Extreme Temperature Conditioning of Small Arms Ammunition For the Proof of Non-CIP Cartridges

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KEY PRACTICAL OUTCOME:
The extreme temperature conditioning method offers the London Proof House a straightforward and reliable method of proving firearms in non-CIP calibres.

Background and Objectives:

Background:
By law, all firearms and pressure-bearing firearm parts must be proved before the can be sold. Two cartridges, each producing 25% over maximum service pressure are fired, if the firearm or part remains undamaged, it is "proved".

For non-CIP approved cartridges there is no published maximum service pressure and therefore no proof ammunition can be developed. The 2006 Rules of Proof [1] allow for the proving of these cartridges by ascertaining the "mean service pressure" and increasing it by 30%. Where a pressure barrel is not available, two cartridges are simply overloaded by 10% of their original propellant mass. This is not a scientific method, and basic internal ballistic modelling using an open source internal ballistics simulator showed the result of a 10% overload to give uplifts between 19% and 39%. The London Proof House required an improved procedure for the proofing of firearms in non-CIP chamberings.

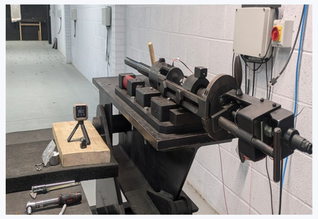
Aim:
Establish whether conditioning alone (at an extreme temperature) can generate the 30% chamber pressure uplift required to proof non-CIP firearms.

Objectives:
1. Test whether heating ammunition can create proof-level pressure uplift.
2. Check whether one general conditioning rule can apply across a range of calibres.
3. Assess whether velocity increase can indicate pressure uplift.
4. Compare single-base and double-base behaviour.
5. Recommend whether the method is suitable to be used as a proofing procedure.

Experimental Setup:

Kistler 6215 transducer & parts

Spotted cases (L) & drilled cases (R)


Test gun & doppler chronograph at EPA range

Method:
- Pressure was measured using the CIP method, velocity was measured using either MagnetoSpeed V3 (hall effect) or Garmin (doppler) chronograph systems.
- Cases were "spotted" using a custom-made spotting punch (transducer blank) then drilled with a 2.5mm bit.
- Equipment was verified after setup by firing ammunition produced by an external organisation, generating a known pressure as given in their datasheet – excellent match.
- Ammunition was conditioned for a minimum of one hour in a recirculating air-type oven, as required by AEP-97.
- 10 different types of ammunition (across eight different chamberings) were fired at ambient after and at 100°C, 110°C and some at 120°C.
- Transducer sealing rings replaced every 10 shots, diaphragm protector replaced every 100 shots or when damaged.

Safe System of Work:

Safety Argument:
A full safety argument was researched and produced to provide a detailed understanding of the risks posed by ammunition potentially initiating while being handled outside of a chamber, and the likelihood of this occurring in the first place. A review of propellant datasheets and reports revealed that the lowest credible Temperature of Ignition (T of I) for nitrocellulose-based propellant was approx. 160°C. Primer compounds had considerably higher T of Is, thus could effectively be ignored. It was agreed that testing would cease at 120°C.

SAAMI conducted full-scale tests in 1974 [2] on the hazard posed by large stocks of ammunition to firefighters. They concluded that standard "turnout gear" offered sufficient protection from any ammunition igniting outside a chamber. They also produced a leaflet in 2004 stating that there have been no substantiated reports of serious or fatal injury due to the initiation of loose ammunition whilst being handled.

Julian Hatcher also conducted his own experiments, documented in the renowned Hatcher's Notebook [3]. He concluded that only the primer caps were capable of causing flesh wounds - *"missile hazard is minimal even at relatively short distances…The missiles of highest velocity are the primer cups which, because of their poor aerodynamic shape and light weight, lose velocity rapidly. At very close distances they could cause superficial flesh wounds [if unprotected]".*

Results:

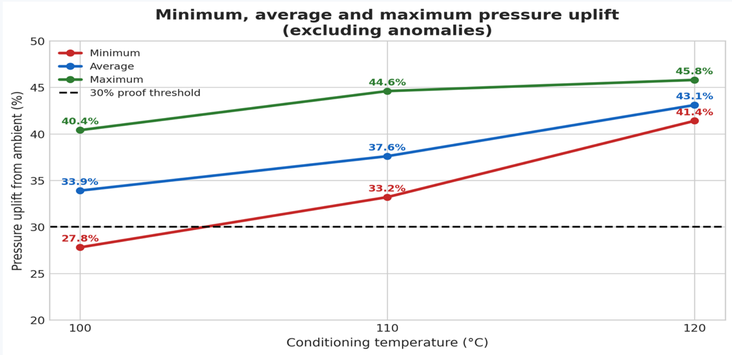
Key:

Double Base
Single Base
Unknown
Outlier Result

Due to time constraints, firings were mostly conducted at 100°C, 110°C and a limited quantity at 120°C. The apparent convergence at 120°C on the graph is a reflection of the reduced sample size.

Cartridge	100°C		110°C		120°C	
	P Uplift (%)	V Uplift (%)	P Uplift (%)	V Uplift (%)	P Uplift (%)	V Uplift (%)
7.62 NATO	27.8	8	35.1	8.8	41.4	9.5
.30-06 Sprg. Hornady	33.7	10	34.9	10.2	41.7	11.6
.30-06 Sprg. Federal	27.4	6.6	27	6.9	30	7.2
.416 Rigby	30.1	9.3	33.2	9.9	43.6	10.9
8mm Mauser	35.5	7.9	37.7	8.5	45.8	9.8
.308 Win.	-	-	39.5	10.7	-	-
.223 Rem.	40.4	7.6	44.6	8.1	-	-
9mm Luger	35.7	7.8	38.4	8.2	-	-
.338 Lap Mag EPA	39.2	13	51.5	15.1	-	-
.338 Lap Mag SM	56.8	12.4	73.2	14.5	-	-
Full Test Average	36.3	9.2	41.5	10.1	40.5	9.8
Full Test Max	56.8	13.0	73.2	15.1	45.8	11.6
Full Test Min	27.4	6.6	27.0	6.9	30.0	7.2
Average Exc. Outliers	33.9	8.4	37.6	9.2	43.1	10.5
Max Exc. Outliers	40.4	10.0	44.6	10.7	45.8	11.6
Min Exc. Outliers	27.8	7.6	33.2	8.1	41.4	9.5

Full results—pressure and velocity uplifts over ambient



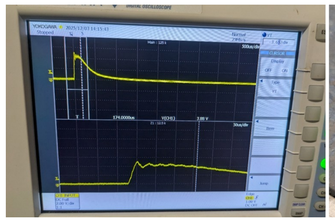
Minimum, average, and maximum pressure uplifts exc. anomalies

Outliers:

Notable Outliers:
- Federal .30-06 Springfield: Case fill percentage was extremely high, making it virtually impossible to drill the pressure port without losing propellant, leading to artificially low pressure uplifts. This is not a problem for actual proving as cases will not be drilled.
- .338 Lapua Magnum EPA Solid AP: Brass projectile expanded 15 microns from ambient to 100°C likely leading to considerable in-bore friction increase.
- .338 Lapua Magnum Swiss Munition FMJHC AP: Older batch of ammunition (more aged propellant) resulted in unusually large pressure increase likely due to the migration of deterrent coatings.

Limitations :

Method Limitations:
- One paper found during research demonstrated one propellant that saw a considerable *drop* in pressure at approximately 71°C [4]. This was theorised to be due to the grain softening and micro-perforations closing, resulting in slower ignition and a reduced burn rate. Recommendations are made such that it will be noted if this occurs during proof.
- Conditioning oven quality: the London Proof House oven fluctuated by around ±5°C, so the report recommends procuring a better conditioning oven before operational use.
- Muzzle pressure was not examined (and is likely to be lower), consequently this method must not be used for the proving of sound moderators.



Strike! The consequences of case misalignment. The £4,000 transducer saved by the £80 "diaphragm protector"

Conclusion and Recommendations:

Conclusion:
1. The heating of ammunition, within an established safe temperature window, is a feasible means of generating the required 30% pressure uplift.
2. Conditioning ammunition to 110°C for a minimum of one hour in a recirculating air-type oven results in a pressure uplift of at least 30%.
3. While an increase in muzzle velocity is indicative of a pressure increase, results were too inconsistent to tie any one minimum figure to a 30% chamber pressure increase.
4. Conditioning at 110°C results in a pressure increase of at least 30% in both single and double base loaded cartridges, the uplifts with respect to each type of propellant were not found to be notably different from one another under such extreme temperatures.
5. This method gives a reliable method for the proof of non-CIP cartridges.

Ammunition and Conditioning Recommendations:
Three cartridges must still be supplied – one for a pressure and velocity baseline, two for conditioning and proof firing. Ammunition supplied must be loaded with a bimetal bullet and loaded with a modern smokeless powder, within its life, which has been stored (either in the canister or in the complete ammunition) according to manufacturer guidelines. The two proofing cartridges must be conditioned for a minimum of one hour in a recirculating air oven.

Pressure Uplift Verification Recommendations:
must also be recorded during ambient (baseline) and proof (conditioned) firing. Case heads are to be inspected by SQEP post-firing, and comparison of velocities is to be made. The proof firing should be considered valid if the case head demonstrates additional pressure *and* the velocity is higher.

Pressure Signs:
The case on the right demonstrates clear signs of excessive pressure compared to that of the (normal) case head on the left:

- Flattened edges of the primer.
- Cratering effect around the firing pin indent.
- Swipe mark on the outer edge (in the L of "Lapua").

These signs are all caused by material flow into unsupported areas under varying degrees of excessive pressure.

Normal & excess pressure signs

Further Work:

Recommended Further Work:
- Conduct firing tests of the legacy 10% overload method.
- Repeat firings of federal .30-06 using the SAAMI pressure measurement technique (no drill).
- Commission closed vessel (bomb) tests of single and double base propellants at extreme temperatures.
- Isolate the effect of monolithic projectile growth alone on chamber pressure (both copper and brass).

References:

[1] The Worshipful Company of Gunmakers of London and the Guardians of the Birmingham Proof House, Rules, Regulations, and Scales Applicable to the Proof of Small Arms, 2006

[2] "Facts about Sporting Ammunition Fires," Fire Journal, pp. 1-6, 1977

[3] J. Hatcher, Hatcher's Notebook, 1957, pp. 532-541

[4] T. Nguyen and R. Spear, "Approaches to Reducing the Temperature Sensitivity of Propulsion Systems for Artillery Ammunition," Department of Defense, 1994.

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