade Associations can usually help to locate a source of advice. However, do not rely on an outside specialist to arrive at the best strategy. He/she will not be fully conversant with your operations, and noise control equipment suppliers may be inclined to concentrate on solutions which use their products. The close involvement of company employees (perhaps the Works Engineer or one of his staff) is essential to reaching a practicable solution to any industrial noise problem.

5 Pilot Projects

Three pilot projects were part-funded within the overall Project. Other projects were proposed but were not taken up by the companies concerned, because of financial or other constraints.

The projects were intended to demonstrate specific principles, and to assess the effectiveness of remedial measures which in some cases have not been systematically applied and evaluated elsewhere. They were not necessarily expected to provide a complete solution to a noise problem, and it was anticipated that some would reveal practical drawbacks which would limit their usefulness.

5.1 Project 1 - *Chamberlin and Hill, Bloxwich*

This is a foundry close to a residential area. The nearest houses share a common boundary with the yard area, beyond which is the finishing building, where castings are fettled and inspected. This building is of part-brick construction, with steel sheeting to upper walls and roof. There are three doors giving access to the yard. The finishing building also serves as a despatch area: castings in bins or on pallets are loaded on to vehicles in the yard by forklift truck, using one of the doors. The general layout is shown below.

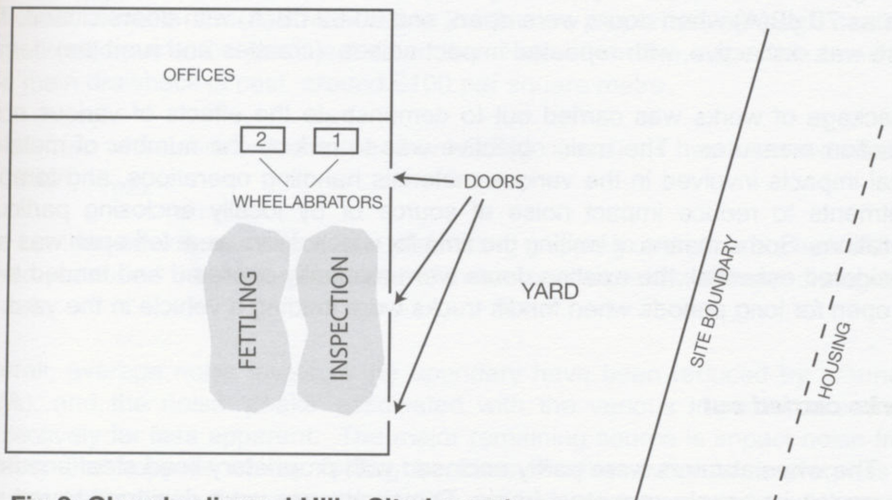


Fig 2: Chamberlin and Hill - Site Layout

An initial inspection revealed a number of noise sources, audible in the yard. All were intermittent in nature and most were caused by metal-on-metal impacts:

- Loading and unloading of the two 'wheelabrator' machines. Castings are loaded into the machine drum from a hopper,which is loaded from a tipping bin using a forklift truck, and after tumbling are tipped out from the drum into a stillage.

- Loading hoppers at fettling and inspection stations. Fettling operators and inspectors are supplied with castings from steel hoppers, which are regularly loaded with castings from a tipping bin using a forklift truck. This tipping operation causes a loud crash.

- Individual castings are dropped into bins after fettling. When bins are near empty, this causes a metallic clang as the casting strikes the inside of the bin. This effect is reduced as the bin fills, because (for most castings) the noise of a component falling on other components is somewhat less.

- Inspected components are dropped on to steel chutes and slide down into finished product bins. This is a frequent occurrence (one impact for every component made) and a significant contributor to overall average noise levels.

- Fettling of components, to grind off sprue and flash, results in some distinctive high-pitched noise.

Average noise levels in the yard area, close to the boundary, were sometimes as high as 70 dB(A) when doors were open, and 60-62 dB(A) with doors closed. The noise was distinctive, with repeated impact noises (crashes and rumbles).

A package of works was carried out to demonstrate the effects of various noise reduction measures. The main objective was to reduce the number of metal-to-metal impacts involved in the various materials handling operations, and to apply treatments to reduce impact noise at source or by locally enclosing particular operations. Some means of limiting the time for which doors were left open was also considered essential: the existing doors were manually-operated and tended to be left open for long periods when forklift trucks were loading a vehicle in the yard.

Works carried out

- The wheelabrators were partly enclosed with proprietary lined steel acoustic enclosure panels on a steel frame. The enclosures were designed to reduce noise from the drum loading and unloading operations.

- A number of inspection hoppers and chutes were lined with high-density polyurethane sheeting, to reduce impact noise. Sheeting was secured using 'pin and washer' fixings, with steel cover strips at edges. (This treatment is clearly only suitable for applications where components are cold).

- The external doors were supplemented by rapid-action roller doors of heavy rubberised fabric material, operated by sensor to allow truck movements and minimum open time. (This type of door, although not particularly heavy, is well sealed and provides 12-15 dB(A) sound insulation in most situations. An additional external door, normally left open when the factory is working, may be required for security in an exposed situation).

- A wheeled 'bin lifter' device was introduced to assess the feasibility of fettling operators working directly from bins, presented to them at working height, to eliminate the need to tip castings into overhead hoppers at each fettling bench

Results

The rapid-action doors have proved to be particularly effective and practicable, reducing door open times to a minimum. The finishing area does not generate significant heat, and there is local air extract from fettling benches, and no adverse effects on building ventilation have been observed.

The lining treatment to hoppers and inspection chutes reduces maximum noise levels (L_{max}) from component impacts by 10 - 15 dB(A). The material is extremely durable and has reasonable low-friction properties, although castings sometimes have to be 'assisted' down the chutes from the inspection benches. The main drawback is cost, around £100 per square metre.

Noise from wheelabrator loading and unloading operations has been reduced by 5-7 dB(A) L_{max}.

The bin-lifter device was effective in eliminating a tipping operation but lack of floor space precluded the widespread use of these devices, without major changes to layout.

Overall, average noise levels at the boundary have been reduced by around 5 dB(A), and the noise 'peaks' associated with the various impact sources are subjectively far less apparent. The major remaining source is impact noise from loading the hoppers at the fettling benches. Further work is in progress to construct a partial wall between the fettling and inspection areas to limit the spread of noise from this area into the inspection area, and to outside.

The various measures, although intended to demonstrate reductions in external noise, have also significantly reduced work-area noise.

Other details

Cost:	Approximately £25k
Contractors/suppliers:	Clark Door Limited
	The Noise Control Centre
	Polyurethane Products Ltd.

5.2 Project 2 - *Clydesdale Forge, Netherton*

This is a large site with two forge shops. The larger shop houses 6 hydraulic and gravity forging hammers and 3 forging presses. Billet heating is mainly by electric induction. There are two bar cropping machines in an adjoining shop. There is a history of complaints from residents who live 60 - 100 metres away from the large forge, mainly concerning noise in the early morning.

The forge building is mainly of corrugated sheeting on a steel frame, with some lower walls of brick. The roof sheeting incorporates translucent sheeting, to provide some natural light, and has open roof shutters and full-length ridge openings for ventilation. Access is through roller shutter doors. The layout is shown on the sketch below.

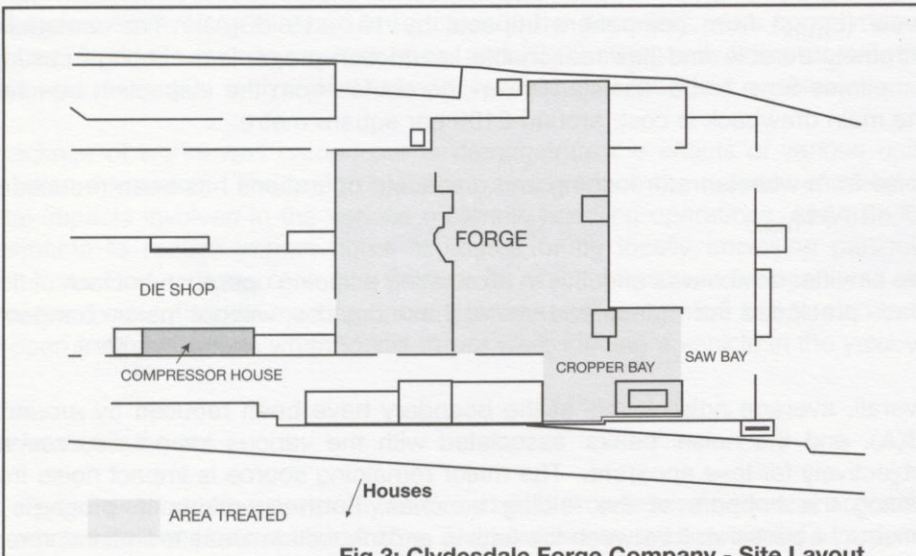


Fig 3: Clydesdale Forge Company - Site Layout

The main noise sources were identified as follows:

- Repetitive 'bangs' from the forging hammers and presses
- Intermittent crashes from materials being moved by forklift truck,
- Regular thumps from the croppers, from the impact of the shear on the bar and from the cropped length falling into a bin
- A low-frequency rumble from the air compressors, located in the compressor house as shown
- A general roar from the fans on the air-cooled heat exchangers, located externally.
- A high-pitched whistle from the induction heaters.

Previous noise surveys revealed average (L_{eq}) typical noise levels of 60 - 62 dB(A) at the nearest houses. The impulsive character of the noise was clearly a major feature. Noise levels inside the main forge are 94 - 102 dB(A).

The high external noise levels result from the high noise levels inside the main forge and the poor sound insulation provided by the building. The feasibility of enclosing individual forging units, to reduce noise within the forge, was assessed. This approach was judged impracticable because of problems of access for production and maintenance. There was no prospect of reducing noise from the hammers and presses at source. The more obvious but potentially the most costly approach was to improve the sound insulation of the building.

Following preliminary costing exercises, this was the course of action adopted.

Works carried out:

- The existing sheeting on the main forge building and cropper bay was repaired where necessary, roof ventilators removed and all openings sheeted over with mineral board of equivalent density to the existing sheeting.
- The section of the building comprising the forge and the cropper bay were over-clad with profiled steel sheeting (0.7mm to roof, 0,55 mm to walls) on 150 mm sheeting rails with 100 mm glass-fibre in the airspace between existing and new sheeting. All laps and eaves details were mastic-sealed. A limited area of roof (10%) was sheeted with double-glazed translucent panels, to retain some natural light. (This is a 'standard' over-cladding treatment for existing buildings, primarily intended to improve weather-resistance, appearance and thermal insulation. However, it incorporates all the necessary

elements for enhanced sound insulation. Calculations indicated that only small improvements in sound insulation would be achieved by increasing cladding thickness, infill density or separation between skins, although these variations would have added substantially to the cost).

- Roller shutter doors facing houses were replaced with vertical sectional doors with a rated sound insulation of 25 dB.

- The cropper bay was separated from the adjoining saw bay (which was not over-clad) with an internal sheet-steel partition including a roller shutter door.

- A ventilation system providing a ventilation rate of $25m^3/s$ (52,000 cfm) was installed in the forge. This comprised a centrifugal fan in an intake chamber at ground level, drawing in air through an external louvre on the far end of the forge (away from houses). The fan supplied a system of high-level ductwork with discharge grilles. Extract was provided by an open vent and a ducted axial fan, again located on the far end gable. Silencers were fitted to the fan intake and the discharge vents.

- The cladding treatment was extended to the roof and end wall of the compressor house. A mechanical ventilation system, with silencers at intake and exhaust, was installed in the compressor house. The wall between the compressor house and adjoining die shop, previously a partial wall of corrugated steel sheeting, was backed with a second skin of pre-screeded wood wool cement slabs, incorporating an access door of 30 dB rating.

Results

The building modifications (cladding and doors) were carried out successfully with little or no disruption to production.

Installation of the forge ventilation system involved some out-of-hours and weekend working for access to install high-level ductwork. It became apparent the ventilation was inadequate to maintain reasonable working temperatures close to the forging units during warm weather. This problem could not be overcome by local 'man-cooler' fans or portable evaporative cooler units. It was resolved by the addition of a powered extract system, together with uprating the supply fan, to provide an air change rate of 10 changes per hour. The retention of adequate ventilation to control internal temperatures is clearly a major concern, since to obtain significant improvements in sound insulation it is necessary to close off any unsilenced openings in the building.

Measurements after completion of works demonstrated that with doors closed, noise emitted from the forge building and cropper bay had been reduced to less than 48 dB(A)at the nearest houses, a reduction of about 14 dB(A). Actual noise levels remained above 50 dB(A), because of the steady noise from the heat exchanger fans. However, with these fans running the impact noise from the forging units cannot generally be distinguished, and the 'masking' noise they create is probably beneficial.

Compressor noise is not generally detectable beyond the site boundary.

Other details

Costs:	Approximately £200k
Contractors/suppliers:	UK Industrial Roofing Ltd.
	Fumac Ltd.
	Clark Door Ltd.
	Amber Doors Ltd.

5.3 Project 3 - *Henley Foundries Limited, Halesowen*

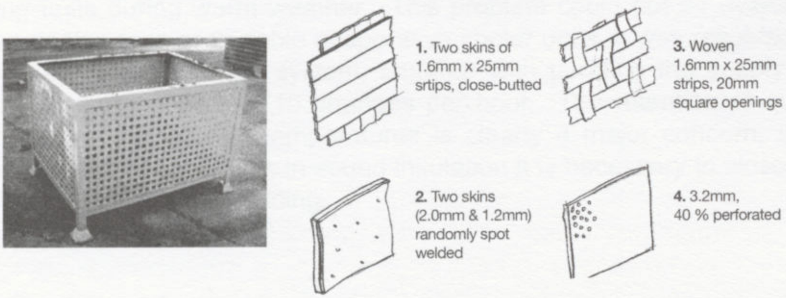
This is a foundry with housing in close proximity on two sides. There is a history of noise complaints, most of which have been resolved by major works - installing a new cupola, improving buildings, and re-locating the stockyard. Some problems remain, including noise from the two shot-blast machines in the finishing shop, which is a lightweight building close to the boundary. It is sometimes necessary to work these machines during the evening, and the loud crashes during loading and unloading can be audible in residential areas (although it may be masked by noise from passing traffic). Within the finishing areas, short-term average noise levels during loading and unloading the shot blast machines are around 100 dB(A). There is also a more general problem of noise from materials being dropped into stillages, particularly in open areas.

Two projects were carried out:

- The shot blast machines were completely enclosed in proprietary lined steel acoustic encloses, with hinges and sliding doors for loading and unloading. On one machine, the barrel is emptied into a stillage which is removed by forklift truck, requiring a large access door. The second machine discharges on to a conveyor, which requires only a small opening in the enclosure.

- A number of prototype 'quiet' stillages, intended to reduce the impact noise of falling castings, were manufactured to assess their effectiveness. It was judged possible to use 'quiet' stillages in some locations, such as in the fettling shop and in the stockyard. However, dedicating stillages to particular areas of the foundry does present problems, and the need for the additional transfer of castings to 'standard' stillages at some point would clearly be undesirable and might defeat the purpose of the 'quiet' version. These quiet stillages were therefore intended primarily to demonstrate the principles involved in reducing impact noise, rather than to provide a solution to noise problems a this site. See Fig. 4.

Fig 4: Reduced Noise Stillages



Results

The shot blast machine enclosures reduced noise levels from these machines, during loading and unloading, by 10-12 dB(A). However, maintaining this reduction has proved difficult because the enclosures, particularly the doors, suffer regular impact damage from forklift trucks. This is to some extent the result of limited access round the machines. made even more limited by the enclosures. More robust enclosures and local barriers would alleviate this problem, but probably not resolve it (and barriers round the enclosure would further restrict access).

The quiet stillages reduced maximum impact nose levels, when dropping a single casting, by up to 15dB(A) L_{max}. Average noise levels $L_{eq,10s}$ when dropping a load of scrap into the stillages were reduced by 7 - 10dB(A). The quiet stillages are also noticeably quieter when carried on a forklift truck, unloaded - the characteristic metallic rattle at the stillage bounces on the forks is noticeably dulled. There is clearly scope for further development, and for consideration of adoption of a 'quiet' design as standard. The most practicable alternative to the standard single-skin construction is the double-skin spot-welded type. This would seem to have no significant disadvantages (apart from first cost) compared with the standard stillage. Other types are likely to be less robust. The 'woven' type, although very effective, appears more liable to damage and to components becoming 'hooked' into the mesh.

The double-skin technique can also be used effectively on chutes and tables which are subject to metallic impact. This form of construction is unlikely to be as effective as a resilient lining in reducing impact noises, but it has the advantage of being suitable for dealing with hot components.

Other details:

Costs (typical)	Shot blast machine enclosures:	£20k
	Quiet stillages (each)	£200 - £300
Contractors/suppliers:	The Noise Control Centre	

The CD or video tape which accompanies this handbook gives further information about these projects.

Annex 1

The Black Country Forging and Foundry Project

The Background

This project was conceived in 1996 by forging and foundry industry groups, the Black Country local authorities (the Boroughs of Dudley, Sandwell, Walsall and Wolverhampton) and the GMB Union. It was perceived that companies in these industry sectors were experiencing a growing number of complaints from local residents concerning the environmental impact of their operations, from smoke, dust, fumes, odour, vibration and noise. These problems were to a large extent due to the location of the forges and foundries in the Black Country. These traditional industries are often based on sites which are within or close to residential areas.

There was a general concern that the profitability and even viability of some companies might be seriously compromised by adverse community reaction to their operations, with consequent effects on the local economy and on employment. The extent of the perceived problem was investigated by questionnaire, which was sent to approximately 170 forges and foundries during October and November 1996. The company list was compiled by the GMB Union from information provided by the Confederation of British Forgers (CBF), the British Foundry Association (BFA), local authorities and other sources. From this survey, it was concluded that a significant number of companies, accounting for perhaps 3000 jobs (out of a total of 10,000 in this industry sector in the Black Country) were receiving complaints about environmental problems which they thought might adversely affect their ability to maintain or expand their businesses.

Noise was clearly identified as the most widespread cause of unresolved problems.

As a result of this preliminary survey, a project proposal to investigate environmental noise and vibration in the forging and foundry industries was developed jointly by industry, local authorities (led by Dudley MBC) and the GMB Union. This proposal was submitted by Dudley MBC to the Government Office for the West Midlands, and was accepted for grant assistance under the Regional Development Fund in November 1997.

The Objectives

The overall objectives of the project were:

Research

To make contact with (as far as possible) all forges and foundries in the Black Country area and to identify companies interested in participating in the project.

To collate the experience of these companies and to identify the principal causes of environmental noise and vibration problems in these industries.

To carry out a review of published research into noise and vibration in these and related industries.

To identify the techniques and solutions currently available to deal with the most widespread noise and vibration problems experienced by forges and foundries, and to identify where innovative solutions might be required.

To carry out, if appropriate, theoretical and experimental research into novel methods of noise and vibration control, suitable for the specific conditions in these industries.

Reports on the Research phase of the project can be seen on-line on the CMB website (see cover page for contact details)

Pilot Projects

To set up, within forges and foundries, pilot projects to demonstrate and further develop cost-effective and practicable methods of noise and vibration control.
To implement the pilot projects.

Informing the Industries

To disseminate the project outcome throughout the industries through organised visits to completed pilot projects, journal articles, presentations and other media.

Project Organisation

The progress and direction of the work was supervised by a Steering Committee comprising:

N Powell	Dudley MBC
R Winzer	Dudley MBC
J Mundell	Woodcote Industries Limited (CBF)
J Wood	Caparo Engineering Limited (CBF/BFA)
J Young	Henley Foundries Limited (BFA)
B Johnson/C Humphries	GMB Union
B Parkin/G Field	CBM (Confederation of British Metalforming)
J Parker	CMF (Cast Metals Federation)

Some meetings were also attended by G Johnston (representing S Murphy MEP).

Contracts for technical work were placed with the following consultants:

ISVR Consultancy Services, University of Southampton
(Acoustics Consultants)

Paul Mantle Partnership, Halesowen
(Building Consultants and Quantity Surveyors)

Engineering Design Partnership, Alcester
(Building Services Consultants)

Structural Design Services Ltd., Stourbridge
(Consulting Civil & Structural Engineers)

Tunnicliffe Wall Associates, West Bromwich
(Building Services Consultants)

Contracts for video/CD production were placed with:
LBV Television, Northorpe, Lincolnshire.

Annex 2

Explanation of Various terms – Noise and Vibration

Frequency and Hertz

Frequency (or pitch) is measured in Hertz (Hz) or cycles per second. The normal human ear can detect frequencies between about 20 Hz and 15,000Hz, although it is most sensitive to sound in the range of frequencies between 500Hz and 5,000Hz.

Sound at a single frequency of (say) 100Hz might be described as a low-pitched 'drone' or 'hum'. Sound at a frequency above 1,000 Hz might be described as a 'whine' or 'whistle;. Most industrial noise arises from a large number of machines and processes and contains a range of frequencies.

Noise level and decibels

The magnitude of the changes in air pressure are used to determine the sound (or noise) level. The human ear is very sensitive and can detect very small repeated changes in air pressure, as low as around 20 microPascals ($2x10^{-5}$Pa). Repeated changes in pressure greater than about 200 pascals are perceived as painfully loud noise and can damage the hearing instantaneously. Even this is a very small change in pressure compared with the mean steady atmospheric pressure of 100,000 (10^5 Pa). For a number of reasons which we do not need to explain here, noise levels (or sound pressure levels) are almost always measured in decibels (dB). In decibels, the range of sound pressures between 20 microPa and 200 Pa is represented by a a scale from 0 dB to 140 dB. Most commonplace sounds have levels between about 20 and 100 dB. The decibel scale is *logarithmic* - each increase of 10 dB means that the sound energy has increased by 10 times, so that (for example) if a machine produces a noise level of 70 dB, ten machines of the same type would produce 80 dB and 100 machines would produce 90 dB. It follows that decibel levels cannot be added in the normal way - two machines each giving 70 dB would give 73 dB, not 70 + 70 =140 dB (which would be the noise level produced by 10 million of these machines!)

Measuring noise level

Noise levels are most often measured using a sound level meter. This is a hand-held instrument using a microphone connected to an amplifier and signal processing circuitry to provide a direct indication, usually on a digital display, of the noise level in dB.

As pointed out above, the human ear is not equally sensitive to all frequencies of sound. This means that a simple statement of a noise level in decibels does not describe the apparent loudness of the noise. This has been overcome to some extent by the use of electronic filters or 'weighting' networks in sound level meters to simulate the frequency response of the ear. For most purposes, the weighting network called 'A' is used. Noise levels measured using a sound level meter using the 'A' weighting network are expressed in **dB(A).**

Many sound level meters, except the simplest, can also provide information about the frequency content of the measured noise as well as giving an overall dB(A) level. This extra information is often vital for identifying a particular source of noise or for devising methods of noise control. The most basic form of frequency analysis is so-called octave band analysis, where the noise can be 'split' by electronic filters into frequency bands which are identified by their centre frequency. The standard octave band centre frequencies are 63,125,250, 500, 1000,2000,4000 and 8000 Hz. More sophisticated meters and specialist frequency analysers can analyse noise in more detail using filters of narrower bandwidth.

What if the noise is not steady?

The level of a steady noise can be described by a single measurement in dB(A). However, noise levels are rarely steady. Noise may fluctuate slowly, or may change rapidly from second to second. Noise caused by impacts, such as the operation of a forging hammer or castings being dropped into a steel bin, or by explosions such as gunshots, is termed 'impulsive'. Additional units of measurements are needed to describe non-steady and impulsive noises. Three commonly-used measurement units (there are many others) are:

The equivalent continuous level or $L_{eq,T}$. This is a time-average level over time T. For example, if a noise level is stated as being 60 dB(A) $L_{eq,5m}$ this means that the time average level over a period of 5 minutes was 60 dB(A). The time average level gives no information about the range of noise levels actually occurring during the measurement period

The maximum noise level L_{max}. L_{max} is the highest noise level during the measurement period. For impulsive noises, the value of Lmax depends on the response time of the sound level meter. Most meters have two response time settings termed 'fast' or 'F' and 'slow' (S), which are defined by international standards. A measurement of L_{max} using the 'fast' setting would be expressed as (for example) 70 dB(A) Lmax(F).

The noise level exceeded for a given percentage of the time, L_N. The L_{90} noise level is often used to describe the noise level during the quietest periods of a measurement. L_{90} is the noise level exceeded for 90% of the time - for example, 45 dB(A) L_{90}.

The meaning of these noise measurement units is further illustrated on the figure below, which shows the values of L_{eq}, L_{90} and L_{max} for a measurement period during which the noise varies in level with time and includes some impulsive sounds (the sharp 'peaks' on the graph).

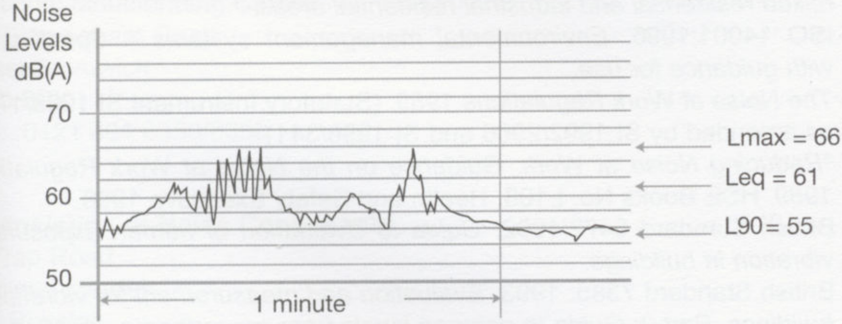


Fig 5: Different noise measurement 'units'

Vibration

Measurement and assessment of vibration is outside the scope of this handbook, and it is likely to be beyond the scope of most manufacturing companies. Measurements generally involve the use of transducers called accelerometers, which are fixed to the surface (the ground or part of a building) to be measured. Vibration intensity or level is commonly expressed in terms of the peak particle velocity (p.p.v.) in millimetres per second (mm/s), although other units are widely used.

Standards for assessing the response of people and structures to vibration are given in 5 and 6.

Annex 3

Sources of Information

References in the text

1 British Standard 4142:1997. *Method for Rating Industrial noise affecting mixed residential and industrial residential areas.*

2 ISO 14001:1996. *Environmental management systems – Specification with guidance for use.*

3 *The Noise at Work Regulations 1989.* (Statutory Instrument SI 1989/1790, as amended by SI 1992/2966 and SI 1996/341)

4 **Reducing Noise at Work. Guidance on the Noise at Work Regulations 1989.* HSE Books No. L108. Health and Safety Executive 1998.

5 British Standard 6472:1992. *Guide to Evaluation of human exposure to vibration in buildings.*

6 British Standard 7385: 1993. *Evaluation and measurement for vibration in buildings. Part 2: Guide to damage levels from groundborne vibration.*

Other suggested reading

The following provide a useful introduction to the principles and practice of noise control.

(i) *Noise Control in Industry*. Sound Research Laboratories Limited. Pub. E & F N Spon.

(ii) *Woods Practical Guide to Noise Control.* Pub. Woods of Colchester Limited.

(iii) **Sound Solutions. Techniques to reduce noise at work.* HSE Books. HMSO (1995).

*Note: HSE Publications on noise are directed primarily towards reducing noise in the workplace. However, many of the principles are equally applicable to the reduction of neighbourhood noise. Some HSE reports and notes are specifically about reducing noise in forges and foundries.

Advice

The following organisations can provide general information on how to approach noise problems, and can give assistance in locating specialist advice:

Confederation of British Metalforming
Cast Metals Federation
Both at:
National Metalforming Centre
47 Birmingham Road
West Bromwich
B70 6PY
Tel: 0121 601 6350/6390

Association of Noise Consultants
6 Trap Road
Guilden Morden
Nr. Royston
Herts. SG8 0JE
Tel: 01763 852958

Acknowledgments:

Dudley Metropolitian Borough Council
Clydesdale Forge Co. Dudley a trading division of
Caparo Engineering Ltd., Walsall
Henley Foundries Ltd., Halesowen
Chamberlin & Hill Plc., Walsall
Paul Mantle Partnership, Chartered Surveyors,
Cast Metals Federation
Confederation of British Metalforming
GMB Union
Institute of Sound and Vibration Research
University of Southampton

cbm

GMB
BRITAIN'S GENERAL UNION

cast metals cmf federation

Copies of a video/cd together with this booklet on noise reduction methods in these industries can be obtained from;

Environmental Services
Dudley Metropolitian
Borough Council
Mary Stevens Park
Stourbridge DY8 2AA
Tel: (01384) 814633

Cast Metals Federation
Tel: (0121) 601 6390

Confederation of British Metalforming
Tel: (0121) 601 6350

Both at:-
National Metalforming Centre
47 Birmingham Road
West Bromwich
B70 6PY

Dudley
Metropolitan Borough Council

on behalf of the Black Country Authorities