WA sc 22 48

Two drafts by
Bryan Howard
relating to
history of
South Site

1. INTRODUCTION

For the early history of the Site I have drawn liberally on the report by Steve Chaddock and the accounts in "Dangerous Energy" by Wayne Cocroft . I have used living memory of the years following the Second World War

2. SOME MEMORIES OF THE SOUTH SITE

1. Introduction
   Scope: 100 years of energetic materials
   Achievements: RDX, Guncotton, Modern Propellants

2. List of significant dates

3. Site as it is now compared with the recent past (flora and fauna) . Size of present site

4. Pre-World War I and World War I (Railway)

5. World War II road network (Names). P1, P2, PR, ISRG, ENG. (Later "E" Branch, Polymers, Whiskers)

6. Post World War II, build-up, Nationalisation, various projects.

7. Closure, post-closure and decontamination

8. Artefacts retained by Royal Gunpowder Mills.

Front cover could feature a photograph of the cordite press (now on North Site roundabout)

South Site

TESTING GUN PROPELLANTS

Gun propellants achieve pressures between 30 to 50 times higher than rockets. Typically a rocket works at, say, 10 MegaPascal (MPa) or 1500 pounds per square inch (psi) but a gun might reach 300 MPa or 20 tons per square inch (tsi) or for a modern tank gun 600 MPa or about 39tsi in old money!

Needless to say any venting of gases at such a high pressure is a noisy affair and for this reason the standard piece of equipment used to test batch to batch variability is a closed vessel which is slowly vented once all of the propellant has burned. Maximum pressure and the rate of pressure rise are measured using tourmaline or quartz piezo gauges and the signal captured by a transient recorder coupled to a computer.

In addition to the closed vessel the use of a strand burner to determine the rate of burning over a range of pressures avoids the need for correcting the geometric factors in the closed vessel.

Two gun pressure strand burners were made , one to operate up to 300 MPa and the other to 700 MPa; they were also able to measure burning rates from -40°C to +60°C.

To study the brittleness of new gun propellant formulations another piece ofapparatus was the "Shatter Test" vessel, which subjected a cold sample propellant to a realistic pressure rise rate found in a gun by firing a fine granular charge and then venting the vessel before it had burned.

More than a small amount, an inspection of three samples so treated allowed a grading of propellant integrity. Firing this vented vessel became routine at Waltham Abbey but at Bishopton MQAD (as it was then), they were opnly allowed to fire this vented vessel at the weekend to avoid scaring the process workers making propellants!

2. LIST OF SIGNIFICANT DATES

1887.	Land purchased from the Grundy family. Quinton Hill Farm?
1887-1890	Guncotton Factory built. Also Gun Proof Range
1891	Nitroglycerine Plant built on Quinton Hill
1894	NG Plant Explosion
1900-1913	Cordite MD (MoDified) required more drying stoves
1914-1918	RGPF made large amounts of of Cordite. Tramway link made with North Site. Acetone Recovery Plant built.
1919-1938	Most of the Factory "moth-balled" New type of "Potcher" invented to purify guncotton
1938	New plant constructed to make RDX. Old buildings refurbished (anticipating WW2) Passive air defences made e.g.Air Raid Shelters.
1939-1945	Until 1942 the RDX plant was the sole producer (for use in 'bouncing bombs' and 'tallboys'.)
1945	Explosives production ceased and role changed to research. Project I was to develop 'plastic' composite rocket propellant Project II CDB Project III EDB Project IV Project V Project VI Remote Handling of Explosives
1977	Waltham Abbey North and Soutrh Sites joinedc with RPE Westcott to become PERME
1984	South Site privatised by sale to BAe
1989	Site closed – all work on energetic materials ceased.
1989-1998	Site rented to various firms.
1998	Site decontaminated, trees removed and contours altered
?	Officially handed over to Lea Valley Park

<u>WALTHAM ABBEY SOUTH SITE</u>

It is ironic that the name 'Gunpowder Park' was given to an area that never produced gunpowder!

In 1889 the farmlands bounded by the Sewardstone Road, the present day M25, the Lea Navigation and the Royal Small Arms Factory were bought by the Government to extend the capability of the long established gunpowder mills on the north side of Waltham Abbey.

One of the first buildings to be built was part of the Guncotton Factory and carried a plaque with the dates 1888-9; this plaque has been preserved and is on show at the Royal Gunpowder Mills in the min exhibition, Some of the window frames from this guncotton building are also stored there.

A separate building, part of the Guncotton Factory, was the P & M (Pressing and Moulding) Room and an acid plant for the onsite production of Nitric and Sulphuric was nearby.

These three units were located where the Sainsbury's Distribution Depot now stands.

<u>THE CASE OF THE DISAPPEARING BUILDINGS</u>

Among the Water Stoves on South Site, each with its surrounding mound, was a building which was missing. The mound was there, but no building!

It disappeared one night during WW2; nobody saw it go and it is thought that a German incendiary bomb was to blame but nobody really knows for certain.

Much later, in the 1980s, another water stove 'went up' one night. Immediately it was thought that the I.R.A. were to blame but since the magazine was used to store experimental high energy rocket propellants it was suggested that one batch didn't contain enough stabiliser and had spontaneously ignited, generating enough heat to start a major fire.

RATIONALISATION or THE TRANSFER FROM NORTH TO SOUTH SITE

In the 1960s ? it was decided to relocate the North Site facilities to South Site. Combustion research moved from H10 to P742 and 'E' Branch (E=Explosives) set up an oblique impact test to the west of M343 which was the home of Project 6, often referred to as 'Campbell's Kingdom'. M343 had its own railway made by Bassett-Lowke to move highly energetic explosives from mixer to curing ovens.

Project 6 came to an abrupt end when, to the consternation of the staff in the control room, all of the CCTV screens went blank! There was no noise of an explosion there but in the P2 tearoom, half a mile away, the detonation was very obvious!

Rationalisation got serious when the renovated gunpowder boat was removed from the water outside the North Site Library and put on a plinth just inside Quinton Gate. Later the boat was moved to Fort Halstead (near Sevenoaks) and then back to Waltham Abbey North Site, where it resides today.

Subsequently, the Drawing Office, Instrumentation Polymer Research and P1 Ballistics all moved to South Site.

Finally the South Site was privatised as part of the sale of the Royal Ordnance Factories to British Aerospace. The staff on South Site who had not been privatised were moved to North Site until it closed in 1991 and the staff were posted to Fort Halstead or Central London.

THE FINAL YEARS BEFORE CLOSURE

Research after privatisation was done by contracts issued by MoD with carefully specified targets; in effect it was an accountant's way of doing research, i.e. the opposite of 'Blue Skies' (could that be 'Black Clouds?)

Because of the all-importance of cost, grass mounds surrounding explosives took on a neglected appearance as cutting grass did not produce money.

Under these circumstances it seemed likely that sooner or later there would be an 'incident' (an explosion). Eventually the expected happened when an order for a quantity of N.T.O. (Nitrogen Tetroxide?) explosive was placed by an American Company. It was known to be a stable explosive but the reaction to make it is 'autocatalytic'. That is, as the N.T.O. is made it accelerates the production of yet more N.T.O.

A large reaction vessel was being used with a thick cast iron lid held down by steel bolts. When the temperature was climbing out of control the staff rushed out of the building. The pressure blast lifted the lid through the roof and dropped it some 50 yards away. Nobody was hurt but the cloud of brown fumes caused the local police to advise schools to keep children inside. All this happened close to the M25 which was only about 100 yards away! This incident may well have hastened the closure of the site.

THE CLOSURE OF THE SOUTH SITE

All scientific work finished at the end of 1989 after 100 years of production and research into propellants and explosives. Royal Ordnance staff were retired or posted to other ordnance factories. Similarly MoD staff were relocated or retired.

There followed a period in which British Aerospace, who owned the site, leased some of the less contaminated buildings to create an industrial site that even boasted a café called Red's Diner. The police used the Rolls House P705 and some of the surrounding buildings to train marksmen. Caravans were stored and car repairs carried out. Among the staff looking after the site was Ed Andrews, Lynne Lennard, Alan Heath and Terry Stemman.

In 1998 the tenants were evicted and the decontamination process begun. Any artefacts that remained, after the removal of equipment to the other R.O. factories in 1989, were removed for safe keeping on North Site (now the Royal Gunpowder Mills)

Royal Ordnance had commissioned a professional archaeologist, Steve Chaddock, to provide a history of South Site with detailed maps of building locations with photographs. However most of the buildings were devoid of any equipment apart from NG Extraction for which the asset-strippers had shown a healthy respect.

Howard Prosser, employed at R.O. Chorley, headed a team to glean any remaining artefacts for preservation on North Site. He was helped by Ron Treadgold, Dennis Mansell and Bryan Howard

Finally all of the buildings were 'thermally remediated' (burnt out) and flattened. At this stage a German 10kg bomb was unearthed close to where Sainsbury's warehouse is now sited. The Bomb Disposal Team used one of the existing mounds to explode it.

All the trees were removed and the site contours altered so that the high ground where the original NG Wash houses and the RDX plant had been, was lowered by some 20 feet and the spoil dumped in the marshy south western corner of the site.

All of the roads were dug up so that as far as the huge earth-moving equipment was concerned, rain stopped play (for several weeks).

An inglorious end to a once proud site!

ARTEFACTS FROM SOUTH SITE HELD BY THE ROYAL GUNPOWDER MILLS

1. Two solvent gun propellant presses
2 Windows and a stone tablet 'GUNCOTTON FACTORY 1888-89" from G....
(used as a stores building post WW2.
3. Two NG wash tubs and the Wash House building (in sections).
4. The 'Box and Tray Store' (in sections) M....
5 Sample of elephant hide floor from M346.
6 Road signs 'Cob Mead Path' , 'Centre Way', etc.
7 Rope mantlets.
8 Solvent storage tanks for acetone, alcohol and ether
9 Fire alarm pillars
10 Dilly carts
11. Bronze safety tools
12. Lead workers tools
13. Operating instructions for the various processes

MODERN GUN PROPELLANTS

1. Higher energy
2. Lower vulnerability
3. Reduced smoke and flash
4. Reduced barrel wear
5 Replacement of brass cases by C.C.C (Combustible Cardboard Case?)
6 Integrity at low temperatures

1 RDX – higher flame temperatures – traditional c. (meaning?) vessel sealing problem
2 Higher operating pressures – more robust c vessel.
3 'Nova' – rubbery properties
4 Talc and wax additives for reduced barrel wear
5 Burning rates at high pressure. Higher P/t (Pressure/temperature?) slope with RDX
6 Shatter test
(7 Loadability – graphiting/grain regularity →straightness)
(8 Semi-solvent)

Picrite – cooler propellant → smoke
Picrite/Carbamite complex

<u>MEMORIES OF SOUTH SITE FROM 1964 TO 1989</u>

By the time that Jack Powling's combustion section moved to P1 Branch on South Site, there were four well- established main research and development groups.

P1 was concerned with nitrocellulose-based propellants for guns and rockets.
P2 studied composite propellants.
PR was concerned with chemical engineering of new materials and
ISRG was an out-station for home office interests in energetic materials

In addition the main machine shop for both North and South Sites was located near the Boiler House.

Dr N G Williams was the Superintendent of P1 Branch in 1964 and had an office in P743 near the Sewardstone Gate. P 743 was the main office block. The Combustion Group was housed next door in P742, a building that had been intended as a ladies shift changing facility. Originally there had been four baths, two banks of hand basins and five toilets. Until the building was modified as a research lab, use was made of two labs in P704.

P1 was concerned with gun propellants, combustible cases and double base rocket propellants including extruded and cast double base methods of manufacture. Since most military propellants are nitro-cellulose based, there was a need for scientific support for production at Bishopton and IMI Summerfield. One topic studied was the emission of smoke from line-of-sight guided missiles.

<u>HISTORIC BUILDINGS ON SOUTH SITE</u>

1	Acid factory	near Quinton Gate; demolished early 60's
2	'Ransley's Folly'	N.T.O. – Deroofed
3.	Guncotton factory building	Stores
4	P and M Room	Pressing and Moulding
5	Fibre Alignment Building	Opposite P and M
6	S/S Canteen	WW2 Building?
7	LRE	on crossroads
8	N500 Magazine on Centre Way	Razed by G Hooper
9	N346? Elephant hide floor	Near M343
10	Box and Tray Store	Early corrugated iron building
11	Railway Control Building	On Centre way
12	Water Stoves Area 'R' series	Two disappeared
13	WW1 Acetone Recovery Building	
14	Two WW2 Acetone Recovery Buildings	
15	P719 P1 Store	Ex Engine Shed?
16	10½ inch Press House WW2 vintage	
17	N562	P1 CDB & RO Offices
18	N550	'Modern ' building for Blue Water
19	RDX Buildings	Compressed asbestos
20	NC Wash House	
21	NG Extraction and large Wet Mix House	
22	P742 and P743	Post WW2
23	Fire Station and Surgery	Post WW2 ?
24	P2 Offices and Laboratory	
25	SS Proof Stand and Temperature Conditioning	
26	P2 Process Buildings	
27	Small brick pillbox	May still exist for bats
28	ISRG area buildings	Including Nissen Hut

BOB TOB AND THE CHINESE TAKE-AWAY

Dave Sims's group specialised in making small numbers of special components of rubber or plastics

One challenging job was to make inhibitor tuibing of 7 inch diameter with a 1mm wall thickness (hope you'll forgive the mixed units)

Making plastic pipe involves extruding hot polymer into a water-cooled sizing bath followed by haul-off and length cutter. This is a real 'fun' job to start up as the water easily finds its way to the extruder causing all sorts of shapes that are anything but tubular.

Once good tubing is being made the system must be watched for any hiccups and cannot be left.

If you thought science was a 9 to 5 job, think again...... When Bob Tobias had been liking after the extruder all day and into the early evening, he decided he needed feeding; hence the Chineses take-away!

The only problem was extracting the cost of the meal from Admin!

<u>THE HISTORY OF WALTHAM ABBEY SOUTH SITE</u>

The history covers 100 years from 1889 to 1989. It is convenient to divide the time into separate phases.

1 The purchase of land and building of a guncotton factory
2 WW1
3 Mothballing between WW1 and WW2
4 WW2 (RDX plus ?)
5 Post WW2 research and rationalisation
6 Privatisation
7 Closure and decontamination
8 South Site artefacts (held on North Site)

5 1964 on
- a) Combustion Section moved from H10 to P742 and post 1981 to P704
- b) Rubbers and Polymers to P & M Room
- c) Ballistics moved from H67 to M343 (1983)
- d) Gunpowder Boat – Library to Quinton Gate area

REMAINING ARTEFACTS FROM SOUTH SITE

1 The tablet from the Guncfotton Factory and some of the window frames are stored on North Site
2 A sample of the elephant hide floor
3 A dismantled Box and Tray Store
4 A dismantled NC Wash House with two wash tubs
5 Three solvent containers used to make gun propellants
6 A small powder blender from P2
7 Parts of a Crawford Strand Burner (ex M343)
8 A Rocket Ballistic Simulator
9 Various drawings of buildings
10 Map of the railway

GUN PROPELLANTS

P1 Branch made a significant contribution to the development and testing of gun propellants for use in artillery, tanks, small arms and mortars. Nitrocellulose was a main ingredient in all of these applications but it was also used in combustible cases to contain tank gun propellant instead of brass shell cases.

Traditionally smokeless gun propellants have been based on nitrocellulose using a solvent such as acetone to provide an extrudable dough. The shape may be long cords of slotted tube or short grains of multi-tubular shape.

WALTHAM ABBEY – THE RESEARCH YEARS 195? -1991

INTRODUCTION

Ken Bascombe arrived with me in October1961 when we were to work under Jack Powling in H10 (an ex-cordite reeling house) studying combustion of solid propellants.

Already some years had elapsed since the inception of research at Waltham. On North Site there was, as I recall, a group studying composite propellants of ammonium perchlorate bonded with a number of polyurethane rubbers under Dr Young. I was aware of other sections studying polymer chemistry from basic research to moulding and extrusion. Chemical analysis, pyrotechnics and explosives were also major topics for study by other sections. As I had little or no contact with these groups at that time I cannot detail the main thrusts of their work.

However I recall that H16 housed (North Site) glassblowing and instrumentation at one end of the building and heat transfer in liquid propellants (under Hans Ziebland) at the other end.

South Site was remote from H10 but had P1 Group working on a range of 'new' cordites. P2 was concerned with composite propellants based on polyisobutene while PR (Process Research was unknown territory at that time. I.S.R.G. (Inter Services Research Group) was even more of an unknown area.

COMBUSTION RESEARCH

Gordon Adams had Jack Powling and Les Phillips studying the chemistry and physics of propellant combustion and they, in turn, indoctrinated a number of graduates into the work at Waltham.

The surface temperature of Ammonium Perchlorate when it was burning was studied using an infra-red technique invented by Jack Powling who published a number of papers with Bill Smith on this subject. Further studies were made on various polymer 'binders' used to make composite propellants to understand how the overall burning rate of propellants was controlled by polymer gasification and flame penetration between the oxidiser-fuel interface.

In 1964 the Combustion Group was split up and Jack Powling and his staff were moved to P742 and P704 as part of a rationalisation move in which we became the research part of P1 under Dr W. G. Williams. Initially Jack Powling was housed in P742, built as a Ladies Changing Facility with four baths, numerous hand basins and cloakroom lockers. Practical combustion wark was done in P704 until P742 was ready for use as a laboratory.

For me 1965 was a milestone as I was sent to Picatinny Arsenal for a year as part of an exchange with an American scientist. I achieved a rare distinction by spending a year in America without flying across the Atlantic!

Returning to the UK was at a time when the smoke problem surfaced. This is a separate story in itself and engaged the resources of P1 Branch and materials for some time. Briefly, a wire-guided anti-tank missile, *Swingfire*, was emitting a plume of smoke which obscured the missile and its target. Since a smokeless(?) propellant was being used, it was found that of all of the complex components in use in the rocket motor, the inhibition was the culprit. Many alternatives were made and tested and the final solution adopted was from a combination of polyoxymethylene mixed in an acrylic rubber supplied by I.C.I.

Once Jack Powling had ben promoted, Steve Bell took over and the emphasis was on projects where propellants could produce gas or release energy rapidly. Aircraft escape chutes, mine lifting bags etc., were designed in conjunction with firms such as Leafield Engineering. At this time gas generator cartridges for missile guidance in weapons such as *Rapier* were developed.

Then there were L.A.W (Light Anti Armour) weapons. Eventually the propellant chosen was a composite one but double base charges gave clean gas but failed to achieve the high burning rate.

I took charge of Ballistics on the retirement of Geoff Stocks and expanded the capability of assessing gun propellants which were becoming too energetic for the standard closed vessel which could withstand only 20 TSI (300MPa). The new vessel could reach twice that pressure and two new strand burners working at 300 and 700 MPa respectively were designed and made.

About 1983, Ballistics were moved from H67 (North Site) to M343 (South Site), where the new closed vessels and strand burners were commissioned.

South Site was sold to B.Ae in 1985 and became, with Westcott, the research unit of Royal Ordnance. I was transferred to Process Research for a while and then introduced into P1 to develop new propellants, finally inventing micelle propellants which were platonised composites. I retired in November 1989

THE STRAND BURNER

Critical to the design and operation of rockets is a knowledge of the burning rates of propellants.

For solid nitrocellulose propellants the Crawford Strand Burner enables cords of propellant to be tested for burning rate over a range of pressures in the laboratory.

A maximum operating pressure of the strand burner of 40 MPa (6000 psi) is sufficient to cover the range of pressures that solid fuel rocket motors achieve in normal operation.

Burning rates at high and low ambient temperatures may be also measured since the pressure vessel is surrounded by a liquid, usually water, thermostatted to maintain an even temperature.

To reduce the rise in pressure as the propellant strand burns, the 'bomb' is connected to a ballast volume. Preparation of 3mm cords x 150mm long involves dipping the cords in an inhibiting solution and drying in racks to ensure a flat burning surface (uninhibited strands tend to 'cone' burn and give erratic results.

Once the inhibiting layer has dried, by leaving it overnight, three small holes are drilled through each strand using a brass jig to ensure two of the holes are exactly 125mm apart to accept fusible timing wires while the third hole locates a nichrome ignition wire.

Four electrically-conducting posts are fitted to the breech, one for the igniter current, a second one for the first timing wire which starts an electronic timer when fused. The third post is for a second timing wire to stop the timer and the fourth post forms a common earth.

In operation a strand is wired to the four posts and held in position by the aid of a small amount of 'Plasticene' at the base . The breech is screwed into the strand burner bomb and tightened. Electrical circuits are plugged in and the unit is ready for pressurisation.

Once the required pressure is reached for the burner and ballast volume, the firing circuit safety plug is inserted, the electrical circuits checked for continuity and if all is well, the strand fired. The burning rate is found by referring to a 'ready-reckoner' chart; the pressure and rate are then recorded.

Several developments of the standard strand burner have been made including a 'window' bomb for visual and/or photography of the combustion process.

In the late 20th century, further developments included a high capacity strand burner for testing cast double base strands with a 12mm diameter that had been cast in a special mould making four strands at a time.

Until the advent of high pressure strand burners operating up to 300 MPa and eventually 700 MPa, the burning rates of gun propellants were calculated from closed vessel results with allowances for grain geometry and other factors such as erosive burning and charge integrity, gave some doubts of the accuracy of such derived burning rates.

Since guns operate at pressures about 30 times higher than rockets the first gun pressure strand burner was designed for a maximum pressure of 300 MPa (20 tsi). Nitrogen gas is stored in cylinders at about 40 MPa (6000 psi) so that a pump is necessary to reach 300 MPa from an inlet pressure of 40 MPa

Following the successful introduction of a 300 MPa strand burner it was decided to investigate burning rates at even higher pressures and a second vessel was made to achieve up to 700 MPa (46 tsi) to reach pressures found in modern tank guns.

Apart from making a strong pressure vessel a double-length strand was catered for, anticipating much higher burning rates. The long times required to reach high pressure meant that the ballast volume vessel was important in reducing the time to reach operational pressure. Gauge calibration for the high pressure quartz transducers needed a pressure balance (dead load tester) which allowed calibration up to 800 MPa.

Very few results were available before all high pressure equipment was transferred to R.O.F. Bishopton in 1990.

THE SHATTER TEST

Traditionally gun propellants have been based on Nitrocellulose once it had replaced black powder in the 19th century. Smokelessness, combined with increased energy has maintained its use into the 20th century.

However, at low temperatures, nitrocellulose (NC) becomes brittle and may shatter when subjected to the rapid pressure rise at ignition, resulting in over pressures and the ejection of unburned propellant.

Addition of plasticisers may reduce charge break-up but with a trade-off of lower energy. Military demands for higher performance, particularly with tank guns, has led to the addition of energetic solids such as RDX which, in turn, makes charge break-up at low temperatures more likely.

In developing new high-energy gun propellants it is essential to have a laboratory test for new formulations. Early attempts were devised to eject propellant granules in a semi-burned stage from a vented vessel and quenching any combustion by firing into water. The question then arises as to whether the propellant has been broken as the result of ignition or the force of hitting the water.

To measure the pressure rise rate the vented vessel was fitted with a tourmaline transducer which is traditionally protected with a small amount of plasticene.
In some water-quenching tests it was noted that some granules had become embedded in the plasticene, had been subjected to the ignition conditions but not the impact into water. The rapid depressurisation of the vessel had quenched the burning.

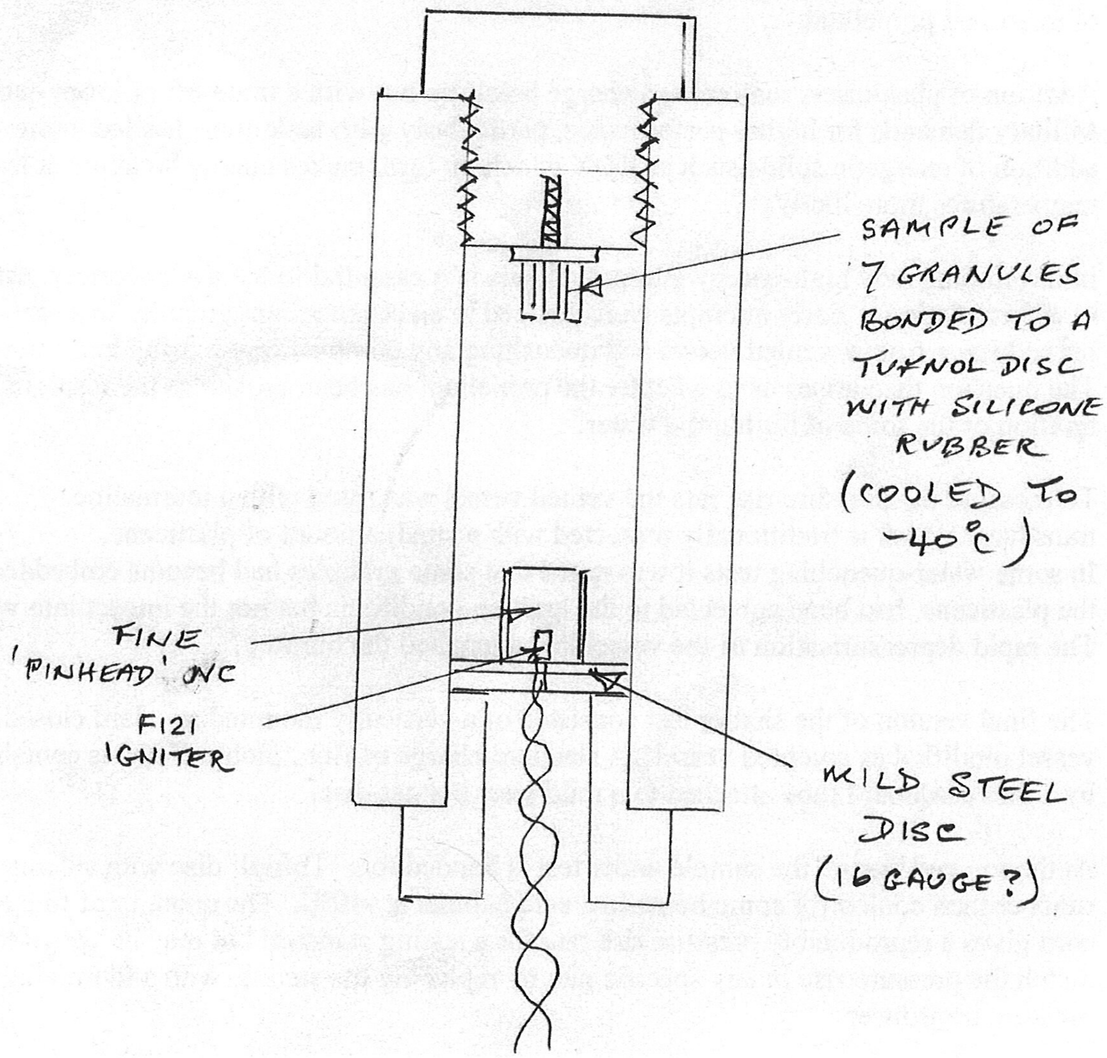
The final version of the shatter test consisted of a vertically mounted standard closed vessel modified as a vented vessel. A standard charge of fine 'pinhead' NC is contained by a thin cardboard tube attached to a mild steel burster disc.

At the top end breech the sample under test is bonded to a 'Tufnol' disc with silicone runbber then cooled for some hours in a cold cabinet at -40ºC. The quantity of fine NC cord gives a reproducible pressure rise rate for a testing standard but may be varied to match the pressure rise in any specific gun by replacing the sample with a tourmaline pressure transducer.

Three samples, with 7 grains per disc are fired and assessed visually for integrity.

Although the test was developed on North Site at H67 (now the RGPF car park) most of the testing was on South Site at M343 where it was considered as important as the closed vessel as a scientific tool.

MODIFIED STANDARD 700ml VESSEL FOR SHATTER TEST.



THE K-ROUND

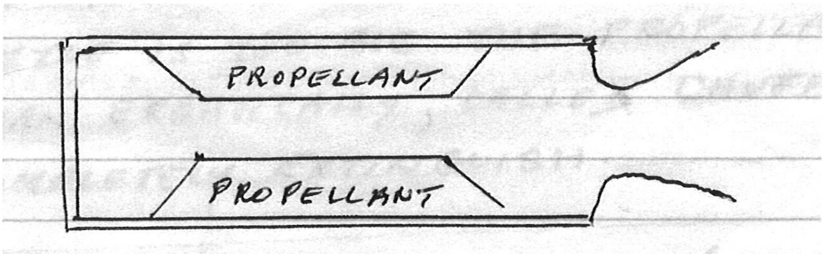
Initial propellant assessment used the traditional Crawford Strand Burner to measure burning rates over a range of pressures up to 40 MPa (pprox 6000 psi).

Any promising candidates would then be tsted, still in strand form, at +60° C and -40°C.

As strands were only 3mm in diameter and about 120mm long only a small amount of propellant was needed.

The next stage was the K-Round which would use a charge of about 450 gm (1 lb). A K-Round charge of an extruded double base (EDB) was a loose ended tubular shape with the ends inhibited with ethyl cellulose (EC) discs and with small EC discs to ensure even burning round the outside of the charge. In addition, to equalise pressure between the centre and outside of the charge three equally spaced holes were drilled along the length at 120° to each other.

For cast double base (CDB) and composite propellants a case-bonded double-cone charge was used.



K-Round hardware consisted of a tube closed at the head end by an end cap sealed with either a 'copandas' washer (a deformable copper seal) or a plain copper washer. A quartz 'Kistler' pressure gauge was also fitted to the head end. The nozzle could be either a 'choke' with a radiussed inlet into a parallel-sided hole or a venturi with T:I expansion cone.

Chokes were used to define the approximate restriction to develop a specific chamber pressure.

Restriction Ratio = <u>Propellant Surface Area</u>

Throat Area Of Nozzle

Rate of gas generation = $\dot{m} = R_b\ A_s\ \rho$
where R_b is burning rate
A_s is burning surface area
ρ is propellant density

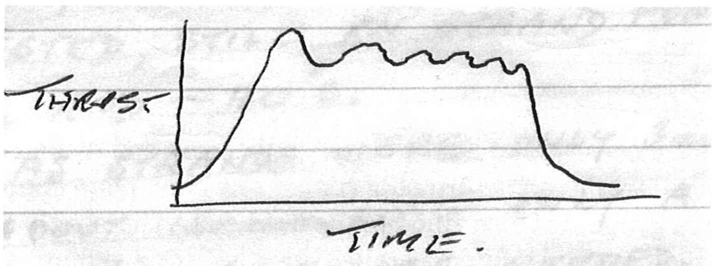
The rate of gas discharge through the venture must equal the rate of gas generation., If the nozzle is too small the motor could burst and if the nozzle is too big the propellant may burn erratically, called 'chuffing', or completely extinguish.

Rate of gas generation, $\dot{m} = A_t\ P_i\ C_d$
where A_t is throat area
P_i is chamber pressure
C_d is discharge coefficient, dependant on the propellant

$\frac{1}{C_d}$ is known as C-star

$$\underline{\dot{m} = R_b\ A_s\ \rho = A_t\ P_i\ C_d}$$

At Waltham Abbey only chamber pressures were measured. Clearly, it is essential to know what thrust id generated but the response of a thrust gauge gives a damped waveform.



The oscillations are a function of the rig which 'rings' like a bell. Modern computer programmes could subtract this ringing waveform from the raw data to give the 'true' thrust/time curve

Ignition of a K-Round used a Perspex burster disc with, typically, a 3 gm or 5 gm pyrotechnic igniter.

ADD

1. Spider for loose K-Round charge
2. Choke – thin carbon to act as a safety feature – blown out by over-pressure.
3. Thin wall and thick wall motors
4. Jack Plummer cleaned motors for re-use (in H16 on Hoppit Island). He got an award for suggesting the method.

SOLID PROPELLANTS

Gun propellants

1. Gunpowder
2. Single base – nitrocellulose (NC)
3. Double base – NC and Nitroglycerine
4. Triple base - NC, NG and Picrite
5. Composite – RDX in a polymer matrix

Rocket Propellants

1. Gunpowder
2. Solvent – 'Cordite' NC, NG stabiliser
3. Solventless - (As solvent but with lead salts)
4. Cast doublebase - (plus elastomer modified)
5. Composite (plastic) - Polyisobutene base and Ammonium Perchlorate
6. Composite (Rubbery) - {AP = Ammonium Perchlorate
   {CTPB and HTPB = Polybutadienes
7. Composite modified double base (AP or RDX)

Gun propellants

Gunpowder is low energy, smoky and prone to unreliable ignition because of absorption of water.
Single baser (nitrocellulose) is smokeless and is still widely used in small arms.
Double base gun propellants require a stabiliser such as carbamite and additives to reduce barrel erosion.
Picrite (nitroguanidine) is added to make 'flashless' propellants but at the cost of being smoky.
Modern high energy propellant for e.g. tank main guns uses composites of RDX in a polymer matrix with an energetic plasticiser

Rocket propellants

Gunpowder is still used to propel fireworks since the ingredients are low cost compared with other options.

Single base (nitrocellulose) has probably never been used as a rocket propellant but has always been plasticised with nitroglycerine or a similar nitrated polyol e.g. DEG'DN or TEG'DN (Di- or tri-ethylene glycol dinitrate). The NC and NG propellants are known as 'double base' for obvious reasons.

1948 was a milestone in the history of double base propellants when lead stearate was used as an ingredient to aid extrusion of solventless ('nosol') propellants in the USA.

This additive produced 'platonised' ballistics (where the burning rate remains stable over a range of pressures; normally burning rate increases with increased pressure).

Extruded Cordite is limited in diametrer byther diameter of the extrusion pres. The largest press in the UK was at Bishopton and boasted a cylinder diameter5 of some 22 inches.(approximately 56cm) i.e. a cross-section area of 2463 cm^2 , the extruderd propellant area being considerably less.

For larger diameters a different technique was needed and CDB (cast double base) was the answer. A casting liquid of NG, de-sensitiser and stabiliser is drawn up through a bed of NC granules (with additives) known as a casting powder. I.M.I. Summerfield was set up to exploit the commercial possibilities of this system with I.C.I Nobel at Ardeer supplying the casting powders.

Waltham Abbey also had facilities for making CDB charges to develop new compositions and help with any problems at Summerfield and Ardeer.

Composite propellants are usually based on ammonium perchlorate bonded in a polymer matrix. They offer higher energy and a more rapid delivery of that energy. Many different binders have been studied including polyisobutene (so-called 'plastic' propellant), polyurethane and various synthetic rubbers (polybutadienes). Aluminium powder is often added to give more energy. Generally the exhaust smoke of HCL and aluminium oxide has not found favour with line-of-sight guided weapons. LAW 80 is an exception as it is aimed and not guided.

Ammonium nitrate has been used by the Americans as gas generators for guidance of missiles. It might have been used instead of Potassium Nitrate in gunpowder but crystal phase changes over a range of temperatures make it an unreliable ingredient.

Ammonium perchlorate added to double base gives composite modified ddouble base vand in a castr system gives C.M.C.D.E but destroys platonisation. However RDX can be added to double base with plateau retention. Better physical properties can be achieved by elastomer modification of CDB. The modern trend in propellants has been to pack more energy into a smaller volume.

Amateur rockets may use a zinc-sulphur mix, Jetex (ammonium dichromate plus guanidine nitrate) or ammonium nitrate based pellets.

P1 BRANCH (Originally PRIII)

Dr N. G. Williams (Sup SPRIII)

Richard Wallace
Gun Propellants (Solvent)
Combustible Cartridge Cases

Laboratory Testing

Colin Lawson
Rocket Propellants

(EDB) Extruded
- Small Scale
- Large Scale (Charlie Stacey)
- (Ron Walley & Eric Baker)

CDB (Cast)
- Gordon Palmer

Ballistic Assessment

WHAT ARE COMPOSITE PROPELLANTS?

They are solid propellants in which a granular component, the 'oxidiser' is embedded in a rubbery matrix, the 'fuel' known as the 'binder'.

In modern propellants a typical oxidiser is Ammonium Perchlorate, and the fuel could be a synthetic rubber such as a polyurethane, polyisobutene or a polybutadiene.

There are further additives to the basic ingredients such as
a) Aluminium powder to increase the energy
b) Catalysts to control the burning rate
c) Wetting agents to improve bonding between the granules of Ammonium Perchlorate, aluminium and catalysts and the rubber in which they are embedded.

WHAT ARE THE PROPERTIES OF COMPOSITE PROPELLANTS ?

Advantages
a) They are more energetic than 'cordites'
b) They can achieve higher burning rates than 'cordites'
c) Large charges are easily cast
d) Charges may be bonded to the wall of the rocket motor
e) They are less susceptible to accidental ignition by random stimuli such as bullets and shrapnel.

Disadvantages
a)They are 'Smoky' having a white exhaust which obscures the target and reveals the launch position
b) The exhaust is corrosive so rules out the possibility of use as a gun propellant.
c) Components must be kept very dry during manufacture
d) Burning rate is more dependent on pressure than 'cordites' and so tend to require stronger rocket motors.

WHAT IS IN A PROPELLANT?

A propellant contained in a pressure vessel is an example of a combustion engine and consists of two components, a fuel and an oxidiser.

A comparison can be made with the internal combustion engine found in a motor car where the fuel is petrol or diesel and the oxidiser is oxygen from the air.

In a rocket the fuel is usually based on compounds of carbon and the oxidiser on compounds of oxygen often combined with nitrogen.

Rocket propellants are generally divided into two main types

1. Liquid propelled, usually found in space rockets
2. Solid propelled, usually found in terrestial rockets

Waltham Abbey was largely concerned with category 2 when it was a factory and later as a research establishment.

Solid propellants may be further divided thus

a. Nitrocellulose-based, so-called 'cordites'
b. Composite in which the oxidiser is evenly mixed in a rubbery fuel (Although gunpowder is not rubbery it may be classed as a composite propellant)

Modern Composite propellants usually contain Ammonium Nitrate or Ammonium Perchlorate as oxidisers.

A number of fuels have been used in the past including polyisobutene, polyurethane and polybutadienes.

The Advantages of Modern Composites are

a) More energy than cordites
b) Higher burning rates than cordites
c) Less sensitive to external stimuli such as shrapnel and bullets
d) Case-bonding to the wall of the motor is possible

Disadvantages include

a) Smoke emission from Ammonium Perchlorate based propellants (and gunpowder)
b) corrosive gas plume ruling out their use in guns
c)Various problems such as ignition, age hardening and de-wetting of the oxidiser

Solventless Double Base Propellants

Solventless processing was a development designed to overcome the limitations of the solvent system that restricted web size, required stoving which would affect the nitroglycerine content and lead to some distortion of the final product.

In the absence of solvent, gelatinisation is achieved by passing the NC/NG 'crumb' through a pair of steam-heated rolls. The gap between the rolls is progressively decreased until a uniform sheet is obtained.

Rolling is a hazardous operation with energetic compositions and an automatic drencher system fitted with an infra-red sensor is considered essential. (Blackened walls in some rolls houses seen abroad have shown that this is not a universally adopted safety feature).

At Waltham Abbey discs were then cut from the rolled sheet as feed stock for the extruder in contrast to Bishopton which favoured a carpet-roll method.

Higher extrusion pressures for solventless propellants led to the inclusion of extrusion aids such as Candelilla wax, and as Les Tucker has already pointed out, Carbamite. However, when Lead Stearate was added as a potential extrusion aid it resulted in an unexpected bonus in the form of 'Platonisation' ballistics.

Normally the burning rate of propellants increases with increased pressure but for platonised propellants the burning rate remains constant over a specific pressure range, or may even decrease depending on the lead salt used.(Some copper salts may enhance this effect). Platonisation also leads to a reduced dependence of burning rate on ambient temperature, a desirable factor in the design of rocket motors.

It is interesting to note in passing that Les has not found any buildings on North site that were used for rolling so I conclude that P705 on South site was unique at Waltham Abbey.

Solventless extrusion does allow for larger propellant webs but is eventually limited by the diameter of the barrel of the press and the cross-sectional area of the propellant required. The largest press at Waltham was a mere 10.5 inches (267mm) in diameter compared with 22 inches (559mm) at Bishopton.

Larger web sizes with carbamite stabiliser led to problems of gas cracking and hence research into new stabilisers. Another problem with rolling propellant is that the tensile strength is reduced and which needs to be improved for high acceleration applications.

Finally, to overcome the limitation imposed by press size it is necessary to revert to solvent manufacture for making casting powder for the Cast Double Base system; but that is another story.

B.C. Howard - 25 Mar 2004