OFFICIAL SENSITIVE

HSE	FIELD OPERATIONS DIRECTORATE MECHANICAL SPECIALIST GROUP SOUTHERN TEAM	REPORT

Title: Assessment of a hydraulically powered, vertical sliding door

Company	Foodles Production (UK) Ltd
Address	3 Queen Caroline Street London W6 9PE
Initiator	Mr G Tompkins HM Inspector of Health and Safety
Date of Report	6th February 2015
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Summary

On the 21st July 2014, I attended the "M" stage at Pinewood Studios, Pinewood Road, Iver Heath, Buckinghamshire SL0 0NH to mechanically assess a hydraulically powered, vertically sliding door on a Foodles Production (UK) Ltd film set. It was reported that, on the 12th June 2014 and during rehearsals, the hydraulically powered door closed on an actor as he passed under it, wherein, the actor received fracture type injuries.

Even though the door was designed for and operated on a film set, it was a machine and as such, the mandatory essential health and safety requirements of the Machinery Directive 2006/42/EC and The Supply of Machinery (Safety) Regulations 2008 should have been met to ensure that it was safe before being placed into service.

I am of the opinion that the machine did not meet the objectives of the mandatory essential health and safety requirements because, amongst other reasons, the doors design did not include guards or protective devices to reduce or prevent the risk of contact, impact and/or crushing to persons from the closing door leaf.

I estimated that for the 2.0 m high door leaf travelling at 80% or incident speed, its closing time and speed were nominally 1.3 seconds and 1.54 m/s respectively. The 1.54 m/s speed of the closing door leaf exceeded the maximum speed of 0.5 m/s as recommended by the European door and gate standards.

With the hydraulic cylinder pressurised to 80 Bar g (8 MPa), using static analysis and excluding gravitational forces, the Health and Safety Laboratory calculated potential static forces that may be applied by the closing door leaf edge to an object or 1.8 m tall male at various body part heights.

The potential static forces that could be applied to the object or person by the closing edge of the door leaf ranged between 10754 N (eye height) and 13623 N (hip height). The calculated static forces significantly exceeded the maximum allowable dynamic force of 400 N or static force of 150 N as considered to be safe by the European door and gate standards.

I am of the opinion that the door's design was dangerous with foreseeable, residual, significant risk of impact and/or crushing to persons by the closing door leaf.

Operation of the door involved a system of work that was based on visual and manual functions performed by an operator who was external to the film set. Emergency stop commands were also based on visual and manual functions performed by operators within and external to the film set.

1. Introduction

1.1. On the 21st July 2014, I attended the "M" stage at Pinewood Studios, Pinewood Road, Iver Heath, Buckinghamshire SL0 0NH to mechanically assess a hydraulically powered, vertical sliding door on a Foodles Production (UK) Ltd film set. It was reported that, on the 12th June 2014 and during rehearsals, the hydraulically powered door closed on an actor as he passed under it, wherein, the actor received fracture type injuries.

1.2. At site, I liaised with Mr G Tompkins (HM inspector of health and safety), [redacted] (HM specialist inspector of health and safety – human factors), Miss J Gebauer (HSE visiting officer) and met with representatives from:

Pinewood Studios:
[redacted])
[redacted])

Foodles Production (UK) Ltd:
[redacted])
[redacted])
[redacted]
[redacted])
[redacted])
[redacted]

[redacted].

1.3. On the 10th September 2014, I requested scientific support from the Health and Safety Laboratory in relation to the mechanical investigation of the incident door.

1.4. On the 17th September 2014, Mr Tompkins gave me a package of drawings and specifications issued by Foodles Production (UK) Ltd. I subsequently attended a meeting with Mr G White (principal mechanical engineer) of the Health and Safety Laboratory to discuss the information received and the required mechanical investigation assistance. I issued Mr White with relevant drawings and specifications from the received package. Details of drawings and specifications received from Mr Tompkins are shown in Appendix 1 of this report. Items 1 to 21 of Appendix 1 were issued to and referenced by the Health and Safety Laboratory during their investigation work.

1.5. On the 15th and 22nd October 2014, [redacted] provided email confirmation of the incident doors operational procedures, hydraulic design and operating pressures respectively.

1.6. On the 6th February 2015, Mr G White of the Health and Safety Laboratory issued me with the report ES/2014/88 [1] regarding the assessment of closing forces for the hydraulically powered door.

1.7. For this report:

Foodles Production (UK) Ltd = FPL   Incident door = door

2. Machine Details

2.1. As part of the film set, the door was a curved single leaf that travelled up and down within a curved track system by a hydraulically powered linkage and a computerised control system. [redacted]

[redacted]

2.2. External to the set, a ground mounted and curved steel structure provided support whilst acting as a track system for the door linkage and its roller carriages. [redacted]).

2.3. Pin joined linkages connected the door leaf to a hydraulic cylinder whose extension and contraction provided the door leaf movement in its curved track.

2.4. With the hydraulic system pressurised, a door "close" command resulted in the extension of the hydraulic cylinder, thereby pushing the attached linkage and door leaf around and down the curved steel structure to the door leaf's closed position. Conversely, an "open" command resulted in the retraction of the hydraulic cylinder, thereby pulling the door leaf up and around the track to its fully "open" position.

2.5. Of approximate 1.2 m width and 2.0 m height, the door was a single, curved, sliding leaf consisting of a steel framework over laid with inner and outer steel facings and cladding.

2.6. Eight guide wheels mounted on the doors side profiles guided its vertical travel within a curved track mounted on either side of the film set door frame.

2.7. The doors hydraulic system included a mobile hydraulic power pack with its pressure compensated piston pump, 4 bladder accumulators with direct operated pressure relief valves, a pilot operated 4/3-way servo solenoid directional control valve (proportional valve), a directional pilot operated spool valve, a double acting cylinder, a vented counterbalance valve and numerous hydraulic hoses. See Appendix 2 for details of the machines hydraulic circuit diagram.

2.8. The machine contained no identification plate, information, manufacturer's details or overall CE marking.

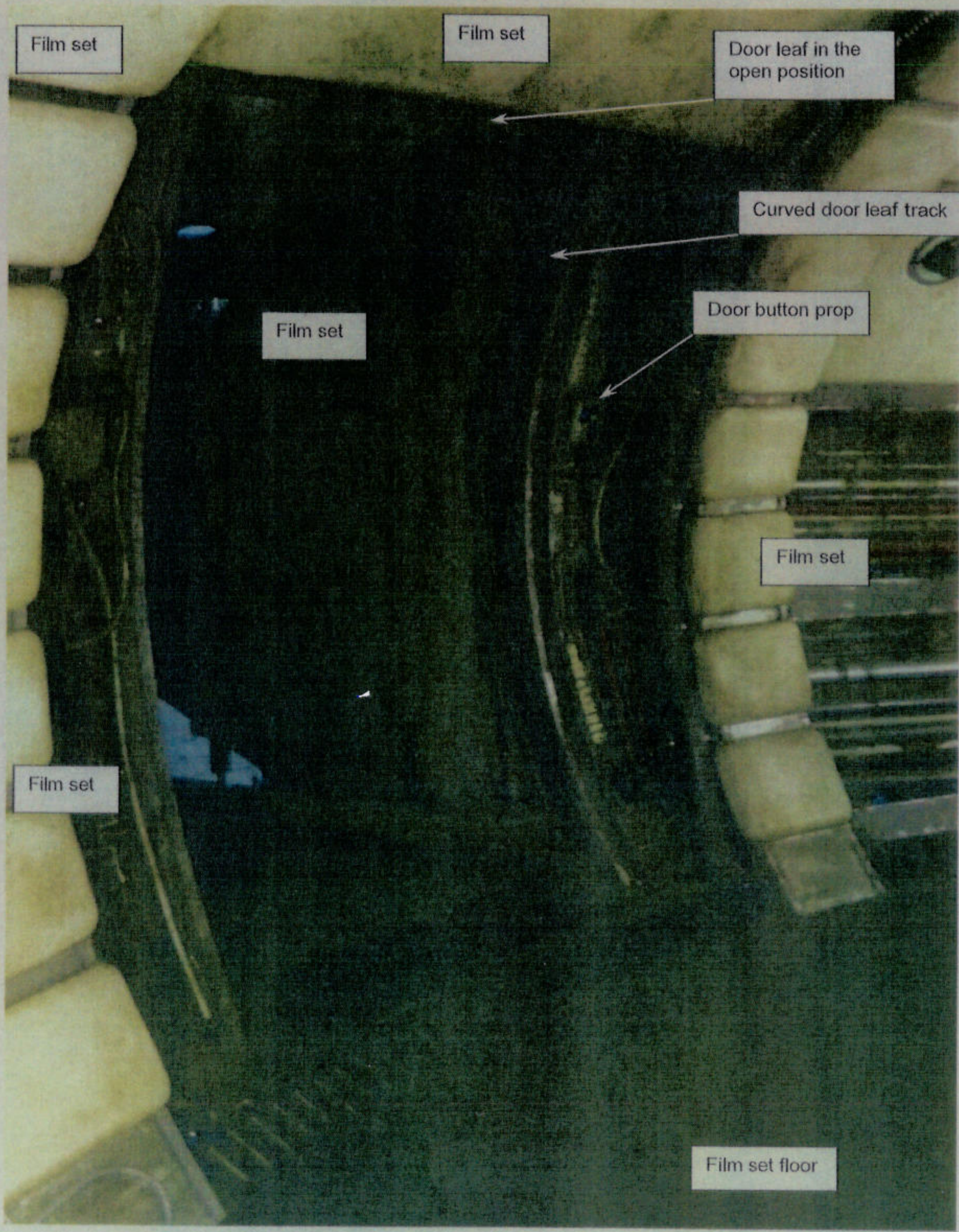
2.9. Hydraulic system design and operating pressures were provided [redacted] namely :

Design Pressure (max output of hydraulic power pack)	= 210 Bar g
Operating Pressure	= 150 Bar g
Hydraulic accumulator set pressure	= 80 Bar g

3. Observations and Measurements

3.1. At site, Mr Tompkins explained to me that as a sequel and for continuity, the film set and the closing speed of the door were intended to be as per the original film.

3.2. He also said that the door button on the inside of the set was a prop to be used by the actor during the scene for door closure and that door operation was controlled by FPL special effects personnel (operators). See photograph DS/02.



Photograph DS/02 – General arrangement of the incident door in the open condition

3.3. On the film set of "M" stage, [redacted] showed me the overall arrangement of the incident door and its components. See Appendix 3 of this report for details.

3.4. Via the laptop software of the doors control system, an operator could electronically adjust the door's travel speed.

3.5. [redacted].

3.6. With the exception of the manually held, separate Estop device inside the set, the door contained no operator control functions for use by persons passing through or local to the door.

3.7. I observed that during the doors closing travel, activation of the Estop inside the set commanded a door stop function, requiring a system reset command prior to continued door operation.

3.8. The design drawing of the door leaf ([redacted]) indicated that the door leaf's internal steel rib and tubular framing terminated local to the closing edge of the door, and that inner and outer steel door facings and cladding were noted as being absent from the drawing.

3.9. Following my initial site assessment site, I was unable to determine the closure forces generated by the closing door leaf or the force imposed on the film set by using force measurement equipment.

3.10. I formed opinion that the use of force measuring equipment to determine the closure force of the door leaf edge was not practicable. I therefore engaged the Health and Safety Laboratory (HSL) to theoretically calculate the relevant door leaf closure forces.

3.11. With the hydraulic cylinder pressurised to 80 Bar g (8 MPa), using static analysis and excluding gravitational forces, HSL [1] calculated potential static forces that may be applied to an object by the closing door leaf edge. It was agreed with HSL that force estimates for various door gaps be considered for approximate body parts heights for a 1.8 m tall male.

3.12. The HSL analysis provided the following closing door edge forces that may be applied to an object or person at various body part heights :

1) A static force of 10754 N at a height of 1.72 m above floor level or at eye height.

2) A static force of 12167 N at a height of 1.49 m above floor level or at shoulder height.

3) A static force of 13623 N at a height of 1.03 m above floor level or at hip height.

4) A static force of 13400 N at a height of 0.465 m above floor level or at the back of the knee height.

5) A static force of 11842 N at a height of 0.0 m or floor level.

4. Discussion and Comment

4.1. The door comprised of a hydraulically powered assembly of linked moving parts and components that were joined together and installed within a structure on a film set, intended to be used as a door by actors during filming.

4.2. In my opinion, the door satisfied the definition of a "machine" as given within the Machinery Directive [2] (MD) which applied to all new machinery placed on the Economic European Area (EEA) market or put into service (first use for its intended purpose).

4.3. As FPL brought together and installed the various equipment and components and placed the machine into service, as defined within the MD [2], FPL are deemed to be the machine's manufacturer.

4.4. The machine was placed into service within the UK by FPL, therefore the relevant supply legislation for the machine was The Supply of Machinery (Safety) Regulations [3] (SOMR's).

4.5. As the manufacturer, FPL had the duty and responsibility to ensure the requirements of the MD [2] and SOMR's [3] were complied with and that prior to putting the machine into service, they should, amongst other things :

1) Ensure the machine was safe.

2) Ensure that a risk assessment for the machine was conducted.

3) Ensure that the machine satisfied the relevant essential health and safety requirements (EHSR's).

4) Ensure that a technical file was compiled and available.

5) Affix a CE conformity marking.

4.6. To date, I have not seen a risk assessment for the machine.

MD and SOMR Considerations

4.7. As defined within the MD [2] and the SOMR's [3], the mandatory EHSR's to be satisfied during the machines design and construction shall include and meet the objectives of, amongst other things :

1) *1.1.2 - Principles of safety integration –*

   (a) *Machinery must be designed and constructed so that it is fitted for its function, and can be operated, adjusted and maintained without putting persons at risk when these operations are carried out under* *the conditions foreseen but also taking into account any reasonably foreseeable misuse thereof.*

2) *1.2.1 – Safety and reliability of control systems –*

Control systems must be designed and constructed in such a way as to prevent hazardous situations from arising. Above all, they must be designed and constructed in such a way that:

- *reasonably foreseeable human error during operation does not lead to hazardous situations*

3) *1.3.7 – Risks related to moving parts –*

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.

4.8. It is considered that the machine did not meet the essential health and safety requirements of the MD [2] or SOMR's [3] for the following reasons:

1) There was foreseeable risk of impact and/or crushing to persons passing through the door as its leaf closed.

2) Door function commands i.e. door open, close or stop commands, were not performed or controlled by persons passing through the door during its operation.

3) The door's control system and door functions relied upon the visual and manual ability of its operators to remotely operate and control door function and emergency commands i.e. door open, close or stop commands.

4) The door's control system did not prevent the hazardous situation of a person being impacted or crushed by the closing door leaf.

5) The door's design did not include guards or protective devices to reduce or prevent the risk of contact, impact and/or crushing to persons from the closing door leaf.

Relevant European Standards

4.9. According to section 3.7 of BS EN 12433 1 [4], a door with one or more vertically guided leaves which are raised and/or lowered is known as a vertical sliding door.

4.10. The European standard of BS EN 12604 [5] specifies the mechanical aspect requirements for doors and gates, providing guidance, information and recommendations for, amongst other things :

1) *Section 4.1.2 - a door should not cause injuries or damages due to intentional movements of a door leaf (opening or closing) thereby trapping or crushing persons or objects in any position.*

2) *Section 4.5 – the mechanical features of a door shall be designed so that as far as possible, the risk to the operator and adjacent persons of crushing, cutting, shearing, entanglement, drawing in and trapping is eliminated. This shall be done primarily by the door design, setting suitable clearances or provision of guarding.*

4.11. Section 5.1 of BS EN 12453 [6] recommended that hazardous situations such as crushing between the closing edge of any door and an opposing edge or impact between the moving door and a person, shall be avoided or safeguarded against by a combination of one or more measures, including installing guards, operating the door in the "hold to run" control mode, limiting the forces generated by the door leaf when meeting a person or obstacle or installing sensitive protective equipment.

4.12. Section 5.1.1.4 of BS EN 12453 [6] recommended that hold to run controls shall be designed and installed in order to fulfil specific requirements, including:

1) *The person controlling the door shall be in full view of the door and in the vicinity of the door during the leaf movement and shall not be in a hazardous position himself.*

2) *The door leaf shall stop when the manual control device is released. The overrun distance of the door leaf, after the control has been released, shall be not > 50 mm when the opening gap is ≤ 500 mm and not > 100 mm when the opening gap is > 500 mm. Alternatively the door leaf shall be fitted with a deformable closing edge where the available deformation shall be more than the stopping distance which shall result in a static force of no greater than 150 N on a 80 mm diameter test piece.*

3) *The speed of the main edge shall be < 0.5 m/s. In case of two main edges, e.g. bi-folding doors, the speed of closing the gap shall not exceed 0.5 m/s.*

4.13. The door's design did not meet the recommendations for hold to run control within section 5.1.1.4 of BS EN 12453 [6] due to :

1) The doors control system included a "hold to run" foot pedal, laptop and monitor. The control system and its operator were external to the film set with only a monitor providing an internal image of the set and door movement. The door operator did not have full view of the door and was not in its vicinity.

2) The doors design provided no hold to run control functions for persons at the door or passing through it.

3) The door leaf's design included internal steel sections local to its closing edge. The FPL design drawings made no reference to the door leaf design having a deformable closing edge.

4) The door design and operational procedures provided no information relating to door leaf overrun distance.

5) Using my site video footage of the door operating, I estimated that for the 2.0 m high door leaf travelling at 80% or incident speed, its closing time and speed were nominally 1.3 seconds and 1.54 m/s respectively. The 80% or incident speed of the closing door leaf (1.54 m/s) exceeded the recommended maximum speed of 0.5 m/s.

4.14. Section 5.1.1.5 of BS EN 12453 [6] recommended that crushing points may be safeguarded by limitation of the forces and that such *forces shall be considered to be safe if the values specified in Annex A* for a vertically moving door *are not exceeded* in that the admissible forces between a closing gap greater than 50 mm as:

- A maximum force of 400 N during the 'dynamic' period (max. 0.75 seconds)
- A maximum force of 150 N outside the 'dynamic period i.e. during the 'static' period (max. 5 seconds)
- A maximum force of 25 N outside the 'static' period.

HSL Analysis

4.15. The HSL report [1] of static analysis for the door arrangement indicated that the closing door leaf edge forces (ranging from 10754 N to 13623 N for the chosen heights above the floor) significantly exceeded the 400 N dynamic and 150 N static force considered safe within BS EN 12453 [5].

General Findings

4.16. As per section 5.1.1.6 of BS EN 12453 [6], safeguarding the door leaf operation could also be achieved by the design and installation of sensitive protection equipment including pressure sensitive protective equipment (PSPE), electro-sensitive protective equipment (ESPE) and inherent protection equipment built into the drive system.

4.17. As safety devices attached to the doors control system, PSPE's (safety edges) and ESPE's (photoelectric cells or light curtains) may provide a means of safeguarding the door leaf during its operation with regards to force limitation and/or object presence detection, thereby preventing persons from being injured or trapped by the door.

4.18. As per section 4 of BS EN 12978 [7], whether attached to the control system directly or through external transmission systems, the safety devices should be of appropriate safety category 2, 3 or 4 in the performing of safety functions of the control system and be monitored to prevent undetected faults from occurring in the system resulting in the unsafe operation of the door leaf.

4.19. The doors design or its control system did not include sensitive protective equipment.

4.20. Operation of the door involved a system of work that was based on visual and manual functions performed by an operator who was external to the film set. An emergency stop command was also based on visual and manual functions performed by operators within and external to the film set.

5. Conclusions

5.1. Even though the door was designed for and operated on a film set, it was a machine and as such, the mandatory essential health and safety requirements of the Machinery Directive 2006/42/EC and The Supply of Machinery (Safety) Regulations 2008 should have been met to ensure that it was safe before being placed into service.

5.2. I am of the opinion that the machine did not meet the objectives of the mandatory essential health and safety requirements because, amongst other reasons, the door's design did not include guards or protective devices to reduce or prevent the risk of contact, impact and/or crushing to persons from the closing door leaf.

5.3. I estimated that for the 2.0 m high door leaf travelling at 80% or incident speed, its closing time and speed were nominally 1.3 seconds and 1.54 m/s respectively. The 1.54 m/s speed of the closing door leaf exceeded the maximum speed of 0.5 m/s as recommended by the European door and gate standards.

5.4. With the hydraulic cylinder pressurised to 80 Bar g (8 MPa), using static analysis and excluding gravitational forces, the Health and Safety Laboratory calculated potential static forces that may be applied by the closing door leaf edge to an object or 1.8 m tall male at various body part heights.

5.5. The potential static forces that could be applied to the object or person by the closing edge of the door leaf ranged between 10754 N (eye height) and 13623 N (hip height). The calculated static forces significantly exceeded the maximum allowable dynamic force of 400 N or static force of 150 N as considered to be safe by the European door and gate standards.

5.6. I am of the opinion that the door's design was dangerous with foreseeable, residual, significant risk of impact and/or crushing to persons by the closing door leaf.

5.7. Operation of the door involved a system of work that was based on visual and manual functions performed by an operator who was external to the film set. Emergency stop commands were also based on visual and manual functions performed by operators within and external to the film set.

6. References

6.1. At site, I took 39 digital photographs and 5 digital videos of the door, 3 digital photographs are used in this report.

6.2. All photographs were copied to disc and placed in the Basingstoke evidence store, references CD05270 and CD05271.

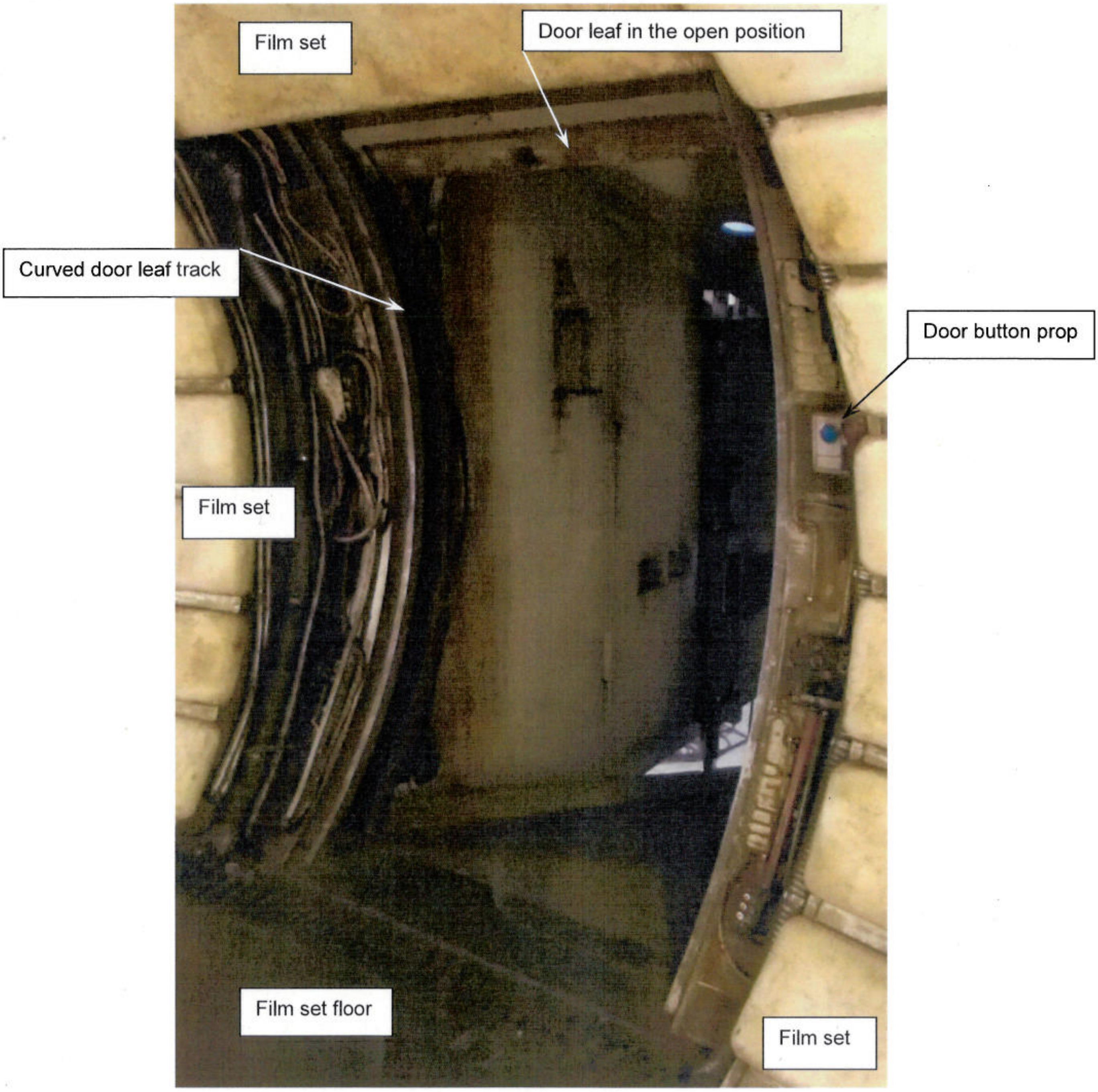
6.3. Documents referenced :

[1] Health and Safety Laboratory report ES/2014/88 – Hydraulically operated door incident, Pinewood Studios, Buckinghamshire – Assessment of closing forces
[2] Machinery Directive 2006/42/EC
[3] The Supply of Machinery (Safety) Regulations 2008, as amended
[4] BS EN 12433 1 2000 - Industrial, commercial and garage doors and gates - Terminology – part 1 - Types of doors.
[5] BS EN 12604 2000 - Industrial, commercial and garage doors and gates - Mechanical aspects – Requirements.
[6] BS EN 12453 2001 - Industrial, commercial and garage doors and gates – Safety in use of power operated doors – Requirements.
[7] BS EN 12978 2003 + A1 2009 - Industrial, commercial and garage doors and gates – Safety devices for power operated doors and gates – Requirements and test methods.

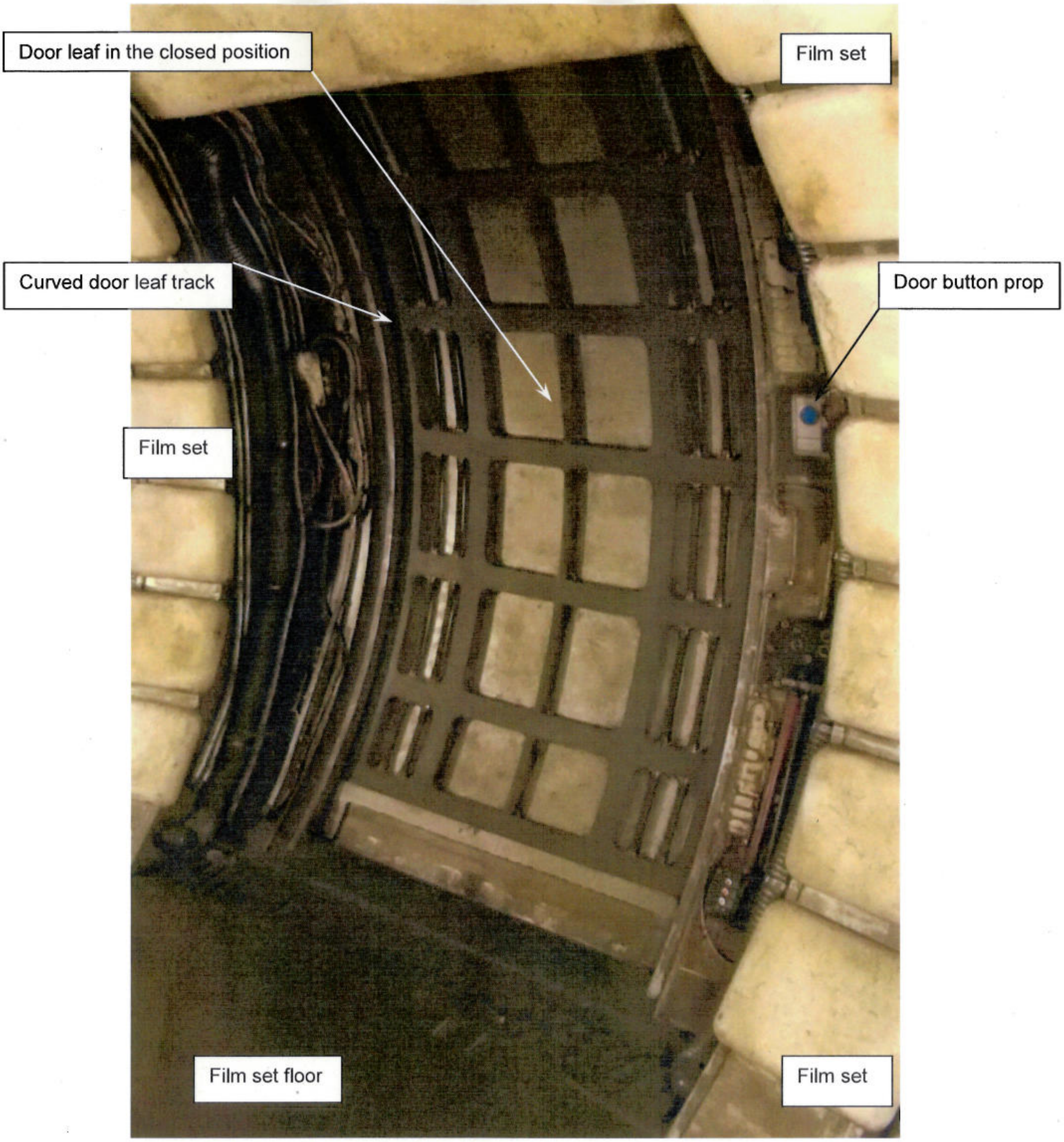
7.3. **Appendix 3 – Observations regarding the film set and door.**

7.4. With the exception of the doors supporting structure, linkage and track system, the remainder of the set appeared to be constructed of wooden or wood composite material sections supported by light weight ground structures, scaffolding and suspended supports from the stage ceiling.

7.5. In the open position, the door leaf retracted into the set permitting personnel access through the door aperture. In the closed position, the doors bottom rail closed against the floor threshold. See photographs DS/04 and DS/05.

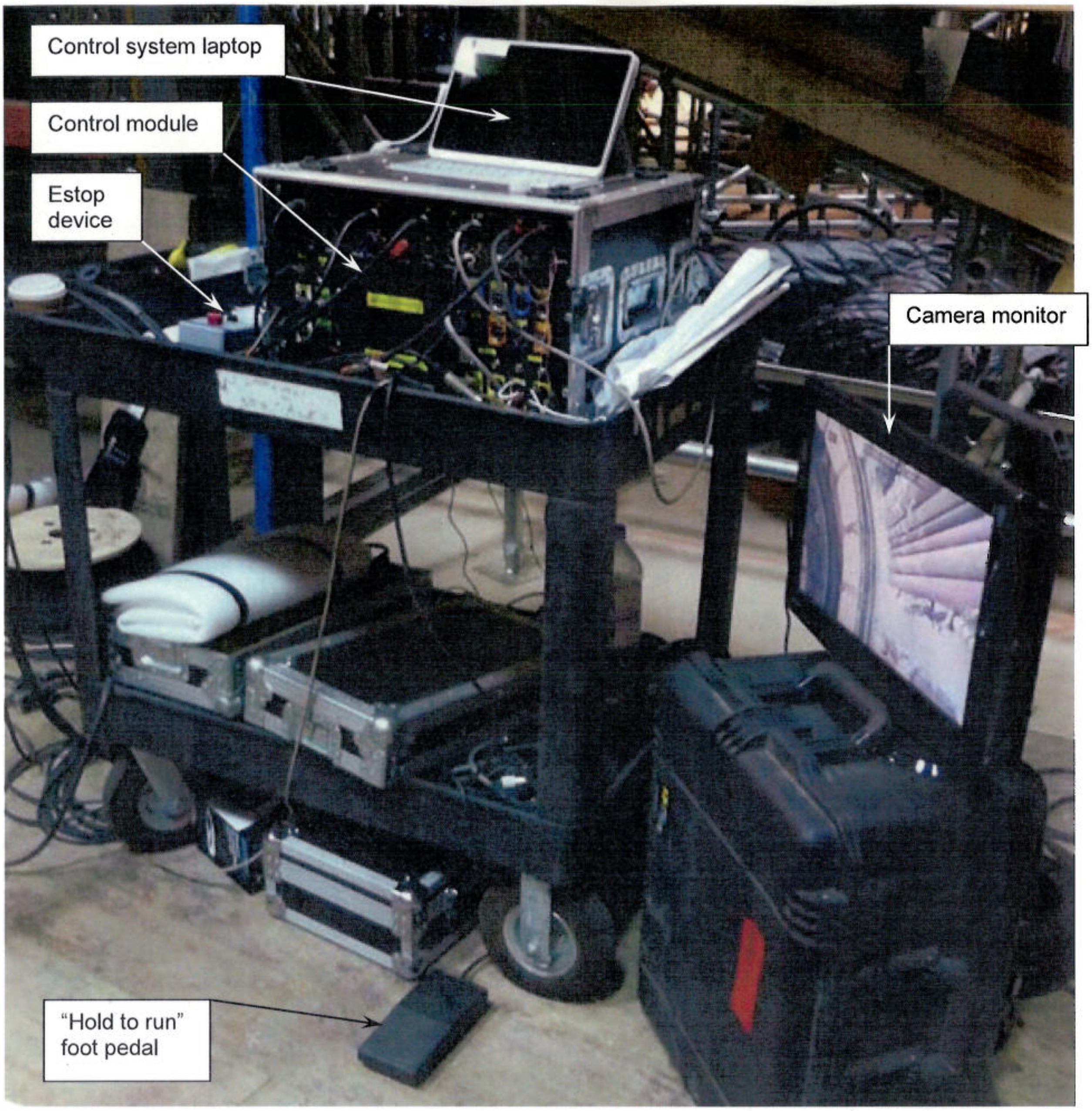


Photograph DS/04 – Incident door in the open position (still captured from video P1000671)



Photograph DS/05 – Incident door in the closed position (still captured from video P1000671)

7.6. Externally and remotely positioned to the set, the door control system included a laptop based computer software and control module with a "hold to run" operator foot pedal and a camera monitor that displayed the door and its button from a dedicated camera inside the set. See photograph DS/06.



Photograph DS/06 – External of the set, the door control system (reference G Tompkins image P1000907)

7.7. A linear encoder attached to the hydraulic cylinder provided positional and speed information for the doors control system.

7.8. The control system included 3 emergency stop (Estop) devices, each operated by a dedicated operator at a specific location during door operation. The 3 Estop and operator locations were, one inside the set observing the actors and door leaf travel, with two external of the set, one at the door control system laptop and one at the rear of the set local to the doors hydraulic cylinder and structure.

7.9. The 3 dedicated operators involved with the door's control, its operation and Estop communicated via headsets with microphones.