

Oct. 29, 1946.

L. A. BURROWS ET AL

2,410,047

METHOD OF EXPLOSIVELY BLASTING JOINTS

Filed Jan. 9, 1942

2 Sheets-Sheet 1

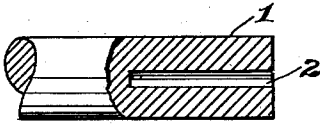


*Fig. 1*

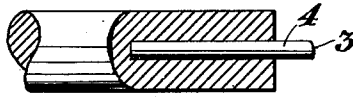


*Fig. 2*

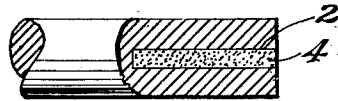


*Fig. 3*

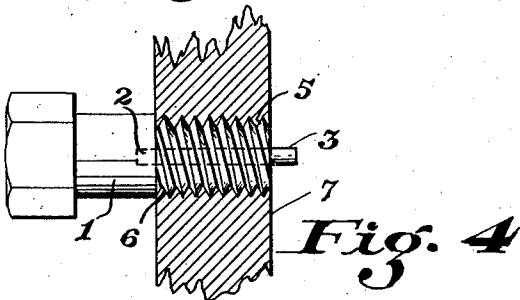


*Fig. 4*

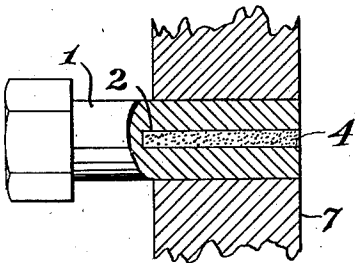


*Fig. 5*

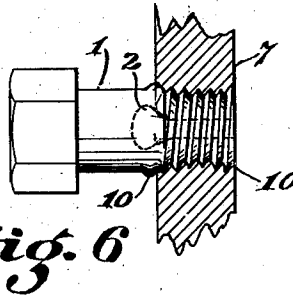


*Fig. 6*

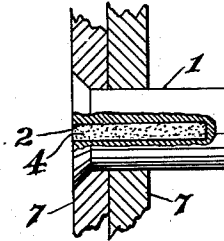


*Fig. 7*

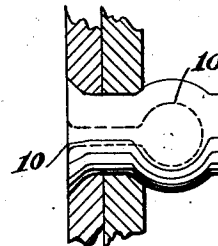


*Fig. 8*

*Lawton A. Burrows*  
*Walter E. Lawson*  
INVENTORS

BY *Thos. A. Wilson*

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2 Sheets-Sheet 2

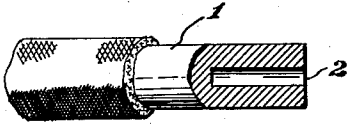


*Fig. 9*

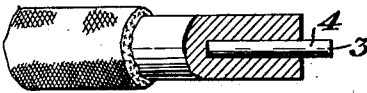


*Fig. 10*

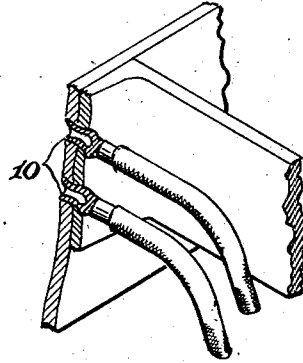


*Fig. 12*

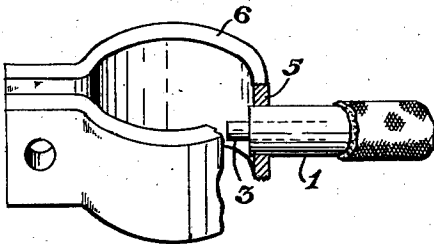


*Fig. 11*



*Fig. 13*

*Lawton A. Burrows*  
*Walter E. Lawson* INVENTORS

BY

*Thos. A. Wilson*

## UNITED STATES PATENT OFFICE

2,410,047

## METHOD OF EXPLOSIVELY BLASTING JOINTS

Lawton A. Burrows, Woodbury, N. J., and Walter E. Lawson, Westover Hills, Del., assignors to E. I. du Pont de Nemours & Company, Wilmington, Del., a corporation of Delaware

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3 Claims. (Cl. 218—29)

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This invention relates to the art of explosively blasting a contact between objects.

The present application is a continuation-in-part of our copending application Serial No. 274,772, filed May 20, 1939.

The original application discloses a modified explosive rivet wherein an unusually tight joint is obtained by providing a cavity from the head end of the rivet extending into the shank thereof. The explosive is disposed from the shank well up into the head end of the cavity. When the rivet is fired to hold several sheets together, the shank expands to produce a rivet effect, but in addition, the body of the rivet expands within the hole through the sheets to produce a bolting effect holding the sheets in position from within.

The object of the present invention is to apply this explosive principle to the problem of joining any objects by means of a metal connecting element. A further object is to apply the principle in fastening one or more articles. Additional objects will be disclosed as the invention is described in greater detail in the following.

According to our invention a recess or perforation is formed in the article or articles to be fastened or joined, and the metal fastening element is inserted into said recess. The metal fastening element contains a charge of explosive which when fired causes at least a portion of the metal of the fastening element to expand within the recess. The resulting joint not only possesses great physical strength but is capable of resisting substantial fluid pressures. For instance, without particular care, expansions have been effected producing joints sufficiently tight to withstand 4800 pounds per square inch water pressure without leaking. To produce a pressure-resistant joint, it is preferable that the explosive column extend not only within the recess but also emerge from the recess and extend beyond the mouth of the same. If a hole in a plate is involved, it is preferable to have the explosive column extend out of the hole beyond both faces of the plate.

Within the scope of the term "metal fastening element," we intend to include rivets, bolts, pins, fasteners, electrical connectors, bonds, and the like.

In order to insure an adequate fastening action, the explosive employed must be one which detonates at a high velocity, namely, a velocity greater than 1000 meters per second. While the primary detonating explosives such as mercury fulminate, lead azide, and the like may be employed, we preferably utilize a more powerful explosive giv-

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ing greater gas volume on detonation, for instance, tetryl, pentaerythritol tetranitrate, nitromannite, trinitrotoluene, and the like, explosives commonly designated as "secondary explosives."

Such low velocity explosives as black powder and smokeless powder would be unsuited to the purposes of our invention, since they would not develop adequate force without the use of complicated auxiliary structures to produce confinement. In using an explosive such as tetryl and the like, it will be desirable to use a primary charge to bring about its high velocity detonation. Materials such as mercury fulminate or lead azide are suitable for such purpose. In addition, an initial ignition composition may be desirable. The explosive charge preferably should be compressed and either may be loaded directly into a cavity in the metal fastening element, or first charged into a metal capsule or the like, which structure in turn may be inserted into the metal cavity which is to be expanded. The explosive may be fired by heat, fuse, electric spark, percussion, electrical heating either by hot wire or induction heating, or by any other suitable means.

The following examples set forth particular embodiments of the invention.

#### Example 1

For the riveting together of two aluminum sheets, each of  $\frac{1}{8}$ " thickness, a headed aluminum alloy rivet of  $\frac{3}{8}$ " diameter was used, having a length of shank of approximately  $\frac{5}{8}$ ". A hole of 0.067" diameter extended from the head end of the rivet  $\frac{3}{32}$ " past the further side of the bottom sheet. A charge of 0.45 grain of a 75-25 mixture of lead azide-lead styphnate-tetryl was loaded into the bottom of the hole and fired by a static spark. The expansion of the rivet shank held the two sheets firmly together.

In the case of another similar aluminum sheet assembly, an explosive charge of 0.55 grain was loaded almost to the head of the rivet. The sheets were again firmly joined.

#### Example 2

In joining together two steel plates of  $\frac{3}{8}$ " thickness each, a  $\frac{3}{8}$ " diameter steel rivet was used, having a length of  $1\frac{1}{8}$ ". A hole of  $\frac{1}{8}$ " diameter extended through the head of the rivet to a depth of  $\frac{7}{8}$ ", i. e.,  $\frac{1}{8}$ " past the lower side of the farthest plate. An explosive charge was introduced into the hole, comprising a base charge of 0.7 grain tetryl pressed at 50 lbs./sq. inch and a primer charge comprising 1.0 grain of a 70-

20-10 blend of lead azide-lead styphnate-tetryl pressed at 10 to 50 lbs. The explosive charge was fired by means of a static spark and the metal bulged satisfactorily, giving a good juncture.

#### Example 3

Three  $\frac{7}{8}$ " threaded bolts of Monel metal were threaded for  $\frac{1}{2}$ " at one end. An axial hole was drilled  $\frac{5}{8}$ " deep and 0.235" in diameter in the threaded end of the bolt. These bolts were screwed into threaded openings in a steel plate. Into the axial cavity of each bolt was inserted a cylindrical metal container charged with explosive. Each contained a main explosive column, a primer charge and a conventional ignition mixture. The main explosive charges employed were 10 and 10.5 grains of pentaerythritol and 10.5 grains of tetryl, respectively. These were all loaded in the containers under a pressure of approximately 5000 pounds per square inch. They were primed by 2 grains of lead azide. The explosive charges were fired by means of a fuse and the explosion resulted in fluid-tight joints between each bolt and the surrounding metal, the tightness being enhanced by a slight flaring of each bolt just beyond both edges of the plate.

It was found, generally, in this type of work that the tightest joints resulted when the explosive charge overlapped both edges of the plate. Under conditions where the charge extended slightly beyond both edges of the plate, tests indicated that no leaking occurred even under a fluid pressure of 4800 pounds per square inch. In no case did even a slight leak occur at a pressure less than 2200 pounds per square inch.

It will be understood that the bolts, fasteners, or the like may be composed of any suitable metal; for instance, aluminum, stainless steel, Monel metal, copper, copper alloys, steel alloys, and many others. The metal employed should have sufficient ductility. It is preferable to use a metal having a potential elongation value of 20%.

Another adaptation of our invention is a new method for supplying electrical connectors for automobiles, trains, telephone installations, radio and other high frequency apparatus, building construction, railway bonding, and the like. The essential features are a cable or rod bearing on at least one end a metal plug with a hole drilled or otherwise formed coaxially from either the head or the shank end. The explosive is inserted into this hole in the plug, preferably contained in a copper tube if the plug is large, but perhaps loaded directly into the hole if the plug is small. For small plugs up to  $\frac{1}{4}$ " in diameter an explosive comprising lead azide and tetrazine, lead azide and lead styphnate, or mixtures such as nitromannite, aluminum, and tetrazene can be used. For larger plugs copper tubes containing pentaerythritol tetranitrate or tetryl as the main explosive charge with superimposed ignition charges of mercuric fulminate, diazodinitrophenol, or agents of comparable sensitiveness can be used.

Through employment of this principle, electrical bonds or connectors may be made which will be much more resistant to deterioration than those now employed. The plug when inserted into a metal receiving socket, expands with such force as to bring about a permanent electrical connection which does not deteriorate on aging because the ingress of water or oxygen is prevented. There will be no gradual loosening as in the case of bolts; and there will be no change

in temper or composition due to heat as occasionally is noted with brazed connectors. Although the explosive itself generates a great deal of heat, the time is so short that the reaction is essentially adiabatic; that is, from a practical standpoint no heat is absorbed by the plug or the metal to which the plug is bonded. Examples 4 and 5 describe in detail the application of the method of our invention to different types of electrical connectors.

#### Example 4

One lead from the storage battery in an automobile was grounded to the frame in the following manner. The cable leading from the battery terminated in a steel plug adapted to fit with slight clearance into a cavity previously drilled in the frame. The plug was provided with a cavity of approximately  $\frac{1}{8}$ " diameter sufficiently deep to extend slightly beyond the far side of the frame member. A compressed charge of an explosive comprising a mixture of lead azide and tetrazene in the ratio of 85-15 parts, respectively, was introduced into the hole in the plug, preferably enclosed in a capsule. The explosive charge was loaded the entire length of the plug so that it extended slightly beyond the metal at either end. When the charge was exploded, the metal was compressed into tight electrical connection with the surrounding framework.

#### Example 5

A rail bond connection was made by blasting the metal together by means of high velocity explosives. Holes of 1" diameter were drilled in adjoining rails. A conductor comprising stranded copper connected two copper alloy plugs adapted to fit into the apertures in the rails with slight clearance. A hole was formed longitudinally into each of said plugs sufficient in depth to extend slightly beyond the far edge of the rail when the head of the plug was flush with the nearer edge. A charge of compressed explosive contained in a metal cylinder was introduced into each of said holes, the explosive consisting of a base charge of tetryl and a primer charge of 80-20 fulminate-chlorate mixture. The charge was exploded by means of the spit of a fuse, and an excellent electrical connection resulted between said adjoining rails.

#### Example 6

In the case of many large machinery installations; it is desirable to ground said machines because of accumulations of static electricity. This is particularly the case, for example, with paper machinery where dry paper is handled. Such machines were advantageously grounded by use of an electric cable of conducting material having a plug at one end adapted to fit into a prepared hole in the framework of the machine. A hole in said plug allowed the introduction of explosive charges of the nature disclosed in Example 2. When such explosives were detonated, a good electrical connection was assured. The other end of the cable was connected in suitable manner with grounding equipment.

The types of our invention will be appreciated more readily by referring to the accompanying drawings. Figure 1 is a view of the metal fastening element with a cavity therein to receive the explosive. Figure 2 is a view of said element containing an explosive capsule. Figure 3 is a view of said element with the explosive loaded directly into the cavity. Figure 4 is a view of

an explosively charged bolt disposed in a plate with threaded connection. Figure 5 is a similar view of an unthreaded bolt and plate. Figure 6 is a view in cross-section of the explosively blasted pressure-tight joint between the bolt and the plate. Figure 7 is a view of our improved rivet passing through two plates to be joined. Figure 8 is a view of the explosively blasted pressure-tight joint which holds these plates together. Figure 9 is a view of our improved electrical connector with cavity for receiving the explosive. Figure 10 is a view of said connector with an explosive capsule disposed in the cavity. Figure 11 is a view of said connector disposed in a body of metal to which connection is to be made. Figures 12 and 13 are views of the explosively blasted pressure-tight electrical connections between the connectors and the metal to which the plugs of said connectors are to be bonded.

Referring to the drawings in detail, Figure 1 shows the metal fastening element 1 which is provided with the cavity 2 adapted to receive the capsule 3 containing the explosive 4 as shown in Figure 2. In Figure 3, the explosive 4 is loaded directly into the cavity 2 under pressure. In Figure 4, the metal fastening element takes the form of the bolt 1, likewise having the cavity 2 containing the explosively charged capsule 3. The bolt is disposed through plate 7, the threads 5 of the bolt fitting into complementary thread 6 of the plate. The same embodiment loaded directly and without the thread is shown in Figure 5. After the explosive has been fired to blast the pressure-tight joint between the bolt and the plate, the cross-section of the joint appears as shown in Figure 6, which shows the metal of the bolt expanded into the walls of the cavity and the plate at 10.

Referring to Figure 7 in detail for a description of our improved rivet embodiment, the shank of the rivet 1 is inserted through the drill hole in the metal sheets 7, which are to be joined together. The relatively narrow recess or cavity 2 is present in the rivet, opening through the head and extending into the shank beyond the farthest edge of the metal sheets. The explosive charge is set at 4. This explosive charge is loaded well up into the cavity toward the head end of the rivet, to lie partly within the hole through the sheets. This explosive charge is ignited in any suitable fashion with the result that the rivet takes the form shown in Figure 8. The combined riveting and fastening effect of the operation will be appreciated. The explosion acts to throw together the metal sheets by the riveting bulge beyond the same and at the same time makes a completely tight juncture within the plates by the blast within the hole therethrough, as shown by the expansion 10 of that portion of the rivet lying within the plates.

Referring in greater detail to Figure 9, the improved electrical connector is provided with the plug 1 with cavity 2 for receiving the capsule 3 containing the explosive 4. The assembly is shown in Figure 10. The charged plug of the connector is then disposed in the recess 5 in the metal body 6 to which the connection is to be made, as shown in Figure 11. The completed pressure-tight electrical connection is shown at the locus 10 of Figures 12 and 13. The electrical connector of Figure 13 is illustrated with two plugs and a connecting cable, but may contain more or less plugs as required for a particular purpose.

It will be appreciated by those skilled in the various arts requiring metal fastening elements,

that there are innumerable specific applications of the principle of our invention. For instance, it may be applied to the construction of pressure-resistant tanks, airplane wings, autoclaves, boilers, rail bonds, to the construction of automobiles, trains, and other vehicles, to telephone installations, radio and other high frequency apparatus, building construction, railway bonding, and the like. The use of our invention may be extended to the joining of any metal objects where metal rods may be inserted through openings in other metal structures with slight clearance, so that explosive charges can then be employed to expand the rod walls and tighten the joint. Such a method can be employed, for instance, for anchoring various objects which are subject to movement. While we have referred particularly to metal rods inserted into openings in other structures, it will be understood that the invention applies equally well where a metal pipe is the object inserted, i. e., where the rod is hollow throughout its entire length.

The present application relates to the broad invention, and accordingly we do not claim herein specifically the structure of boilers having the stay bolts explosively fitted, nor the method of explosively fitting stay bolts in boilers, which subject matter is covered in copending application Serial No. 474,480, filed February 2, 1943, nor specifically, the structure of the electrical connector which is covered in copending application Serial No. 274,772, filed May 20, 1939.

The numerous advantages of the principle of our invention will be appreciated all the more when it is realized that in the conventional swedging of bolts for the formation of joints to resist pressure, special qualifications and skill are required of the workmen and no little time is consumed in producing a satisfactory pressure-tight joint. Even then the apparatus frequently must be taken apart for the installation of a new bolt after a short period of time. It will be noted that the nature of the principle of our invention makes possible efficient repair work, in many instances without disturbing the completed assembly.

In the foregoing we have disclosed broadly the principle of our invention. It will be appreciated that many modifications may be made therein without departing from the scope of the invention. For instance, while we prefer to detonate an explosive charge extending beyond both faces of the plate, it will be appreciated that a joint which is to some extent pressure-tight, can be produced by having the explosive extend only within the plate. A seal or attachment suitable for some purposes may be attained by having the explosive extend only through a portion of the plate. With respect to the metal employed for the fastening element and the object to be fastened, while we prefer to have the fastener and the object of substantially the same hardness, we do not wish to be limited thereby. In the foregoing we have described the fastening of metal objects. It should be appreciated that our invention is not limited to metal objects alone, but is likewise applicable to the fastening of sheets or other objects composed of non-metallic materials such as wood, plastic, fiber, and the like. It is especially advantageous for instance to employ our rivet structure for holding together sheets of fiber and the like, or even to employ our rivets or bolts for fastening together objects one of which is metallic and the other a non-metallic material such as a plastic or the like. Accord-

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ingly, we intend to be limited only by the following patent claims.

We claim:

1. The method of explosively blasting a fluid-tight joint between a metal fastening element provided with a central axial cavity and another body provided with a recess to receive said metal fastening element, which method comprises inserting the hollow portion of said fastening element into the recess of said body, providing an explosive unit at least partly within said element cavity and at least partly within that portion of said element cavity which extends within said body recess, and expanding the walls of said cavity into contact relationship with the walls of said body recess, said explosive being characterized by a velocity of detonation of at least 1000 meters per second, at least a portion of said explosive unit being in contact with the atmosphere at the time of detonation to permit escape of explosion gases.

2. The method of explosively blasting a fluid-tight threaded joint between a metal plate and a threaded metal bar screwed through a threaded hole in said plate, which method comprises forming in the threaded end of said bar a central axial cavity longer than the thickness of the plate, screwing the hole portion of the bar through the threaded plate hole, inserting in the cavity a

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capsule containing a detonating explosive charge so that the charge extends at least partly within the bar cavity and therein through the plate hole beyond both faces of the plate, and detonating said charge, said explosive charge being characterized by a velocity of detonation of at least 1000 meters per second, at least a portion of said explosive unit being in contact with the atmosphere at the time of detonation to permit escape of explosion gases.

3. The method of explosively blasting a fluid-tight joint between a metal plate and a metal bar disposed through a hole in said plate, which method comprises forming in the end of said bar, a central axial cavity, inserting the hollow portion of the bar through the hole in the plate with the end flush with the face of the plate and detonating an explosive unit at least partly within said bar cavity and extending therein through the plate hole and beyond at least one face of the plate, said explosive unit being characterized by a velocity of detonation of at least 1000 meters per second, at least a portion of said explosive unit being in contact with the atmosphere at the time of detonation to permit escape of explosion gases.

LAWTON A. BURROWS.  
WALTER E. LAWSON.