A review of Explosives Accidents in the UK in the Year 2001

Contents:

Introduction

In this report we present a review of the accidents that occurred on licensed explosives manufacturing sites during the year 2001 and were reported to the Health and Safety Executive (HSE) under the terms of the 1875 Explosives Act. We hope that the information presented in this paper will be useful in helping organizations identify potential problems that can arise during explosives manufacturing operations and, most importantly, identify measures that might be implemented to reduce the risks of those operations.

Categorization of Accidents

We have categorized accidents by the type of explosives involved:

Primary Explosives
Secondary Explosives
Propellants
Pyrotechnic Substances
Explosives Articles
Fireworks and Pyrotechnic Articles

We have analysed the accidents coming under each of the above headings to determine, so far as possible, root cause and identify measures that might be taken to prevent recurrences.

Total number of accidents reported

Twenty-one accidents were reported during the year in which a total of eight workers were injured. Most of these injuries were of a relatively minor nature, involving no more than cuts and abrasions, but three people were injured to the extent that they required hospital treatment. A complete list of these accidents is presented in Appendix 1, while a breakdown according to type of explosives and type of operation is presented in Appendix 2. A description of each accident is presented on the following pages.

Primary Explosives

Only two of the incidents reported during the year came under this heading.

Incident No. 1

Date:	24/09/2001	**Substance:**	VH2 composition
Operation:	Filling	**Event:**	Explosion
Stimulus:	Friction	**Proximate cause:**	Rough handling? Abnormally sensitive comp?
No killed:	0	**No Injured:**	0

A small quantity of VH2 composition[1] initiated during the process of filling percussion caps. The incident occurred as an operative was brushing away the remaining traces of the composition from the filling plate into a waste pot, using a camelhair brush for the purpose. The exact cause of the ignition was not established, but it is possible that either excessive force was used or the composition was abnormally sensitive. The quantity of explosive initiated was very small and the operative was uninjured.

Primary explosives, such as VH2 composition, are particularly susceptible to accidental initiation. Indeed such explosives can be initiated by exposure to small impact and frictional forces – such as may occur, for instance, if a container of the composition were to be dropped. HSE consider that whenever such material needs to be handled this should only be in minimum quantities and that personnel should be protected against the effects of any initiation by the use of screens and personnel protective equipment. Operations that necessarily involve exposure of this material to mechanical forces, e.g. pressing, should be done remotely if there is a significant potential hazard to personnel. These precautions are in place at the factory concerned.

Incident No. 2

Date:	09/05/2001	**Substance:**	RD1303, RD1652
Operation:	Assembling	**Event:**	Explosion
Stimulus:	Not known	**Proximate cause:**	Not known
No killed:	0	**No Injured:**	1

The second incident in the primary explosives class also involved a slight explosion and occurred as celluloid cups containing RD1303[2] and RD1652 compositions were being inserted into a fuze component. The operative sustained a laceration to the tip of an index finger.

Secondary Explosives

Two of the incidents reported during the year came under this heading. Both occurred during the manufacture of RDX but in neither case did an explosion occur and nor was anyone injured.

Incident No. 3

Date:	31/01/2001	**Substance:**	Hexamine
Operation:	Nitrating	**Event:**	Fire

[1] VH2 is a primary explosives composition comprising a mixture of lead styphnate, tetrazene, barium nitrate, lead dioxide, antimony sulphide, calcium silicide. It is used in percussion caps for small arms ammunition.
[2] RD 1303 is essentially a form of lead styphnate.

Stimulus:	Chemical reaction	**Proximate cause:**	Pipe blockage; spillage; excursion of temperature outside process limits
No killed:	0	**No Injured:**	0

A small hexamine fire occurred in the nitration building. Hexamine is a raw ingredient used in the manufacture of RDX and is fed to the nitrator from a constant-weight-feeding conveyor located above the vessel, the flow being directed through glass tubes. These tubes are routinely changed every four hours, or more often if they become opaque or if a build up of hexamine causes a blockage.

On the day in question, the operatives decided to change the glass tubes towards the end of the morning shift. During this operation, some of the hexamine fell on to the floor next to the nitrator. However, crucially, while this operation was in progress the operative in the control room had reduced the flow of cooling water to the nitrator. Once the feed was restored, the temperature in the nitrator began to rise, which the operative than tried to control by further opening the cooling water control valve. This proved to be ineffective and within a matter of seconds the high temperature alarm, set at 35° C, began to sound.

The operatives then speedily stopped the hexamine feed and continued to turn the valve to increase the flow of coolant, but this action was unable to prevent the temperature rising to 38° C, at which point the auto-drowning system was activated and the contents of the nitrator vessel dumped. It was during the dumping process that concentrated nitric acid fume ignited the spilt hexamine. The fire was of a minor nature and was quickly extinguished by one of the operatives with the aid of a hosepipe[3]. As an added precaution, the CO_2 fire extinguishers linked to the hexamine feed system also were manually activated.

The auto-drowning system functioned as designed and there was no risk of an explosion. There was, however, a risk of injury to the operative in the main hall of the building[4] from the nitrous fumes released during the auto-drown procedure, and as a result of this incident the company instituted a number of changes:

1. The Operating instructions were amended to ensure that the chilled water valve is manually set at 75% to 100% before hexamine feed is reinstated.

2. The Operating Instructions were amended to ensure that following a tube change the man changing the tubes finishes his work and returns to the Control Room BEFORE feeds are restarted.

[3] The nitration is performed in a building that is deliberately kept wet and to this end hosepipes are placed at strategic points in the building.
[4] Operatives in the control room are protected by the maintenance of a positive air pressure.

3. Operatives were retrained in the above changes.

4. The alarm for high temperature in the nitrator was relayed outside of the Control Room. This alarms when the temperature is at 35°C and so gives warning of an imminent autodrown.

Incident No. 4

Date:	08/02/2001	**Substance:**	RDX
Operation:	Nitrating	**Event:**	No ignition
Stimulus:	Not applicable	**Proximate cause:**	Lightning strike; power cut
No killed:	0	**No Injured:**	0

This incident, which occurred in the same building as that immediately reported above, also involved the activation of the auto-drowning system. In this case the system was activated as a result of a power dip, which in turn was caused by a lightning strike some 5 to 10 miles from the site. During the drowning procedure an operative noticed an orange glow in the drown compartment of the nitrator, whereupon a water hose was played into the compartment and the glow diminished. It is not certain that a fire caused the glow; it may have been no more than nitrous fumes.

Once again it is gratifying that the auto-drowning system functioned as designed, resulting in no one being injured or any property damage being sustained.

Pyrotechnic Substances

No less than 11 incidents, i.e. just over half of the total number of incidents reported during the year, came into this category.

Incident No. 5

Date:	14/03/2001	**Substance:**	Experimental comp
Operation:	Pressing	**Event:**	Fire
Stimulus:	Friction	**Proximate cause:**	Extrusion of comp from mould
No killed:	0	**No Injured:**	0

The ignition occurred as the pressed pellet of an experimental pyrotechnic composition was ejected from the mould. The operation was conducted in a Robotic Press Building using the remote pressing facility[5]. At the time of the ignition all personnel were in the Operating Cell, a separate compartment within the building, and no one suffered injury.

[5] But not using the Robotic composition handling facility, which was carried out by hand.

The correct procedures for such an event were followed: the building was evacuated and the factory emergency alarm raised; the Fire Service was summoned and a full evacuation and roll call of all personnel carried out. Personnel were accounted for within five minutes, and upon arriving members of the Firebrigade entered the building wearing breathing apparatus and confirmed that the fire had been extinguished and the building was safe.

There was no evidence to suggest that the ignition had been caused by the presence of foreign matter (the composition had been mixed by the R&D Chemist and no foreign matter was found in the ash removed from the press mould after the incident) or as a result of faulty tooling (the damage subsequently observed to the press mould and tooling was the result of the extreme heat and gas pressure generated during the incident; furthermore the press was not under load when the ignition occurred). It was therefore concluded that the ignition was most probably due to friction, created by a "nipping" effect on semi pressed composition, which had been extruded between the top drift and the inner surface of the mould during consolidation. The "nipping" occurring when the "approximate" 20 ton pressure was released by the sudden upward movement of the top drift responding to the manual controls.

HSE recognizes that there will always be a need to carry out research and development work with experimental compositions. In such cases it is important that proper precautions are taken to ensure the safety of the personnel involved, particularly when such compositions are subjected to mechanical forces. In the present case the pressing operation was undertaken remotely and no injuries resulted. Remote operation is considered to be particularly pertinent in the present case as there was a potential for a much more energetic event: had the ignition occurred during consolidation and with the press fully closed and under load, it is highly likely that a detonation would have resulted leading to a total failure of the press and press tooling and most probably structural damage to the building.

Incident No. 6

Date:	18/01/2001	**Substance:**	ZPP comp
Operation:	Filling	**Event:**	Fire
Stimulus:	Not known	**Proximate cause:**	Not known
No killed:	0	**No Injured:**	0

An ignition of a zirconium / potassium perchlorate mixture (ZPP composition) occurred whilst the composition was being filled into a gas-generating machine. The ignition was confined within the hopper box on the volumetric dispense system and the gases vented through the flue, ensuring that there were no injuries and minimal damage.

Incident No. 7

Date:	20/03/2001	**Substance:**	ZPP comp
Operation:	Testing	**Event:**	Fire
Stimulus:	Friction?	**Proximate cause:**	Dried residue; inadequate disposal
No killed:	0	**No Injured:**	1

A second ZPP incident occurred in a laboratory following an analysis of the composition for chloride content. In this case some residue in a glass sinter ignited and the bottom of the sinter then fell on to a tray containing glass beakers of waste material. This resulted in a small fire, which was put out with the aid of a CO_2 fire extinguisher. The laboratory technician suffered from shock and smoke inhalation and was kept in hospital overnight for observation.

Incident No. 8

Date:	10/05/2001	**Substance:**	Magnesium/Viton/PTFE
Operation:	Machining	**Event:**	Fire
Stimulus:	Friction?	**Proximate cause:**	Faulty tool
No killed:	0	**No Injured:**	0

An ignition occurred during the machining of flare pellets. The purpose of this operation is to provide grooves in the flare for the application of priming composition, which assists in the take over of the flare. It was during this process that the ignition occurred. The fire was confined to the immediate machining area and did not spread to the swarf, which was kept wet. The plastic relief panels in the ceiling above the machine and adjacent to it were dislodged, but otherwise no structural damage was done. The operative was located behind a blast panel and was uninjured.

The company investigated the incident and concluded that it was caused by a mechanical failure of a carbide tip, which resulted in the tooth dragging through the flare composition. As a result of the investigation a number of recommendations were made, amongst which were the following:

1. Introduce a system to trace the cutter sets and record the regrind history. The information should be incorporated within the Planned Maintenance System.

2. That the re-sharpened cutters be tested by the supplier for the integrity of the tip brazing and for the presence of cracks and if possible fatigue of the brazing. The appropriate tests to be agreed between the company and the suppliers

3. Introduce daily inspections to check the cutters for wear and tear.

Finally, a longer-term solution was identified in that tool designs are now available to press grooves directly into flares. This will effectively engineer the machining operation out of the general manufacturing process[6].

Incident No. 9

Date:	14/05/2001	**Substance:**	Red phosphorus
Operation:	Handling	**Event:**	Fire
Stimulus:	Friction	**Proximate cause:**	Contamination
No killed:	0	**No Injured:**	0

An ignition occurred as an operative was untwisting a plastic-coated metal tie on a bag containing approximately 10kg of red phosphorus. During this operation the operative noticed a glow appearing from the tie; this dropped onto and burned through the surface of the plastic bag, igniting the contents.

The operative left the building at this time and sounded the alarm, following which there was a full evacuation of the red area of the site. The fire was quickly doused by activation of the fire suppression system installed in the building, though the phosphorus continued to generate smoke for some time. The wash water from the fire suppression was subsequently collected for disposal.

The company investigated the incident and concluded that the most probable cause was friction-induced ignition of red phosphorus dust trapped in the plastic coated tie. This resulted in a small particle of burning material falling onto the surface of the bag, igniting a thin layer of dust, which then burned through the bag and ignited the main body of red phosphorus. The following recommendations were made as a result of this investigation:

1. The supplier of the red phosphorus to be contacted regarding cleanliness of the bags of supplied material.

2. The supplier to be contacted and instructed to change the material of the ties and the method by which they are attached to the bags.

3. Review arrangements for handling existing stock of phosphorus to provide a safe system of work for removing the ties. To this end consider: (i) installing a Makrolon shield between the operative and the sack of phosphorus; (ii) investigate the effect of orientation of the sack during opening and the use of a remote sack-opening device; (iii) investigate an alternative approach in which the sack is enclosed in a fireproof container fitted with a lid designed to drop down in the event of an ignition.

4. Review the evacuation arrangements for the building, particularly the requirement for isolating the power as this also shuts down the fire suppression system.

[6] This solution has now been implemented by the company

Incident No. 10

Date:	24/05/2001	**Substance:**	SR57A
Operation:	Pressing	**Event:**	Fire
Stimulus:	Friction	**Proximate cause:**	Procedure not followed
No killed:	0	**No Injured:**	1

An ignition occurred during the process of pressing of SR57A composition[7]. The incident occurred between pressing and a brushing operation on a Take Over Cup containing the composition. The operative was wearing personal protective equipment (this included leather gloves, leather sleeves and leather apron, an earth strap and safety glasses) but nevertheless sustained burns to both her hands and required hospital treatment.

The company investigated the incident and found that that the main ignition took place in the palm of the leather glove on the left hand. There was a small amount of damage to the top of the index finger and knuckle of the right glove. The company concluded that the likely cause of the incident was a friction-induced ignition of the Take Over Cups as the operative scooped them into her left hand, possibly from the top of the press or as she held them in the palm of her left hand between processes. Consideration of the evidence lead the company to conclude that the operative was not following written Process Instructions in that at least six units were held in the palm of her left hand, instead of just one.

Following an investigation the company made a number of recommendations and actions. With respect to combating rule flouting, these were:

1. Present the findings of the investigation to the operatives involved in the manufacture of Take Over Cups.

2. Review risk assessment for this process and the Process Instruction sheets to clarify the inspection points.

3. Retrain the operatives in this process.

4. Brief supervisors on techniques of observing operative behaviour in order to recognize signs of pressure and anxiety.

5. Put in place a system whereby, when supervisors visit a building, they observe a complete cycle of the process before leaving the building.

6. Interview the operative on her return to work to determine the underlying reasons for her approach to the job and the reasons for deviating from the authorized method.

[7] This is essentially a mixture of boron, bismuth trioxide and Viton. The composition is designated as very sensitive to impact, friction and static.

Incident No. 11

Date:	11/06/2001	**Substance:**	SR399
Operation:	Pressing	**Event:**	Fire
Stimulus:	Not known	**Proximate cause:**	Not known
No killed:	0	**No Injured:**	0

This was a comparatively minor incident in which an operative noticed a small puff of smoke while removing surplus SR399 composition from a tracer following pressing. It was subsequently decided to degrease the tracer bodies and provide a better brush for cleaning.

Incident No. 12

Date:	12/06/2001	**Substance:**	Red Lead Silicone
Operation:	Pressing	**Event:**	Fire
Stimulus:	Friction	**Proximate cause:**	Incorrect use of machinery
No killed:	0	**No Injured:**	0

An ignition occurred during the pressing of Red Lead Silicone composition using a Manesty Press. The process was carried out remotely and the operative was not injured.

The company investigated the incident and determined the cause to be a friction-induced ignition resulting from the top tooling of the Manesty impacting on and penetrating the shoe. At the time of the ignition the majority of the 2 kg batch of composition had been pressed into pellets and these were consumed in the incident. However, the standards of housekeeping within this building were high and there were no surplus materials present in the press bay. Consequently there was no fire damage to the building or the equipment.

The investigation noted that the method of securing the top tooling relies on the operative pushing the tooling fully home and securing it in place using a locking screw. It was determined that the tooling had not been pushed fully home and when under load moved. It was subsequently recommended that:

1. The method of removing and replacing the tooling be examined to ensure that when the tooling is refitted after cleaning it is fitted correctly (a gauge has been provided to check that the tooling is correctly positioned in the holder and the locking screw is fully home).

2. The Process instruction sheet be amended to require operatives to gauge the position of tooling before pressing a batch of composition.

3. The operatives be retrained in the operation of the Manesty press, in particular the fitting and securing of the tooling.

4. The earthing arrangements on the Manesty be checked to ensure the appropriate standard is achieved.

5. Replace the interlock on the door with a timed system to prevent access to the building while the Manesty is still in motion.

6. Ensure that changes made to the operation of the Manesty are read across to any other Manesty presses on site.

7. Review the risk assessment on this process in light of the conclusions of the investigation.

8. Review other presses in relation to the way in which the top tooling is attached to ensure that a similar incident can not occur.

Incident No. 13

Date:	14/08/2001	**Substance:**	SR372
Operation:	Pressing	**Event:**	Explosion
Stimulus:	Not known	**Proximate cause:**	Procedure not followed
No killed:	0	**No Injured:**	0

A minor ignition occurred as members of an engineering team were inducing a Manesty press through its cycle during a fault-finding mission. The event was contained and only minor damage occurred with no injury to personnel.

Incident No. 14

Date:	20/08/2001	**Substance:**	Magnesium/Viton/PTFE
Operation:	Machining	**Event:**	Fire
Stimulus:	Friction	**Proximate cause:**	Procedure in error
No killed:	0	**No Injured:**	0

An ignition occurred during the process of machining flare pellets. The operative was not injured and there was little damage to the equipment or to the fabric of the building. This incident is very similar to that which occurred at the site three months previously (see Incident No. 8). In this case the company concluded that the most likely cause of the incident was a friction-induced ignition: the combination of high approach and traverse speed, cutter speed and number of cutting teeth is believed to have generated sufficient friction to cause the ignition.

As previously noted, the process of machining flares has been identified as an area for improvement. Tooling designs are now available for the pressing of grooves directly into the flare and in the loner term this will eliminate the need for the present machining operation. In the meantime it is noted the arrangements for ensuring segregation of the machining processes behind blast screens and the remote operation proved to be satisfactory.

Incident No. 15

Date:	06/11/2001	**Substance:**	Tracer composition
Operation:	Pressing	**Event:**	Fire
Stimulus:	Not known	**Proximate cause:**	Not known
No killed:	0	**No Injured:**	0

A minor ignition occurred during the process of pressing tracer pellets. The ignition was discovered as the operative opened the access door to retrieve the pellet and noticed a flame.

Explosives Articles

Three of the incidents reported during the year came under this heading.

Incident No. 16

Date:	07/02/2001	**Article:**	Detonator
Operation:	Assembling	**Event:**	Explosion
Stimulus:	Not known	**Proximate cause:**	Not known
No killed:	0	**No Injured:**	1

An operative sustained cuts to his fingers when a 2.3-grain detonator to which he was assembling a disc and washer exploded. The operation was being carried out according to process instructions: he was wearing PPE and using specified tools.

Incident No. 17

Date:	21/05/2001	**Article:**	Detonator
Operation:	Disposal	**Event:**	Explosion
Stimulus:	Not known	**Proximate cause:**	Not known
No killed:	0	**No Injured:**	2

A grass fire started in an area surrounding a remote sand "quarry" used for controlled explosions (in the present case for destroying boxes of waste detonators). The operatives believed it would be safe to approach and combat the fire as it was outside the licensed area. Two operatives duly went to beat out the flames with shovels when an explosion occurred. One operative was hit and seriously injured by flying debris while the other suffered only two very minor cuts.

The operative who was seriously injured was given immediate first aid treatment for cuts – mainly to the face and chest areas – and then taken in the section van to the Main Gate where he received further treatment from the security staff until the ambulance arrived. At the hospital a number of small fragments were removed from his eyes and he was discharged two days' later.

The company investigated the incident and concluded that the cause of the grass fire was the ignition of dry grass by material ejected from the detonator destruction operation in progress, almost certainly by still hot tube / delay element / hot delay composition slag assembly. The explosion was most probably caused by the initiation of one or two live detonators that had lain undetected in the deep grass from a previous waste detonator destruction operation[8]. The actual initiation of the detonator(s) was as a result of either heat from the burning grass or from being hit by a shovel during beating.

As a result of the investigation, the company produced a number of recommendations/actions:

1. The method of carrying out and recording risk assessments should be improved so that the full scope of possible risks is captured

Action 1. Devise a thought prompt matrix of potential hazards verses individual tasks – to be included as the first page of the risk assessment form.

Action 2. Update instructions as required including the use of the thought prompt matrix and a new appendix to indicate the pool of trained risk assessment leaders.

Action 3 - Train the "pool" of risk assessment leaders in the use of the thought prompt matrix.

2. A review of the scope and adequacy of a selection of risk assessments already done should be carried out to determine if there are other learning possibilities.

Action 4. Organise a review / audit of a range of existing risk assessments.

3. If the burning ground is to be used again for the destruction of any of the current inventory of waste detonators, an assessment should be made as to under what conditions and following what remediation work, if any, could this work be carried out.

[8] Using a technique different to the current operation

Action 5. Assess and define the conditions and remediation work required, if any, to allow destruction at the burning ground of any of the current inventory of waste detonators.

Action 6. If Action 1 requires any remediation work prior to recommencement of operations at the burning ground, carry out this work.

4. If Action 5 indicates that the burning ground may be used again, review the risk assessment and Operating Instructions for this operation, including: (i) guidance on PPE, especially what is compulsory and what is optional; (ii) definition of "boundaries" of where and when PPE must be worn, (iii) Emergency Procedure requirements, especially the response in the event of a fire.

Action 7. If the burning ground is to be used again, review detonator destruction at burning ground, risk assessment and Operating Instructions, especially PPE requirements and Emergency Procedures / required emergency response.

Action 8 - Train the relevant operators prior to recommencement of activity on any new procedures produced for the burning ground.

5. Review other Operating Instructions to assess if modification / clarification is required with respect to the use of PPE and Emergency Procedures (Also see Recommendation 2 above)

Action 9. Perform review of site-wide Operating Instructions with respect to PPE and Emergency Procedures / required emergency response.

Incident No. 18

Date:	06/10/2001	**Article:**	Boxer caps
Operation:	Drying	**Event:**	Fire
Stimulus:	Not applicable	**Proximate cause:**	External fire
No killed:	0	**No Injured:**	0

This incident did not involve an ignition of explosives material, but rather a fire on that part of the site used in the manufacture of boxer caps – specifically an oven used for conditioning rolls of paper. The fire was discovered during the process of unlocking the building prior to shift commencement. A fire extinguisher was used to put out the flames and no explosives were involved.

Fireworks and Pyrotechnic Articles

Four of the incidents reported during the year came under this heading.

Incident No. 19

Date:	10/02/2001	**Article:**	Gas generator
Operation:	Testing	**Event:**	Explosion
Stimulus:	Not known	**Proximate cause:**	Procedure not followed
No killed:	0	**No Injured:**	1

An operative carried out a test procedure on a gas generator in a manner which was contrary to process instructions. The generator exploded causing a minor cut in the index finger of the left hand of the operative. The injury required only a plaster, but the operative was taken to hospital as a precaution.

At the time of the incident, the gas generator contained 70 mg of ZPP explosives and 650 mg of propellant. The company carried out an investigation but could not draw any definite conclusion as to the root cause, though it was noted that previous experience has shown that gas generators are susceptible to static discharges. In this regard, the wearing by the operative of the personal earthing connection on the ankle (which could result in the band slipping over a sock and thus isolating the operative from the earthing network) rather than the wrist may have been a contributory factor. Other factors that may have been pertinent are as follows:

- The requirements of the Manufacturing Instructions were not complied with: the toggle clamp should have been in place before the contact arm was applied.

- The design of the test fixture and the test process is such that it can result in the operative forming a circuit with the Gas Generator. This is because the fixture is restrained manually by the operative's left hand whilst the metallic contact arm is applied by the operative's right hand. The left hand can make physical contact with the copper contact strip and as such any static build-up not leeched away via the personal earthing connection can be discharged through the gas generator / test fixture.

- The recovery of three springs following the incident could not be explained. None of the springs exhibited evidence to show that they were from the gas generator that initiated. The absence of a spring could have resulted in the inadvertent ignition of the gas generator via static discharge.

The inquiry team made the following recommendations:

1. Introduce a covering of insulating material over the copper contact strip.

2. Introduce a positive clamp to restrain the test fixture and prevent need for manual restraining action when applying the contact arm.

3. Review the design of the contact arm to introduce non-conductive materials where handled by the operative.

4. Re-train the operatives to carry out the procedure in accordance with the Manufacturing Instructions, with particular emphasis on need to apply the toggle clamp before application of the contact arm.

5. Improve housekeeping activities to prevent surplus component parts from contaminating the subsequent workstations.

6. Revisit the Risk Assessments specifically to address the aspects of the electrical test.

7. Introduce Preventative Maintenance Schedule for personal earth test points; changing of the copper contact strip; electrical function of the machine

8. Install an additional interlock to disable the circuit until the start pushbutton is operated

9. Fit a protective cover over each rig to prevent finger contact during the resistance check process.

Incident No. 20

Date:	26/03/2001	**Article:**	PIC
Operation:	Cutting	**Event:**	Fire
Stimulus:	Friction	**Proximate cause:**	Not known
No killed:	0	**No Injured:**	0

An ignition occurred during the manufacture of plastic igniter cord[9]. This happened at the reeling station as the operative was cutting the cord using approved, earthed secateurs. The operative immediately vacated the building according to instructions and was unharmed. However, fire spread to a production reel as a result of a failure of the operative to activate the guillotine. As a consequence both the reels in the production cell ignited. Although the flame was contained within the cell, i.e. did not spread to anywhere else in the building, it did ignite part of the cell roof and this was subsequently extinguished by the local fire service.

[9] Plastic Igniter Cord (PIC) is a long thin "string" comprising a pyrotechnic composition supported on a central metal wire and covered by a protective plastic coating, It burns slowly and steadily but does not explode. The size of the flame propagating along the cord length is small (approximately 1 cm across) but will produce a larger fire ball when burning on mass on a reel.

The most likely cause of the initial ignition was friction on the pyrotechnic composition during the cutting operation. The composition is known to be friction sensitive and is tested for suitability before manufacture into PIC. The secateurs were immediately examined and were found to be in perfect condition, and when tested, repeatedly cut PIC cleanly and without effect.

Incident No. 21

Date:	01/11/2001	**Article:**	Signalling Flare
Operation:	Testing	**Event:**	Fire
Stimulus:	Not applicable	**Proximate cause:**	Procedure in error
No killed:	0	**No Injured:**	1

During the process of proofing flares on the burning ground, an ignition occurred which resulted in the operative sustaining a cut to her hand that was sufficiently serious as to require hospital treatment.

The immediate cause of the accident was a movement of the trigger while the flare was being loaded to the gun. The company subsequently improved the system of work for proofing operations. The specific measures taken were as follows:

- Additional training of the Burning and Proof Ground staff. Training to be refreshed annually.
- A review of the experience required by proofing supervisors.
- No lone working on proof activities.
- Systems for checking PPE for proofing and burning activities introduced, supplemented by independent monthly inspections by senior managers.
- Revision of the risk assessment for proofing
- Defining the minimum PPE requirement for proof operations, following a review.
- Changes to the system of work, including:
    - Visual inspection of proof items prior to firing
    - Improvements to the location and stability of the proof firing gun
    - Modification to the proof firing gun to prevent accidental cocking
    - Limiting the life of the proof gun
- Improvements to the site Tannoy system
- Provision of a radio for the sole use of the duty first aider.

Appendix 1

Listing of reportable accidents during manufacture for the year 2001

Class of explosives	Substance/ Article	Accident Number	Location	Date of accident	Circumstances	Killed	Injured
Primary	VH2 composition	1	Factory 712	24/09/2001	At the end of the shift, an ignition occurred as an operative was brushing away the remaining traces of VHZ comp from the plate into a waste pot using a camel hair brush. Excessive force may have been used or the comp may have been abnormally sensitive.	0	0
Primary	RD1303 and RD1652 Composition	2	Factory 712	09/05/2001	A slight explosion occurred during the process of inserting celluloid cups into the TVE L4A2 component. The exact circumstances of the incident have not yet been determined. The operative sustained a laceration to the tip of an index finger.	0	1
Secondary	Hexamine (RDX)	3	Factory 711	31/01/2001	During the removal of a blockage in the hexamine feed line to an RDX nitrator, a small quantity of hexamine fell onto the floor. This was splashed by nitric acid as a result of the automatic drowning of the nitrator. The split hexamine ignited. No damage.	0	0
Secondary	RDX	4	Factory 711	08/02/2001	RDX nitrators went into autodrown due to "dips" in the power supply to the site. The operative saw an "orange glow" in the drown chute.	0	0

Class of explosives	Substance/ Article	Accident Number	Location	Date of accident	Circumstances	Killed	Injured
Pyrotechnic substance	Experimental composition	5	Factory 398	14/03/2001	An ignition occurred when a pressed pellet was ejected from the press mould. The operation was carried out remotely and there were no injuries. The automatic fire extinguishing system operated correctly & there was no secondary fire within the press cell.	0	0
Pyrotechnic substance	ZPP composition	6	Factory 712	18/01/2001	An ignition occurred during automatic filling on the Gas Generator machine. The ignition was confined within the hopper box on the volumetric dispense system and the gases vented through the flue - no injuries & minimal damage.	0	0
Pyrotechnic substance	ZPP composition	7	Factory 712	20/03/2001	Some residue in a glass sinter ignited in a laboratory following chloride analysis of zirconium, potassium perchlorate mixture. The bottom of the sinter fell on to a tray containing glass beakers of waste material. CO_2 extinguisher used.	0	1
Pyrotechnic substance	Flare composition – magnesium/ Viton/ PTFE	8	Factory 334	10/05/2001	Ignition during maching of flare pellets. The fire was confined to the immediate machining area & did not spread to the swarf, which was kept wet. Plastic relief panels in the ceiling above the machine & adjacent to it were dislodged. No structural damage.	0	0
Pyrotechnic substance	Red phosphorus	9	Factory 334	14/05/2001	An ignition occurred as an operative was untwisting a plastic-coated metal tie on a bag containing red phosphorus. The contents of the bag caught fire, the operative left the bay and the fire suppression system activated. No damage	0	0

Class of explosives	Substance/ Article	Accident Number	Location	Date of accident	Circumstances	Killed	Injured
Pyrotechnic substance	SR57A composition	10	Factory 334	24/05/2001	Ignition during the pressing of SR57A composition. The ignition occurred as the operative was moving the pressed cup to the jig for cleaning. The operative sustained burns to her hands. The operative was not following process instructions.	0	1
Pyrotechnic substance	SR399 composition	11	Factory 713	11/06/2001	Ignition during the process of removing surplus SR399 composition from the tracer following pressing - the operative saw a small puff of smoke. It was subsequently decided to degrease the tracer bodies and provide a better brush for cleaning.	0	0
Pyrotechnic substance	Red Lead Silicone	12	Factory 334	12/06/2001	Ignition during remote pressing of Red Lead Silicone composition. The tooling of the Manesty Press had not been pushed fully home and moved when under load. There was no fire damage to the building or the equipment.	0	0
Pyrotechnic substance	SR372 Composition	13	Factory 713	14/08/2001	A minor ignition occurred as members of an engineering team were inducing a Manesty press through its cycle during a fault-finding mission. The event was contained and only minor damage occurred with no injury to personnel.	0	0
Pyrotechnic substance	Flare composition – magnesium/ Viton/ PTFE	14	Factory 334	20/08/2001	Ignition during machining of decoy flares. There was no secondary fire and outside emergency assistance was not required. Ignition probably due to friction caused by combination of the cutter rotational speed and the traverse speed of the machine.	0	0

Class of explosives	Substance/ Article	Accident Number	Location	Date of accident	Circumstances	Killed	Injured
Pyrotechnic substance	Tracer composition	15	Factory 713	06/11/2001	An ignition occurred during the process of pressing No 33 tracers. The ignition was discovered as the operative opened the access door to retrieve the pellet and noticed a flame.	0	0
Explosives article	Detonator	16	Factory 712	07/02/2001	An operative sustained cuts to his fingers when a 2.3 grn detonator to which he was assembling a disc and washer exploded. The operation was being carried out according to process instructions. The operative was wearing PPE and using specified tools.	0	1
Explosives article	Detonator	17	Factory 3	21/05/2001	During the process of destroying boxes of waste detonators by controlled explosion, a grass fire started on the site. Operatives went to beat out this fire & an explosion occurred. A det left over from a previous op was either initiated by impact or fire.	0	2
Explosives article	Boxer caps	18	Factory 712	06/10/2001	An oven used for conditioning rolls of paper caught fire. The fire was discovered during the process of unlocking buildings prior to shift commencement. A fire extinguisher was used to put out the flames and no explosives were involved.	0	0
Pyrotechnic article	Gas generator	19	Factory 712	10/02/2001	An operative carried out a test procedure on a gas generator in a manner which was contrary to process instructions. The generator exploded causing a minor cut in the index finger of the left hand of the operative.	0	1

Class of explosives	Substance/ Article	Accident Number	Location	Date of accident	Circumstances	Killed	Injured
Pyrotechnic article	Plastic igniter cord	20	Factory 3	26/03/2001	Ignition of PIC at the reeling station as the operative cut the cord using approved, earthed secateurs. The operative immediately vacated the building and was unharmed. Fire spread to a production reel following a failure to operate the guillotine.	0	0
Pyrotechnic article	Mini Flare	21	Factory 409	01/11/2001	During the process of proofing mini flares, one such flare initiated in the operative's hand. The trigger of the penjector moved as the flare was screwed into place.	0	1

Appendix 2:

Breakdown of manufacturing accidents by type of explosives and type of process

The following table presents a breakdown of accidents during manufacture by type of explosive and type of operation. The figures in parenthesis specify numbers of injuries.

	Assembly	Cutting	Disposal	Drying	Filling	Handling	Machining	Nitrating	Pressing	Testing
Primary Explosives	1 (1)				1					
Secondary Explosives								2		
Pyrotechnic Substances					1	1	2		6(1)	1(1)
Explosives Articles	1(1)		1(2)	1						
Pyrotechnic Articles		1								2(2)

Definitions:

Assembly: Denotes an operation in which the components of an explosives article are assembled or in which components are removed, e.g. insertion of fuzes into ammunition, insertion of wadding into shotgun cartridges, breaking down of ammunition.

Cutting: Denotes the process of cutting explosives material, e.g. by band saw, knife, etc.

Disposal: Denotes the process of disposing of explosives – by burning, settling in waste pit, etc.

Drying:	Denotes an operation in which explosives material is dried. This is normally achieved by the use of an oven of some description.
Filling:	Denotes an operation in which an article is filled with explosives material – from a hopper, for example – but other than by the process of extrusion.
Handling:	Denotes an operation involving the manual handling of explosives material.
Machining:	Denotes an operation in which explosives material is machined on a lathe, or explosives articles are engraved.
Nitrating:	Denotes a chemical synthesis procedure in which nitrate groups (-NO2) are added to organic compounds to produce explosives material, for example, nitration of toluene to produce TNT. Nitration reactions normally involve mixtures of nitric and sulphuric acids.
Pressing:	Denotes an operation in which explosives material is compacted or pressed. This would normally involve the use of conventional or isostatic pressing equipment.
Testing:	Denotes an operation in which explosives material is subject to some sort of test procedure, either in a laboratory or on a range.