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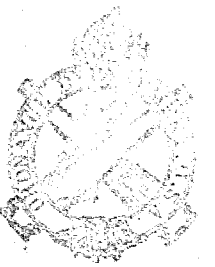

REPORT NO. 662/8

Extracts from

# IMPROVEMENTS IN GUN-CONSTRUCTION AND ALLIED PROBLEMS

By

T. Tanimura, I.J.N.

The Journal of the Faculty of Engineering

Tokyo Imperial University

Tokyo, Japan

INDEX

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IMPROVEMENTS IN GUN-CONSTRUCTION AND ALLIED PROBLEMS

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Reference:

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An excellent review of early literature on subject. Refers to "cold working" as "self-shrinking". Compares wire wrapped process to built-up methods. Describes cold working by three methods: (1) conical bore and tapered exterior, (2) tapered exterior and step-by-step bore, (3) wire wrapping on exterior during cold working and then removed. Gives mathematical equations for elastic strength for all three methods based on maximum shear theory.

Four theories of elastic strength are reviewed:

Maximum stress - Rankine

Maximum strain - St. Venant

Maximum shear - Guest and Turner

Internal friction - Perry

Tanimura concludes that Rankine and St. Venant do not agree with actual strengths, but Guest's maximum shear theory was close to actual.

Now looking back upon the results obtained we notice:-

1. That both Rankine's and St. Venant's theories have two criteria, tangential and radial, and indicate that it is impossible to build guns having purely elastic stresses or strains of a power superior to the limit of elasticity of the metal of which the inner tube is made. By misunderstanding these theories, however, all the calculations which govern the process of manufacture, up to the present moment, have been carried out on the assumption that it is the tangential stress or strain which determines failure, and in consequence, extraordinary powers of resistance have been attributed to guns thus constructed.

2. That according to the results we derived from both Rankine's and St. Venant's theories, it is clear that the usual practice of giving initial stresses in order to reinforce the strength of guns is overdone and an initial stress higher than (  ) only serves to resist tangential stress or strain and is of no practical value since failure would take place radially before the maximum tangential resistance is reached. So that the unduly high initial stress only increases the difficulties of manufacture. Turning to the results derived from the other two theories, we see that they require as high

initial stresses as possible--of course the limits must be observed, viz., the admissible compression of the material of the inner tube at rest and the admissible tension of the outer layers on firing--and they suggest the advantage of the wire system over the other, since the allowable tension of the wire is in itself considerably higher than that of the hoop material.

3. That the results derived from both Guest's and Perry's theories suggest the possibility of the construction of a gun of a power slightly superior to the limit of elasticity of the material of the inner tube.

A considerable amount of experiment has been carried out of late years in an endeavour to ascertain which theory accords best with the facts observed. According to the excellent experiment made by Cook and Robertson on thick cylinders under internal pressure[1], it is found for mild steel cylinders of widely varying ratios of thickness to diameter, that consistent results for the stress at yield point, lay about halfway between the values demanded by the theories of maximum principal strain and maximum shear. But C. A. M. Smith in his article "Experiments on combined

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1 Cook and Robertson: Strength of thick hollow cylinders under internal pressure, Engineering, Dec. 15, 1911.

stress[2] states that there is reason to believe that nickel and some other high tensile steels behave in a similar manner to mild steel and in his article "The strength of guns and cylinders"[3], he states that very high tensile steel is used in gun-construction, and it has not yet been demonstrated that this material fails elastically by Guest's law, but there has been a certain amount of evidence supplied to warrant the assumption that this is the case.

According to the impression received from the literature on this subject, Perry's theory seems to be one of the most promising theories and although Guest's theory is by no means a general law which covers all elastic material, yet so far as the experiments go, they show that the shear theory is at least not far from accurate for gun steel which has an appreciable difference between the limit of elasticity and rupture. It should be remarked, however, that decisive experimental evidence as to which theory applies best to gun steel is urgently required. It must also be noted that our long experience and practical knowledge indicates the fact that the higher the initial

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2 C. A. M. Smith: Combined stress experiments, Proc. of the Ins. of Mech. Engs., Dec., 1909, or Engineering, Dec. 24, 1909.

3 C. A. M. Smith: The strength of guns and cylinders, Engineering, Sept. 2, 1910.

stresses the greater becomes the elastic resistance of a gun, and this had led to the adoption of the modern method of initial reinforcement of inner A-tubes. With regard to this aspect of the subject, it seems to the author, that so far as the amount of the initial stress permitted is concerned both Rankine's and St. Venant's theories have no probability of correctness in their favour.

## Section V.

## One-Piece Self-Shrinking Gun and Its Improvements

Now we feel that the matter narrows down to the question as to the details of the self-shrinking technique. If our aim were only to build a new light powerful gun, it would be advisable to apply such self-shrinking pressure in the preliminary treatment that would cause the whole metal permanent deformation everywhere and the thickness of the gun wall might be determined accordingly. But in the case of re-lining a gun the said thickness is already given and if we apply the necessary high pressure, due to the thick wall found in modern practice, there would be induced a permanent set on removal of the said pressure. In other words, it would set up too high initial compressive stresses which would deform the innermost surface

permanently in the opposite direction. The repetition of the application of such a pressure must ultimately lead to rupture due to the phenomenon well-known as fatigue.

In the next place, it must be noted that the self-shrinking process is originally introduced with a view to making a gun of a single tube and to minimize the labour and time of manufacture. So far as we know, nobody has yet attempted to apply the idea to the manufacture of a big gun, probably, owing to the difficulty of making a big ingot of homogeneous quality throughout. The great advantage referred to in the method of re-lining a gun by this method leads us to the expectation of the feasibility of lessening the cost and time of big-gun production and it may be built up of a less number of elements.

Now turning to the details of applying the self-shrinking pressure, there are two existing methods:

One is to first make a thick cylinder, and after having applied the same self-shrinking pressure throughout, the whole bore to turn it down to the dimensions prescribed. But it would be rather wasteful of material to turn down the outside of the cylinder and especially more so in the case of big guns.

<u>First improved method</u>.

To remedy this defect the author proposes a method as follows:

To first turn down the outside of the gun to near the dimensions prescribed and then to bore it such variable dimensions that the whole of the material would be simultaneously brought to the required condition on application of one and the same self-shrinking pressure throughout the whole conical bore. The advantage claimed for this proposed method is that great economy of material would be effected, because the part to be machined off afterwards is inside instead of outside the gun.

The other existing method is to bore and turn down a gun approximately to the dimensions prescribed and then as the walls of the gun are of different thickness in different parts, it will be found best to make the apparatus such that we may use this self-shrinking pressure only on such part of the bore at one time and then use such pressure as the part we are treating may require. It is, as a rule, effected by dividing the whole bore into many compartments, and to each one is applied the corresponding self-shrinking pressure. This entails a rather lengthy and tedious operation. Although Schneider's patent improved this to a certain extent[1], it does not yet appear to get rid of

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1 Schneider et Cie: Improved process and apparatus for the manufacture of metal tubes by the "self-hooping" process, A. D. 1919, Patent No. 1642.

having an abrupt change of strength at the boundary of the consecutive compartments, and this is known as one of the causes of premature explosion of the projectile.

Second improved method.

To counteract this the following method has been proposed by the author. This method is to machine down a gun approximately to the dimensions prescribed, and reinforce the part where rupture is likely to occur on applying the same self-shrinking pressure throughout the whole bore, by winding wire with such constant tension that will produce the required initial stress in the gun material on removal of both fluid pressure and the said wire. We will not elaborate the advantages of this method as it will be self-evident to ordnance engineers.

Under present conditions, none of the existing theories are satisfactory. As to the last two theories, due to the fact that the equations contain the term of with a fractional power, the analytical complexity involved in developing the theories would be very great, and would render it quite beyond the reach of arithmetical expression, and consequently valueless for the purposes of the engineer. Moreover, each theory starts from some fixed preconceptions which are unwarranted, so we cannot say off hand which accords best with the facts without decisive experimental

evidence, and consequently to translate the theory into intricate elaborate analytical formulae seems to the author a premature effort. With this point in view, as a first approximation, the simplest theory will be developed in the next section.

Summary and Conclusion.

The erosion of gun tubes is quite without a remedy at present, so that the gun-construction which renders re-lining most easily is worth while studying as a policy of salvage.

From our calculations of strength of re-lined guns, it is found that whatever theory of failure we may adopt the inner surface of the bore of the re-lined gun is always subjected to a stress beyond the elastic limit.

Contrary to this theoretical conclusion, however, it is said that the strength of a usual re-lined gun is sufficient. Accepting this view for the sake of argument, we have shown that the ordinary method of designing a gun to facilitate its re-lining is entirely wrong in its principle.

Remembering the so-called mysterious action of the first round together with difficulties of the use of the high-temperature process, the self-shrinking process seems to be an ideal gun-construction; and, in this connection,

two new methods which have some advantages over the existing methods of effecting the said process, have been proposed by the author.

The advantage resulting from the improvements in gun-construction may be enumerated as follows:

To make a big ingot of homogeneous quality throughout is a matter of utmost difficulty, so that for a big gun, we propose first to put all cylinders together loosely and the parts do not, before operation, require accurately fitting, and then to have the inner parts expanded by fluid pressure until they fit the outer parts, then the pressure may be raised until we not only have the desired pressure between the parts but each has been expanded as desired, although this method was originally introduced with a view to making a gun of a single tube.

This results in the saving of time in highly accurate machining; and several tubes can be kept in reserve in a state ready for the operation. Indeed most part of the time of making a gun is spent on this machining.

This process answers well also for the purpose of re-lining and the strength of a gun thus re-lined can be made exactly equal to that of the original.

By so doing we can avoid the use of high-temperature process which is always accompanied by many dangers and difficulties.

For this method, the question as to which system wire or built-up is more advantageous is quite immaterial, because we need not impart the high initial stress by the usual methods.

Owing to the fact that the capacity of the gun is equal to the self-shrinking pressure, the gun thus constructed may be looked upon as having passed proof in a more certain sense than is the case with present practice, which is largely based on theoretical calculation. Further, since the gun has been subjected to the self-shrinking pressure and the elastic limit has been raised a corresponding amount on re-applying any pressure below that it will behave entirely elastically.

Investigation of what temperature caused by a sustained rapid fire will just cause a change of internal structure of the metal thus treated is urgently wanting.

It is undoubtedly certain that the saving of time as well as money would be enormous if mass production should be attempted on this basis, and we feel that we are on the eve of a new epoch to provide the nation with the best weapons that can be obtained.

Technology of Ordnance, Imp. Univ. of Tokyo.

November, 1920.