THE DESIGN OF EXPLOSION RELIEFS FOR INDUSTRIAL DRYING OVENS

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SUMMARY

The drying of manufactured articles is a very common industrial process and usually involves the evaporation of a flammable solvent in an oven so that there can be the possibility of an explosion. In practice the hazards accompanying this process can be eliminated by an explosion relief. This paper reports an investigation to determine the data required for the design of satisfactory explosion reliefs. Measurements of the pressure developed by explosions in ovens were made over a wide range of conditions, including the effects of the type of solvent, the size and shape of oven, the size, shape and weight of explosion relief, the presence of shelves, the proximity of walls, and some assessment of oven strengths.

On the basis of the results obtained, a procedure is given for the design of explosion reliefs which will remove the danger to personnel and prevent all but minor internal damage to the oven if there is an explosion.

Introduction

The application of paint, lacquer, enamel, etc., to manufactured articles is widely used throughout industry to provide decorative and protective finishes. This process involves drying the painted articles. A common method is by heating in an oven to evaporate the solvent which is then carried away by a stream of air so that further evaporation is encouraged. The solvent is frequently highly flammable and when vaporised may form an explosive mixture with the air stream. If this mixture becomes ignited, a serious explosion could occur. Faulty operation, also, may result in filling an oven with a fuel/air mixture so providing another source of explosion.

Explosions in drying ovens have caused concern for some time to the Factory Department of the Ministry of Labour and National Service. Although most reported incidents involve vapour explosions, and these occur whatever fuel is used to heat the oven, the majority of the ovens are gas-heated, and so an investigation aimed at the prevention of casualties and damage caused by these explosions was undertaken by the Gas Council.

When there is an explosion in an oven the effects depend on the design of the particular oven involved. Drying ovens may be either continuously or batch operated, and are usually referred to as conveyor or box ovens respectively. The Factory Department statistics show that, of the explosions in drying ovens one-third were in conveyor ovens and two-thirds in box ovens, while of the explosions in drying ovens causing fatalities one-sixth were in conveyor ovens and five-sixths in box ovens. It was clear, therefore, that the immediate problem was the protection of box ovens against the effects of explosions.

Conventional box ovens consist of a metal surround to a heated region through which a stream of air can be drawn by either natural or forced convection. They are usually rectangular in section and have doors forming practically the whole of one side. Either direct or indirect firing can be used. Directly fired ovens for low temperature work can be single-cased with no heat insulation ; for higher temperature work, they are double-cased with heat insulation held between the outer case and inner metal lining. The heating in these ovens is normally by bar burners running across the bottom of the oven. In the indirectly fired ovens, usually called treble-cased, the hot combustion products are led through narrow spaces between the outer insulated double wall and an inner metal lining, which forms the third case, so that there is no contact between the flame and vapours formed in the drying process. Figs 1 and 2 represent typical designs for double and treble-cased ovens respectively. There is considerable diver-

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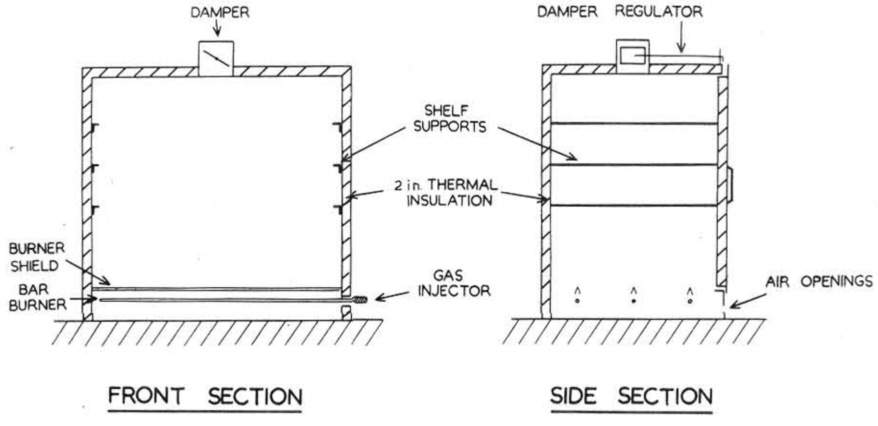


Fig. 1.—*Sections of a typical double-cased oven*

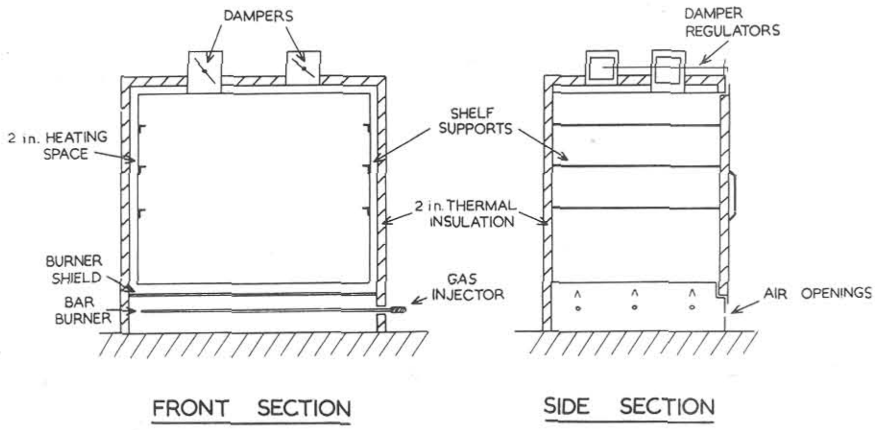


Fig. 2.—*Sections of a typical treble-cased oven*

sity both in the design and size of these ovens for although specialist firms make ovens of a standard size, as advertised in catalogues, particular sizes are made to order, and it is possible for the user to construct his own ovens.

When considering damage due to explosions, the size of an oven is best defined by the volume of the enclosed space in which an explosion can occur. Assessed on this basis the sizes of ovens normally range from about 10 ft^3–600 ft^3. Box ovens are generally approximately cubical in shape, but wide variations do occur.

The damage caused by explosions in these ovens could obviously be prevented either by stopping the explosions or by arranging that explosions could occur without causing damage. Safety devices that would prevent the formation of dangerous concentrations of vapours would be complicated and expensive compared with the cost of a box oven. Attention was consequently directed to relieving the pressure developed by an explosion so that damage was prevented ; this could obviously be done for either vapour or gas explosions by the use of vents to act as explosion reliefs. The provision of explosion reliefs is in fact recommended by the Factory Department.[1] However, there was no direct evidence on which to base the design of such reliefs and the Factory Department was only able to suggest, on the basis of experience, that the area of the vent should be 1 ft^2 for each 15 ft^3 of oven volume, that the relief should be light, that care should be taken to prevent its becoming a dangerous missile after an explosion, and that precautions should be taken to direct the flame and blast away from workpeople.

The urgent requirement was, therefore, to obtain data on which the design of explosion reliefs for box ovens could be based, and this was the object of the investigation reported in this paper.

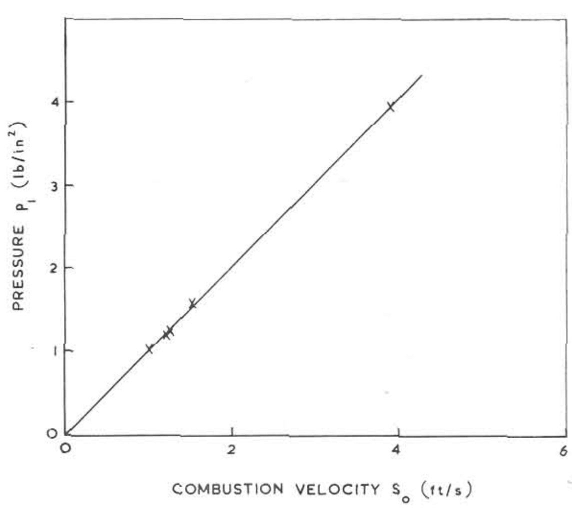
Experimental Results

The general case—empty, cubical ovens

At the start of the investigation very little was known quantitatively about the effect of explosion reliefs on the pressure built up in an oven during an explosion. Furthermore, the size, shape, and construction of the ovens, the drying temperature, the load being processed, and the solvent being evaporated could all very over wide limits. It was decided, therefore, to obtain first some basic information for a general case and then to determine in turn the effect of various departures from the conditions for this case necessary to match industrial working conditions. The empty cubical oven was taken as the general case, and design data for explosion reliefs were determined over a range of oven volumes, vent areas, and weights of explosion relief.

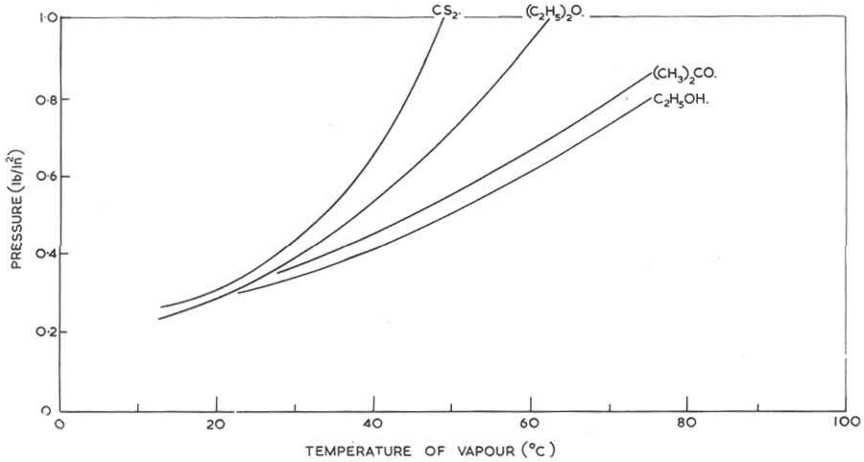
NATURE OF COMBUSTIBLE MIXTURE

Experiments were carried out in which an oven fitted with a relief was filled with a vapour/air mixture which was ignited at the centre of the oven and the pressure developed was measured by a capacity-type gauge inserted in the oven wall and recording on a drum camera. For a number of vapours it was found that the maximum pressure attained for the mixture concentration producing the most severe explosion was proportional to the normal combustion velocity of the mixture as shown in Fig. 3, in which the point for the highest flame speed represents town gas and the vapours are in a bunch at lower speeds. However, if there is an explosion, in practice



Oven volume = 8 ft^3
Vent area = 3·2 ft^2
K = 1·25
Weight of relief = 4·36 lb/ft^2

Fig. 3.—*Variation of the peak pressure developed by an explosion with the maximum normal combustion velocity of the combustible. In each case the mixture concentration producing the most severe explosion was used*



Oven volume $= 48\ ft^3$
K $= 1\cdot 1$
Weight of relief $= 1\cdot 0\ lb/ft^2$

Fig. 4.—*Variation with temperature of the maximum pressure developed in an oven by explosions of various vapour/air mixtures*

the oven and the vapour/air mixture will be hot; experimental measurements of the increase of pressure generated by an explosion with mixture temperature are shown in Fig. 4.

It was concluded from this that vapour explosions in practice, that is with heated mixtures, produce pressures similar to those obtained with town gas. Most of the experimental work was therefore carried out using town gas since it was quite difficult to fill an oven with a hot vapour/air mixture of accurately controlled proportions. In most cases, the town gas concentration giving the greatest pressure was used.

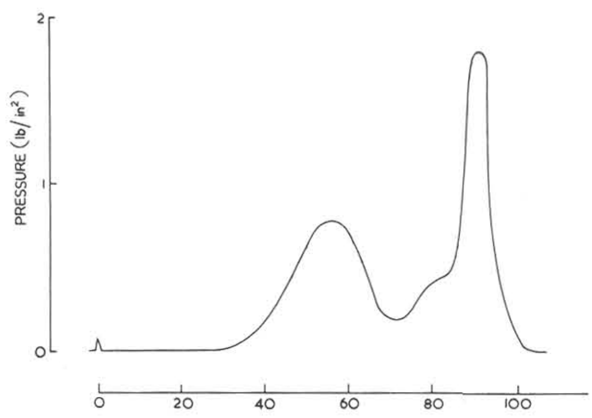
POSITION OF IGNITION

The effect of the position of ignition was studied next and from pressure measurements taken for 17 ignition positions distributed throughout the oven, it was found that the pressure developed was greatest for central ignition, that it decreased slightly as the ignition position was moved away from the centre, and that there was a more marked decrease as the edges were approached. Therefore central ignition was adopted as the standard position in the subsequent work.

VARIATION OF EXPLOSION PRESSURE WITH TIME

For an explosion in an oven fitted with a relief it was found that the variation of pressure with time took a somewhat unexpected form as shown in Fig. 5. This shows a short delay period after ignition, followed by a build up of pressure which eventually becomes rapid, then the relief is ejected and the pressure falls. So far the events are as would be expected. Next, however, there is a sudden rapid rise in pressure followed by a drop to atmospheric pressure.

The origin of the second pressure peak and the shape of the pressure-time curve may be explained by consideration of the course of events in an oven during an explosion. Imagine a flammable mixture ignited at the centre of an oven. Then, as the mixture burns, the volume of the products formed by combustion is much greater than the volume of the mixture before burning, and the pressure inside the oven increases. Ideally, the combustion wave will form a spherical surface centred on the point of ignition. For pressures around atmospheric, the rate of burning is constant and so the rate of formation of products, and consequently, the rate of rise of pressure, depends on the surface area at which combustion can take place. This increases rapidly as the combustion wave spreads outwards and so the pressure rises rapidly until the relief is hurled from the oven and the gases are vented so that the pressure in the oven decreases. Owing to the inertia of the relief, the pressure reached in the oven before the relief is moved far enough for any effective venting to occur is many times the pressure necessary simply to balance the weight of the relief, which is, therefore, projected violently from the oven. The sequence of events does not stop at this point. Combustion is still proceeding in the oven and products are being formed at an ever-increasing pace. It is therefore possible for venting to occur at such a rate of flow that there is an appreciable pressure drop across the vent, and thus a pressure is built up again in the oven. This increases until the combustion wave first reaches the walls of the oven, when the



Oven volume $= 98\ ft^3$
Vent area $= 9\ ft^2$
Weight of relief $= 1\cdot 0\ lb/ft^2$

Fig. 5.—*Under these conditions a towns gas explosion would produce a maximum pressure of 0·8 lb/in². Reproduction of a typical photographic record of the variation of pressure with time in an oven during an explosion*

area at which combustion can occur decreases and so the rate of production of products decreases. Thus the pressure inside the oven reaches a second maximum and then falls to atmospheric, so that there is a second peak on the pressure-time curves.

DEPENDENCE OF THE FIRST PEAK PRESSURE ON OVEN VOLUME AND WEIGHT AND AREA OF THE RELIEF

For the general case of an approximately cubical oven using a range of volume and various weights and areas of relief in the top of the oven, it was found possible to correlate the first peak pressure with the oven volume, the weight of the relief and the vent area coefficient. The relation obtained was* :

$$p_1 V^{\frac{1}{3}} = 1 \cdot 18 \text{ Kw} + 1 \cdot 57 \quad . \quad . \quad (1)$$

The agreement of the experimental results with this relation is shown by Fig. 6. The range of oven volume was 8–500 ft^3, of relief weights 0·3–7 lb/ft^2 and of vent area coefficients 1–3.

Some evidence was obtained to show that equation (1) could be expressed in the form :—

$$p_1 V^{\frac{1}{3}} = S_0(0 \cdot 30 \text{ Kw} + 0 \cdot 40).$$

The practical case

The various departures from the general case of an empty cubical oven which are likely to occur under industrial conditions are that the oven may not be cubical, the vent may not be located centrally, and the oven will be loaded or at least contain shelves. The effect of each of these factors was therefore investigated.

EFFECT OF OVEN SHAPE

From the point of view of shape, ovens may be divided into those which have one dimension much greater than the other two and those having all three dimensions of the same order. Ovens in the first category can be considered to be built up of several ovens of the second category placed end to end, and each section can have a suitable relief. The problem thus reduced to determining what range of shapes occurs in the second category. The examination of ovens and catalogues showed that the large majority had dimensions within the ratios 3 : 2 : 1 and 1 : 1 : 1. Experiments with an oven of 100 ft^3 volume and dimensions 3 : 2 : 1 gave the results of Table I and showed that whatever side the relief was inserted

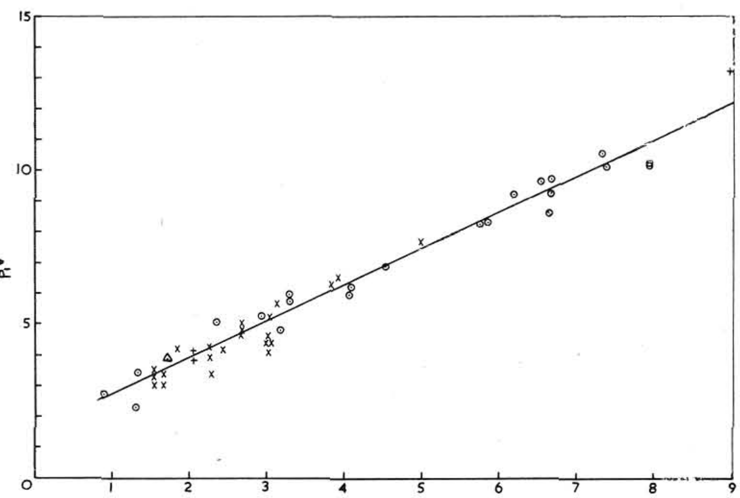


Fig. 6.—*The correlation between first peak (pressure p_1 lb/in^2), volume of oven (V ft^3), vent area coefficient (K) and weight per unit area of the relief (w lb/ft^2)*

DEPENDENCE OF THE SECOND PEAK PRESSURE ON AREA OF THE RELIEF

The variation of second peak pressure p_2 (lb/in^2) with the vent area coefficient is shown in Fig. 7 whence it is clear that for design purposes it is reasonable to use a value of p_2 given simply by

$$p_2 = K.$$

In large ovens for values of K greater than 2·5, that is for small vent areas, p_2 increases rather more slowly than given above but, as is shown below, the relation given covers the practical working range.

* *Symbols have the meaning given them on p. 77.*

the first and second peak pressures were always less than those obtained in a cubical oven of the same volume. In these experiments, the weight per unit area of the relief was kept constant and the relief always occupied the whole of the side of the oven.

Thus the design of reliefs could with safety be based on the results for cubical ovens.

EFFECT OF RELIEF SHAPE AND POSITION

It is shown below that the size of a relief must approach that of the oven cross-section in the plane of the relief so that no great variation in shape is possible. However, experiments were carried out with a relief with an area one half of the oven

TABLE I.—*Results of Experiments on 100 ft³ Oven with Shape-factor 3 : 2 : 1*

	Non-cubical Oven 1	2	3	Cubical Oven 4
Vertical dimension of oven	7 ft 8 in.	5 ft 1 in.	2 ft 7 in.	4 ft 8 in.
Nominal vent area (ft²)	12·5	18·8	37·5	21·0
Oven horizontal cross-section (ft²)	13·3	19·8	39·0	21·0
p_1 (lb/in²)	0·75	0·7	0·3	0·75
p_2 (lb/in²)	1·1	0·85	0·5	1·15

cross section. From these it was found that the explosion pressure was lower when the relief was centrally situated than for any other position. Therefore reliefs should always be located centrally in the sides of ovens.

SHELVES

The presence of shelves and load in an oven would be expected to have a considerable effect on the performance of an explosion relief. The usual type of shelf is a metal grid forming an open mesh.

It was found experimentally that the presence of even one shelf in an oven with a relief in the top caused a great increase of pressure for explosions ignited beneath the shelf (and indeed an appreciable increase for explosions ignited above above it). Unless the fraction of the cross-sectional area occupied by the shelf and load were less than 15%, the pressure became too great for the oven to withstand without some damage. It is therefore essential to use side reliefs for all ovens with shelves. In general this means that the relief must be in the back of the oven since it is then easier to arrange that, if an explosion occurs, the relief is discharged into a region from which personnel are excluded than when the relief is in the side of the oven. Experiments showed that the results already obtained for top reliefs applied directly to back reliefs.

The presence of shelves could affect the performance of a back relief and experiments were carried out to find the effects on the peak pressures of the number of shelves and of the type of shelf, the latter was specified by the degree of blockage that it caused, that is the proportion of the oven cross section

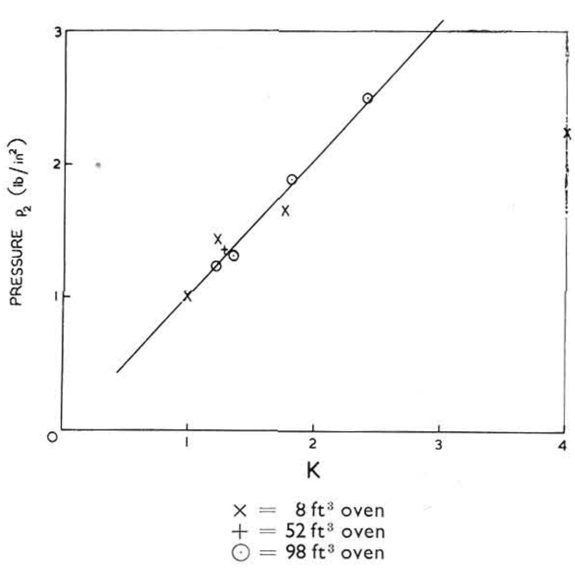


Fig. 7.—Variation of the second peak pressure with the vent area coefficient

occupied by the metal strands comprising the shelf. Some of the results are shown in Figs 8 and 9.

The general form of each of these curves was predicted by the following arguments. With zero shelf blockage (*i.e.*, with no shelf) the pressure generated is that already known for an empty oven. The effect of inserting a shelf is to promote turbulence in the oven so that explosions are more violent and pressures generated are higher. As the degree of blockage is increased, more turbulence is introduced and higher pressures are produced. However, in the extreme case (*i.e.*, with solid shelves firmly fixed in the oven), the volume of mixture exploding (V) is that contained between two shelves and is only a fraction of the volume exploding when the oven is empty. For such an explosion, the vent area coefficient (K) is unity and the weight per unity area of the relief (w) is the weight of the whole relief divided by the vent area of the compartment in which there is an explosion. Thus the pressure may be calculated from the formula

$$p_1 V^{\frac{1}{3}} = 1 \cdot 18\, Kw + 1 \cdot 57.$$

For example, in a cubical oven of 100 ft³ volume which is fitted with the recommended pattern of relief divided into two equal compartments, the first peak pressure will be 0·65 lb/in² in the complete oven and 0·95 lb/in² in either compartment.

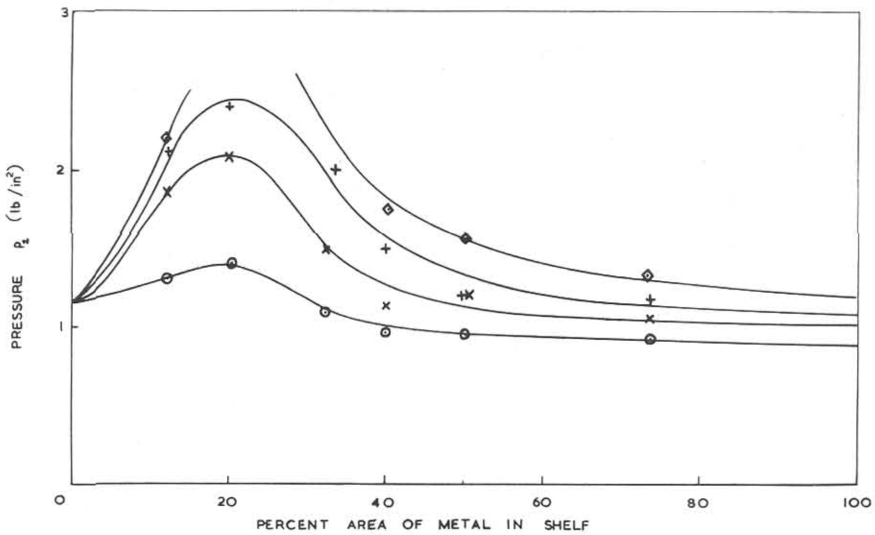
The values plotted in Fig. 8 at 100% metal area were calculated in this manner.

Thus the pressures generated with solid shelves are not greatly in excess of those obtained in the empty oven. Since a shelf was known to cause a marked increase in explosion pressure, it followed that the curve showing the variation of pressure with extent of shelf blockage would rise from the pressure for an empty oven at zero blockage to a maximum as the blockage increases and then decrease again reaching a value for a solid shelf not greatly above the initial pressure with no shelf. The position and height of the maxima were, of course, not predictable. It would also be expected that the effect and, therefore, the maximum pressure would be greater the larger the number of shelves.

On the basis of these results it is recommended that the material of each shelf should occupy at least 50% of the cross-sectional area of the oven. If, with heavy loading, the loaded shelf is virtually solid following this recommendation, lighter shelves should be used and only inserted into the oven when loaded.

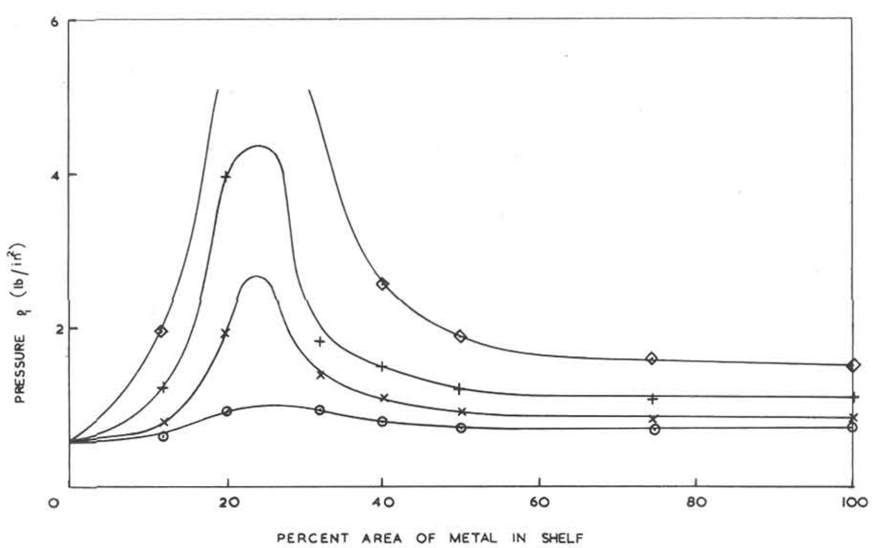
SITING OF OVENS—EFFECT OF PROXIMITY OF WALLS

The functioning of a relief is obviously affected by the siting of an oven—particularly by the proximity of walls. Measurements were therefore made of the pressures developed in an oven with a side relief situated at various distances from (*a*) a rear wall, (*b*) rear and side walls or rear wall and floor, and (*c*) rear and side wall and floor. From the results, it was



⊙ = One shelf
× = two shelves
+ = three shelves
◇ = four shelves

Fig. 8.—*Variation of first peak pressure with shelf area for ovens with back reliefs with 1, 2, 3, or 4 shelves*



⊙ = One shelf
× = two shelves
+ = three shelves
◇ = four shelves

Fig. 9.—*Variation of second peak pressure with shelf area for ovens with back reliefs and with 1, 2, 3, or 4 shelves*

deduced that to prevent a considerable increase in the pressure due to an explosion, an oven should always be spaced at least 15 in. from a wall behind it. If the oven is in a corner, then it should be at least 2 ft from the rear wall and 2 ft from the side wall. Strictly these spacings apply to an oven with a volume of 100 ft^3, but since they are relatively modest and vary only as the linear dimensions of the oven, the spacings quoted may be used for ovens with volumes not greater than 150 ft^3. For larger sizes the spacings quoted should be scaled by $(V/100)^{\frac{1}{3}}$ where V is the volume of the oven in cubic feet.

The strength of box ovens

For the purpose of designing explosion reliefs the strength of an oven is best specified by the internal pressure that it will withstand. Information on oven strengths is difficult to obtain since it depends on the detailed construction of each oven and moreover it is necessary to test an oven to destruction in order experimentally to determine the pressure it will withstand.

As this work progressed it was found useful to adopt two criteria for oven strengths. These were the pressure below which no damage is caused and above which only minor internal damage occurs, and the pressure below which there is only minor internal damage and above which severe internal damage results. The pressure defined by the latter criterion may be the result of a fairly severe explosion, but since there is no external damage there is no danger to persons in the vicinity of the oven. Both criteria are therefore safe values on which explosion reliefs can be designed.

Experiments have been carried out on three ovens. Two of these were of the normal type using heavy angle-iron and braced sheet metal construction, and the third was the new-style oven of interlocking pressed-steel construction.

The old type, made with a heavy angle-iron frame covered by sheet metal firmly bolted to the framework, is inherently of great strength and rigidity, whereas the new-style oven, constructed from pressed steel sections, is flexible. Because of this, the new style ovens are liable to absorb explosion pressure better than the rigid type of construction which is more liable to disintegrate.

The ovens were all fitted with explosion reliefs. The tests were made at gradually increasing pressures, using centrally ignited explosions of 25% town gas in air mixtures; the pressure variations were obtained by altering the relief weight or by inserting shelves.

Oven A had a volume of 120 ft^3 and was double-cased. The doors had an area of 36 ft^2 and were fastened by an externally mounted bar bolt of $\frac{5}{8}$ in. diameter, which was pivoted centrally. The ends of the bar bolt passed into securing eyes mounted on the main framework.

Oven B was treble-cased and had a working space of 48 ft^3. The doors had an area of 25 ft^2 of which 18 ft^2 actually covered the working space. The door fastening was of a similar type to that used on the oven described above, but incorporated an additional safety bar.

Oven C was of modern design made from interlocking pressed steel panels, the door bolt being incorporated in the door, which also had a safety bar. The oven was double-cased with a volume of 67 ft^3, having doors with an area of 20 ft^2 and a back relief.

The pressures at which minor and severe damage occurred with the three ovens tested are summarised in Table II.

TABLE II.—*Pressures at which Damage Occurred in Ovens*

Oven	A	B	C
	Pressure (lb/in^2)		
Minor Damage	0·75	0·75	3·7
Severe Damage	2·8	3·5	5·0

From these results it is concluded that :—

(1) The new constructional method using lightweight pressed steel sheets resists considerably greater explosion pressure than the old heavy angle-iron type of construction.

(2) For the ovens tested, the maximum pressure that may be allowed to develop is of the order of 3 lb/in^2 for the usual, rigid type of construction, and 5 lb/in^2 for the new, flexible type.

It should be emphasised that the evidence on oven strength is still very sparse. The actual strength will depend on the size of the oven amongst other factors. Bearing in mind the fact that most manufacturers use the rigid type of construction, the only possible general conclusion appears to be that oven strengths must not be assumed to be such to withstand explosion pressures above 2·5 lb/in^2.

The Design of Explosion Reliefs

In designing an explosion relief each of the following requirements must be fulfilled :—

1. The reliefs must be constructed in such a way that they do not form dangerous missiles if explosions occur.

2. The weight of the reliefs must be small in order that the reliefs open fully before the pressure inside can build up to a dangerous level.

3. The areas and positions of the relief openings must be such as to prevent the pressure in the ovens from building up to a dangerous level during the discharge of the products of combustion formed by an explosion.

4. The free space above and around the ovens must be sufficient to allow the reliefs to operate satisfactorily, and attention should be paid to the risk of burns to personnel by the flames discharged from an oven if there is an explosion.

5. The doors of ovens must be provided with secure fastenings; otherwise the doors can fly open in a dangerous manner simultaneously with the operation of the reliefs.

General case—Box ovens

POSITION AND SIZE OF RELIEF

If shelves are used, the relief must be at the back of an oven. The peak pressure developed by an explosion must be safely less than the strength of the oven, *i.e.*, 2·5 lb/in^2. The pressure developed depends on the weight and area of the relief, the size of the oven, the presence of shelves, and the proximity of walls. Allowing for four shelves and accepting the oven spacing from walls given above, it is necessary to use the whole of the back of an oven for a relief in order to keep the second peak pressure suitably low. With this area of vent and a very light relief which is not dangerous when ejected from the oven, it is found that the first peak pressure is always less than the second, and is therefore safe. Thus, the relief should occupy the whole of the back of an oven.

If the load is suspended from the top of the oven, the relief should be at the back but may be in the top. It is worth noting that it is only rarely that sufficient area is available in the top, and, in fact, one advantage of siting the relief in the back is that the necessary area can be obtained. The only case when a top relief is necessary is the unusual one when the load consists of sheets suspended parallel to the door and substantially covering the cross-section of the oven ; the relief should then occupy the whole of the top of the oven.

CONSTRUCTION OF RELIEF

A suitable method of relief construction is illustrated in Figs 10 and 11, the relief being constructed in the following manner.

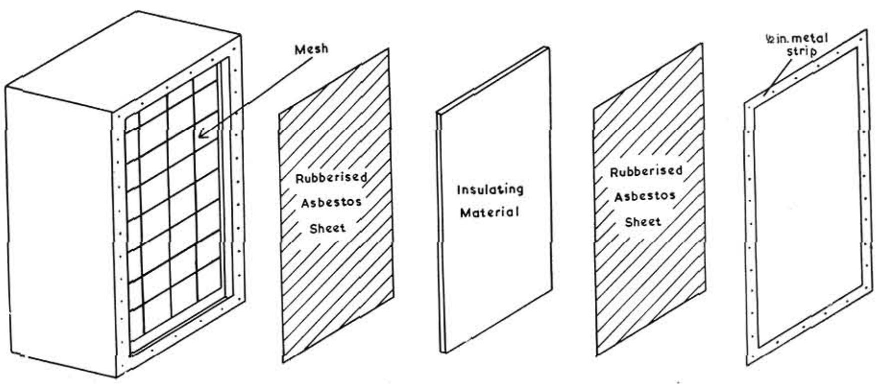


Fig. 10.—*The recommended method of constructing a relief*

The hole in the back of the oven forming the vent is covered by a lightweight metal mesh which is firmly attached to the oven. This mesh should block as little of the area of the vent as possible. A layer of rubberised asbestos, 1/32 in. thick, covers the outside of the mesh and forms a seal. This in turn is covered with a layer of lightweight insulating material such as mineral wool, which is held in place by inserting it about $\frac{1}{4}$ in. into the double lining of the oven. Finally, this is covered by a layer of rubberised asbestos, which is held in place by $\frac{1}{2}$ in. wide metal strip screwed to the outside of the oven. The screws must on no account pass through or into the rubberised asbestos.

SHELVES

Shelves used in ovens should preferably be made in such a way that the shelf material occupies not less than one half of the shelf area.

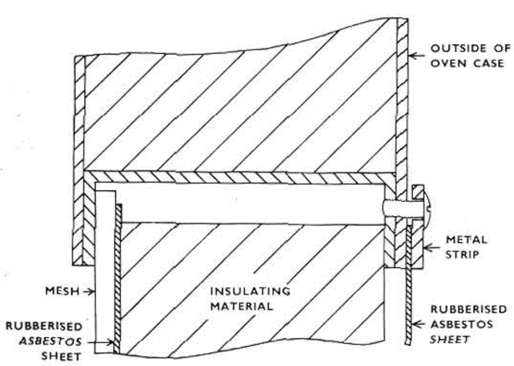


Fig. 11.—*Detail of explosion relief assembly*

The basis for this recommendation is the experimental fact that unless such shelves are used there is a considerable increase in pressure if an explosion occurs. It is realised that if the oven is heavily loaded with stock it may not be possible to use the recommended type of shelf since this would cause almost complete blockage. The best procedure in such cases is to use a lighter type of shelf but to insert the loaded shelves after lighting up the oven.

POSITIONING OF OVEN

An oven should always be spaced not less than 15 in. from a wall behind it. [This applies to ovens smaller than approximately 150 ft^3 ; for large ovens of volume V, the spacing should be $15(V/100)^{\frac{1}{3}}$ in.].

If an oven is in a corner, it should be 2 ft from the side wall and 2 ft from the rear wall. [The provision regarding oven volume applies similarly so that the spacing should be $24(V/100)^{\frac{1}{3}}$ in.].

On the few occasions when a top relief is permissible similar recommendations regarding the spacing of the relief from the ceiling must be observed.

PERSONNEL

Precautions should be taken to prevent the entry of personnel to the region into which the relief is discharged and consideration should be given to the risk of operators being burned by flames discharged from an oven.

Special cases

TREBLE-CASED OVENS

The working space of treble-cased ovens may be treated in just the same way as double-cased ovens. Since the relief must be fitted in the back of the oven it is impossible for the heating passages to occupy the back as is the present practice in some ovens.

In treble-cased ovens, the combustion chamber is sealed from the working space and in the larger ovens of this type may be large enough—*i.e.*, greater than 15 ft^3—to require a relief of its own which should be inserted in the back of the combustion space.

LARGE BATCH-TYPE DRYING OVENS

Large batch-type ovens, *e.g.*, core-drying ovens, can give rise to the same kind of explosion risk as box ovens. In fact, the only difference is that of size. The range of size of the experimental ovens was such that it was considered justifiable to extrapolate the results to volumes as large as this type of oven. Thus reliefs for these large ovens can be dealt with on the same basis as given for box ovens. Because of the nature of the load it may often be permissible to use a top relief with these ovens. In some cases this could ease the constructional difficulties likely to be met with a back relief.

CONVEYOR OVENS

Conveyor ovens usually have approximately square cross-sections but the length is greater than the other dimensions. Any procedure for designing reliefs for conveyor ovens must involve distributing the relief along the length of the oven. It is suggested that the best procedure is to regard them as divided into a number of parts, each of which is approximately cubical, and then to insert a suitable relief into each part. Each of these reliefs can be designed on the basis given above for box ovens.

Conveyor ovens commonly have cross-sections up to about 8 feet square (64 ft^2 area) and so the unit cubes fall in the range of oven volumes experimentally investigated. Although these ovens have open ends, the area of relief provided by the ends is neither large enough nor in the correct position to prevent the oven being damaged by an explosion. Whether the reliefs are inserted in the side or top of the oven will depend on the situation, construction, and loading of the oven.

Practical Verification

Tests on a standard production oven incorporating a back relief designed as specified above showed that the relief limited the pressure to the predicted level and that there was no serious internal damage to the oven and no external effects. It was thus proved that the relief design is satisfactory and a sound production proposition.

It is of interest that an oven manufacturer has independently fitted explosion reliefs to his products following the above procedure and carried out test explosions. No pressure measurements were made but again it was found that there was no serious internal damage and no external effects.

Conclusions

To prevent damage arising from vapour or gas explosions in drying ovens, the following procedure is recommended :—

(1) Explosion relief should be inserted into all ovens, preferably at the back.

(2) The relief should be constructed so that it is harmless and effective. A suitable method is specified.

(3) The relief should occupy the whole of the back of the oven.

(4) Shelves used in ovens should preferably be made in such a way that the shelf material occupies at least one half of the shelf area.

(5) Clearances must always be left between ovens and rear or side walls. Suitable spacings are given.

(6) For treble-cased ovens, the relief (covering the whole of the back) should be divided into two parts that do not connect with each other. One should cover the back of the working chamber and the other the back of the combustion chamber if the volume of this is greater than 15 ft^3.

(7) Precautions should be taken to prevent the entry of personnel to the region into which the relief is discharged.

(8) Consideration should be given to the risk of operators being burned by flames discharged from an oven.

These recommendations apply to box ovens and very large ovens (*e.g.*, core drying ovens). A method of designing reliefs for conveyor ovens is given in the paper.

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Symbols Used

A = area of relief (ft^2).
A_1 = area of oven cross-section (ft^2).
K = vent area coefficient ($= A_1/A$).
p_1 = first peak pressure (lb/in^2).
p_2 = second peak pressure (lb/in^2).
S_0 = normal combustion velocity of mixture in oven (ft/s).
V = oven volume (ft^3).
w = weight of relief (lb/ft^2).

References

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