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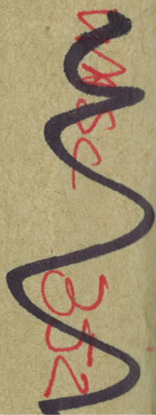
F.h. Nathan
Report on
Explosion
15.12.1902



"PROCEEDINGS OF A COURT OF ENQUIRY AND A REPORT BY MAJOR F L NATHAN, RA., ON THE CIRCUMSTANCES ATTENDING AN EXPLOSION WHICH OCCURRED AT THE ROYAL GUNPOWDER FACTORY WALTHAM ABBEY ON THE 15TH DECEMBER, 1902".

Major F L Nathan RA

Dear Malcolm, 29.2.65

The attached came to light during a recent purge. Please destroy if of no interest to you.

Kindest regards,

Yours sincerely,

Mark H. Baigh

With Compliments

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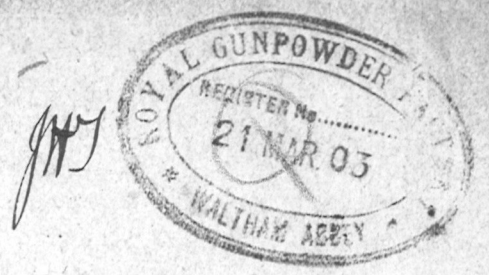


PROCEEDINGS

OF A

COURT OF ENQUIRY

AND A

REPORT BY MAJOR F. L. NATHAN, R.A.,

Superintendent, Royal Gunpowder Factory,

ON THE

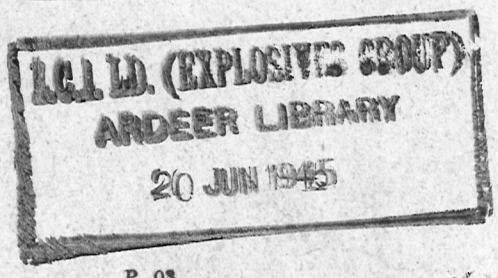
Circumstances Attending an Explosion

WHICH OCCURRED AT THE

ROYAL GUNPOWDER FACTORY,

WALTHAM ABBEY,

ON THE 15th DECEMBER, 1902.



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ON THE 15th DECEMBER, 1902.

(Wt. w.7705 40 3 | 08—H & S 3566)

Proceedings of a Court of Inquiry assembled at Waltham Abbey on the 22nd December, 1902, by order of Director-General of Ordnance, instructions dated 12.5.99, 75/Gen. No./1955, for the purpose of inquiring into the circumstances attending an Explosion in a Cordite Incorporating House at the R.G.P.F., on 15th December, 1902.

President.

Colonel E. BAINBRIDGE, C.B.

Members.

Dr. W. KELLNER, F.I.C., F.C.S.
Major F. L. NATHAN, R.A.

In Attendance.

Major E. S. COOPER, R.A.

The Court, having assembled pursuant to order, proceed to take evidence :—

Major F. L. Nathan, R.A., Superintendent R.G.P.F., read a full report, going into every circumstance connected with the accident; he also handed in certificates of the searching of the men employed in the Group. 71 Gen. No. 3991

OPINION.

The Committee are of opinion that a charge of 57 lb. cordite M.D. paste was in the machine at the time of the explosion, and that the machine had just been started.

The possible causes of the explosion are :—

(1) The presence of some fairly large foreign body (*a*) introduced in the paste, or (*b*) which had fallen into the machine.
(2) The sudden fracture of one of the blades.
(3) The absence of acetone in the machine which might allow of sufficient friction to ignite the guncotton and lead to explosion.

The explosion was due to accident and not to malice.

In the absence of any clear indication, it is impossible to say which or what combination of these causes led to the accident.

E. BAINBRIDGE, Colonel, *President.*
W. KELLNER, Chem. W.D.
F. L. NATHAN, Major R.A., Supt. R.G.P.F. } *Members.*

SEARCHING.

The Police Search Book for the 15th December, 1902, shows Walter Iron searched at 6 a.m. by P.S. 35 (Beckett); William Mecklenburgh at 9 a.m. by P.S. 89 (Avery).

P.S. 35 (Beckett) states:—"Walter Iron was asked if he had pipes or matches. He replied, 'No.' He was then searched in the usual way by feeling his pockets from outside. Nothing unusual was found on him."—S. BECKETT, P.S. 35.

P.S. 89 (Avery) states:—"Mecklenburgh was asked if he had pipes or matches. He replied, 'No.' He was then searched in the usual way by feeling his pockets from outside. Nothing unusual was found on him."—T. AVERY, P.S. 89.

No. 1,015, Chapman, T. J., chargeman at Groups G and D, first shift, 15th December, 1902, states:—"I searched Iron and Page at about 6.55 a.m. on coming to work, and again at 11.35 a.m. after dinner. Both men were correct. The Visitor of Danger Buildings was present at 11.35 a.m. during the latter part of the search."—T. J. CHAPMAN.

Warder T. England states:—"I searched both Iron and Page about 6.10 a.m. on the 15th December, 1902, and found nothing unusual about them."—T. ENGLAND, Warder.

E. Knowler, V.D.B., states:—"I was on the outer platform of Group G at about 11.35 a.m. on 15th December, 1902, and saw Chapman, the chargeman, searching Page. Iron was standing close by."—E. KNOWLER.

ROYAL GUNPOWDER FACTORY,
WALTHAM ABBEY,
21st December, 1902.

C.S.O.F.,

An explosion of cordite M.D. paste occurred at 12.3 p.m. on the 15th December, 1902, at the Royal Gunpowder Factory, Waltham Abbey, in one of the cordite incorporating houses.

By this explosion three men lost their lives—viz., Eli Page, aged $25\frac{7}{12}$ years, service $2\frac{5}{12}$ years, danger-house man; Walter Iron, aged 24 years, service $2\frac{9}{12}$ years, danger-house man; William Henry Mecklenburgh, aged $28\frac{8}{12}$ years, service $1\frac{4}{12}$ years, fitter and turner.

Eli Page leaves a widow and one child.

One man, D. Clements, received a slight blow on the knee from falling *débris;* and two other men, A. Springham and G. T. Taylor, were placed on the sick list, as suffering from nervous shock. These two men were cleaning the boilers in the adjacent boiler house at the time.

Site of the explosion and description of the building and machinery.

The building in which the explosion occurred is known as Bay 3, Group G, and its position in the factory is shown on the maps attached to this report. The building known as Group G was constructed in 1888–9 as a range of black gunpowder incorporating mills, and consists of six compartments or bays, three bays on either side of an engine house, with a boiler house for two Lancashire boilers behind it. In 1898–9 the gunpowder mills were dismantled, and the whole group was converted to take cordite incorporating machines. The group as it stood at the time of the explosion is shown on Print No. 914 attached.

This print also shows the construction of the building, the heating and lighting arrangements, and other details. Bay 3 contained two medium-sized, and one small-sized incorporating machines. A plan, showing the inside of the machine, and an elevation, are given on Print 917 attached. A description of the machine and of its action is given in "Treatise on Service Explosives, 1900," page 90. A list of the authorised tools and implements in use, is given in Appendix I. The special rules for incorporating houses are given in Appendix II.

Nature of the operations.

The only operation allowed in the building is that known as "incorporating," or the conversion of "paste," a mixture of guncotton and nitro-glycerine, to which mineral jelly is added after half the incorporation is completed, into "incorporated material" by means of the solvent acetone. The proportions of the ingredients for cordite M.D. are as follows :—

	Per cent.	Per charge. lb.	oz.
Guncotton	65	39	0
Nitro-glycerine...	30	18	0
Mineral jelly	5	3	0
Total	100	60	0
Acetone...	42·8	25	11

The paste for cordite M.D. is prepared by weighing the quantity of guncotton into an india-rubber bag, and then running the nitro-glycerine into the centre of it. To prevent as much as possible the handling of the ingredients, which, owing to the small bulk of the nitro-glycerine to that of the guncotton, is a more risky and dust-producing operation than is the case with cordite Mark I, the preliminary mixing of the two ingredients through copper-wire gauze sieves, as carried out with Mark I, is not done in the case of M.D. The paste is taken to the incorporating houses in the original bags, and the operations of charging the machines are as follows :—The machine is stopped, and the safety catch, to prevent accidental revolution of the blades, is placed in position. About half the total acetone, 23 lb. 7 oz., is

first of all poured into the machine, and the wooden loading hopper is placed in position on top. Wooden steps of three treads are next placed in front of the machine to raise the man loading high enough for the work. He mounts the steps with the bag of paste in his arms, having previously untied the tape securing the mouth of the bag, enters the mouth of the bag into the hopper, and empties the paste from it into the machine, taking care not to allow any more guncotton dust to escape than he can help. When the bag is empty the man comes down the steps, ties up the mouth of the bag, waits about a couple of minutes, removes the safety catch and starts the machine. A medium-sized machine incorporates 120 lb. of material; a second bag of paste is therefore added after the machine has been running for a minute or two on the first one, in much the same way.

Circumstances of the explosion.

On the morning of the explosion the men employed in Group G were Thomas Chapman, the chargeman, and the two deceased men, Eli Page and Walter Iron. The three machines in Bay 3 were charged on Saturday, 13th December, and were ready for unloading after the dinner hour (11.30 a.m.) on the Monday. The main driving engine was under repair, and the deceased fitter Mecklenburgh was at work on it in Group G engine house at the moment of the explosion. This end of Group G was being driven from Group C engine house. Page and Iron went to their dinner at the usual time—viz., 11 a.m., Chapman, the chargeman, remaining to oil the pulleys on the machines, in accordance with the usual practice on Monday mornings. The two men returned shortly after 11.30 a.m., and were searched by Chapman before going to work. Chapman then went to the dining room for his dinner, where he was when the explosion occurred, leaving Page and Iron to empty the three machines. When Chapman left the group the three machines were all loaded, and there was only one bag of paste (57 lb.) in Bay 3 ready for use. From the statement made to me by Chapman, the three machines would, in the usual course, be all unloaded before any of them were re-charged, the unloading commencing with the right-hand one (No. 1 on Print No. 914); it was also Iron's turn to unload and re-charge, Page assisting him.

The three finished charges would fill five barrels, each containing about 60 lb. of incorporated material. Of these five barrels one was found in Bay 1 and one in Bay 2 after the explosion, and a third had been taken away just before the explosion by a truckman, William Hind; two were unaccounted for.

There were no empty barrels in the whole group when Chapman went to his dinner. Five were brought to Bay 3 subsequently, for the material from the three machines. Pieces of barrel and the remains of two barrel covers were found in the plantation in front of the group after the explosion, as were also several lumps of incorporated material. Dr. Robertson, who was standing in the new upper room of the laboratory with his back to Group G, turned round immediately on hearing the explosion, and saw the flame of burning cordite rise from the demolished bay. It is, therefore, extremely probable that the explosion ignited and dispersed the incorporated material in the two barrels without exploding it. Moreover, no one appears to have heard more than one report. Incorporated material full of acetone and unconfined is not liable to explode. The two incorporating machines on the left-hand side of the bay (*see* Print 914) were more or less damaged externally by the explosion, but no explosion had evidently taken place in either of them.

The last person who saw Page and Iron alive was the truckman, William Hind. He was coming with his truck along the tramline platform from Group D for incorporated material, and saw Iron roll two barrels of material out of Bay 3 into Bays 1 and 2, where they were subsequently found. On arriving at Bay 3 he was given a barrel of incorporated material over the barrier from the bay by Page, who went back into Bay 3. Iron went into Bay 3 from Bay 2 at the same time. He did not see what either of them was doing in Bay 3. After receiving the barrel from Page, Hind put it into his truck and returned with it to opposite the shoe room in front of the Mineral Jelly and Acetone Store in the centre of Group D, stopping for a moment at Bay 6, Group D, to ask if any incorporated material was wanted

there. He had only just entered the shoe room when the explosion occurred. His proceedings from the time of his taking the barrel of incorporated material from Page to the time of his entering the shoe room, were repeated after the explosion, and were timed to take 1½ minutes. As already mentioned, Chapman left only one bag of paste in the group in Bay 3 when he went to his dinner, and the paste truckman, it has been ascertained, did not take any more bags of paste to the group after the dinner hour.

It therefore appears most probable that, about two minutes before the explosion occurred, Page and Iron had just completed the unloading of the three machines of Bay 3, and were in the bay preparatory to commencing loading the charge of paste they had into the right-hand machine, No. 1 on Print 914.

After the explosion the remains of Iron, very much blown to pieces, were found in the vicinity of No. 1 machine; Page's body was found entire on the clean platform under a mass of *débris* in front of the partition in the verandah between Bays 2 and 1, with his feet towards Bay 1. His skull and right leg were fractured, but whether by the force of the explosion or by falling *débris* is not certain; neither his clothing nor his head or hands showed any signs of burning. The fitter Mecklenburgh, who was at work on the engine in the back left-hand corner of the engine room, *see* Print 914, was killed by falling *débris*. The man Clements was struck by falling *débris* as he was coming out of the Mineral Jelly and Acetone Store.

Effects of the explosion.

The effects of the explosion on Bay 3, on the adjacent engine room to the north of it, and on Bays 2 and 1 to the south of it, on the rest of the group, and on Group E, which lays about 150 feet to the east of Group G, are shown on photos numbered 1 to 8 attached to this report.

The damages done to buildings in the factory are given in Appendix III. Serious structural damage was only done to Group G, Bays 3, 2, and 1, and to its engine and boiler houses, but this damage was extraordinarily severe in view of the small quantity of explosive (57 lb.) involved. The massive construction of the engine-room wall, and of the partition walls between the bays, no doubt accentuated the damage in the immediate vicinity, but at the same time tended to localise it. It is remarkable that although the partition wall between Bays 3 and 2 fell into the two left-hand incorporating machines in Bay 2, which had only been charged about one hour, yet these charges were unaffected. Slight structural damage to the roofs of the dining room at Group D, and to the engine house at Group F, was done, 170 feet and 210 feet south and north respectively; there was no structural damage done east or west. Minor damages to windows, doors, roofs, group shutters, &c., were done within a radius of 1,230 feet. The zones of damage are shown on Map A.

The wind was blowing from the W.S.W., and the report of the explosion was heard at Gillwell, High Beach, Epping, Nazeing, St. Margarets, and the districts to the east of the factory. No damage was done in the town of Waltham Abbey itself, but windows are said to have been broken in Crooked Mile, about 1,000 yards distant, and in the vicinity of Nazeing, which lies about four miles off in a north-easterly direction. It is also reported that the explosion was distinctly heard at Ponders End and Goffs Oak; but the report that it was heard and felt at Southend, no doubt arises from the fact that a serious explosion occurred almost at the same time at Messrs. Curtis and Harvey's Cliffe Factory on the Thames, not very far distant from Southend.

The distribution of the *débris* and its general nature is shown on Map B, and in Appendix IV. Owing to the construction of the buildings and the direction of the wind, the *débris* has taken almost entirely an east and west direction. There was very little fire amongst the woodwork *débris*, mainly from the roofing, and what there was was very soon put out by the hydrants, which were got smartly to work.

Site of the explosion.

It was not difficult, after a careful examination of Bay 3, to locate with certainty the actual spot where the explosion occurred. As stated above, it may be regarded as a certainty that the only explosives in the bay were two barrels of M.D. incorporated material, about 120 lb. in all, and one bag containing 57 lb. of cordite M.D. paste. It is a certainty that the two barrels of incorporated material were only ignited and scattered by the

explosion. In the ordinary course they would have stood on the floor somewhere in front of the machine No. 1, and if their explosion had produced the results detailed above, there must have been a crater in the floor where they stood; none, however, existed. The paste, therefore, must have exploded; and it must have been in the incorporating machine when it exploded, for the following reasons :—

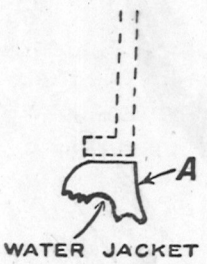
(1) The incorporating machine was entirely destroyed, the bulk of the recovered fragments being very small. If the paste had exploded outside the machine it is probable that of the recovered pieces some at least would have been larger.

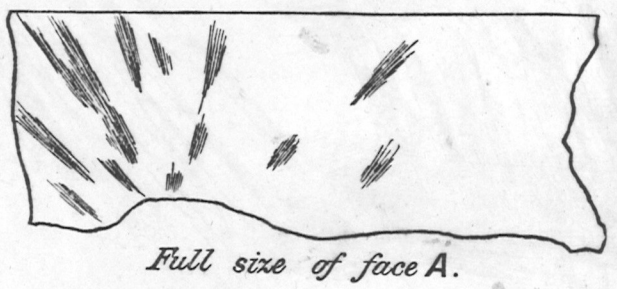
(2) The fragments were projected downwards, and in all directions. The elevating screw was found about 680 feet to the east in a field outside the factory; portions of one of the lugs securing the top portion of the machine to the bottom portion were projected to the west, and went through the roof of No. 3 gunpowder dusting house, a distance of about 340 feet. Some small pieces were also found in the steam pipe on the right of the bay, and the wall on the left was marked by others. That portion of the iron framework of the front of the bay which faced the machine, was struck in many places by what were evidently fragments of the machine (*see* photo No. 9). One of the blade spindles with the blades broken off was found on the floor where the machine had stood. An explosion outside the machine would probably have sent the fragments in one direction only (*see also* Map B).

(3) The asphalte and concrete floor directly under the machine was disintegrated, and many small pieces of what had evidently been the lower portion of the machine were found embedded in it. There would have been a crater in the floor at some other spot if the explosion had occurred outside the machine.

(4) The only parts of the man Iron of any size which were recovered were his legs: one was hanging over the edge of the old gunpowder mill gear tank, the other had fallen into the gear tank below it. These were in front of and to the right of the site of the machine. A small piece was found just beyond the pond in front of Bay 3. The rest of the fragments of the body were recovered in small pieces to the right of the site of the machine, and behind it, the portions behind having no doubt been deflected from the wall dividing Bays 3 and 2, on which there were blood stains. If the explosion had occurred on the floor the legs would probably have suffered as much as the rest of the body.

(5) A piece of cast iron, belonging to the lower half of the body of the machine, was found in Group E, Bay 6. The shape of this piece is roughly thus :—





Full size of face A.

There is evidence from dark markings on the inner face of this piece, which is the inside face of the machine, of an origin of the propagation of an explosion from a point below the planed edge on which the top half of the incorporator rests. The radial condition of the markings points to a centre of explosion lying at least a short distance below the fracture. Microscopically, the darkened portions of the inner surface appears to be carbonaceous. These effects could only have been produced by an explosion occurring in the machine itself.

Work actually in progress at the moment of the explosion.

The actual spot where the explosion occurred having been determined, it is now necessary to try and establish what was being done in the bay at the moment of the explosion. From the position in which Page's body was found he could not have been in the bay. It was Iron's turn to charge the machine, and as the charge exploded in it, it is certain that he had done so. If he had, as was the practice, first unloaded the three machines and then disposed of the incorporated material before commencing to recharge, as from Hind's statement and the distribution of the five barrels of incorporated material he had apparently done, then he must have charged No. 1 machine in the interval between the time when Hind saw him enter Bay 3 and the explosion. From the statement made by Hind, this time could not have been much more than a couple of minutes, as explained above, a period barely sufficient for the operation, and the probability, therefore, is that Iron was actually starting the machine when the explosion occurred. The distribution of his remains makes it almost certain that he was at the starting wheel. Only this position in the bay could account for his legs being found over and in the gear tank, for portions of his body being in a line with the right-hand or starting side of the machine, and against and under the partition wall dividing Bays 3 and 2 (the wall had lifted slightly at the floor line), and for the blood splashes on the wall immediately above. The portions of the body found in the *débris* behind the bay had no doubt dropped there after striking the wall where the blood splashes were, and being deflected.

After a very careful examination of all the evidence, in which I have received very great assistance from Captain M. B. Lloyd, H.M. Inspector of Explosives, who spent some time on the spot with me on the morning of the 17th, and with whom I further discussed the subject on the 19th, I am of opinion that there is no doubt that the explosion was one of 57 lb. of cordite M.D. paste in the right-hand machine (No. 1) of Group G, Bay 3, and that the explosion occurred in starting the machine by the deceased man Iron. In this opinion Captain Lloyd concurs.

Probable cause of the explosion.

The circumstances of the explosion having been determined with practical certainty, it remains to consider the probable cause or causes. For this purpose it will be convenient to examine in detail all possible sources whence the accident could proceed, in accordance with a list prepared by the late Sir Vivian Majendie, and presented as Appendix XVI of "The Report of the Committee appointed to inquire into the Accident of the 13th December, 1893, at the Royal Gunpowder Factory, Waltham Abbey." This list is reproduced in Appendix V.

A.—Causes immediately concerning Tools and Machinery.

1. *Inherent Defects in Construction of Machinery or Implements.*

The kneading machines of Messrs. Werner, Pfleiderer, and Perkins are almost universally employed for the incorporation of modern smokeless explosives, when the ingredients are gelatinized or brought into a colloidal condition by means of a promoting liquid or solvent; they are also sometimes used when there is no solvent employed, as in the case of blasting gelatine, gelignite, &c. The only accident which, as far as I can ascertain, has occurred in their use, is the one dealt with in Report No. CIX of the Inspector of Explosives, on the circumstances attending an explosion which occurred in a mixing house at the factory of the National Explosives Company, Limited, near Hayle, Cornwall, on the 4th September, 1894. This accident will be referred to later.

The machines are of strong construction, and very rarely require repairs of any kind. They have been in use at the R.G.P.F. for the incorporation of cordite since 1890, and out of a total of 52 in use for various periods, not a single one has ever broken down or given any trouble. The actual machine in which the explosion occurred was one of 14 supplied towards the end of the year 1900, so that it is not likely to have had any inherent defects. The machine was taken to pieces, thoroughly overhauled and cleaned on the 24th October, 1902.

2. *Defective working of Machine or Tools due to—*

(1) *Fracture or distortion by wear or otherwise.*—The only working parts inside the machine are the two spindles, each with two blades. Each spindle with its blades is a solid casting. The sudden fracture of one of the blades, caused either by its encountering some hard, foreign body, or by some jar in starting, would no doubt be sufficient to have caused the explosion; at the same time, it is very difficult to see how such a jar could arise, although it is a possibility. The question of the presence of a foreign body will be considered later. In connection with the subject of blades breaking, I have been informed, since the accident, by Mr. C. O. Lundholm, Manager of Messrs. Nobel's Ardeer Factory, that they have recently had two cases of this occurring when incorporating cordite M.D. rework.

(2) *Clogging;* (3) *other disturbance;* (4) *improper application.*—These defects are not applicable to this class of machine, and need not therefore be considered.

3. *Fall of Tool or portion of Machinery.*

No tools are used in charging, nor are there any loose portions of machinery.

4. *Heated Bearing.*

Heated bearings are most unusual. The machine, moreover, had been standing still for at least a quarter of an hour previous to being charged. A bearing would have to be very hot indeed to cause ignition or explosion. Guncotton requires a temperature of 170° C., and nitro-glycerine one of over 200° C., to ignite them.

5. *Ignition caused by Cleaning or Repairing Machinery.*

There can be no question of either cleaning or repairing.

Before proceeding with the consideration of the second series of possible causes in Sir Vivian Majendie's list, it will be convenient to deal with the possible causes connected with this class of machine enumerated by Colonel Ford in his report on the Hayle accident :—

(1) *Explosion in a recess in the framework of the machine below the centre cog-wheel or on a tooth of a cog-wheel.*—These parts are carefully protected so as to prevent the accidental presence of any explosive, and the cog-wheels are kept well greased. It must also be renembered that the Hayle machine was in use for the manufacture of gelatine dynamite, a very sensitive explosive, in the production of which no solvent is used.

(2) *Blow or friction on the machine with the spud by workmen when putting in the explosive.*—Not applicable.

(3) *Foreign substance (either from the nitro-glycerine or nitro-cotton, or fallen into the trough) causing friction in the machine.*—This cause will be dealt with later.

(4) *Spud dropped into the machine by man when putting in explosive.*—Not applicable.

(5) *Fracture of a tooth of cog-wheel or other part of gearing, or of a driving band.*—These if they occurred, as they must, outside the machine, would be most unlikely to cause an explosion in it.

(6) *Fracture or distortion of one of the revolving paddles.*—This has already been dealt with.

(7) *Nitro-glycerine in bearings.*—Free nitro-glycerine could not have been present, it is all absorbed by the guncotton.

(8) *Heating of the bearings.*—This has already been dealt with.

(9) *Race of the engine.*—Not applicable.

To resume the consideration of Sir Vivian Majendie's possible causes :—

B.—Causes Independent of Tools and Machinery.

(A) *Accidental Causes.*

6. *Lightning.*

The morning of the 15th was fine.

7. *Fire from External Source.*

(1) *Adjacent chimney.*—Adjacent chimneys at Groups F, E, D, and C, all 80 feet high, were at work; but the wind was blowing the smoke from all of them away from Bay 3, Group G. Moreover, it is extremely improbable that a spark would cause a violent explosion of dry guncotton.

(2) *Passing engine.*—There were none.

(3) *Other sources*, e.g. :—

(*a*) *Men taking fire from watch-house or engine room on their clothes or cooking utensils, or otherwise.*—Iron and Page had been at work since 6 a.m. They went to dinner at 11 and returned at 11.30. They had not been near a fire since starting work in the morning. No cooking utensils or drink cans are ever allowed out of the dining rooms, nor do the workmen ever bring the former into the factory, as cooking is done for them in the dining rooms by the man in charge.

(*b*) *Fire from glue pot.*—Not applicable.

(*c*) *Concentration of sun's rays.*—It was more or less sunny during the morning, but the explosion occurred at noon, and there were no windows in the roof, and the side ones were high up and were protected by the verandah and roof.

(*d*) *Lamp or fire.*—There can be no question of either.

(*e*) *Electric lighting or other apparatus.*—The bays are electrically lighted (*see* Print 914), but the light was not in use. Since "Beltine" has been in use on the incorporating machine belts there has been no generation of electricity.

8. *Spark from—*

(1) *Articles of iron.*—There were no iron articles in the building, and, as already remarked, it is extremely unlikely that a spark could cause such a violent explosion of loose guncotton.

(2) *Articles of glazed earthenware.*—There were none in the building.

9. *Spontaneous Ignition of Cotton-waste, &c.*

Not a possible cause in this instance. No cotton-waste is used in R.G.P.F. danger buildings.

10. *Smoking.*

(1) *In or near building.*—There are always so many persons in and out and about the incorporating houses that it would have been impossible for either of the men to have been smoking. They had been searched by their chargeman, Chapman, on their return from dinner about 11.35. Charles Iron informed me that his brother was only an occasional smoker of cigarettes.

(2) *Unextinguished pipe in workman's pocket.*—No pockets of any description are allowed. The two men had been searched three times that morning since changing into danger-building clothes.

11. *Lucifer Match.*

(1) *From workman's pocket.*—No pockets are allowed. Iron was searched by the police at the main gate on entering at 6 a.m. Both he and Page were searched by the warder at the entrance to the danger area after changing into danger-building clothes. They were also searched by their chargeman before going to work, and on return to their work after dinner.

Visitor of danger buildings, Knowler, saw them searched on this latter occasion.

(2) *Left lying about.*—The introduction of a match in this way into a danger building is an impossibility.

12. *Foreign substances, such as small stones, gritty particles, articles of metal, nuts, bolts, nails, &c., introduced :—*

(1) *On shoes or clothes;* (2) *on tools, machines, or cotton waste;* (3) *on barrows or barrels;* (4) *by being blown in.*—There is a clearance of $\frac{1}{4}$ inch between the blades and all parts of the machine, so that supposing small-sized foreign substances, such as could be introduced in any of the above ways, were present, there is no likelihood of their causing sufficient friction to explode the charge. Moreover, the introduction of a foreign substance of any size, in any of the ways enumerated above, amounts almost to an impossibility.

(5) *In the ingredients :—*(*a*) *If improperly sifted;* (*b*) *contracted from walls or roofs of buildings after sifting;* (*c*) *derived from a machine or tool;* (*d*) *contracted during conveyance.*—The introduction of a foreign substance of some size in the ingredients, or by falling directly into the machine, causing sufficient friction in the machine to explode the contents, is one of the most probable sources of the accident. The possible means in which such a body could get in must, therefore, be examined in detail. The most convenient course to pursue will be to trace the ingredients through the various operations until they reach the incorporating machine.

The guncotton after pulping goes through a $\frac{1}{8}$-inch mesh wire sieve into a labyrinth, the wire sieve retains the larger foreign substances, the smaller are retained in the bottom tray of the labyrinth. The labyrinth consists of a box divided down the centre by a board which does not go to the bottom. The guncotton pulp, together with a large bulk of water, passes down one side of the box, under the partition, and up on the other side, and then down a long sloping chute covered with blanket for retaining fine sand and grit, into the poacher. From the poacher the guncotton pulp and water are drawn up by means of a vacuum into a large elevated tank or "stuff chest," in which it is kept in agitation by revolving paddles. From this tank it is run through a valve into a small gauge tank, and from this tank into the moulding machine. There are various nuts and bolts both in the poacher and in the stuff chest. It is, however, most improbable that any of these large and somewhat heavy articles from the poachers could ascend into the stuff chest, nor could they or similar articles from the stuff chest pass the valve into the gauge tank. The stuff chest has been examined since the accident, and no bolts or nuts are missing. In November, 1900, however, an iron bolt was found in a guncotton primer when mixing cordite Mark I paste. It did not belong either to the poachers or to the stuff chest; how it could have got into the primer was never discovered; it was supposed at the time that it was dropped either accidentally or wilfully into the moulding machine. After the guncotton is moulded, it is placed in boxes and sent to the zinc-lined guncotton stoves, where the primers are placed by hand on the trays. The primers when dry are removed again by hand, broken up roughly, and placed in the indiarubber bags, which are then tied up at the mouth. The bags are removed in covered trucks to the guncotton weighing room, where the charge of each bag is adjusted to the correct weight—viz., 39 lb. The charges are sent to the mixing house, where the 18 lb. of nitro-glycerine are run in from the measuring vessel, and the mouth of the bag tied up. The bags are removed by covered trucks and covered boats to the paste store. In none of the buildings into which the guncotton is taken after it leaves the guncotton factory—viz., guncotton stove, guncotton weighing room, nitro-glycerine mixing house, and paste store—are there any small tools or implements, or any articles, such as bolts and nuts, in the building construction, so that it seems an absolute impossibility for any such articles to get into the charge bags, unless they are wilfully put in, and I have no suspicion that anything of the sort is at all likely to have occurred.

The nitro-glycerine, after final washing, is run in the washing house through a filter of salt contained in a flannel bag, and from the filter tank it flows down a covered lead gutter into the nitro-glycerine mixing house, so that it is quite impossible for any foreign substance to get into it. The acetone is weighed into the bottles through a fine wire gauze sieve.

As regards the introduction of foreign substances into the machine, this could only occur in the interval after the machine is unloaded from a previous charge and during loading. It does not seem at all probable that anything of any size could fall in when the men are in the bay without their hearing it, so that the time during which such a thing could happen is very limited. If it occurred during loading, the man must see or hear it; still, it is a distinct possibility. Directly over the centre of each incorporating machine is a galvanised-iron pipe in connection with a water service, controlled by a valve at the end of the group. This drenching apparatus was fitted up after the ignition in Group G, Bay 2, of a charge of partially-incorporated cordite Mark I on the 14th February, 1901. To equalise the delivery of the water through the group, reducing sockets are screwed on to the delivery pipes. These sockets are $1\frac{3}{8}$ inches long, 1 inch outside diameter at the thicker end, and $\frac{3}{4}$ inch diameter at the thinner end. It is possible that the socket over the machine which exploded had become unscrewed, and dropped into the machine after it had been unloaded, during the absence of the two men from the bay. After the explosion I picked up in Bay 3 the screwed end of a delivery pipe broken off short, minus the reducing socket.

Another course of bolts and nuts and screws occurs in the construction of the roof. Immediately over the machine a rafter of T-iron intersects a tie-rod also of T-iron, and they are secured together by iron rivets and iron bolts and nuts. There are also five coach screws securing the roof boards to the iron rafter above the machine. The construction is shown on Print No. 918, on which the loading hopper is also shown.

Two other causes for the explosion have been suggested, viz.:—(*a*) That the paste, where nitro-glycerine was present, was frozen; (*b*) the friction set up between the blades and the unbroken pieces of guncotton primers which exist in M.D. paste. As regards (*a*) the paste was made at Quinton Hill on 9th December, the particulars of it are given in Appendix VI, and show nothing abnormal. It was sent in the afternoon of the 9th to No. 5 Paste Store, which is not heated, and remained there about 40 hours. The minimum temperature during the period was $37\frac{1}{2}°$ F., the maximum 41° F. On the morning of the 11th it was sent to No. 4 Paste Store, where it remained until the morning of the 13th; minimum temperature 59° F., maximum 70° F. On the 13th it was sent to Bay 3, Group G, and remained there until charged into the machine. The bay was kept warm, at about 60° F., during Saturday and Sunday; it is most improbable, therefore, that it was frozen. Six bags of paste from the same batch which had been kept under the same conditions, and which were removed from Group G, Bays 4, 5, and 6, were examined after the explosion by Principal Foreman Skerman, and were found not to be frozen. As regards (*b*) unbroken pieces of primer are no doubt harder than finely-divided guncotton, but I do not think they are hard enough to offer sufficient resistance to the slow motion of the blades, making 11 and 5 revolutions per minute respectively, to cause friction sufficient to explode the charge, particularly as there should be about $23\frac{1}{2}$ lb. of acetone present. The presence of so much acetone should, in fact, tend greatly to prevent an explosion, even assuming some fairly large substance had got into the machine.

During the year 1895, quantities of fairly large stones were found on several occasions in incorporated material and in paste. They most fortunately never caused an accident, although at that time the clearance between the blades and the machine was trifling. Both blades and bottoms of the machines were often found to be scored. There was very little doubt at the time that the stones were wilfully introduced into the paste during or after hand mixing.

If, on the other hand, no acetone was present in the machine which exploded, the chances of an accident become very much greater, and it is possible that with such a large proportion of dry guncotton as there is in M.D. paste an explosion might be brought about even without the intervention of any foreign substance. Moreover, the absence of acetone would, I think, partly

explain the remarkably severe nature of the effects produced by the explosion of such a comparatively small quantity as 39 lb. of guncotton and 18 lb. of nitro-glycerine—a total of only 57 lb. That no acetone had been poured into the machine is, I think, distinctly possible. As I have already pointed out, assuming that the usual routine had been followed—that is to say, that the three machines had been unloaded and the incorporated material disposed of before starting to recharge, and, having regard to the statement of the truckman Hind, the time taken to charge the machine was not sufficient for the operations to have been carried out in accordance with the instructions. Both Iron and Page had been at this work since the 20th January, 1902, having taken the place of two men whom I myself found had loaded and started an incorporating machine without the acetone, and whom I in consequence discharged. They should therefore have been thoroughly acquainted with the work, and should have been warned by the example of their predecessors. Unfortunately, even in the manufacture of explosives, familiarity breeds contempt, and it is just possible that, in order to get through the work in the easiest way, Iron simply emptied the bag of paste straight into the machine and started it without having, either owing to forgetfulness or carelessness, poured in the acetone.

(B) *Wilful Acts.*

13. *Matches, &c., Wilfully Introduced during the Absence of Workpeople.*

This is in the highest degree improbable, and it is most unlikely that ignition of M.D. paste by means of a match could produce such a violent explosion.

14. *Wilful Ignition of Powder Dust outside.*

Not applicable.

15. *Wilful Introduction into Ingredients of Foreign Substances before the same were brought into the Building.*

There are no grounds for suspecting anything of the sort.

16. *Wilful Acts of Workmen.*

(1) *While in a state of insanity.*

(2) *While in a state of intoxication.*—There is no question of insanity, and both Iron and Page had been at work since 6 a.m., and were quite sober.

(3) *With object of committing suicide.*—I questioned Iron's brother, Charles Iron, a truckman on the same shift, who told me that his brother lived with another married brother, and was as comfortable and happy as could be; also that he had seen his brother at work frequently that morning, and that he was in good health and spirits, and had nothing on his mind.

17. *Explosion of Building by Fuze, or other means.*

Not applicable.

To sum up:—I feel certain that the explosion was one of 57 lb. of cordite M.D. paste, and that it occurred in the right-hand incorporating machine No. 1, of Bay 3, Group G, at the moment of starting the machine by the deceased man Iron.

The possible causes in order of probability are:—

(1) Presence of some fairly large foreign body: (*a*) introduced in the paste; or (*b*) which had fallen into the machine.
(2) The sudden fracture of one of the blades.
(3) The absence of acetone.

F. L. NATHAN, Major R.A.,
Superintendent, R.G.P.F.

21*st December*, 1902.

I attended the adjourned inquest on the 29th December. The jury returned a verdict of "Accidental death."

F. L. N.

APPENDICES.

APPENDIX I.

Incorporating House G.

Use List.

Boxes, chalk	—	In Bay 1.
„ sweepings	—	„
Brooms, hair	2	
Brushes, hand	2	1 in Bay 1.
Buckets, leather, fire .. each bay	2	
„ wood, ash bands	—	On truck platform at time of explosion.
Cans for acetone	—	In Bay 4.
„ and pots for oil and lubricants ..	—	1 tin lubricator .. .. } 1 gallon can .. .. } in Bay 1. 1 tin can or pot for grease }
Cleaners, wood	1	
Desks, wood	—	In Bay 1.
Hoppers, brass .. .. each bay	1	
„ wood .. .. „	2	
Ladders and steps, wood .. „	1	
Mops	2	
Pencils	—	In Bay 1.
Scoops, wood	1	
Spatulas, wood	—	In grease can—Bay 1.
Stools, wood	—	In Bay 1.
Thermometers, glass	—	„
„ wood .. each bay	1	
Trays, zinc	—	In Bay 1.

APPENDIX II.

INCORPORATING HOUSE G.

Special Rules.

1. Workmen are on no account to take material out of incorporating machines, nor put their hands into them for any purpose whatever, while the machines are in motion or while stopped, unless the safety catch is in its proper position.

2. Belts are only to be replaced and shafting oiled by those detailed for the purpose. Their names are posted up.

3. During incorporation the temperature of the material is never to exceed 40° C. (104° F.).

4. Boxes, whether containing mixed or incorporated material, are to be placed in the positions set aside for the purpose.

5. The doors in the partitions between bays are always to be kept closed.

6. Only one incorporating machine in a bay is ever to be uncovered at the same time for any purpose whatever.

7. Empty barrels, boxes, and bags for explosives are not to be deposited on the outside platform, or where the sun can play on them.

APPENDIX III.

Damage to Buildings Inside the Factory.

Building, &c.	Distance from centre of explosion.	Nature of Damage.
	Feet.	
Group G—Bay 3 ..	—	Wrecked. East and west sides (wood, canvas, and glass), including supporting frames of angle iron, blown outwards. Slates and wood lining of roof blown away. Ironwork of roof and shafting partly blown away, rest collapsed. South wall of brick collapsed. North wall of brick—whole of east upper portion blown north into engine room, lower portion still standing. Inner platform blown outwards and brickwork below carried with it. Hood with iron supporting pillars blown west. West supporting frame of iron blown over truck platform and lying in plantation. This frame is struck in many places by flying *débris*, evidently portions of metal from incorporator. Inner truck rail blown west into plantation. Outside pump blown west. Electric mains across west front damaged; 3 switch-boxes smashed, and pole shifted. East supporting frame blown east against coal-yard wall. Two rectangular holes north and south in centre of floor, opening up shafting-pit below. North-west machine blown over, and top part blown partly away. North-east machine blown bodily north, holding-down bolts sheared, and starting wheel, pulleys, &c., bent and broken. South-east machine blown completely to pieces. Only one blade-spindle and a few small fragments of spur wheels and jamming wheel left on the spot. Many fragments found in crater below.
Group G—Bay 2 ..	25	Roof wrecked and partially burnt. North end of roof fallen in. Shafting snapped and bent. The two north incorporators buried under ruins of north wall. Five full acetone bottles on south side hardly damaged. South-east machine—cover broken, leaving charge exposed. Thermometer broken. Electric mains in plantation west damaged. South wall cracked. East and west frames in place.
Group G—Bay 1 ..	40	Roof lifted. East and west sides completely blown out except frames. North and south walls cracked. Nearly all slates fallen. Machines intact.
Group G — Engine House.	20	South wall of brick has top easterly portion blown north from about half-way up, nearly burying the engine. Roof completely collapsed. North wall shaken. West wall tottering.
Group G — Boiler House.	50	Outside gas-lamp glass blown away, south-east corner. South side of roof much damaged, and whole roof lifted. Top of all walls damaged and some bricks fallen. All three windows on south side wrecked, including frames; 48 panes. North side—46 panes out of 48 broken. East side—6 panes out of 6 broken; door-bolt torn off. West end—doors and partition blown away. South wall struck in several places by hard *débris*.

Building, &c.	Distance from centre of explosion.	Nature of Damage.
	Feet.	
Group D — Dining Room.	170	Roof lifted. Top of north and south walls a good deal shaken. Horizontal crack in north wall, about 5 feet from roof. North side—23 panes out of 36 broken. South side—6 panes out of 36 broken. East side—5 panes out of 11 broken.
Foreman's Dining Room.	160	Roof lifted slightly.
		Structural damage ends here (except G coal-yard wall, and perhaps chimney shaft).
Group G — Chimney Shaft.	20	Brickwork scarred by flying *débris* on west side. A horizontal crack near top on east side, but it is not certain that this was caused by the explosion.
West Wall—Coal Yard	20	Bulged to the east. A bicycle standing on east side shattered.
Plantation west of Group G.	60	Two poplars of 18 inches diameter snapped off about 15 feet from the ground, tops blown west.
	70	Portion of curved platform, 18″ × 10″ × 3″, carried away by fall of pillar-head from hood. Many small branches brought down. Trees in vicinity struck in many places by hard *débris*.
Group G—Bay 4 ..	40	A few bricks blown north from centre of south wall, near opening for shafting (*see* Group G, Engine House). Electric main and outside lamp broken. Machines loaded and intact. A sprinkler pipe had dropped on to cover of south-east incorporator, but without damaging it. The pipe was merely shaken from its fastening and bent. The west front was blown inwards, all the glass and shutters being broken, but the iron frame was still in place. The south door was badly splintered. The east side had 1 shutter out of 8 out, and 3 torn; 1 pane broken out of 8. The roof was much shaken, but was not lifted.
Group G—Bay 5 ..	65	West side—8 shutters out of 14 out; 6 panes out of 14 broken. East side—4 shutters out of 8 out, and 3 others burst. All 8 panes broken.
Group G—Bay 6 ..	90	West side—3 shutters out of 14 out, 1 started. No glass broken. Many slates shaken down. East side—13 shutters out of 14 out, and the one left was burst. A few slates off.
Group E—Bay 1 ..	190	East side—5 shutters out of 10 damaged; 4 panes out of 8 broken. West side—all 14 shutters blown out; 12 panes out of 14 broken. Doors intact. Many slates down.
Group E—Bay 2 ..	180	East side—all 10 shutters damaged; 6 panes broken out of 8. West side—all 14 shutters out; 13 broken. South door broken; north door intact. All 14 panes blown inwards. Many slates down.
Group E—Bay 3 ..	175	East side—5 shutters out of 8 damaged; 8 panes out of 8 broken. West side—14 shutters out of 14 damaged; 13 panes cut of 14 broken. North door much damaged; south door not so much. Large hopper broken in two.
South Cabin	200	Door-post damaged.

Building, &c.	Distance from centre of explosion.	Nature of Damage.
	Feet.	
Group E—Bay 4 ..	160	East side—8 panes out of 8 broken; 8 shutters out of 10 blown out. West side—12 panes out of 14 broken; 14 shutters out of 14 damaged. One hopper splintered. Thermometer broken. South door damaged by flying *débris*. Two baulks of inner platform displaced. Slates shaken down.
Group E—Bay 5 ..	166	East side—8 panes out of 8 broken; 9 shutters out of 10 damaged. West side—6 panes out of 14 broken; 13 shutters out of 14 blown out. Gutter broken. Hopper pierced in one place. Lightning conductor damaged. Hole in roof, north end. Slates shaken down.
Group E—Bay 6 ..	170	East side—8 panes out of 8 broken; 1 sash blown out; 4 shutters out of 10 damaged. West side—8 panes out of 14 broken; 4 shutters out of 14 damaged. South door struck in two places. Slates shaken down.
North Cabin	170	West side—door-post driven in. East side—partition damaged.
Group E—Magazine ..	170	Door blown off.
Group E—Shoe Porch	160	Clock damaged.
Testing House ..	180	North side—1 pane out of 8 broken.
Group E—Boiler House	220	East side—1 pane out of 3 broken. South side—2 panes out of 36 broken.
Feed Pump Room ..	230	Skylight—1 pane broken.
Hydraulic Pump Room	210	North side—12 panes out of 24 broken.
Engine Room	180	Skylight—4 panes out of 6 broken. Roof—east side broken in two places by falling *débris*.
Accumulator House ..	150	Door shattered and blown off. Outside gas-lamp glass broken. Fanlight—11 panes out of 11 broken. Upper windows—9 panes out of 9 broken.
Group F	210	Roof—several slates dislodged both on east and west sides. Plant intact.
Group F—Bay 1 ..	140	East side—3 panes out of 8 broken; 8 shutters out of 8 blown out. West side—8 shutters out of 14 blown out; 1 burst. Cement in north-west corner shaken down.
Group F—Bay 2 ..	165	East side—4 panes out of 8 broken; 8 shutters out of 8 blown out. West side—2 shutters out of 14 started; 3 bolt-heads (probably from roof) on floor. Some cement shaken down.
Group F—Bay 3 ..	190	East side—8 shutters out of 8 blown out; 6 panes out of 8 broken. West side—4 shutters out of 14 blown out; 1 pane out of 14 broken. North-east corner suffered most. Some cement shaken down.
Engine and Boiler House.	210	Lead sheeting on ridge of roof shifted.

Building, &c.	Distance from centre of explosion.	Nature of Damage.
	Feet.	
Group F—Bay 4 ..	225	East side—3 shutters out of 8 blown out. West side—3 shutters out of 14 blown out; 1 window frame started.
Group F—Bay 5 ..	250	East side—2 shutters out of 8 blown out; 2 panes out of 8 broken. West side—1 shutter out of 14 blown out.
Group F—Bay 6 ..	275	East side—2 shutters out of 8 blown out. West side—1 shutter out of 14 blown out.
South Cabin	125	South side started, and 1 pane out of 5 broken.
Group D — Ramming House No. 3.	250	Two panes out of 12 broken. Thermometer broken.
Group D—Bay 1 ..	230	Five shutters out of 14 out. Roof intact.
Group D—Bay 2 ..	210	Roof intact. West side—9 shutters out of 14 out. East side—11 shutters out of 14 out. Glass intact. Cement shaken down slightly.
Group D—Bay 3 ..	185	Roof—one or two slates loose. A little cement shaken down. East side—13 shutters out of 18 blown out. West side—10 shutters out of 14 blown out; 2 panes out of 14 broken. Bolt on north door broken; lock on south door burst off.
Acetone and Mineral Jelly Store.	165	Roof—slates shaken loose. East side—2 panes out of 14 broken. West side—top sash blown in and hanging by lines; 10 panes out of 22 broken.
Group D—Bay 4 ..	150	Roof—slates shaken down. East side—all shutters (18) out. West side—15 shutters out of 20 out; iron frame bent; 6 panes out of 14 broken. South door lock burst off.
Group D—Bay 5 ..	125	Roof—slates shaken down. Skylight—1 pane cracked. East side—all 18 shutters blown out. West side—13 shutters out of 20 biown out.
Group D—Bay 6 ..	100	Roof—many slates shaken down. All shutters blown out—12 east, 16 west. West side—6 panes out of 22 broken. Much cement shaken down. Door shattered.
Filling Cabin	80	North wall shaken. 2 panes out of 3 broken. East side—side blown out.
Incorporated Material Store.	270	Door split.
Ramming House, No. 2	320	North side—1 pane out of 12 broken. Belt case outside, north; 1 shutter out of 1, out.
Group C—Bay 6 ..	340	East side—9 shutters out of 12 out. West side—5 shutters out of 16 out. No glass broken. A little cement shaken down.

Building, &c.	Distance from centre of explosion.	Nature of Damage.
	Feet.	
Group C—Bay 5 ..	365	East side—17 shutters out of 18 out. West side—3 shutters out of 20 out. No glass broken. No cement on floor.
Group C—Bay 4 ..	385	East side—14 shutters out of 17 out. West side—2 shutters out of 20 out.
Group C—Bay 3 ..	420	East side—3 shutters out of 12 out. West side—1 shutter out of 20 out.
Group C—Bay 2 ..	445	East side—1 shutter out of 12 out. West side—1 shutter out of 20 out.
Group C—Bay 1 ..	470	East side—2 shutters out of 6 out. West side—4 shutters out of 16 out. North door lock started.
Ramming House, No. 1	490	Door almost burst open.
Engine House.. ..	400	East side—1 pane out of 11 broken. West side—3 panes out of 21 broken.
Boiler House ., ..	410	North side—9 panes out of 83 broken.
Group A—Bay 7 ..	720	North side—1 shutter out of 20 out.
Machinery Store ..	730	North side—i pane out of 22 broken. West side—1 pane out of 33 broken.
Machinery Shop ..	740	Office—1 pane out of 24 broken. West side—5 panes out of 72 broken. North side—15 panes out of 100 broken; 3 sashes started.
Cylinder House ..	650	Chargeman's lobby—2 panes out of 12 broken. One door burst open and splintered. Glass hood south—4 panes out of 120 broken.
Gas Factory—Retort House.	590	Galvanised corrugated-iron roof damaged. West side—2 panes out of 11 broken. Outside gutter, west, fallen.
Coal Shed	570	Slates loosened; 8 down.
Meter House	580	One pane out of 12 broken.
Regulator House ..	570	One pane out of 2 broken.
Stokers' Lobby ..	610	South side—1 pane out of 4 broken.
S.O.'s House	1,250	One large pane, 3′ × 1½′, broken. Kitchen ceiling shaken down.
Manager s House ..	1,650	Study ceiling partly shaken down.
No. 2 Mill, magazine..	650	Porch window—1 pane out of 1 broken.
No. 2 Mill, north end	580	East side—1 pane broken and 1 shaken loose out of 8; 4 shutters out of 32 started.
No. 3 Mill	530 to 460	Skylight—3 panes broken out of 6. East side—12 shutters damaged out of 50; 1 pane shaken loose out of 8. North side—1 shutter out of 36 out.
No. 4 Mill, south end..	730	One lamp-glass shaken loose and 1 lamp-glass broken out of 12.
No. 6 Mill	530	Drowning tank overturned and catch damaged.

Building, &c.	Distance from centre of explosion.	Nature of Damage.
	Feet.	
Barrel House, No. 1 ..	410	East side—3 panes broken out of 24.
Manager's Office ..	450	East side—3 panes broken out of 60. South side—2 panes broken out of 30. West side—1 pane broken out of 70.
Experimental House ..	400	Pressure gauge—glass front broken. Thermometer broken. West wall bulged out 6 inches at bottom. Leak started in East London water pipe outside at south-west corner.
Group H	450	Some grit shaken down.
Old Accumulator House	500	South side—1 pane out of 2 broken.
No. 2 Press House ..	1,220	Door-bolt broken.
No. 3 Dusting House..	350	East side—3 panes out of 84 broken. Roof struck in six places by flying *débris*. Timber beam over water wheel damaged. Hole pierced through roof of engine-house and in partition between engine-house and dusting-house, both probably caused by same piece of *débris*. Steam pipe in engine-house slightly shifted.

APPENDIX IV.

Nature and Position of Débris.

Note.—Distances measured from centre of south-east incorporator, Group G, Bay 3

Group G, Bay 3:—

South-east Portion.—Incorporator blown into fragments. Blade-spindle lying north and south, with north end slightly inclined west; the blades were broken off, and portions of the large and small spur-wheels, and of the jamming wheel, and a steel sleeve were lying near. A considerable quantity of fragments of the incorporator was found in the crater, which had been blown in the floor on the site which the incorporator had occupied.

It was evident that Walter Iron had been blown violently against the south wall here, close to the floor; that portion of him which was recovered here was torn into small pieces.

One of Iron's legs was found on the east edge of a hole opened by the explosion into the shafting gallery below. It was lying north and south, with the foot north.

Iron's other leg was found at the bottom of this hole.

North-east Portion.—Incorporator shifted bodily north almost to the north wall, the holding-down bolts being sheared. The starting wheel, pulleys, and spur-wheels were destroyed as from a blow from the south.

The body of the machine was not greatly injured, nor was the machine overturned.

The blade-spindles and blades were intact; the machine was empty, and the cover had gone.

The brass hopper was lying in a second hole opened into the shafting directly north of that in the south-east portion; it was considerably crushed. A large acetone bottle was also in this hole almost intact.

This portion was somewhat buried under *débris* from the roof and engine house.

North-west Portion.—The incorporator was blown over, and the body or box portion blown away at the top. The top of the machine lay open to the west, inclining south. Blade-spindles and blades not injured; wooden cover gone.

A crushed acetone bottle was found.

The portion was more or less clear of *débris* from overhead.

South-west Portion.—A crushed acetone bottle was found under *débris* from roof.

Part of an incorporator pulley, about 1 foot long, on floor under *debris* from roof.

Inner Platform.—Blown outwards, including brickwork supports. Among the ruins were fragments of a hand-brush, a hair broom, and two crushed mineral jelly tins.

Group G, Bay 2:—

Page was found here, lying on the inner platform under *débris* from the hood. He was just north of the gangway, round the galvanised-iron partition door between G 2 and G 1.

The north wall and roof had collapsed on to the two north incorporators.

A crushed mineral jelly tin was lying near the south wall in the centre of the bay.

Plantation, West, of Group G:—

Front iron frame of Bay 3 blown over the outer or truck platform. Distance to centre of frame about 50 feet. The inside of the frame was up, and there were numerous scars upon it indicating blows from small but hard and sharp fragments. The original top north corner was resting on the truck platform, the original bottom south corner being the farthest point from the bay, and lying about 62 feet west and 15 feet north.

A leather fire bucket, with handle and top blown off, was lying under curved platform, 60 feet west, 20 feet north. The angle iron from the front edge of the hood was lying across the truck platform, the south part being still attached at G 1, and the outer end lying 60 feet west, 4 feet south,

The inner truck rail from the front of G 2, about 20 feet long, was blown due west, and was lying north and south in the plantation, 56 feet west.

A portion of the abdomen of Walter Iron was found on the west edge of the small pond, about 60 feet west. A portion of a pulley and piece of leather belting were lying on curved platform, about 80 feet west, 20 feet north. Several fragments of incorporator lying near ash path.

The top of an indiarubber paste bag, with red tape attached, was lying 57 feet west, 22 feet south.

Two jelly tins close together, 30 feet north, 70 feet west.

Top of hood pillar under west edge of curved platform, 80 feet west.

A 5-feet length of pipe (iron), 130 feet west, 30 feet north.

A 4-feet length of angle iron, 140 feet west.

Fragments of incorporated-material barrel, some charred, some not, and scattered unburnt incorporated material, 90 feet to 100 feet west, 20 feet to 30 feet north.

The grass was burnt as though by burning material in several places about this part of the plantation.

A 7-foot wood splinter, 70 feet west, 150 feet north.
A 4 „ „ 80 „ 170 „
A 3 „ „ 90 „ 140 „
A 3 „ „ 130 „ 200 „

An isolated 3-foot wood splinter near south-west corner of manager's office.

Most of the large splinters fell west and north, only one or two to the south.

Limit of *débris* area north line at right angles to F 3.
„ „ south „ „ D 3.

No *débris* could be found west of Millhead, except two or three fragments of slate, though No. 3 Dusting House was severely struck by small pieces of metal in at least two places.

East Traverse. No. 3 Dusting House:

On east side.—Two pieces sheet lead, 2 feet by 8 inches.

On west side.—One piece sheet lead, 2 feet by 8 inches.

In top of tree on east side.—One piece of sheet lead about 1½ feet by 8 inches.

South side.—Two 2-foot splinters about 30 feet south of traverse.

North Traverse. No. 3 Dusting House:

East end.—A 4-foot wood splinter at foot.

Summary of Débris Found.

West of Group G:—

Fragments of wood and canvas from front face and inside of Group G, Bay 3, between the truck platform and ash path as a general rule. Mean distance, 110 feet.

Large splinters from roof, lying chiefly between ash path and east traverse of No. 3 Dusting House, but several blown away to the north and lying between ash path and Group F. Mean distance, 230 feet.

Sheet lead chiefly found at east traverse, No. 3 Dusting House. Mean distance, 280 feet.

As No. 3 Dusting House was struck by flying metal in at least two places high up on the roof, it is probable that several pieces passed over it. Most of the fragments of incorporator were found near ash path. Mean distance, 170 feet.

The whole area up to No. 3 Dusting House and to the north and south limit lines was strewn with fragments of slate; largest pieces about 4 inches across. Mean distance, 175 feet.

Many small boughs were brought down, chiefly by the concussion. The trees were not much scarred.

East of Group G, and between it and Group E, the *débris* was small, and consisted of slate, wood splinter from roof, fragments of iron from incorporator and roof, and some sheet lead and canvas.

Group E was considerably protected by Group G chimney shaft, but was struck in several places by hard and sharp fragments, especially at Bays 5 and 6.

In the space between G 3 and the coal-yard west wall, several portions of the incorporator were found, notably the hollow rocking shaft of the elevating gear, which was more or less intact.

Parts of the upper portion of Iron's body were found lying at the foot of the boiler shaft.

The iron frame of the east side of G 3 was swung out against the chimney shaft, the north edge remaining more or less in its original position.

In the coal-yard east of G 3 several fragments of incorporator were found lying along the foot of the south wall of Group G Boiler House.

The shafting bearing cover from outside G Engine House was found here, as were several portions of shafting and shafting pulleys from G 3.

On west bank of cut, near coal-yard gate, were found:—

Two fragments of incorporator.
One piece sheet lead, 4 feet by 8 inches.
One piece leather belting, 3 feet by 4 inches.
One piece of incorporator pulley, 8 inches long.

GROUP E:—

At E 6 a conical bolt-head was found near the north steps. An 8-inch bolt on east bank of cut, probably from roof of G 3, and also a fragment of incorporator about 2½ inches long.

A 4-inch fragment of incorporator was found on the floor.

At E 5 the cylindrical lifting lug of the incorporator was found imbedded in the north part of the roof on the west side and about half-way up.

The roof here had been struck in three places.

A 4-inch fragment of incorporator was lying on bank of cut opposite this bay.

At the back or east side of this bay were found:—

A square lug from side of incorporator, 8 feet east.
Two fragments of leather belting.
A triangular fragment of incorporator, 45 feet east.

Several fragments of leather belting and incorporator were found near the north end of Group E, and the belting appeared to have been scorched, if not actually fired.

On the ash heap behind E 4, 5, 6, were found:—

A 4-inch fragment of iron gutter.
Two pieces of leather belting.
A 6-inch fragment of sheet lead.

On the footbridge over cut opposite the accumulator house was a piece of sheet lead, 2 feet 6 inches by 8 inches.

E Engine House roof was broken in two places by falling *débris*, not seriously. At the north-east corner was a small piece of incorporator and a 4-inch piece of iron gutter.

At the south-east corner was a piece of sheet lead, 18 inches by 8 inches.

The whole of Group E was surrounded by fragments of slate, but the larger wood splinters passed over it into the fields still further east.

ABBEY FIELDS, EAST OF GROUP E:—

Limit of *débris* area:

Lines at right angles to Group G, and 60 feet south, 200 feet north.
Line parallel to Group G, and 680 feet east.

Débris found:

Elevator screw, 3 feet long, 680 feet east.
Lightning conductor tape from south side Group G Engine House, about 12 feet long, 390 feet east, 90 feet north.
18 inches by 8 inches piece of sheet lead close to lightning conductor.
Square piece of corrugated iron, 2 feet by 2 feet, 400 feet east, 50 feet north.
A 6-inch piece of iron gutter, 460 feet east.
An isolated 8-foot wood splinter, 680 feet east, 250 feet north.

The greater portion of the *débris* here was lying in a sheet east of Group E, 4, 5, 6, between the stream and the ditch to the east of it. Only large splinters (about six) had passed east of this ditch. It consisted of large splinters, 3 feet to 4 feet long, with smaller ones and a considerable quantity of broken slate. There was not much lead, but two or three fragments of incorporator were found, one piece being 8 inches by 3 inches by 2 inches, beside the elevator screw already mentioned.

The lead here did not fly so far as the large splinters, whereas to the west the contrary is the case.

APPENDIX V.

Appendix XVI of the First Report of the Committee appointed to inquire into the Accident of the 13th December, 1893, at the Royal Gunpowder Factory, Waltham Abbey.

Summary of Causes whence Accidents in the Manufacture of Gunpowder may proceed. Prepared by Colonel Majendie, C.B., Her Majesty's Chief Inspector of Explosives.

A.—*Causes immediately connected with Tools or Machinery.*

1. Inherent defect in construction of machinery or implements.
2. Defective working of machine or tools, due to—
    (1) Fracture or distortion by wear or otherwise.
    (2) Clogging.
    (3) Other disturbance.
    (4) Improper application.
3. Fall of tool or portion of machinery.
4. Heated bearing.
5. Ignition caused in repairing or cleaning machinery.

B.—*Causes independent of Tools and Machinery.*

(A) Accidental Causes.

6. Lightning.
7. Fire from external source—
    (1) Adjacent chimney.
    (2) Passing engine.
    (3) Other sources, *e.g.* :—
        (*a*) Men taking fire from watch-house or engine-room on their clothes, on cooking utensils, or otherwise.
        (*b*) Fire from glue-pot.
        (*c*) Concentration of sun's rays.
        (*d*) Lamps or fire.
        (*e*) Electric lighting or other apparatus.
8. Sparks from—
    (1) Articles of iron.
    (2) Articles of glazed earthenware.
9. Spontaneous ignition of cotton waste, &c.
10. Smoking—
    (1) In or near building.
    (2) Unextinguished pipe in workman's pocket.
11. Lucifer match—
    (1) From workman's pocket.
    (2) Left lying about.
12. Foreign substances, such as small stones, gritty particles, articles of metal, nuts, bolts, nails, &c., introduced—
    (1) On shoes or clothes.
    (2) On tools, machines, or cotton waste.
    (3) On barrels or barrows.
    (4) By being blown in.
    (5) In the ingredients—
        (*a*) If imperfectly sifted.
        (*b*) Contracted from walls and roofs of the buildings after sifting.
        (*c*) Derived from a machine or tool.
        (*d*) Contracted during conveyance.

(B) Wilful Acts.

13. Matches, &c., wilfully introduced during the absence of workpeople.
14. Wilful ignition of powder dust outside.
15. Wilful introduction into ingredients of foreign substance before the same were brought into the building.
16. Wilful acts of workmen—

(1) While in a state of insanity.
(2) While in a state of intoxication.
(3) With object of committing suicide.

17. Explosion of building by fuze or other means.

APPENDIX VI.

Analyses of Nitro-glycerine and Guncotton.

Ingredient.	Moisture.	Mineral Matter.	Nitrogen.	Heat Test.	Insolubility in Acetone.	Solubility in Ether Alcohol.
	%	%	%	mins.	%	%
NITRO-GLYCERINE—						
Charge No. 640 Y	—	—		24	—	—
GUNCOTTON—						
Stoving No. 936*a*	0·56	—	12·82	14	—	11·63
Test No. 4230*c*	—	·33	12·86	16	—	10·36
Test No. 4235*c*	—	·36	12·90	19	2·20	10·84
Test No. 4236*c*	—	·30	12·81	20	—	10·63

Analyses of Materials used in the Manufacture of the above Nitro-glycerine and Guncotton.

Material.	Contractor.	Consignment No.	Date received.	Specific gravity.	Mineral matter.	Suspended solid matter.	Colour.	Smell. Hot.	Smell. Cold.	Free acid.	Fatty acids.	Lime.	Magnesia.	Iron and alumina.	Arsenic.	Phosphorus.	Gums or sugars.	Potash and soda.	Chlorides.	Combined sulphuric acid.	Sulphuric mono-hydrate.	Lead.	Sulphates.	Residual matter.	Nitrous acid.	Oil.	Water.
					%	%				%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
FOR NITRO-GLYCERINE—							pale																				
Glycerine	Domeir	227	19.9.02	1·2626	·024	none	amber	good		none	·005	none	none	none	none	none	trace	trace	trace	none	—	—	—	—	—	—	—
Acid, sulphuric ..	Spencer Chapman	1,014	17.11.02	1·8425	—	—	—	—	—	—	—	—	—	—	,,	—	—	—	—	—	96·40	none	—	—	—	—	—
,, ,, ..	,, ,,	1,024	2.12.02	1·8425	—	—	—	—	—	—	—	—	—	—	,,	—	—	—	—	—	96·41	,,	—	—	—	—	—
Acid, Nitric	Wallace	960	22.9.02	1·5005	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	trace	·064	1·02	—	—
,, ,, ...	,, ...	964	1.10.02	1·5005	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	,,	·041	1·06	—	—
FOR GUNCOTTON—																											
Cotton waste	Adams	308	15.9.02	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	·65	7·81	
,, ,, ...	,, ...	309	19.9.02	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	·83	7·48	
,, ,, ...	,, ...	311	7.10.02	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	·88	7·10	
Acid, sulphuric ..	Spencer Chapman	1,009	6.11.02	1·8425	—	—	—	—	—	—	—	—	—	—	none	—	—	—	—	—	96·41	none	—	—	—	—	—
,, ,, ..	,, ,,	1,010	10.11.02	1·8430	—	—	—	—	—	—	—	—	—	—	,,	—	—	—	—	—	96·53	,,	—	—	—	—	—
,, ,, ..	,, ,,	1,011	11.11.02	1·8420	—	—	—	—	—	—	—	—	—	—	,,	—	—	—	—	—	96·60	,,	—	—	—	—	—
,, ,, ..	,, ,,	1,012	13.11.02	1·8435	—	—	—	—	—	—	—	—	—	—	,,	—	—	—	—	—	96·57	,,	—	—	—	—	—
,, ,, ..	,, ,,	1,013	14.11.02	1·8420	—	—	—	—	—	—	—	—	—	—	trace	—	—	—	—	—	96·36	trace	—	—	—	—	—
Acid, Nitric	Waltham Abbey..	974	8.11.02	1·5015	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	trace	·042	1·14	—	—
,, ,, ...	,, ,,	976	15.11.02	1·502	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	,,	·043	1·02	—	—
,, ,, ...	,, ,,	977	22.11.02	1·5015	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	,,	·050	1·10	—	—

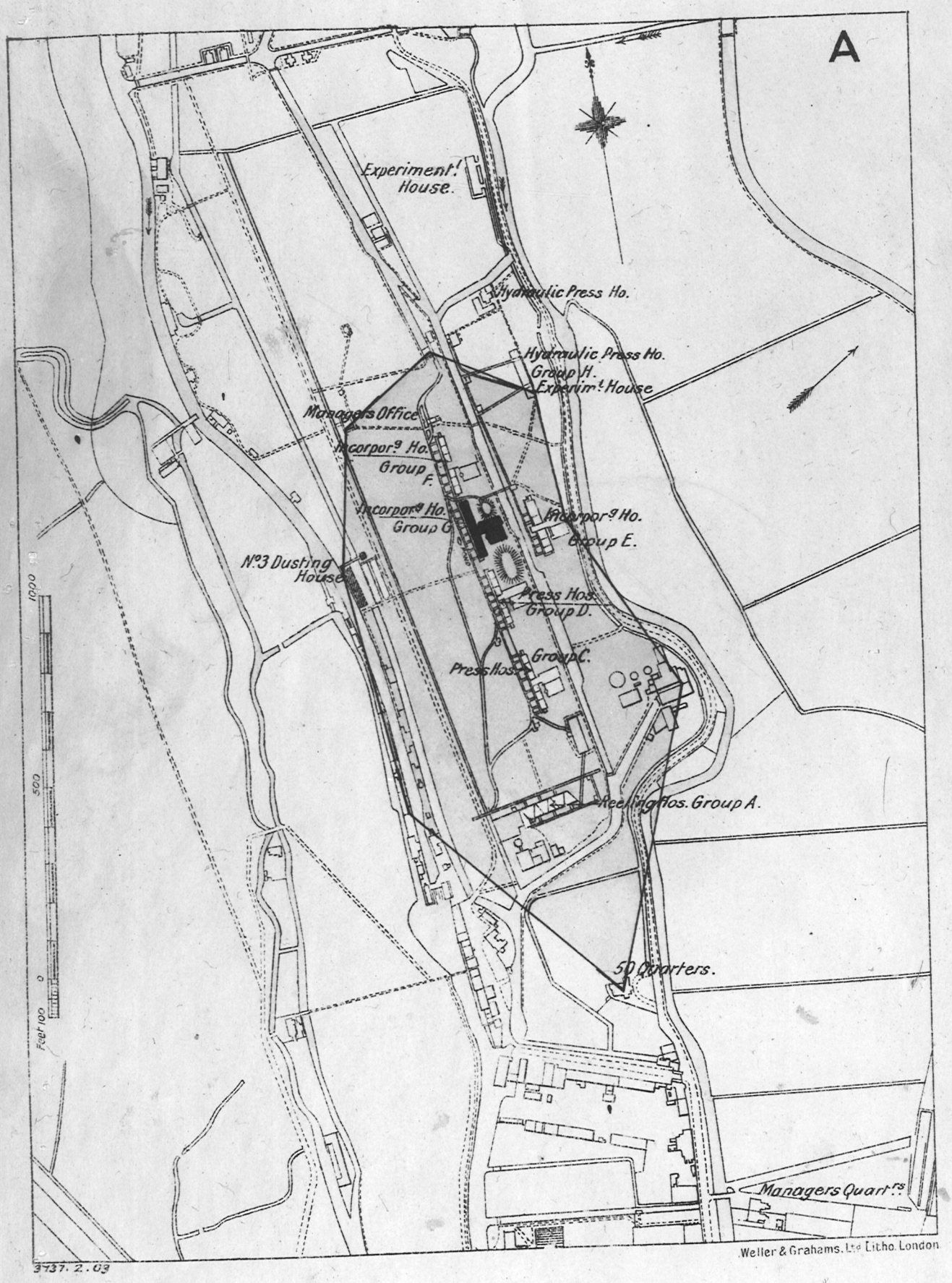
No 1.

Bay 3 and Engine House, Group G.

No. 2.

Engine House And Bays 3, 2, 1, Group G.

15-12-1902
Explosion Enquiry



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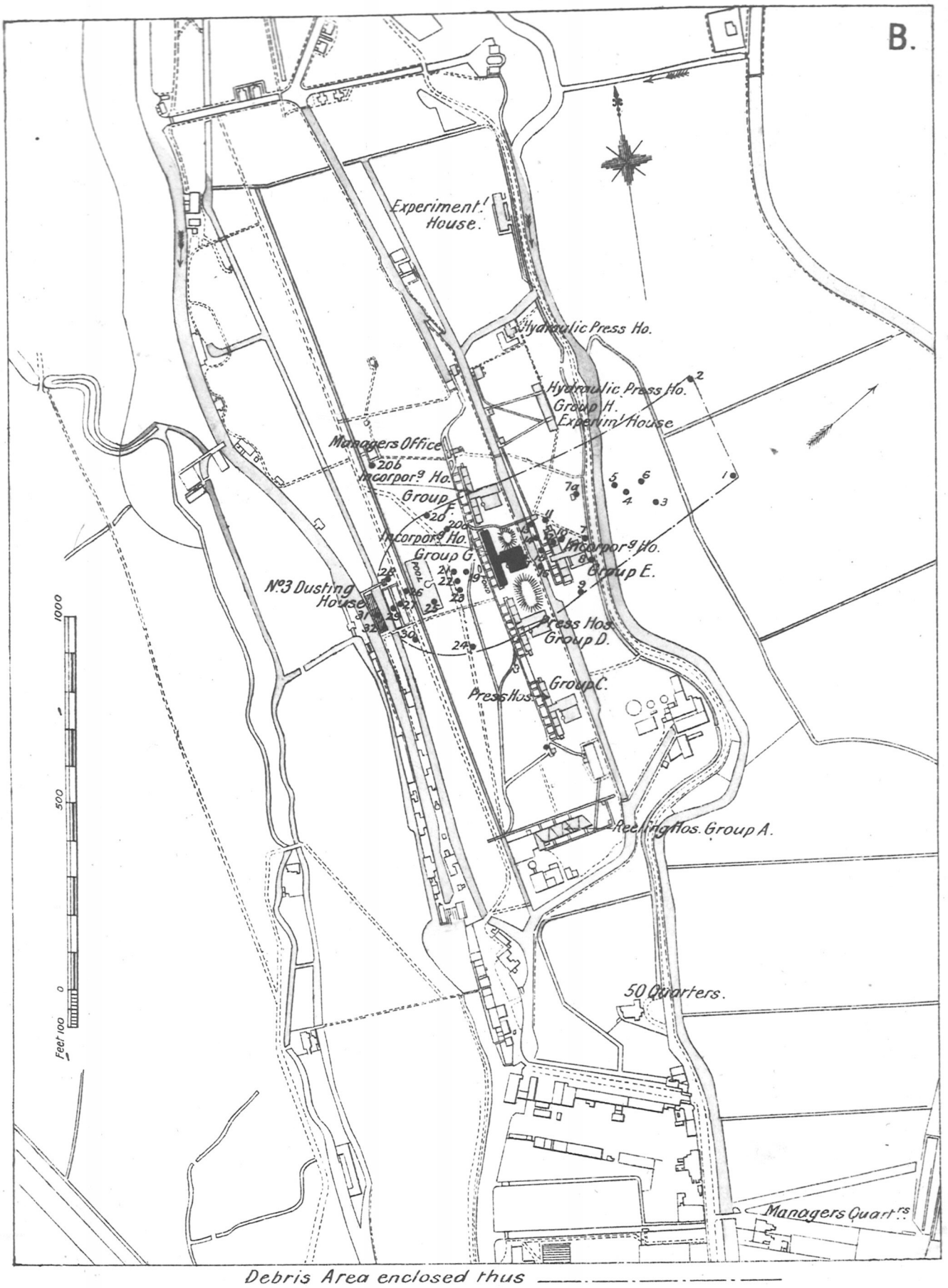

Debris Area enclosed thus ——.——.——.——.——

1 Elevator Screw.
2 Eight Feet wood splinter.
3 Six inch fragment Iron Gutter.
4 Corrugated Iron sheet 2'x 2'
5 Twelve feet of Lightning conductor tape and piece of Sheet Lead 18"x 8"
6 Centre of Large wood splinters
7 & 7a Fragments of Incorporator
8 Sheet Lead 18"x 8"
9 Steam pipe struck here
10 Fragment of Incorporator
11 Fragments of Leather belting
12, 13, 14, 15 Fragments of Incorporator
16 Sheet Lead 2'.6" x 8"
17 Sheet Lead 4'.8" & two Fragments of Incorporator.
18 Fragments of Incorporator & several planks from roo
19 Charred fragments of Barrel.
20 Three feet wood splinter.
20a Seven feet wood splinter.
20b Three feet wood splinter.
21 Fragments of Incorporator.
22 Five feet Iron pipe.
23 Four feet Angle Iron.
24 Three feet wood splinter.
25 Several wood splinters 6' to 8' long
26 Sheet Lead 2'x 8"
27 " " " x "
28 Four feet wood splinter.
29 Sheet Lead 2'x 8'
30 Two 2' splinters
31 Fragment of Incorporator which pierced Roof.
32 Roof pierced, Fragment not found.

3737.2.03.

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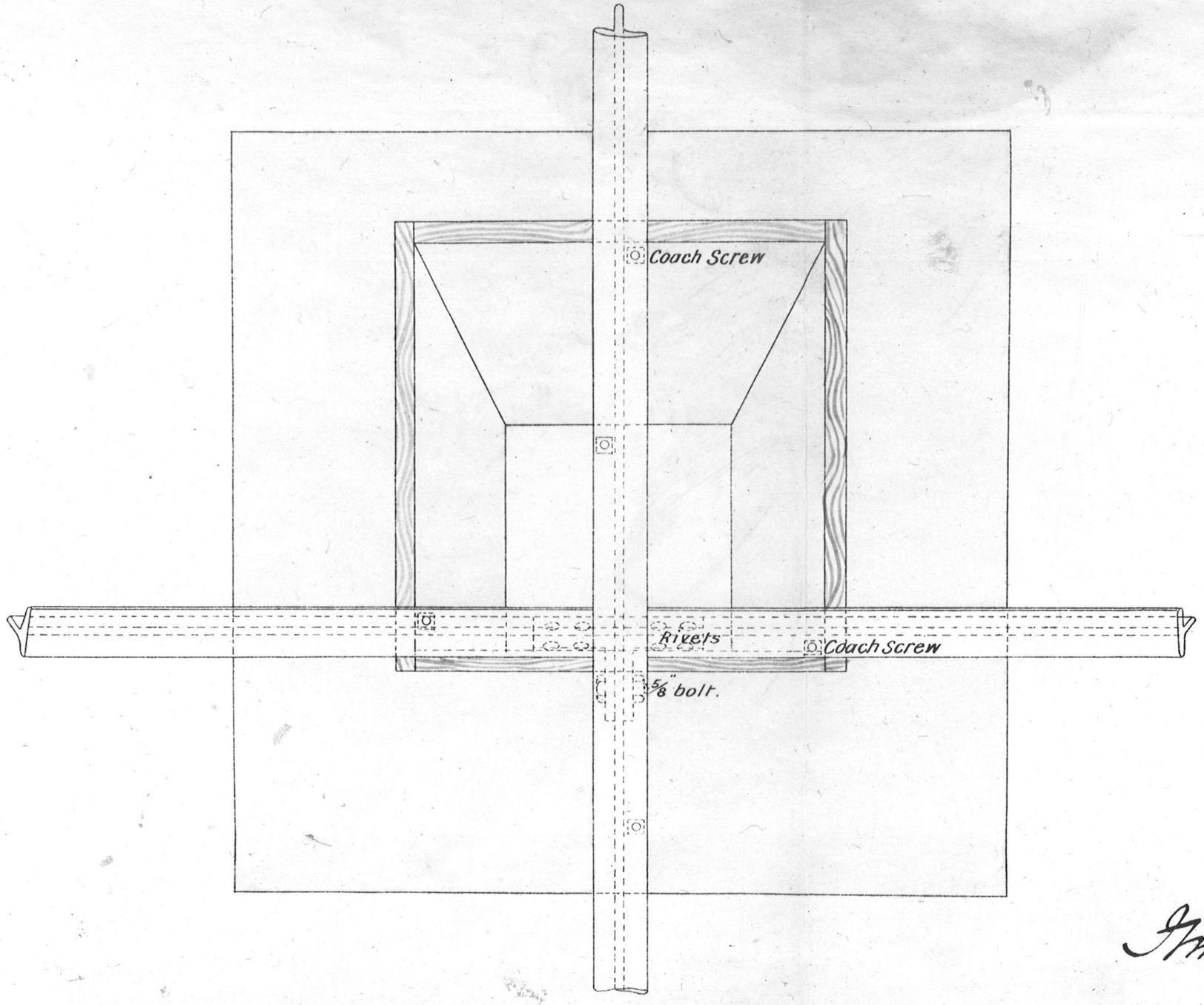

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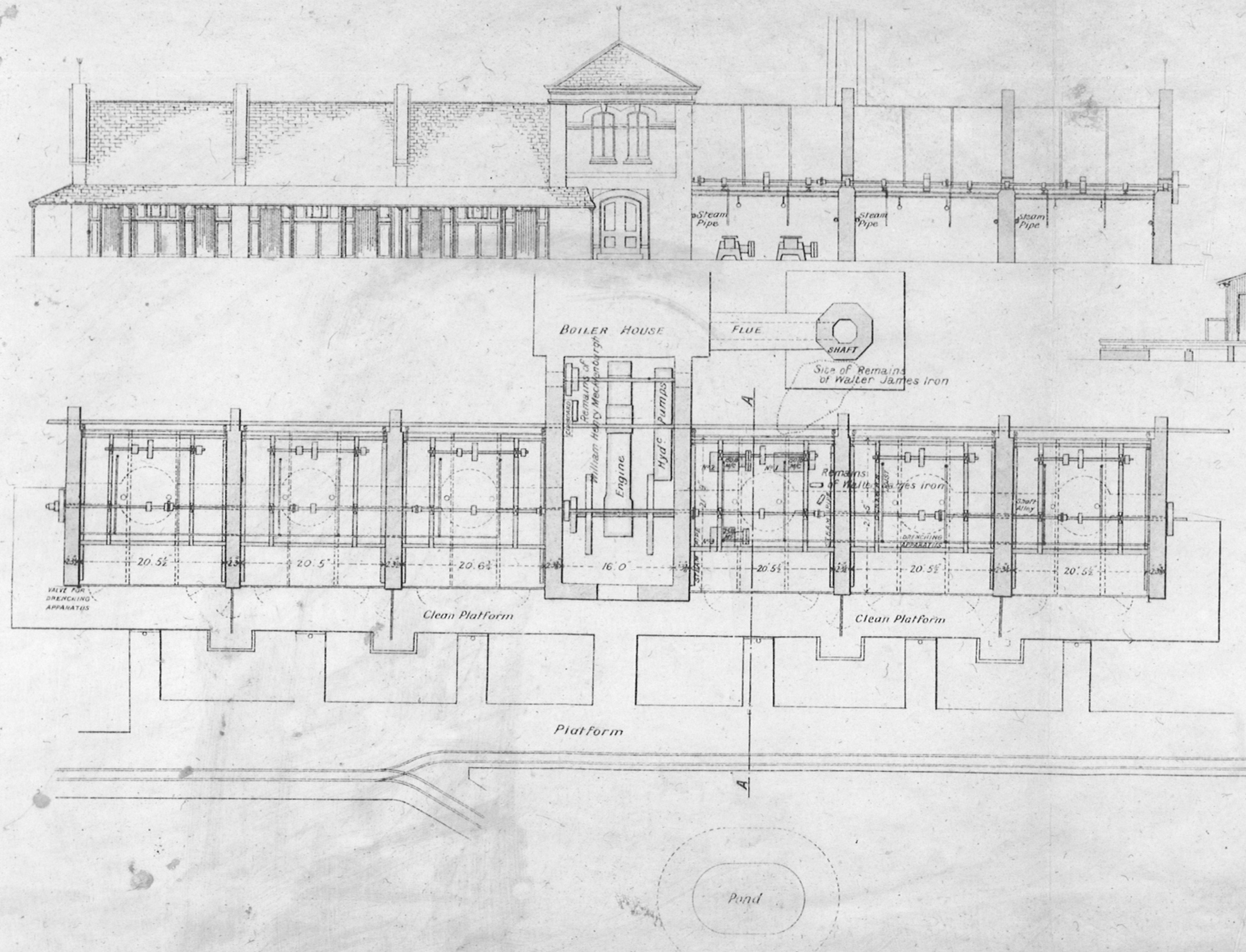
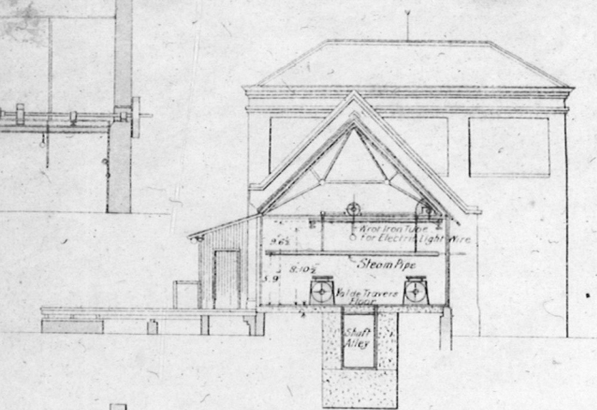
Superintendent R.G.P.F.

R.G.P.F.

GROUP G MILLS FOR MANUFACTURE OF CORDITE.

NOTE :- Electric Lights thus ○





SECTION AT A.A.

No 914.

Superintendent R.G.P.F.

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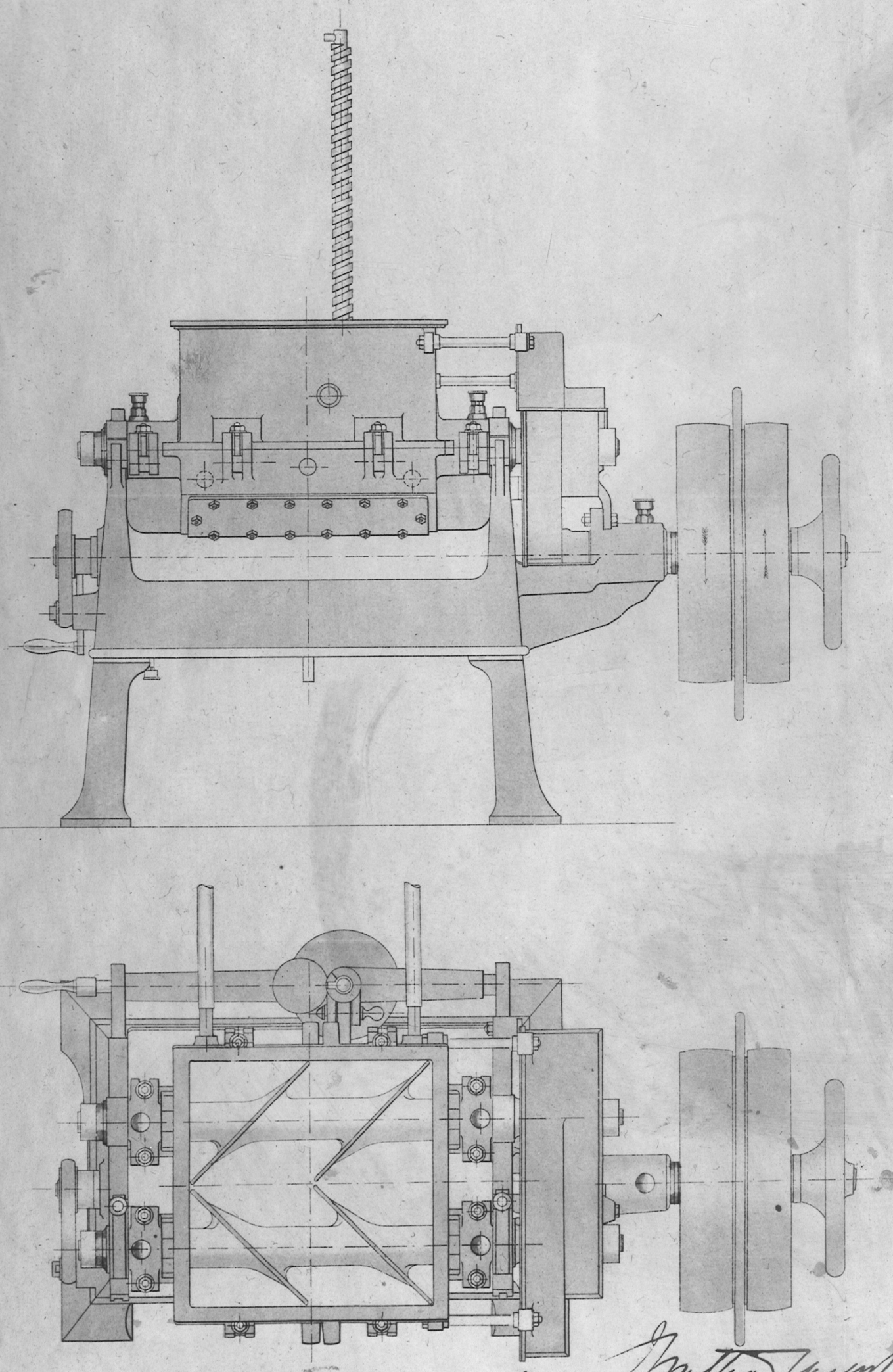
R.G.P.F.

INCORPORATING MACHINE FOR CORDITE FACTORY.



Superintendent R.G.P.F.

No. 917.

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