Critical analysis of safety related design of powered gates

Prepared by the Health and Safety Laboratory for the Health and Safety Executive 2015
The original aim of this project was to perform a theoretical assessment into safety measures that may reduce the risks associated with mechanical hazards of powered gates. In order to simplify the analysis, it was agreed that it should be based on specific (albeit theoretical) gate designs - one sliding and one hinged. These were intended to be representative of real-life designs, using typical drives, control systems and safety measures.

A critical analysis of the designs presented in this report highlights several safety-related inadequacies, which are discussed in detail. In particular, the use of typical drive system control functions to limit crushing forces is shown to be inadequate. Alternative safety measures are suggested to address these inadequacies. Alternative means of risk reduction are discussed; pressure sensitive edges are presented as an effective means of delivering force limitation.

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KEY MESSAGES

This report presents the design of two ‘theoretical’ powered gates - one sliding and one hinged. They are intended to be representative of real-life designs, using typical drives, control systems and safety measures. A critical analysis of the designs presented in this report highlights several safety-related inadequacies, which are discussed in detail. In particular, the use of typical drive system control functions to limit crushing forces is shown to be inadequate. Alternative safety measures are suggested to address these inadequacies. Alternative means of risk reduction are discussed; pressure sensitive edges are presented as an effective means of delivering force limitation.
EXECUTIVE SUMMARY

The original aim of this project was to perform a theoretical assessment into safety measures that may reduce the risks associated with mechanical hazards of powered gates. These measures should not only be capable of satisfying the requirements of applicable standards but also achieve significantly lower impact forces than the limits presented in Annex A of EN 12453: 2000 Industrial, commercial and garage doors and gates. Safety in use of power operated doors. Requirements.

In order to simplify the analysis, it was agreed that it should be based on specific (albeit theoretical) gate designs - one sliding and one hinged.

The intention was to take typical available gate components (drives/drive units and controllers) intended to be fitted to gates to see how they could be deployed for the two gate types, and demonstrate whether they could be improved to present a lower risk by the use of appropriate pressure sensitive edges.

It follows then that the theoretical designs would need the following characteristics:

- They would have no pressure sensitive edges (to start with);
- They would have to rely on force limitation as delivered by the drive/drive unit to safeguard against crushing hazards - as opposed to non-contact means, such as full opto-electronic sensing;
- They would be ‘just’ compliant, i.e. they would just satisfy the 400 N and 1400 N measured force limits currently prescribed in EN 12453, together with all other applicable normative requirements.

Whilst creating the design of the theoretical gates, the project evolved because achieving a design that satisfied the characteristics listed above was not possible, given the physical characteristics of the proposed theoretical designs and available technology.

This last point actually constitutes a significant conclusion of the report and deserves further explanation. Typically, powered gates employ drive systems of sufficient power (needed to reliably move the gate leaf) which allow the gate system to exceed the impact force limits presented in EN 12453. However, the electrical control systems of typical drives provide various configurable features which can reduce potentially dangerous impact forces, i.e. speed control, deceleration control and obstacle detection functions. Careful configuration of these variables can enable the gate system to satisfy the impact force requirements. The issue is that the safety measure is then reliant on the control system. Control systems that perform safety functions must have appropriate integrity. It is considered highly likely that control systems of proprietary gate drive systems do not have adequate integrity. Within the rationale framework of ‘machinery safety’, it is normal to assume that control systems with unproven or inadequate integrity are untrusted and will not function at all, i.e. that the drive system will operate at maximum speed and without any form of obstacle detection. If this were the case, the gates described would impart a much higher impact force than allowed by the standards, and would therefore be unsafe.

It is possible to inherently limit the driving force produced by a motor and limit the kinetic energy of the gate (by limiting its mass and velocity) and thereby limit the impact force to less than the limits in the standards. This approach has the advantage of not relying on control system functions; the disadvantage is that driving force and gate momentum must be restricted. This may be feasible on smaller gates but on larger gates, it may prove impracticable in the case of sliding gates and impossible for hinged gates.

Pressure sensitive edges provide a means of satisfying the normative requirements regarding force limitation; indeed they can exceed them and therefore reduce the force to a lower level than currently allowed by the standards.
Proprietary pressure sensitive edge systems achieve adequate integrity in themselves but they must also be incorporated into a control system of adequate integrity. The drive control systems of the two example gates cannot be modified and so one means of reliably stopping the motor is for the pressure sensitive edge output device to cut the power, either to the drive control system or directly to the motor. This would achieve adequate reliability in stopping the gate. However, once the gate is stopped, it must then reverse to relieve crushing force. This simple means of connection would prevent this. It is not clear whether it would be possible to integrate a proprietary pressure sensitive edge with the drive systems proposed that would both satisfy integrity requirements and allow reversing.

Except for low-powered gates, (with a driving force of less than 150 N), in order to satisfy the normative requirements for force limitation, it is necessary to reverse the motion of the gate, both to remove crushing force and enable release of trapped persons. Entrapment can present a significant risk, with severe consequences (even death). Reliable stopping of a gate drive is readily achievable; reversing (with a sufficient degree of reliability) however, cannot be readily achieved with current technologies. Failure to reverse not only maintains crushing force, thus potentially trapping the exposed person, it also prevents forced release of trapped persons by third parties, due to the fact that gate drive systems typically have self-locking drive systems. This is considered to leave a significant - possibly unacceptable - residual risk.

Pressure sensitive edges rely on the coordination of over-travel distance of the pressure sensitive edge and stopping distance of the moving parts such that the maximum force experienced is limited to an acceptable level. Therefore the stopping characteristics of the drive are important. Self-locking drives generally stop within a very short distance but it is expected that this distance could increase significantly during the lifetime of a gate drive system.

An interesting point to note that arises from the theoretical analysis of impact forces is that the requirements for force/impact limitation are more stringent for powered gates than for passenger lift doors. This analysis indicates that gates exhibiting the maximum admissible dynamic forces for gaps between 50 to 500 mm (of 400 N) - as stipulated by EN 12453, would satisfy the normative requirements for lift doors. Conversely, lift doors exhibiting the maximum impact forces allowable according to lift door standards would fail to satisfy the impact force requirements for powered gates.
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1. INTRODUCTION

This report presents a critical analysis of two gate designs, one for a sliding gate and one for a hinged gate. The designs are theoretical but are intended to be representative of typical installations using typical components. The designs are described in Annex B. The report discusses alternative solutions to the safety-related inadequacies identified. In summary the two designs are:

- **Sliding gate**, consisting of a single leaf across a 5 m wide gateway, running on a rail in the ground and moved by an electrically powered drive unit via a rack and pinion.
- **Hinged gate**, consisting of two equal leaves across a 5 m wide gateway, hinged at the gateposts and driven by electrically powered actuators.

The report concentrates on mechanical hazards.
2. ANALYSIS OF PROPOSED DESIGN

Section 2.1 discusses the potentially hazardous characteristics of the gates, concentrating on mechanical hazards and, in accordance with the approach presented in EN ISO 12100 Safety of machinery General principles for design. Risk assessment and risk reduction (1), identifies the potential hazards in isolation from the safety measures employed to reduce the risk associated with them.

The safety measures employed are discussed in Section 2.2.

Section 2.3 evaluates the safety measures.

Section 2.4 then associates the safety measures with various hazards and hazardous situations.

2.1 HAZARD IDENTIFICATION

This section discusses potential hazards presented by the gates.

2.1.1 Impact

Impact can occur between a person and the moving gate. It is distinct from crushing in that there is no counter-closing edge to produce a closing gap.

2.1.2 Crushing

Crushing hazards exist where the moving gates present a closing gap. For sliding gates, these crushing areas exist between the gate and the gate posts and adjacent fixed parts, such as fixed walls and the ground. For hinged gates, crushing areas can exist between the gate posts and the gates, particularly where the design creates a reducing gap, and in the gap between the pair of closing gates, hinged areas and to adjacent fixed parts, such as fixed walls and the ground.

The capacity to crush is associated with several characteristics, both of the mechanical equipment and of the person subject to the crushing forces. This report concentrates on equipment related aspects rather than characteristics of the person.

The potential for crushing is a function of many factors inherent to the design, such as:

- speed of motion;
- driving force;
- mass of moving parts; and
- stiffness of closing edges.

It is also influenced by the characteristics of the safety measures and the way in which the potential for crushing is measured.

These issues are investigated in more detail in Annex A and discussed in Section 2.3.1.6

For sliding gates, crushing force in line with the gate’s direction of motion is likely to be constant and independent of the location on the gate. On hinged gates, crushing forces vary depending on the distance from the hinge point. As driving torque and inertia remain the same, potential crushing force is lowest at the gate’s outer edge and increases towards the hinge. However, the speed of motion and the travel distance decrease in proportion.

2.1.3 Entrapment

The drive mechanisms for both the sliding and the hinged gates are self-locking. When power is removed, the gates cannot be moved without damaging the gate/drive mechanism. If the gates were to close on a person and then stop, they could not be pushed open without breaking or deforming the gate/drive system, which may take considerable force. Note that a person can become trapped (with potentially serious consequences) without being crushed.
Note that the powered gates are usually intended to prevent access for security reasons; forced opening is prevented by the drive system, which is why self-locking drive mechanisms are employed.

2.1.4 Shearing

2.1.4.1 Sliding gate
The gate presents numerous shear points where it passes fixed parts at both the gate posts, and between the gate and adjacent walls.
Shearing hazards can also exist between the bottom of the gate and the ground.
The forces at these shearing points could be equivalent to the crushing forces discussed above.

2.1.4.2 Hinged gate
The gates present a shear point where the closing edges approach each other as the gates nearly close.
Very slight differences in drive speed will give rise to the gates arriving at the fully closed position at slightly different times, thus giving rise to a shear point momentarily before they are both fully closed.
As for the sliding gate, shearing hazards can also exist between the bottom of the gate and the ground.
The forces at these shearing points could be equivalent to the crushing forces discussed above.

2.1.5 Drawing-in
Drawing-in hazards can exist around rotating parts of drive mechanisms. They can also exist between gaps with parallel relative motion, e.g. between the bottom of the gate and the ground and between a sliding gate and adjacent gatepost. The forces produced in such gaps can be many times greater than the driving and crushing forces discussed above.

2.1.6 Unexpected start-up (or failure to stop/reverse when required)
The drive control system is intended to start moving the gate as described below, but may also start up under foreseeable fault conditions.

2.1.6.1 Activation
The control system can be configured to react to pressing a key fob in various ways. Both the sliding and hinged gates are set to react to a key fob command as follows:

- If the gate is closed, open;
- If the gate is open, close;
- If the gate is opening, stop;
- If the gate is closing, open.

2.1.6.2 Automatic closing
The control system is set to automatically close the gates after a configurable time period, or after re-making light beams (after a car has passed).

2.1.6.3 Reversing
When an obstacle is detected by the force limiting system (in either direction), the gate automatically reverses. If automatic closing is selected, when closing, the gate reverses for a
short distance then attempts to close again; it will repeat this cycle 3 times if the obstacle remains before coming to a permanent stop.

2.2 POTENTIAL SAFETY MEASURES

This section lists the main safety-related features incorporated into the system design of the two example gates. They are categorised as potential safety measures pending the evaluation of each feature in Section 2.3

2.2.1 Force limiting

The potential for crushing is limited by several inherent functions of the drive system (which may be delivered by the drive unit with or without external safety controllers), as described below:

2.2.1.1 Obstacle detection

This detects when the gates hit an obstacle, and stops and reverses the motor. The system detects increased resistance to movement. The sensitivity of the system is configurable – it can be set to one of 6 different levels.

2.2.1.2 Speed control

Speed can be adjusted on the drive unit to one of 4 levels – between 30% and 100% of full speed. The speed of the gate influences the kinetic energy and potential impact force.

2.2.1.3 Deceleration

On the sliding gate, the drive unit can be configured to decelerate during the closing and opening phases. The point at which deceleration begins can be set between 20 cm or 70 cm from end of travel. This will reduce the speed of the gate as it approaches the counter closing edge, and therefore reduce the kinetic energy and potential impact force.

On the hinged gate, the deceleration phase is not adjustable. The control system starts to decelerate the gate at a fixed angular offset in relation to the fully closed position.

2.2.2 Light beams

Both gates also have ‘light beams’ which stop the gates closing when they are interrupted by an object. These are positioned at a height of 400 mm above and parallel with the ground, on each side of the gates. They are intended to prevent the gates closing on obstacles, primarily vehicles.

On the sliding gate, they are positioned approximately 100 mm (horizontally) from the gate. The action of the gate when a beam is interrupted and cleared can be altered, for example, the gate can be programmed to stop or stop then reverse.

On the hinged gates, a light beam is located approximately 100 mm in front of the gates. To the rear of the gates, the light beam is located so it is beyond the arc of the opening gates. This gives rise to a large area inside which a person can stand without interrupting a beam.

On both types of gates, the light beams can be stepped over, or reached over easily. The crushing and shearing points can easily be reached without interrupting the beams.

2.2.3 Fixed guards

Fixed guards are provided around the drive mechanisms which effectively prevent finger access to the rack and pinion drive on the sliding gate and the lead screw drives on the hinged gates.

2.2.4 Safety clearances

Clearances are provided between moving and fixed parts which are intended to prevent the possibility of trapping.
The distance between the floor and the gates in both cases is 50 mm (with little variation as the ground is level in this case).

The distance between the sliding gate and the gatepost is 120 mm.

The distance between the fully opened hinged gate and the adjacent wall is 250 mm.

The design of the hinges and gate posts etc. are arranged such that there are no gaps that create crushing points around the hinge area as the gates operate.

### 2.2.5 Gate release

The self-lock drive mechanism can be mechanically released using a key to enable moving the gates by manual effort.

Table 1 shows which safety measures/functions are incorporated into each gate

<table>
<thead>
<tr>
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<th>Notes</th>
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<td>✔️</td>
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<td>Fixed guards</td>
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<tr>
<td>Reversing on contact with obstacle</td>
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<tr>
<td>Sufficient clearance distances to prevent entrapment</td>
<td>✔️</td>
<td></td>
<td>Between the gate and the drive gatepost Between the ground and the gate</td>
</tr>
<tr>
<td>Sufficient clearance distances to prevent entrapment</td>
<td></td>
<td>✔️</td>
<td>Between the gate and the wall (position 3 in Fig. 2) Between the ground and the gate</td>
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<tr>
<td>Gate release</td>
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### 2.3 EVALUATION OF SAFETY MEASURES

#### 2.3.1 Force limiting

Limitation of crushing and shearing force is achieved in two ways on the example gates, by inherent design characteristics and by drive control system functions.

##### 2.3.1.1 Inherent design characteristics

These include:

- maximum gate speed;
- maximum drive force produced by the drive; and
- gate mass.

##### 2.3.1.2 Drive control system functions

Drive control system functions include:
• speed control, including normal operating speed;
• obstacle detection;
• control of deceleration profile with respect to location of the gate; and
• starting, stopping and reversing.

These control functions are unlikely to satisfy the integrity requirements for safety-related control functions for the following reasons:

• The installation and operating instructions do not indicate a category (according to EN 954-1 - Safety of machinery. Safety related parts of control systems. General principles for design -superseded) (2) or a performance level (according to EN ISO 13849-1 Safety of machinery. Safety-related parts of control systems. General principles for design ) (3) specifically for these functions;
• Generic (i.e. not specifically for powered door/gate operation) safety drives are available which are designed specifically to achieve high integrity in performing speed control, torque limitation, etc. functions. Such drives are fairly specialist and relatively high cost products. It is considered highly unlikely that these relatively low cost powered gate drives achieve an equivalent (or compliant) level of integrity.

2.3.1.3 Reliability of obstacle detection function

The obstacle detection function of the drive system relies on the monitoring of current to detect increases in torque arising from increases in resistance to motion of the gate. The torque required at the motor to move the gate is dependent on many factors such as gate mass, ‘rolling resistance’, acceleration rates etc.; these are expected to be constant for a given gate design. Other factors may also combine to cause the current required to move the gate to fluctuate, such as temperature fluctuations, wear, lubrication, supply voltage, wind loading and other environmental conditions (ice and snow). The force limiting system must be capable of accommodating these variations to give reliable operation (i.e. to avoid nuisance tripping), whilst also being sufficiently sensitive to detect obstructions.

The probability of nuisance tripping will depend on the magnitude of normal operating force (including fluctuations) in proportion to the obstacle detection force. If the operating forces are low in relation to the detection force, nuisance tripping will be less likely. Conversely, if the operating forces are large in proportion to the detection force, nuisance tripping will be more likely.

Allowable detection forces are fixed (defined in standards). Smaller gates of low mass are likely to have lower operating forces (and smaller fluctuations in operating forces) than large gates with higher mass.

Nuisance tripping is likely to reduce the reliability of this safety function if it occurs too often. In such situations, it is foreseeable that the force-limiting system parameters (such as sensitivity, operating velocity, deceleration rates etc.) could be re-adjusted to achieve reliable operation at the expense of reliable force-limiting capability, or the force-limiting feature might be disabled entirely.

2.3.1.4 Wind loading

As indicated above, wind loading will influence the force required to move a gate and it will therefore serve to reduce the effectiveness of force limiting by current sensing.

Wind loading may be expected to slightly influence the force required to move a sliding gate, but it will significantly influence the force required to move a hinged gate.
It is estimated (4) that the wind loading on a hinged gate of 2 x 2.37 m, at a wind speed of 11 m/s (approximately 25 mph) in an urban environment will be approximately 650 N. This force is considered to be evenly distributed along the width of the gate. For a hinged gate in the closed position, it is equivalent to a point load of 325 N at a point furthest from the hinge; when the gate is closing or opening this equivalent point load furthest from the hinge is likely to be slightly higher.

In order for the force limiting system to allow reliable operation of the gate in windy conditions, it must be able to distinguish between wind loading (which is highly variable) and obstacle sensing.

As the wind can blow in any direction, it can act in both the same and the opposite direction to that in which the gate is being driven. If the wind load is acting in the same direction as the motion of the gate, it will add to the potential crushing forces resulting from the momentum and driving force. If the wind loading is acting in the opposite direction to the gate motion the overall effect may be to prevent the gate operating, particularly if set up to operate at minimum force for safety. To improve the functional reliability of the gate, there would be a temptation to increase the tripping force, however this would inevitably decrease the effectiveness of force limitation as a safety measure.

Noting that the maximum impact force should not exceed 400 N in trapping points (according to EN 12453 (4) Annex A), it is expected that force limiting will not provide an effective and reliable safety measure against crushing for large hinged gates. The limits for shearing forces are lower and therefore force limiting is even less likely to be effective for shearing hazards.

2.3.1.5 Force limitation by drive system functions

As a result of the points made in Section 2.3.1.2, it is apparent that the drive control system cannot be relied upon to perform control functions that achieve force limitation as a safety measure, as a consequence of their inadequate safety-related integrity.

Also, apart from the integrity, obstacle detection by the method employed by the example gates is fundamentally flawed because of the marginal nature of the detection method as discussed in Sections 2.3.1.3 and 2.3.1.4.

Drive system functions are likely to be particularly ineffective at limiting impact forces on hinged gates due to the following reasons:

- Wind loading will create large variations in the applied drive torque, which will make achieving reliable object detection together with reliable functioning very difficult.
- Although achieving appropriate force/impact limitation may be possible at the closing edges, the potential crushing forces increase linearly between the outer edge and the hinge. Implementing a force/impact limiting system which relies on torque monitoring of the drive and which limits the force along the whole width of the gates is therefore unlikely to be possible.

In order to determine the magnitude of the risk associated with crushing from the powered motions, it is appropriate to use an approach similar to that presented in EN 12453 (4) Annex A. This produces an impact force measurement in Newtons, taken by a force measuring instrument with a specified stiffness of 500,000 N/m. Using this approach, the complicated set of factors that influence the potential for injury are reduced to a single value, or values over time (force profile).

Having established that the drive system control functions cannot be relied upon to limit impact force, in order to assess the potential risk, it would be beneficial to determine what impact force could be expected in their absence. To this end, Annex A arrives at an expression for maximum impact force, based on inherent characteristics of the gate. The results are theoretical approximations but they give a good indication of the maximum impact force that would be
measured if the gate were operating at maximum speed and continued to drive (i.e. with no obstacle detection).

2.3.1.6 **Discussion arising from analysis presented in Annex A**

The following section discusses the implication of Annex A in more detail. Note that the term “impact force” in this section, refers to the theoretically calculated peak force, which the standard test instrument would record. According to the applicable normative requirements (Annex A, EN 12453 (4)), the limits for this are 400 N for gaps between 50 and 500 mm and 1400 N for gaps over 500 mm.

**Sliding gate (Table A1)**

**Case 1**

Assumptions:

- The motor force remains constant and at the nominal maximum torque during the period from impact to the gate coming to rest;
- The gate is travelling at full speed at impact;
- There is no compliant edge on the gate;
- The only compliance in the system (i.e. the gate and the measuring instrument) is that provided by the ‘spring’ in the measuring instrument.
- The driving force is 600 N as per the theoretical gate’s drive specifications

Implications:

- The impact force is 2800 N, which is well in excess of the 400 N and the 1400 N limits;
- The stopping time is estimated at 0.07 seconds (secs).

**Case 2**

Assumptions:

- As per case 1, but the gate is assumed to have a compliant edge which presents a linear spring constant of 20000 N/m. This is considered to be a value that could approximate the characteristics of a rubber bump strip (passive) attached to the closing edge of the gate.

Implications:

- The impact force 1334 N is lower than Case 1 but still well in excess of the limits;
- Note that the stopping distance increases to 67 mm, which will require a relatively large bump strip to accommodate.

**Case 3**

Assumptions:

- As per case 2, but with an impact speed approximately half full speed and a much lower powered motor (150 N driving force as opposed to 600 N).
Implications:
- The impact force satisfies the normative requirement for gaps between 50 mm and 500 mm.

**Case 4**

Assumptions:
- As per Case 1, except assumes zero driving force. This case estimates the impact force produced as if the gate were ‘free wheeling’ onto the measuring instrument.

Implications:
- The impact force remains very high (2117 N) – still well in excess of the limits.

**Case 5**

Assumptions:
- As per Case 4, except assumes a very low gate speed.

Implications:
- The impact force satisfies the normative requirement for gaps between 50 mm and 500 mm.

**Case 6**

Assumptions:
- As per case 2, but with an impact speed of 0.2 m/sec and much lower gate mass (25 kg).

Implications:
- The impact force satisfies the normative requirement for gaps between 50 mm and 500 mm.

**Discussion, sliding gate**

The various cases presented show that the characteristics (driving force, gate speed, gate mass) must be constrained in order to achieve the impact force required by the applicable standards.

**Hinged gate (Table A2)**

**Case 7**

Assumptions:
- The motor force remains constant and at the nominal maximum torque during the period from impact to the gate coming to rest;
- The gate is travelling at full speed at impact;
- There is no compliant edge on the gate;
- The only compliance in the system (i.e. the gate and the measuring instrument) is that provided by the ‘spring’ in the measuring instrument.
Implications:

- The impact force is 834 N, which is well in excess of the 400 N and the 1400 N limits;
- The stopping time is estimated at 0.018 secs.

**Case 8**

Assumptions:

- As per case 7, but the gate is assumed to have a compliant edge which presents a linear spring constant of 20000 N/m. This is considered to be a value that could approximate the characteristics of a rubber bump strip (passive) attached to the closing edge of the gate.

Implications:

- The impact force 383 N is lower than Case 7, which is below the 400 N limit;
- Note that the stopping distance increases to 19 mm, which is realistically achievable with a compliant edge.

**Case 9**

Assumptions:

- As per case 8, but with lower powered motor (150 N driving force as opposed to 170 N).

Implications:

- The impact force satisfies the normative requirement for gaps between 50 mm and 500 mm, i.e. it is less than 400 N.

**Case 10**

Assumptions:

- As per Case 7, except assumes zero driving force. This case estimates the impact force produced as if the gate were ‘free wheeling’ onto the measuring instrument.

Implications:

- The impact force remains very high (642 N) – still well in excess of the limits

**Discussion, hinged gate**

The various cases presented show that the characteristics (driving force, gate speed, gate mass) must be constrained in order to achieve the impact force required by the applicable standards. Case 7 seems to be realistically achievable and compliant, although the issues associated with wind loading and force amplification (see Section 2.3.1.5) will still mean force limitation is unlikely to be an effective safety measure.

**Comparison between the force/energy limiting requirements for lift doors and powered gates**

Annex A presents an analysis that enables comparison between the requirements for lift doors and powered gates. Table A3 presents several scenarios which are discussed below.
Case 11

Represents a gate that would just satisfy the requirements of EN 81-1 (5), primarily the energy required to stop the gate would be just under 10 J, when measured with a measuring instrument with a spring constant = 25 N/mm. It assumes that the drive motor continues to drive at full power (150 N) after it hits the measuring instrument. Note that this produces a maximum impact force of around 700 N, which is well in excess of the 400 N limit in EN 12453 (4).

Case 12

Represents the same situation as case 11, except that the driving force is zero, i.e. the gate is effectively coasting to a halt. This reduces the energy required to stop the gate and reduces the peak force to 529 N, which is still in excess of the 400 N limit in EN 12453 (4).

Case 13

Represents a situation where the gate drive applies a braking force, equivalent to the driving force. In this case, the peak force is 400 N, which is the limit in EN 12453 (4). Note that the compliance in the system for cases 11, 12 & 13 comes from the spring in the measuring instrument and assumes the moving parts of the gate are rigid.

Case 14

This has the same variables as case 11, except that the spring constant of the measuring instrument is 500 N/mm as per the measuring instrument for EN 12453 (4). It can be seen that the expected peak force is around 2500 N. This indicates that the gate presented in case 11 would satisfy the requirements for lift doors (EN 81-1) (5) but fail to satisfy the requirement for gates (EN 12453) (4).

Case 15

This has the same variables as case 14, except that the drive provides a very high braking force – representative of a self-locking drive system (though actuated instantaneously on contact, which is not possible). Note that the stopping distance and time is very low and the peak force on the test instrument is also low – well within 400 N.

2.3.2 Light beams

There is no evidence that the light beams system satisfies the requirements of clause 5.1.1.6 of EN 12453 (4) or EN 61496-1:2004 (6), and therefore they cannot be considered as a compliant safety measure.

Furthermore, their deployment as single beams close to the sliding gate, or outside the swept arc of the hinged gate, means they can easily be circumnavigated by deliberately or inadvertently stepping or reaching over, or in the case of the hinged gate, bypassed completely. Their primary purpose appears to be vehicle detection, to avoid gate closure on a vehicle and damage. They will only incidentally detect people if they happen to break the beam. Incorporating multiple light beams would partially address this issue.

The light beams can therefore only be considered as supplementary safety measures (which is what is implied by their inclusion as the “D” means in clause 5.1.1 of EN 12453 (4) where they need not necessarily fulfil the requirements of clause 5.1.1.6, and are always only required in addition to either the “C” or “E” means in table 1 of that standard).

2.3.3 Gate release

Trapping can refer to a situation where a person is trapped in an enclosed space on one side of the gate, the only way out being via the gate; or it can refer to a person being physically held between the gate and a fixed object and not being able to escape. This latter situation may
coincide with the gate also applying a crushing force to the person. This section is concerned with the latter meaning of ‘trapped’ and herein is referred to “entrapment”.

In this situation, there is immediate danger to the trapped person, especially if the gate is applying a crushing force. The most serious occurrences may lead to asphyxiation and death. Even if the gate is only applying a very low force and the trapped person is held at a narrower part of the body (e.g. neck) because the gate cannot be pushed back to effect release, there may be prolonged distress caused by the entrapment, especially with gates in remote locations. Therefore, effective means of releasing trapped persons is essential.

The drive systems provide a means of disengaging the drive mechanism, thus allowing the gate to be moved without breaking or deforming it, which is not possible without considerable force. Disengagement requires a key to be inserted into the drive unit.

It is entirely foreseeable, indeed probable, that this key will not be readily available in the event of an emergency and even if it were, release of a trapped person would require a second person to be present who knows how to affect release.

It is noted that other analogous equipment, such as train or passenger lift doors, can be pushed open by the trapped person if required. As these gates feature self-locking drive mechanisms, pushing them open to allow release is impossible.

Mechanical gate release cannot therefore be considered as a primary safety measure, only one of limited usefulness as it relies on the presence of a competent person with the tool to release the gate. Instead, safety should primarily be provided by a system with sufficient reliability and integrity to avoid entrapment in the first place.

2.3.4 Training and familiarisation

These gates are located in public places and therefore it can be assumed that exposed persons will not be trained or even be familiar with the operation of powered gates.

2.3.5 Safety clearances

According to EN 349 (7), the safety clearances between the gates and the floor (50 mm) are adequate for toe clearance but not foot clearance.

Between the sliding gate and the gatepost (120 mm) is adequate for arm clearance but not whole body clearance (Note: whole body access would be hazardous in itself, so this dimension must be limited to prevent whole body access).

Between the hinged gate and the wall (250 mm) is adequate for arm/leg clearance but not head or whole body clearance.

Other measures are therefore needed in addition to the use of safety clearances in certain locations.

2.4 HAZARDOUS SITUATIONS AND EVENTS

Tables 2 and 3 list various hazards and hazardous situations, and associated safety measures for sliding and hinged gates. They categorise the safety measures into primary and supplementary, taking into account the evaluation discussed above.
<table>
<thead>
<tr>
<th>Ref.</th>
<th>Location in Figure 1</th>
<th>Hazard</th>
<th>Hazardous situation</th>
<th>Hazardous event</th>
<th>Primary safety measure</th>
<th>Supplementary safety measures</th>
<th>Alternative safety measures (see Section 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>3</td>
<td>Crushing</td>
<td>Person enters closing gap near to end of travel (500 to 50 mm gaps), whilst the gate is moving at reduced speed.</td>
<td>Crushing injury</td>
<td>None</td>
<td>Force limiting system in drive together with automatic reversing function</td>
<td>Full presence detection. Pressure sensitive edge. Hold to run operation.</td>
</tr>
<tr>
<td>b</td>
<td>3</td>
<td>Impact</td>
<td>Gate impacts person mid travel, (&gt; 500 mm gap) whilst the gate is closing at full speed.</td>
<td>Impact injury</td>
<td>None</td>
<td>Light beams</td>
<td>Shaping. Full presence detection. Pressure sensitive edge. Hold to run operation.</td>
</tr>
<tr>
<td>c</td>
<td>1</td>
<td>Shearing</td>
<td>Person enters shearing point on opening cycle, at any point in travel.</td>
<td>Crushing/severing injury/entrapment</td>
<td>None</td>
<td>Light beams</td>
<td>Shaping. Full presence detection. Pressure sensitive edge. Hold to run operation.</td>
</tr>
<tr>
<td>d</td>
<td>1,6</td>
<td>Drawing-in</td>
<td>Person inserts hand/arm into gap between moving gate and gatepost.</td>
<td>Crushing</td>
<td>Safety clearance</td>
<td>Not required</td>
<td>Shaping. Full presence detection. Pressure sensitive edge. Hold to run operation.</td>
</tr>
<tr>
<td>e</td>
<td>1,6</td>
<td>Drawing-in &amp; Entrapment</td>
<td>Person inserts head/body into gap between moving gate and gatepost.</td>
<td>Asphyxiation, crushing</td>
<td>None</td>
<td>None</td>
<td>Shaping. Full presence detection. Pressure sensitive edge. Clearance gap. Hold to run operation.</td>
</tr>
<tr>
<td>f</td>
<td>4,5</td>
<td>Drawing-in</td>
<td>Person drawn-in at transmission of drive.</td>
<td>Crushing</td>
<td>Fixed guards, instructions not to remove guards</td>
<td>Not required</td>
<td>Hold to run operation.</td>
</tr>
<tr>
<td>g</td>
<td>2</td>
<td>Drawing-in</td>
<td>Person drawn-in at support wheel.</td>
<td>Crushing</td>
<td>Fixed guards, instructions not to remove guards</td>
<td>Not required</td>
<td></td>
</tr>
</tbody>
</table>
Figure 1 Hazard zones on sliding gate
<table>
<thead>
<tr>
<th>Ref.</th>
<th>Location in Figures 2 &amp; 3</th>
<th>Hazard</th>
<th>Hazardous situation</th>
<th>Hazardous event</th>
<th>Primary safety measure</th>
<th>Supplementary safety measures</th>
<th>Alternative safety measures (see Section 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>p</td>
<td>6</td>
<td>Crushing</td>
<td>Person enters closing gap between the two gates, near to end of travel (500 to 50 mm gaps), whilst the gates are moving at reduced speed.</td>
<td>Crushing injury</td>
<td>None</td>
<td>Force limiting system in drive together with automatic reversing function. Light beams.</td>
<td>Full presence detection. Pressure sensitive edge. Hold to run operation.</td>
</tr>
<tr>
<td>q</td>
<td>6</td>
<td>Impact</td>
<td>Gate impacts person mid travel, (&gt; 500 mm gap) whilst the gate is closing at full speed</td>
<td>Impact injury</td>
<td>None</td>
<td>None</td>
<td>Shaping. Full presence detection. Pressure sensitive edge. Clearance gap. Hold to run operation.</td>
</tr>
<tr>
<td>r</td>
<td>7</td>
<td>Shearing</td>
<td>Person enters shearing point created when the two closing edges approach the fully closed position</td>
<td>Crushing/severing injury</td>
<td>None</td>
<td>Light beams</td>
<td>Full presence detection. Pressure sensitive edge. Clearance gap. Hold to run operation.</td>
</tr>
<tr>
<td>s</td>
<td>6</td>
<td>Entrapment</td>
<td>Person becomes trapped by closing gate, between the two gates</td>
<td>Asphyxiation, crushing</td>
<td>None</td>
<td>Shaping. Full presence detection. Pressure sensitive edge. Clearance gap. Hold to run operation.</td>
<td></td>
</tr>
<tr>
<td>t</td>
<td>1, 4</td>
<td>Crushing</td>
<td>Person enter trapping zone between the gate and the gate post</td>
<td>Crushing</td>
<td>None</td>
<td>None</td>
<td>Shaping. Full presence detection. Pressure sensitive edge. Clearance gap. Hold to run operation.</td>
</tr>
<tr>
<td>u</td>
<td>3</td>
<td>Crushing</td>
<td>Person enters closing gap between the opening gate and the adjacent wall</td>
<td>Crushing</td>
<td>None</td>
<td>None</td>
<td>Full presence detection. Pressure sensitive edge. Clearance gap. Hold to run operation.</td>
</tr>
<tr>
<td>v</td>
<td>5</td>
<td>Drawing-in</td>
<td>Person drawn in to the gap between the bottom of the gate and the floor during closing cycle</td>
<td>Crushing, entrapment</td>
<td>None</td>
<td>None</td>
<td>Shaping. Clearance gap. Hold to run operation.</td>
</tr>
<tr>
<td>w</td>
<td>5</td>
<td>Drawing-in</td>
<td>Person drawn in to the gap between the bottom of the gate and the floor during opening cycle</td>
<td>Crushing, entrapment</td>
<td>None</td>
<td>None</td>
<td>Shaping. Clearance gap. Hold to run operation.</td>
</tr>
<tr>
<td>x</td>
<td>2</td>
<td>Crushing</td>
<td>Person crushed in closing gaps around the drive unit</td>
<td>Crushing</td>
<td>None</td>
<td>Light beams</td>
<td>Shaping. Full presence detection. Pressure sensitive edge.</td>
</tr>
<tr>
<td>y</td>
<td>2</td>
<td>Drawing-in</td>
<td>Person drawn-in at transmission of drive</td>
<td>Crushing</td>
<td>Fixed guards, instructions not to remove guards</td>
<td>Not required</td>
<td>Hold to run operation.</td>
</tr>
<tr>
<td>z</td>
<td>1</td>
<td>Crushing/shearing</td>
<td>Person enters trapping zone between the gate and the gate post</td>
<td>Crushing</td>
<td>Remove trapping hazards by design</td>
<td>None</td>
<td>Hold to run operation.</td>
</tr>
</tbody>
</table>
Figure 2 Hazard zones on hinged gate
Figure 3 Hazard zones on hinged gate
3. NON-COMPLIANCES

3.1 WITH REQUIREMENTS OF STANDARDS

A summary of the applicable normative requirements regarding the mechanical hazards presented by these gates is shown in Table 4.

Table 4 Summary of the applicable normative requirements regarding the mechanical hazards presented by these gates

<table>
<thead>
<tr>
<th>Standard</th>
<th>Clause dealing with mechanical hazards</th>
<th>Summary of clause</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN 12453 (4)</td>
<td>5.1</td>
<td>To safeguard hazards, employ one or a combination of:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Safety distances;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Guards;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Shaping;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Hold-to-run;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Force limitation;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Sensitive protective equipment.</td>
</tr>
<tr>
<td>EN 12453 (4)</td>
<td>5.5.1</td>
<td>For gates for untrained users, hazards at main closing edges should be safeguarded by force limitation and person sensing (e.g. light beam), or full non-contact presence detection.</td>
</tr>
<tr>
<td>EN 12604 (H-98/37/EC) (8)</td>
<td>4.5.2</td>
<td>For mechanical hazards on powered gates, see requirements of EN 12453 (4).</td>
</tr>
<tr>
<td>EN 13241-1 (H-2006/42/EC) (9)</td>
<td>4.3.2</td>
<td>For mechanical hazards on powered gates, see requirements of EN 12453 (4).</td>
</tr>
</tbody>
</table>

Table 4 shows that, for the gates in question, mechanical hazards due to powered operation are dealt with by referencing EN 12453 (4).

As Tables 2 and 3 show, many of the mechanical hazards do not have primary safety measures and rely on light beams and drive control system functions as supplementary safety measures. For these hazards, the example gates fail to satisfy the general requirement of EN 12453 (4) clause 5.1.

For the hazards at the main closing edges, the explicit requirement in Table 1 of EN 12453 (4) (automatic control/untrained users) is not satisfied either. The theoretical gates presented have aspects of impulse activation and automatic control and are used by untrained users. The gates do not have presence detection according to 5.5.1 (abbreviation E), and therefore they must have limitation of forces and presence detection (abbreviations C and D). The gates do not satisfy the requirements for these, as explained in section 2.3.1 of this report. Therefore, the design of the gates does not comply with EN 12543 (4) or its referencing standards ((1)(2)(3)(8)(9)(10)(11)(12)(13)(14)(15)(16)).

3.2 WITH ESSENTIAL HEALTH AND SAFETY REQUIREMENTS OF THE EUROPEAN MACHINERY DIRECTIVE 2006/42/EC

For the hazards without a primary safety measure, the design of the gates fails to satisfy the European Health and Safety Requirements of the European machinery Directive (EHSR) (9) Section 1.3.7 regarding risks related to moving parts. According to the first paragraph of this clause:
“The moving parts of machinery must be designed and constructed in such a way as to prevent risks of contact which could lead to accidents or must, where risks persist, be fitted with guards or protective devices”.

The risk of crushing is not prevented and so it persists. Therefore, the hazardous moving parts must be fitted with guards or protective devices. Some of the hazardous motions are safeguarded by force limitation. Force limitation may be an acceptable protective device if the system providing that function were to comply with applicable requirements (e.g. clause 5.1.1.5 of EN 12453 (4)). The force limiting system on the proposed gates fails to satisfy these requirements as discussed in section 2.3.1 of this report.

The light beams and drive control system functions must only be considered as supplementary safety measures, as they fail to satisfy EHSRs (9) 1.2.1 regarding reliability of control systems and 1.4.3 regarding protective devices.

It is noted that the gates are not fitted with an emergency stop. As the gates are used by untrained users and the mechanical hazards are widely spaced, it is considered that an emergency stop would not reduce the risk and therefore, according to EHSR (9) 1.2.4.3, an emergency stop is not required.
4. ALTERNATIVE SAFETY MEASURES

4.1 POWERED HOLD-TO-RUN (NON-AUTOMATIC) OPERATION

The principle of hold-to-run control by a trained operator who has a clear view of the hazard zones, is a well-recognised safety measure to adequately reduce the risks associated with powered motions, provided that the speed of parts is limited. Obviously this has the significant drawback of requiring a dedicated operator whenever the gate is required. This is likely to be undesirable in most situations, except where a very high level of security is required (Note: automatic powered gates do not in themselves deliver a secure site, because there may be significant unsupervised periods of time while the gate is at least partially open).

The hold-to-run control would also need to be performed by a control system of adequate integrity. As discussed in 2.3.1.2, the drive control system on the example gate is unlikely to satisfy this requirement, nor would the remote control system (key fob).

One solution that would satisfy control system integrity requirements for hold-to-run control would be to have electro-mechanical push buttons (open, close) hard-wired to interrupt the power supply to the drive motor which would need to be selected for an appropriate maximum speed of operation compatible with the motor’s stopping performance and human response time.

4.2 LOW DRIVING FORCE/INERTIA

Reducing the force produced by the drive system and the inertia of the gate sufficiently may present a partial solution to the impact, crushing and shearing hazards. This approach may be feasible for small, gates of low mass, but it is not expected to be a solution for larger gates, such as those discussed here. This is demonstrated by cases 3 & 7 respectively in Tables A1 and A2. These show combinations of gate mass, operating speed and driving force, which achieve the 400 N limit in EN 12543 (4). As the tables demonstrate, a dynamic force of less than 400 N can be achieved only with much lower gate speed, driving force or gate mass, or combinations of the three. Note that this approach only deals with the instantaneous crushing forces presented by the gate. It does not reduce the risk associated with entrapment.

4.3 INHERENTLY SAFE DESIGN OF GATE GEOMETRY

Reducing the risk presented by equipment by employing inherently safe design features is preferred over relying on additional safety measures. Inherently safe design features are discussed in more detail below. Sometimes it is impossible to rely on inherently safe design, in which case additional safety measures may need to be incorporated.

4.3.1 Clearance gaps

Clearance gaps are specified in Annex C.3 of EN 12604 (8) and EN 349 (7). These can be used in a number of locations, as described below.

However clearance gaps for arms, for example, can be sufficiently large to create a whole body trapping point, in which case, safety measures to prevent whole body trapping must be provided.

4.3.1.1 On sliding gates

Between the moving gates and the gate support post, to prevent finger/hand crushing and entrapment.

Between the floor and the bottom of the gate, to prevent foot trapping.

Between the gate and drive units, to prevent finger trapping.

4.3.1.2 On hinged gates

Between fully open gates and adjacent fixed objects such as walls (see point 3 on Figure 2).

Between the floor and the bottom of the gate, to prevent foot trapping.

Between the gate and drive units, to prevent finger trapping.
4.3.2 Shaping
Shearing hazards can be reduced by:
- Making surfaces smooth and flat;
- Avoiding protruding parts or indentations;
- Increasing gaps between adjacent moving parts sufficiently to remove the shear point;
- Reducing gaps between adjacent moving parts to prevent possibility of access gaps.

4.3.3 Removal of crushing points on hinged gates
The potential crushing force increases towards the hinge, up to very high values close to the hinge. Neither inherently safe design measures, nor drive control system functions for limiting forces can effectively safeguard against these elevated crushing forces. The simplest way to safeguard against these hazards is to remove all potential trapping points around gate posts and any adjacent structures, such as walls etc. so there is adequate clearance to prevent crushing. If this is not feasible, provision of pressure sensitive edges may be able to reduce the risk of crushing to a tolerable level.

4.4 FULL NON-CONTACT PRESENCE DETECTION
Full non-contact presence detection provides a means for detection of presence that ensures hazards cannot be reached – typically using opto-electronic devices. Typically, this would be very costly and potentially problematic to apply to most gates due to the large approach distances required, susceptibility to spurious tripping due to dirt, water snow & cost, etc.

4.5 AUTOMATIC OPERATION WITH PRESSURE SENSITIVE EDGES
Pressure sensitive protective equipment, in the form of pressure sensitive edges, are a widely accepted means of reducing the risk of crushing and shearing hazards. These can be applied to crushing/shearing points on sliding and hinged gates identified above.

4.5.1 General principle of operation
Pressure sensitive edges detect contact and provide a control signal to the drive or system controller to stop/reverse hazardous motions. They are made of deformable rubber-like material, which deforms slightly prior to switching, and can then continue to deform to accommodate over-travel as motion decelerates to a stop. There is a limit to their deformation, and beyond a certain distance, the profile flattens. A typical pressure sensitive edge profile is shown in Figure 4.

![Typical pressure sensitive edge profile](image-url)
4.5.2 Stopping distances and deformation

When integrating pressure sensitive edges, it is necessary to ensure that the stopping distance of the moving part in combination with the force/travel characteristics of the edge, limits the contact force to within an acceptable value.

The type “B” standard applicable to pressure sensitive edges is EN 1760-2 (12). This requires manufacturers to provide graphs showing how contact force varies with travel and at what point switching occurs. A graph (for an example) of pressure sensitive edge performance is shown in Figure 5. There is also a specific harmonised “C” standard for the requirements and tests methods for safety devices for industrial, commercial and garage power operated doors and gates (EN 12978:2003+A1:2009 (15)) which supports the use of this equipment in all types of premises.

![Graph showing relationship between applied force F and compression distance s for an example pressure sensitive edge](image)

**Figure 5** Graph showing relationship between applied force F and compression distance s for an example pressure sensitive edge

The origin represents the point where contact is first made
Point A represents the end of the initial deformation characteristics and the onset of the linear deformation characteristics
Point B represents the end of the linear deformation characteristics, where the safety edge profile is largely collapsed
Point C represents the beginning of deformation of solid material
Point D represents the end of the test.

4.5.3 Example solution

Assuming the following gate characteristics:

- Stopping distance after cutting power = 25 mm;
- Operating speed = 160 mm/sec;
- Reaction time of sensing unit = 10 ms;
- Force travel characteristics are as shown in Figure 1. The travel before sensing occurs = 7 mm.

The events that lead to the gate stopping are as follows:

1. Gate approaches obstacle;
2. Pressure sensitive edge touches object;
3. Edge deformation and sensing occurs. The distance travelled at this point equals the sensing distance (= 7 mm);
4. Control unit cuts power to control system. This takes 10 ms during which time the gate is travelling at 160 mm/s. Therefore the distance travelled during this stage = 1.6 mm;
5. Control system removes power to motor and the gate decelerates to a halt. This takes 25 mm;
6. Therefore total travel prior to halting = 33.6 mm. This distance corresponds to a contact force of 250 N;
7. This 250 N maximum force is obviously lower than the 400 N peak force stipulated in annex A of EN 12453 (4) and the 400 N maximum force to safeguard against shear hazards stipulated in 5.1.1.5.3 of EN 12453 (4).

Annex A of EN 12453 (4) also requires the force to be reduced to below 150 N within 0.75 secs and to less than 25 N after 5 secs. This would necessitate reversing the drive. The standard also allows contact force to be maintained indefinitely, if the peak force is below 150 N. If the stopping distance was shorter, or the over-travel capacity of the pressure sensitive edge larger, it would be possible to achieve a peak contact force of less than 150 N. Whereas stopping motion can be achieved with a fairly high degree of reliability, reversing cannot, and therefore designing a safety measure that does not rely on reversing is preferable. Note that requiring powered motion (such as reversing) to achieve a safe state is very problematic and not usually used in safety-related design solutions. This is because it becomes necessary to have uninterruptable power supplies, dual drive systems etc.

4.5.4 Pressure sensitive edges on sliding gates

The most obvious locations to fit pressure sensitive edges on sliding gates are on the main closing edge (location 3 on Figure 1), the opposite end of the leaf and adjacent to shearing points next to the gate post.

However, the provision of fixed fencing of a suitable type to prevent reaching of the moving leaf etc. at the rear of the gate (location 6) can reduce the number of edges required to detect hazards during both the opening and closing cycles.

4.5.5 Pressure sensitive edges on hinged gates

There are several crushing zones on hinged gates which could be safeguarded by pressure sensitive edges, such as locations 3, 5 & 6 in Figure 2. However they need careful siting to ensure adequate person detection, particularly towards the hinge area, or at the interface with the ground (on both sides of the gates).
5. CONCLUSIONS

- Drive control systems that provide intrinsic control functions (such as obstacle detection, force limitation, speed control etc.) which are intended to be used as safety measures should comply with applicable normative requirements, such as EN 12453 *Industrial, commercial and garage doors and gates. Safety in use of power operated doors. Requirements*, clause 5.1.1.5 and 5.1.1.6 and EN 60335-2-103 *Household and similar electrical appliances. Safety. Particular requirements for drives for gates, doors and windows*, clause 20.109 or EN ISO 13849-1 *Safety of machinery. Safety-related parts of control systems. General principles for design*, for each safety-related control function provided. The control systems of drives that do not satisfy these requirements should not be relied upon to perform safety functions.

- In the absence of gate control system safety functions of adequate integrity, gates that rely on force limitation delivered solely by the drive/drive unit to safeguard against crushing, must limit impact force by other means, such as inherently safe design measures (by limiting motor and hence driving force, along with limiting the kinetic energy of the moving gate leaves and by the use of compliant edges) or by the use of pressure sensitive edges.

- Small gates, with low-powered drives, may realistically be able to rely on inherently safe design measures to adequately reduce the risk of crushing; this is unlikely to be practicable on larger gates (particularly hinged close boarded gates), and therefore pressure sensitive edges or similar are needed, if force limitation is used as a primary safety measure against crushing.

- As force limits are lower for shearing hazards, force limitation is less likely to be effective and inherently safe design measures are more appropriate, e.g. by eliminating them by design.

- Pressure sensitive edges, appropriately selected (sizes and types) and incorporated (numbers and locations), can satisfy the force limitation requirements presented in EN 12453 and can therefore contribute to adequate risk reduction.

- A comparison of the force limitation requirements for passenger lift doors (according to EN 81-1 *Safety rules for the construction and installation of lifts. Electric lifts.*) and powered gates (according to EN 12453) shows that gates that would just satisfy the lift door requirements will normally fail to satisfy the powered gates requirements (by a significant margin), for typical arrangements.

- To reduce the complexity of pressure sensitive edges in safeguarding crushing/trapping points, it is necessary to remove as many crushing/trapping points as possible using inherently safe design, e.g. by removing counter closing edges, or ensuring adequate safety clearances, careful hinge design, gate positioning, etc.

- When self-locking drive systems are used, a control function must be relied upon to reverse the gate if a person becomes trapped. Owing to the nature of operation of the drive system, this control function must be of low integrity (for instance manually disengaging a pin). As entrapment can cause severe injury or death, self-locking drive systems leave a significant residual risk.

- In order to satisfy the force limitation requirement in Annex A of EN 12453, many typical design solutions rely on the gate motion to be reversed in order to reduce or remove the initial crushing force. This also reduces the risk of entrapment. Whereas stopping motion can be achieved with a high reliability using typical hardware, generating a motion (i.e. reversing) can only be achieved with low reliability with typical mechanical systems. The consequences of failing to reverse can be severe, in which case powered reversing cannot be considered as a suitable safety measure.
6. REFERENCES


ANNEX A - CALCULATIONS

Objective: to estimate the maximum force generated when a powered moving gate impacts a compliant fixed object, which behaves as an ideal spring (such as the test instrument in EN12453 5.1.1.5.) (4).

Initially, the gate has a velocity and mass and therefore a kinetic energy. The velocity is constant, i.e. the net force accelerating the gate is zero. When the gate impacts the object, it begins to slow and kinetic energy is converted to spring energy. Also, during deceleration, the motor provides some energy as it continues to drive, until power is removed. The maximum force occurs when the gate comes to rest (assuming the spring has zero mass).

Equating energies from the point at which the gate contacts the object, to the point at which it comes to rest, we get:

\[ \text{K.E.} + \text{M.E.} = \text{S.E.} \]  

Where:
K.E. = kinetic energy  
M.E. = energy supplied by the driving force  
S.E. = spring energy

We need to determine how much energy the driving force (M.E.) contributes during the deceleration stage. In reality, for gates powered by an electric motor, the driving force will vary in a complex manner throughout the deceleration stage. This would make calculating the exact energy contribution very difficult.

To simplify this process, we will assume that the motor provides a constant driving force \( (= F_\text{m}) \) throughout the deceleration stage.

Therefore, equation A.1 becomes:

\[ \frac{1}{2}mv^2 + F_\text{m}x = \frac{kx^2}{2} \]  

Where:
\( m \) = mass of moving object (kg)  
\( v \) = initial velocity (m/s)  
\( F_\text{m} \) = driving force (N)  
\( x \) = distance travelled (m)  
\( k \) = spring constant (N/m)

Rearranging equation A.2 gives:

\[ \frac{kx^2}{2} - F_\text{m}x - \frac{1}{2}mv^2 = 0 \]

Eq. A.3 is a quadratic equation of the form \( ax^2 + bx + c \). \( x \) can be found using the standard equation:

\[ x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \]
Inserting the coefficients $a$, $b$ and $c$ from eq. A.3:

$$
\chi = \frac{F_m + \sqrt{F_m^2 + kmv^2}}{k}
$$

eq. A.4

But for an ideal spring, the spring force ($F_s$) is:

$$
F_s = kx
$$

eq. A.5

Combining equations A.4 and A.5, we get:

$$
F_s = F_m + \sqrt{F_m^2 + kmv^2}
$$

eq. A.6

Where;

$F_s$ = Force on the spring at maximum extension

Equation A.6 is used in table A1 to produce various scenarios for sliding gates. The equivalent equations for hinged gates are presented below and various scenarios presented in table A2.

Again, to simplify this process, we will assume that the motor provides a constant driving torque ($= T_m$) throughout the deceleration stage.

Therefore, equation A.2 becomes;

$$
\frac{1}{2} I \omega^2 + \frac{T_m x}{l} = \frac{kx^2}{2}
$$

eq. A.7

where

$I$ = moment of inertia (kg-m$^2$)

$\omega$ = angular velocity (rad/s)

$T_m$ = driving torque = $F_m l$ (N/m)

($F_m$ is the driving force at the outer edge)

$x$ = distance travelled (m)

$k$ = spring constant (N/m)

$l$ = length of gate leaf (m)

Rearranging eq. A.7 gives:

$$
\frac{kx^2}{2} - \frac{T_m x}{l} - \frac{1}{2} I \omega^2 = 0
$$

eq.A.8

For a thin plate, rotating along one edge, the moment of inertia is given by:

$$
I = \frac{ml^2}{3}
$$

eq. A.9

Substituting for $l$ in eq. A8 gives:
\[ \frac{kx^2}{2} - \frac{T_m x}{l} - \frac{ml^2 \omega^2}{6} = 0 \]

Eq. A.10

Eq. A.10 is a quadratic equation of the form \( ax^2 + bx + c \). Again, \( x \) can be found using the standard equation:

\[ x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \]

Inserting the coefficients \( a, b \) and \( c \) from eq. A.10;

\[ x = \frac{T_m}{l} \pm \sqrt{\frac{T_m^2}{l^2} + \frac{4k ml^2 \omega^2}{2}} \]

As before, for an ideal spring, the spring force \( (F_s) \) is;

\[ F_s = kx \]

Substituting equation A.11 into A.12 gives;

\[ F_s = \frac{T_m}{l} \pm \sqrt{\frac{T_m^2}{l^2} + \frac{k ml^2 \omega^2}{3}} \]

Again

\[ F_s = \text{Force on the spring at maximum extension} \]

**Table A1** Showing calculated impact forces for sliding gates of various specifications

<table>
<thead>
<tr>
<th>Cases</th>
<th>Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sliding gates</strong></td>
<td>1</td>
</tr>
<tr>
<td><strong>driving force</strong></td>
<td>( F_m )</td>
</tr>
<tr>
<td><strong>Spring constant</strong></td>
<td>( k )</td>
</tr>
<tr>
<td><strong>Mass of gate</strong></td>
<td>( m )</td>
</tr>
<tr>
<td><strong>Initial gate speed</strong></td>
<td>( v )</td>
</tr>
<tr>
<td><strong>Peak force on test instrument (impact force)</strong></td>
<td>( F_s )</td>
</tr>
<tr>
<td><strong>Stopping distance</strong></td>
<td>( x )</td>
</tr>
<tr>
<td><strong>Stopping time (approximate)</strong></td>
<td>( t )</td>
</tr>
<tr>
<td><strong>Motor power (estimated)</strong></td>
<td>( P )</td>
</tr>
</tbody>
</table>
Notes:

i. Force on test instrument $F_s$ in the table corresponds with $F_d$ in figure A.1 of EN 12453 (4).

ii. 500,000 N/m is the spring constant of the measuring instrument specified in EN 12543 (4) clause 5.1.1.5.

iii. If a compliant edge is provided, its compliance will be much less and its effect will overshadow any effect of the spring in the measuring instrument, which can therefore be ignored.

iv. 20,000 N/m is considered to be representative of a compliant edge, such as rubber bump strip, when coming into contact with a test instrument.

v. Case 1 represents the sliding gate presented as an example.

vi. Case 2 represents the same gate as Case 1 except with a compliant edge. Note that the stopping distance is not realistically achievable – pressure sensitive edges with this size of over-travel are not realistically achievable.

vii. Case 3 represents a gate of similar characteristics but lower speed and driving force, sufficient to limit impact force to less than 400 N.

viii. Case 4 represents the example gate but without a driving force.

ix. Case 5 represents the example gate but without a driving force and sufficiently low speed to limit impact force to less than 400 N.

x. Case 6 represents a small gate of low mass with characteristics to limit impact force to less than 400 N.

xi. The figures in the ‘motor power’ row are estimated from the driving force and operating speed to be indicative of the expected motor power rating.

### Table A2 Showing calculated impact forces for hinged gates of various specifications

<table>
<thead>
<tr>
<th>Cases</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>driving force at the outer edge</strong></td>
<td>$F_m$</td>
<td>170</td>
<td>170</td>
<td>150</td>
</tr>
<tr>
<td>Spring constant</td>
<td>$k$</td>
<td>500,000</td>
<td>20,000</td>
<td>20,000</td>
</tr>
<tr>
<td>Mass of gate leaf</td>
<td>$m$</td>
<td>285</td>
<td>285</td>
<td>285</td>
</tr>
<tr>
<td>Initial gate speed (outer edge)</td>
<td>$v$</td>
<td>0.19</td>
<td>0.19</td>
<td>0.19</td>
</tr>
<tr>
<td>Peak force on test instrument (outer edge)</td>
<td>$F_s$</td>
<td>834</td>
<td>383</td>
<td>347</td>
</tr>
<tr>
<td>Stopping distance</td>
<td>$x$</td>
<td>2</td>
<td>19</td>
<td>17</td>
</tr>
<tr>
<td>Stopping time (approximate)</td>
<td>$t$</td>
<td>0.018</td>
<td>0.202</td>
<td>0.183</td>
</tr>
<tr>
<td>Motor power (estimated)</td>
<td>$P$</td>
<td>300</td>
<td>300</td>
<td>275</td>
</tr>
<tr>
<td>Length of gate leaf</td>
<td>$l$</td>
<td>2.37</td>
<td>2.37</td>
<td>2.37</td>
</tr>
</tbody>
</table>

Notes:

i. Case 7 represents the hinged gate presented as an example.

ii. Case 8 represents the same gate as Case 7 except with a compliant edge.

iii. Case 9 represents a gate of similar characteristics but with a lower driving force, sufficient to limit impact force to less than 400 N.

iv. Case 10 represents the example gate but without a driving force.
Comparison with requirements for lift doors

EN 81-1 (5) provides various requirements for lift doors associated with reducing the risk of injury from crushing presented by automatic, powered doors. These include:

- 7.5.2.1.1 - The effort needed to prevent the door closing shall not exceed 150 N. This measurement shall not be made in the first third of the travel of the door;
- 7.5.2.1.1.3 - The kinetic energy of the landing door and the mechanical elements which are rigidly connected to it, calculated or measured at the average closing speed shall not exceed 10 J;
- Note 5) Measured using, for example, a device consisting of a graduated piston acting on a spring with a spring constant of 25 N/mm, and fitted with an easy sliding ring allowing the extreme point of movement at the moment of impact to be measured. An easy calculation allows the graduation corresponding to the limits fixed to be determined.

This provides the opportunity to compare the requirements of lift doors and powered gates. Note 5) above has given rise to lift door test instruments for these requirements which have the appropriate spring characteristics and measure the energy required to stop the moving doors.

Considering the energy measuring system suggested in note 5), the energy required to compress the spring (S.E.) is given by the formula:

\[ S.E. = \frac{kx^2}{2} \]  

Where:
- \( k \) = spring constant (25 000 N/m)
- \( x \) = displacement

Also, the relationship between force and displacement for a spring is given by the equation:

\[ F = kx \]  

Rearranging equations A.14 and A.15 to remove \( x \), gives:

\[ \frac{F}{k} = \sqrt{\frac{2.S.E.}{k}} \]  

Rearranging:

\[ F = \sqrt{2(S.E.)k} \]  

F represents the maximum force experienced by the test instrument (i.e. at maximum displacement). Inserting the values for S.E. (= 10 J) and \( k \) (= 25 000 N/m), we get

\[ F_i = 707 \text{ N} \]

This means that when the lift door test instrument records a ‘kinetic energy’ of 10 J, it experiences a peak force of 707 N.

Note that this analysis assumes the moving parts are rigid and the only compliance in the system is the spring in the test instrument.
Table A3 presents several scenarios that allow comparison between the lift door requirements and those for powered gates. These are discussed in more detail in Section 2.3.1.6 of the report.

Table A3 uses the same equations as Tables A1 & A2.

**Table A3** Showing calculated impact forces for sliding gates of various specifications

<table>
<thead>
<tr>
<th>Sliding gates</th>
<th>Cases</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>driving force</strong></td>
<td>$F_m$</td>
<td>150</td>
<td>0</td>
<td>-150</td>
<td>150</td>
<td>-20,000</td>
</tr>
<tr>
<td><strong>Spring constant</strong></td>
<td>$k$</td>
<td>25,000</td>
<td>25,000</td>
<td>25,000</td>
<td>500,000</td>
<td>500,000</td>
</tr>
<tr>
<td><strong>Mass of gate</strong></td>
<td>$m$</td>
<td>350</td>
<td>350</td>
<td>350</td>
<td>350</td>
<td>350</td>
</tr>
<tr>
<td><strong>Initial gate speed</strong></td>
<td>$v$</td>
<td>0.179</td>
<td>0.179</td>
<td>0.179</td>
<td>0.179</td>
<td>0.179</td>
</tr>
<tr>
<td><strong>Force on test instrument</strong></td>
<td>$F_s$</td>
<td>700</td>
<td>529</td>
<td>400</td>
<td>2523</td>
<td>140</td>
</tr>
<tr>
<td><strong>Stopping distance</strong></td>
<td>$x$</td>
<td>28.01</td>
<td>21.18</td>
<td>16.01</td>
<td>5.05</td>
<td>0.28</td>
</tr>
<tr>
<td><strong>Stopping time (approximate)</strong></td>
<td>$t$</td>
<td>0.313</td>
<td>0.237</td>
<td>0.179</td>
<td>0.056</td>
<td>0.003</td>
</tr>
<tr>
<td><strong>Energy</strong></td>
<td>$E$</td>
<td>9.8</td>
<td>5.6</td>
<td>3.2</td>
<td>6.4</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Note: $N$ and $Nm^{-1}$ are used for units of force and spring constant, respectively.
ANNEX B – DESCRIPTION OF THEORETICAL GATES

B.1 INTRODUCTION

This Annex describes the design of two theoretical powered gates; one sliding and one swinging/hinged. These theoretical designs are the subject of the critical analysis of safety-related design issues in Section 2.

In reality, each powered gate installation is unique due to differences in the following:

- The physical environment in which gates operate;
- The physical size and shape of gates and openings;
- The mechanical design of gates and their supporting structures;
- The components which are integrated together to produce complete assemblies;
- The type of users of the gate – the operators, owners and the people who pass through them;
- The safety measures employed to reduce risks to an acceptable level.

In order to limit the scope of the safety analysis, this document presents a theoretical design for one sliding and one hinged gate. The designs have been chosen to represent a typical installation. The theoretical designs are presented below.

B.2 CHARACTERISTICS COMMON TO BOTH THEORETICAL GATES

B.2.1 Operating environment

The gates are located adjacent to a public road, with a pavement. The pavement is frequented by public of all ages, including children.

The gates are located immediately adjacent to the pavement.

The gates are primarily intended for vehicular access; a separate pedestrian gate is located close-by.

The gate is opened and closed (cycled) 20 to 40 times per day. For security, normally the gate remains closed except when access is required.

B.2.2 Gate characteristics

The gates are installed on level ground. The gateways are 5 m wide.

B.2.3 Drive characteristics

The drives are self-locking, i.e. when it is not being driven by the motor, the drive cannot be moved by applying force to the gate, without breaking the drive.

The drives can be released, allowing free movement, by a manually operated key.

The installation and operating information provided by the drive system supplier indicates that the photocells are safety devices.

B.2.4 Operation

The gates are un-manned. Typically, when access is required, a key fob is actuated from an approaching vehicle. The vehicle waits whilst the gates open, it then drives through and then after a programmed time delay, the gates close automatically.

The photocells stop the gates closing when the beam is broken. They do not stop the motion during opening.

The drive units have a force sensing facility that detects abnormally elevated resistance to the gate moving in either direction. On detection, the gate reverses approximately 200 mm, waits for 5 secs,
then attempts to close again. If an obstacle is still detected, the drive performs this cycle a second time. On the third detection, the gate reverses 200 mm, then stops until another command is given.

The key for releasing the drive mechanism is kept in an office located close by.

A key pad is also provided which enables the mode of operation to be altered from automatic (activated by the key fobs), to hold-to-run, requiring the open or close buttons on the key pad to be held down in order to move the gate in either direction.

B.2.5  **Photocells**

Two sets of photo-electric cells produce two “light beams”, one on either side of the gate, at approximately 400 mm above the ground. These provide an input to the control system when they are broken.

B.2.6  **Supply of system**

The supply structure is shown below.

**Drive system manufacturer supplied the following:**

- Drive unit with built-in control system;
- Photocells;
- Key pad;
- Key fobs.

**Fabrication manufacturer supplied:**

- Gate;
- Photocell stanchions;
- Top guide.

**Gate hardware supplier:**

- Drive system;
- Track rollers;
- Track/hinges etc.

**Electrical equipment suppliers:**

- Electric cable, conduit, terminals etc.

**Gate installer supplied the following**

Assembly, installation and commissioning of the complete arrangement, comprising:

- Connecting electrical equipment;
- Gate hardware;
- Fabrication;
- Drive and electrical equipment.

B.2.7  **Notes on installation and setting**

After installation was completed, the gate was tested using a test instrument that complied with EN 12445:2001 (10), clause, 5.1. The instrument was placed in front of the closing gate at the end of its stroke; the instrument indicated a pass.
B.2.8 Documentation

The installer supplied the customer with technical information that consisted of the operating and installation instructions of the drive and control system. This included the following information:

- A “Declaration of Incorporation” for the drive system containing all the correct information;
- A statement that the complete installation of the gate, drive, control system etc. should satisfy the requirements of the Machinery Directive 2006/42/EC and relevant standards (EN 12445 (10), EN 12453 (4), EN 12635 (14) and EN 13241-1 (9)). This included providing a Declaration of Conformity;
- A description of the intended use;
- Detailed specifications of the drive, control system and associated electrical equipment;
- Installation instructions, including safe working with electricity, isolation etc.
- Commissioning instructions, including instructions to perform force measurements according to EN 12445:2001 (10) and to check ‘safety functions’;
- An instruction to perform an assessment of the risks presented by the equipment;
- Instructions on how to set-up and modify all the configurable characteristics of the control system;
- A trouble-shooting guide;
- A recommendation to prepare a technical file containing overall layout drawing, electrical diagram, risk assessment and a list of applicable EHSRs. [an assessment of compliance with the essential requirements of the Machinery Directive];
- An instruction to provide a rating plate for the completed assembly, with relevant information and a CE mark;
- Draft for the technical information that is to be supplied to the end user, including:
  - Draft declaration for the final assembly;
  - Maintenance schedule and record sheet;
  - Instructions regarding regular testing of safety functions – photocells and force sensing;
  - Recording sheet for servicing, repairs and modifications;
  - Instructions how to manually release the drive with a key.

The installer generated the following information:

- A technical file containing overall layout drawing, electrical diagram, risk assessment and a list of applicable EHSRs;
- A rating plate for the completed assembly, with relevant information and a CE mark;
- Declaration of conformity;
- Maintenance schedule and record sheet;
- Record sheet for servicing, repairs and modification;
- Instructions on how to manually release the drive.

B.2.9 Control system

The control systems have the following characteristics:
Various functions can be configured:

- Operating speed – 4 settings (set to ‘high’);
- Operating force (force sensing) – 4 settings (originally set to high, now set to low);
- End limit positions – by internal mechanical limit switches or electronic limits (adjusted during installation);
- Operating mode – non-automatic/automatic (set to automatic).

The operating mode can be selected so that either another command (e.g. from a transmitter) is required to close the gate, or the gate is closed automatically after a time delay; this delay is adjustable, and is set to 5 secs.

Other devices, such as photocells, key pads, warning lights etc. are connected via a ‘bus’ system, which supplies power and communication via a two-core cable.

The function of the transmitter can also be configured to instigate semi-automatic or automatic operation.

### B.3 CHARACTERISTICS OF THE THEORETICAL SLIDING GATE INSTALLATION

Diagrams, drawings and a photograph of a similar arrangement are shown in Annex C.

#### B.3.1 Physical arrangement

The arrangement consists of a fabricated steel gate, running on wheels on a track that stretches across the gateway. The fabrication consists of a frame of square hollow section with vertical railings spaced approximately 100 mm centres.

A top guide constrains the top of the gate, preventing it falling over and jumping off the track; this is attached to one of the masonry gateposts. The gate is driven by a proprietary gate drive motor mounted at floor level, via a rack on the gate and a pinion on the drive. The drive motor has an in-built electrical control system that connects to the other electrical components.

#### B.3.2 Drive characteristics

The specification of the drive motor is provided below:

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply</td>
<td>230 VAC, 50 Hz, 500 W</td>
</tr>
<tr>
<td>Torque</td>
<td>10 Nm (Nominal), 18 Nm (Maximum intermittent)</td>
</tr>
<tr>
<td>Speed</td>
<td>0.31 mm/s (no-load), 0.16 mm/s (normal operation)</td>
</tr>
<tr>
<td>Linear travel/rev</td>
<td>188 mm</td>
</tr>
<tr>
<td>Driving force</td>
<td>300 N nominal, 600 N peak</td>
</tr>
</tbody>
</table>

In addition to the functions explained in Section B.2.3, the control system has a deceleration mode – opening and/or closing, 4 modes (set to decelerate as the gates approach their fully closed position). Deceleration can be configured to begin at 70 cm from the closed position or 20 cm from the closed position.
B.3.3 **Mechanical characteristics**
The mechanical specification of the gate is provided below.

- Gate mass: 350 kg
- Gate size: 5.2 m wide by 2 m high
- Length of travel: 5 m

B.4 **CHARACTERISTICS OF THE THEORETICAL HINGED GATE INSTALLATION**
Diagrams, drawings and a picture of a similar arrangement are shown in Annex D.

B.4.1 **Physical arrangement**
The arrangement consists of a pair of identical fabricated steel gates, supported by hinges on gateposts at each side of the gateway.

The gates are each driven by a proprietary gate drive motor, which operates on a power screw principle.

The drive motor is connected to a separate electrical control system that connects to the other electrical components.

The gates are solid panelled, rather than mesh or railing.

B.4.2 **Drive characteristics**
The specification of the drive is provided below:

- Supply: 230 VAC, 50 Hz, 300 W
- Driving torque: 10 Nm (Nominal), 18 Nm (Maximum intermittent)
- Torque: 2000 Nm
- Linear travel/rev of pinion: 16 m

The drive has an automatic learn mode which controls the velocity of the gates as they approach fully open and fully closed positions. The velocity profile cannot be altered by the user, only the stop positions.

B.4.3 **Mechanical characteristics**
The mechanical specification of each gate is provided below.

- Gate mass: 285 kg
- Normal operating speed at outer edge: 190 mm/sec
- Max driving force at outer edge: 170 N
- Gate size: 2.37 m wide by 2 m high
- Travel: 90°
Figure C1 Illustration of sliding gate
Figure C2 Illustration of sliding gate
Figure C3 Illustration of sliding gate
Figure C4 Photograph of sliding gate similar to the theoretical design presented
Figure C5 Layout drawing of sliding gate similar to the theoretical design presented
ANNEX D - DESIGN OF TYPICAL POWERED HINGED GATE

Figure D1 Illustration of hinged gate
Figure D2 Illustration of hinged gate
**Figure D3** Illustration of hinged gate
Figure D4 Photograph of hinged gate similar to the theoretical design presented
Figure D5 Layout drawing of hinged gate

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Part Name</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Gatepost</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Offset wall</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Photocell</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Sst wall</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Drive</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Gate</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Photocell post</td>
<td></td>
</tr>
</tbody>
</table>
Critical analysis of safety related design of powered gates

The original aim of this project was to perform a theoretical assessment into safety measures that may reduce the risks associated with mechanical hazards of powered gates. In order to simplify the analysis, it was agreed that it should be based on specific (albeit theoretical) gate designs - one sliding and one hinged. These were intended to be representative of real-life designs, using typical drives, control systems and safety measures.

A critical analysis of the designs presented in this report highlights several safety-related inadequacies, which are discussed in detail. In particular, the use of typical drive system control functions to limit crushing forces is shown to be inadequate. Alternative safety measures are suggested to address these inadequacies. Alternative means of risk reduction are discussed; pressure sensitive edges are presented as an effective means of delivering force limitation.

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