XI.

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TRANSACTIONS.

NYTRO-GLYCERIN—ITS MANUFACTURE AND USE.

A paper read before the Society, June 2, 1869, by STEPHEN CHESTER, Civil Engineer, member of the Society:

It is with some degree of diffidence that I present to the consideration of this Society a paper upon a subject which has been already so ably treated by one of our members. It is with the desire, however, to call attention more particularly to details of the preparation of NITRO-GLYCERIN, its most expedient application to land or submarine blasting, and to invite a consideration of the means that may be successfully employed to render the use of this valuable agent less obnoxious to public sentiment.

As a preface to the statements to which your attention is invited, a few quotations from the able paper of Mr. North, and from other sources, may be permitted.

First known as a medicine.—Nitro-glycerin was discovered in 1846, by Sobrero, and it was first used as a homœopathic medicine, being supposed to be a powerful remedy against nervous headaches. It is true that a minute portion, applied even to the finger, will usually *produce* the most violent and disagreeable headache; and, if there be truth in the adage, "*Similia similibus curantur*," should at times be remedial.

Applied to blasting.—The application of this oil to blasting, and its first practical production in large quantities, is attributed to a brother (now deceased) of Alfred Nobel, though the latter patented its application in 1863.

As its name indicates, it is the result of a combination of glycerin with nitric acid; large quantities of sulphuric acid entering into its manufacture, but forming no part of the product.

Manufacture of described.—Its manufacture is simple and rapid, and attended with no danger whatever, however powerful and explosive the ultimate product may be.

The apparatus used and the process employed under the patent of Stephen Chester and Otto Bürstinbinder is as follows: Any number of stone jars, each of about four gallons capacity, are placed in a trough of ice-water, in which is also placed a leaden worm, connected on one end to a reservoir of compressed carbonic acid gas, and on the other to a horizontal tube, having projecting tubes closed by stop-cocks opposite to and corresponding with each stone jar. Within each jar, and connected to its corresponding stop-cock, is suspended a perpendicular glass tube, its lower end closed, and having, in several horizontal planes, radial tubular arms of diverse lengths, the ends of which terminate in fine orifices, the axes of which are turned in one direction, tangential to the arcs described by the respective arms, from the perpendicular tube as a centre.

On an overhanging shelf are conveniently placed tin cans with faucets, corresponding to the stone jars, to hold glycerin. A thermometer is suspended within each stone jar.

Supplementary to this apparatus, all of which may be contained in a small wagon, should be several wooden tubs, of capacity to contain from sixty to eighty gallons, and a liberal supply of water.

Formula of composition.—The operation is commenced by placing in each of the stone jars sulphuric and nitric acid, and in the tin cans, glycerin, in the following proportions:

Sulphuric	acid, having	specific	gravity......	1.84 —	6	pounds.
Nitric	"	"	"	1.45 —	3	"
Glycerin	"	"	"	1.23 —	1	"

The stop-cocks are partly opened, and the cold carbonic acid gas allowed to pass through the glass apparatus as soon as the acids are introduced.

This is, first, to cool more rapidly the mixture, which immediately becomes quite warm; and, secondly, in order that a mat or superstratum of dry carbonic acid gas may separate the surface of the mixed acid from contact with the moist atmosphere.

Carbonic acid gas anhydrous and refrigerative.—The office of the sulphuric acid is, doubtless, that of dessication, to absorb and take up the water produced by the union of part of the hydrogen of the glycerin (C^6 H^5 N^3 O^{18}) with part of the oxygen of the nitric acid (NO^5). But as sulphuric acid will absorb water from the atmosphere so rapidly as to considerably diminish its specific gravity in a few hours, it is highly important that the "sponge" should not be prematurely saturated.

Previously mixed acids give poor results.—And here it may be said that sulphuric acid that has been exposed to the air, or acids mixed, and thus kept in carboys, will *not* produce favorable results.

As soon as the respective thermometers indicate that the mixture has fallen to a temperature of 62° Fahrenheit, the glycerin may be allowed to pour in, and the gas stop-cocks more fully opened.

Glass apparatus causes to rotate and agitates mixture.—From the description of the glass tubes before given, it will be apparent that a rotary motion will be given to the mixture, which, together with the violent ebullition of gas bubbles, insures the complete distribution of the glycerin throughout the mixture, while the cooling tendency of the compressed and cold gas counteracts the heat produced by the union of the glycerin and acids.

Must not get warm.—The thermometers must be observed, however, and if the temperature should at any time exceed 68°, the flow of glycerin should at once be arrested, until the temperature of the mixture again decreases.

Practically, with a good flow of gas, I have allowed the entire contents of a can to flow uninterruptedly, and the thermometer meanwhile did not vary two degrees.

No danger if it burns.—Should the temperature of the mixture run above 70°, the glycerin will commence burning. This does not infer danger, however, as the mixture is yet unexplosive, and even the burning will be instantly arrested if a small piece of ice be dropped on the burning surface.

As soon as the proper quantity of glycerin is introduced into each jar, its entire contents are plunged into one of the wooden tubs, previously nearly filled with water, and agitated with a stick.

Precipitation of result.—In a few moments, nitro-glycerin will precipitate, and the acidulated water may be drawn off from the surface of the nitro-glycerin, fresh water poured on, and thus the contents of several jars may be precipitated in each tub.

Is now for first time explosive.—This product is now for the first time *explosive*. But it will be observed that now the operation is *complete*, and the article is ready for use.

Should not be placed in metal.—It is *not*, however, ready for packing, nor for transportation. As for that, it needs that every particle of free acid should be removed.

This is, to a degree, accomplished by repeated washings in strong alkaline and pure water. Your particular attention will be hereafter called to this point.

Average result.—With proper attention to the above directions, and using good commercial materials, the average result should be one and a half pounds of nitro-glycerin to each pound of glycerin used.

In our own experience, acids of good quality, previously mixed at the manufactory with excellent oil, gave an average of less than one pound of nitro-glycerin to each pound of glycerin used.

Experimental trial.—The following is the result of a carefully-tried experiment, with a view to estimating the exact value of certain commercial materials:

	Beaumè.		Spec. grav.		lbs. oz.		
Sulphuric acid....	66°	....	(1.82)	....	18 6	@ 2¾ cents.........	$0.50
Aquafortis.........	45°	....	(1.44)	....	9 1	@ 15 “	1.36
Glycerin	28°	....	(1.23)	....	3 0	@ 34 “	1.02
C. A. gas about							.05
Total cost......							$2.93

Cost.—The result exceeded five pounds. Hence, the nitro-glycerin cost less than $58\frac{6}{10}$ cents per pound. But the glycerin used cost exorbitantly; equally good can be procured for 20c., and had such been used the net cost would have been only $50\frac{2}{10}$ cents per pound.

Several hundred pounds of the same materials have been used, with similar average results.

Average cost.—To the above may be added, to cover cost of labor, transportation of materials, loss by breakage, etc,, etc., about 14 cents—making the actual cost of nitro-glycerin, at a point somewhat remote from any depot of materials, about 64 cents per pound.

Capacity of apparatus.—The jars above described will conveniently hold about 45 pounds of acids and 5 pounds of glycerin each, giving an average result of 7½ pounds of nitro-glycerin.

One operator can make.—One operator can with ease attend to ten jars at one time; and, with a liberal supply of carbonic acid gas and cold water, can refill these jars three or four times during the day. With a very inadequate gas generator and reservoir, I have only once had these vessels refilled three times. Hence, one man can readily produce 150, and *may* produce 225 pounds per day. The mere labor, however, of decanting the large amount of acid to produce the larger amount would be very severe for a single man.

Appearance.—When first precipitated, the product appears semi-opaque, about the color of cream. It afterward becomes more transparent, and has a slight straw-color tinge. Its specific gravity is 1.6.

Peculiarities.—When poured into water it does not separate, but large globules form as it touches, which instantly unite as they come in contact with each other.

Produced by explosion.—I am unable to give the chemical formula for nitro-glycerin, but according to the *London Mechanics' Magazine*, September, 1865, by explosion one volume of nitro-glycerin is converted into

Carbonic acid gas..........	429	volumes.
Steam	554	"
Oxygen.....	39	"
Nitrogen	236	"
In all....................	1,258	volumes for one volume

of liquid oil, being thus theoretically five times more expansive than gunpowder.

Not measure of effective force.—But this must not be assumed as a measure of the *effective force* of nitro-glycerin as compared with that of gunpowder.

Powder deflagrates.—The latter does not properly *explode*, but deflagrates with a greater or less rapidity, dependent upon its ingredients, dryness, and size of grain. Hence its force operates accumulatively, and considerable time is required to develop the full bulk of its expansion.

Force required to project masses.—When it is desired to set in motion a mass, as for instance the projection of a ball from a large gun, this force, which commences with the slight expansion due to the deflagration of the surface of a few grains, and rapidly accumulates, as the ball—its inertia being overcome—moves forward with increasing rapidity, is admirably adapted to the exigencies of the case.

Force required to disrupt.—But when complete disruption of all the surrounding parts is desired, it must be at once evident that it is a great defect that powder is *not* more rapid in its action.

In many instances, the rock beginning to move, permits much of the gas to escape, without producing the full effect due to the expansion produced. Secondly, it is a well known fact, that where large quantities of powder are fired, combustion is seldom entire, much of the powder being thrown out unburned.

Nitro-Glycerin percussive.—The combustion or explosion of nitro-glycerin is supposed to be *instant.* Practically it is so. and the effectiveness of its disrupting force is in great measure due to the fact that its maximum of expansion *instantly* acts upon the confining walls with percussive force.

Illustration of percussiveness.—In one instance where a five-pound charge was placed somewhat indiscreetly, in a rock cut on the Boston, Hartford and Erie Railroad, the rock thrown off was entirely shattered; but in the immediate locality where the charge had been, several bushels of impalpable white powder were found; evidently the rock, crushed and calcined by this tremendous force.

Breaking effect under water.—Five pounds, placed in a stone jar, and suspended against the iron side of the steamer Scotland, sunken off Sandy Hook, cut as with a knife a fissure ten or twelve feet in length.

It is believed that an equivalent amount of powder, similarly placed, would have rocked or swayed the whole side, but would not have *cut* it; first because its action would not have been *percussive;* and next, because its initial, or rather resultant force would have been spread over a larger area than would that of the equivalent of nitro-glycerin, the less bulky material.

Percussiveness not always desirable.—But it is highly probable that the "percussiveness" of nitro-glycerin—if that term may be allowed—is to some degree a disadvantage, when not used with discretion, as it is obvious that in many instances a degree of elasticity is desirable to produce the best effects, and to move the largest amount of rock.

Column of atmospheric point of reaction.—Again, as a sequence of the *instant* combustion of nitro-glycerin, its expansion reacts from a *fixed resistance* other than what is met by the more slowly-consuming gunpowder.

The atmosphere, moving at a velocity of one hundred miles per hour, overthrows houses and trees, and bears off heavy masses. With a velocity of one thousand miles per hour, nothing could resist its force.

If it could be conceived that an iron ball should be projected through space with the velocity of hundreds of miles per second, and should with that velocity strike against a wall of air of the usual density, would it not as surely be dashed to atoms as would a ball of glass upon a wall of adamant?

Atmosphere resists instant movement.—It is obvious that to *sudden movement* the air opposes as fixed a resistance as inelastic water, only in less degree, as its particles move more freely among each other, and a corresponding degree of velocity is required to develop that resistance.

What is line of least resistance?—Hence, to the expansion of nitro-glycerin, the *line of the least resistance* is not that apparent, but one modified by the pressure of the superincumbent column of air, which is only less than a fixed resistance, as the expansion of nitro-glycerin is less than *instant.*

A charge exploded upon the face of a rock, in the open air, will shatter the rock beneath it.

Illustrations.—A few years since, a small quantity exploded upon the pavement in Greenwich street, New York. It will probably be recollected that the pavement was torn in pieces, and quite a pit excavated beneath.

If a charge be placed in the bottom of a twelve or fourteen feet hole, and this be covered with sand to within three or four feet of the top, and then another charge be placed above the sand, and *no* covering above it, the explosion of the upper charge will cause the lower one also to explode—both with effect.

How Nitro-Glycerin breaks rock.—It is universally known that while in powder-blasts the break usually occurs near the centre of gravity of the charge, in nitro-glycerin explosions the break is at or below the bottom of the hole, extending outward and *downward.*

Other corroboratory instances can be quoted, but the fact is too obvious to require them.

Nitro-Glycerin not easily caused to explode.—Nitro-glycerin, when newly made, or *free from other elements*, is not easily caused to explode.

Heat will not explode it, unless the nitro-glycerin reaches a temperature of 360°. A small mass of iron, at white heat, and dropped into nitro-glycerin, would not be *liable* to cause explosion, since, the specific heat of the article being great, the heat from the piece of iron would be rapidly disseminated, and no portion of the oil reach 360° before the iron had lost its heat.

Sparks of fire, or scintillations from hammered iron, are instantly extinguished.

A very heavy blow from a hammer upon oil placed upon an anvil is required to make it detonate; and then, as with gun-cotton, only that explodes which is actually crushed between the impinging points of iron, the rest being driven away.

It is not probable that any amount of concussion, short of that produced by contiguous explosion, when developed heat probably assists, will cause it to explode.

Illustrations in use of new oil.—On the B. H. and E. R. R., a charge was placed in a hole; a small wad above it, on which was placed a pound or two of powder, to which fire was communicated by a common fuse.

The hole was carelessly filled with loose earth or sand.

The explosion of the powder blew out the dirt, but did not cause the oil to explode. Shortly after, the oil commenced burning, and seemed to be entirely consumed, no subsequent explosion taking place.

In another instance, similar to the above, the oil did finally explode; but it is probable that it became heated to above 360°.

What is required to cause it to explode.—In practice, the confined explosion of ten grains of fulminate of mercury, or of its equivalent of gunpowder, is required to explode it with certainty. Properly confined, so as to cause the flash to penetrate the body of the oil, this charge will rarely, if ever, fail to produce the called-for effect.

Means used to fire blasts.—The means of firing blasts may properly be considered in connection with this subject.

Common fuse cartridge.—In ordinary railroad or land blasting, contractors and laborers are not easily persuaded to abandon the ordinary *fuse*, for electricity, with its accompanying inconveniences of application. A small cylinder of paper, containing perhaps a half ounce of powder, securely tied around the lower end of the fuse, and also closed at the lower end, the whole, when prepared, being dipped in melted paraffine, makes a cartridge which rarely, if ever, fails under any circumstances, and can always be readily constructed.

Electricity must sometimes be used.—But there are circumstances under which the aid of electricity is indispensable.

First. When a simultaneons line of blasts may be required; and next, in all submarine operations.

Three kinds of electricity.—There are three distinct methods of applying electricity, or it may be conventionally said that three *kinds* of electricity are used, involving three kinds of apparatus for its production, and corresponding means of application.

Kinds of electricity.—These may be classified as follows: *Static electricity*, or that produced by frictional machines and analogous to atmospheric electricity. Second, *Magneto-electricity*. And third, *Galvanic electricity*.

Static most popular.—The first seems at present to be the most popular, on account of the apparent simplicity and ease of application.

Static apparatus.—The apparatus used for the production of the spark is in principle an electrophorus, with a condenser to collect and discharge at once a series of accumulated sparks.

Where and by whom made.—They are manufactured by Smith in Boston, and by the Messrs. Chester, of New York. The machine produced by the latter gentlemen is externally a cylinder of ebonite, about 9 inches long and 4½ in diameter. On one of its closed ends a small crank and trigger, and on the other the two binding screws to which to connect the wires. Its capacity is to throw a large spark of one and one-half inches in length, and would doubtless fire sixty or seventy cartridges simultaneously.

Fulminate fuses.—But this spark will not fire powder, but will fire a mixture of oxygen and hydrogen gas, or certain sensitive fulminates. The caps or cartridges prepared for this kind of electricity contain—first, a minute quantity of very sensitive fulminate as "priming," and a larger quantity (for N. G. at least 10 grs.) of less sensitive fulminate as load, or exploder.

The recipés for their preparation are innumerable, and need not be entered into here.

Fulminate fuses made by.—The preparation of them, however, has become an extensive business, and I know of three firms that manufacture them extensively—viz., Mr. Mobray, and Mr. Smith, of Boston, and Mr. Bishop, of New York. I need hardly say that they have been extensively manufactured and used on the continent and in England, and are not the result of Yankee invention.

Description of fulminate fuse.—In this country the sensitive fulminate is rubbed upon the flat opposing faces of two discs of lead, to the other sides of which are attached the terminal wires which first pass through a small cylindrical block of wood. The exploding charge is usually contained in a copper cap, into which the wooden block is inserted.

Objections to use of fulminates.—Though so very popular, it may very properly be suggested that many grave objections present themselves to our consideration against the use of this form of electricity, and that engineers ought to discourage it.

First. On the ground of expediency. Of course, it is obvious that this machine can *only* be applied to the explosion of cartridges carefully prepared in a laboratory, and if a contractor, by chance, gets out of cartridges in an out-of-the-way place, there is no makeshift or expedient to which he may temporarily resort.

Secondly. It is now practically reliable. The "tension" of static electricity is so great, while the "volume" is so small, that it is very difficult to confine it to ordinary conductors.

Static electricity not easily insulated.—Hence the complete insulation of those conductors is difficult to obtain, especially in the hurry and reckless haste that naturally grows up on all public works. Even if the insulation of the wires be of the best; if at any point between the batting and cartridge the wires are contiguous, or touch any damp surface, the tendency of the spark is to pierce the insulation and travel over the damp surface.

Of course these difficulties are very much increased in submarine blasting. But the third, and most important objection to the use of fulminate cartridges arises from the danger arising from their use.

Sensitiveness of fulminate cartridges.—On a cold, dry day, I have exploded them by touching the end of one wire, the other end lying on the ground.

Danger of fulminate cartridges.—But even if less sensitive than that, it must be remembered that the "torpedo" must, in submarine blasting, be previously prepared, and must *contain* this cartridge. The diver who places the torpedo is swayed about by the tide, and it is subject to violent concussions, which, though inadequate to cause the nitro-glycerin itself to explode, yet may well cause the fulminate to do so; but, lastly, in paying out the wires, there is a great tendency to cause the surfaces of the two leads to rub together; which friction, if it does not cause a premature explosion, at least rubs the fulminate from part of the surface, bringing the leads into metallic contact, and thus causing a failure.

Examples of danger from fulminates.—Mr. Mobray narrowly escaped losing his life, in attempting to draw one of these cartridges from a loaded hole.

Last winter, a frightful accident occurred near Sandy Hook, resulting, without doubt, from the use of these cartridges.

Precautions to be taken.—But if used at all, let them only be used on land, where the cartridge may be lowered into the hole; after the latter is loaded, never let it be placed in the cartridge of nitro-glycerin before placing it in the hole; and if it fails to explode, never withdraw it, but, cutting the wires above, attach them to another cartridge, leaving the first where it is.

Cost of fulminate cartridges.—The best I have used are those made by Smith, of Boston, and cost, I believe, ten cents each.

Magneto-electricity.—The magneto machine is of a more expensive character. The electricity is produced by rapidly revolving an armature of soft iron, covered with a helix of fine insulated wire, between the poles of a number of permanent magnets. As this revolving armature changes polarity with each revolution, a charge of inductive electricity flashes through the wire forming the helix.

"Tension" of current less than Static.—The character of this electricity is a modification between static and galvanic. Its "tension," infinitely greater than that of the galvanic current, is, nevertheless, very much less than that of static electricity. Hence, it does not *jump*, but will follow a relatively poor conductor.

Beardsley's cartridge.—Mr. Beardsley has taken advantage of this in the production of a very ingenious and excellent cartridge. The terminal wires (No. 16 copper) pass through a cylindrical block of wood, about three-quarters of an inch long, and one-quarter inch diameter. The terminals are less than one-eighth inch distant, and, with a triangular file, a small V-shaped groove is cut through the wood and the ends of the wires. A strong lead pencil mark is made to connect the wires. This is sufficient to make continuity of current; but the conductor being *bad* it becomes so heated during the passage of the current as to ignite gunpowder, and even burn the wood.

A mere wrapper of paper, enveloping the cylinder of wood and projecting beyond, when filled with powder, and its end being closed, and the whole rendered impervious to water, completes the cartridge.

Results good, but machine expensive.—With this machine, insulation is much more easily attained, and the element of danger is avoided.

It is, however, expensive, cumbersome, and easily gets out of order.

Galvanic electricity and its production are too well understood to require any explanation.

Of course, explosion depends upon the heating of the fine platina wire connecting the two terminals.

Galvanic cartridges.—So little "tension" has the current required to perform this office, that *bare wires* may be used even in submarine blasting. It is always expedient, however, to use well insulated wires. This is the oldest of all plans for using electricity in blasting, seems the most reliable, and the safest under all circumstances.

Cost of cartridges.—No improvements have been, nor can be made in its application, except in the compactness and durability of the batting used, and in the convenient form and cheapness of the cartridges; and I have again to mention the Messrs. Chester as having produced a very compact batting of great endurance, that can be carried from place to place for weeks without recharging, and in making cartridges which can be procured for about 10 cents each. This batting may be charged and remain thus inactive for six months, and then be brought into action as active as when first charged.

Application of N. G. to blasting.—I approach the question of the most expedient application of nitro-glycerin, and the economy of its use with that of gunpowder, with much hesitation, since the testimony of the various contractors and experts whom I have consulted is so diverse, and so conflicting, that I am compelled to depend upon my own observations, which have been limited.

So far as I have any experience, however, I have, for my own guidance at least, concluded that the following general rules should be observed:

First. That to produce the best effects, though nitro-glycerin should be allowed a certain chamber in which to first expand, to give some *degree* of elasticity, so as to modify its percussive force, yet the limit of its expansion should be *absolutely* confined.

It is certain that the gas forms quickly, and readily percolates through sand. It is obvious that it *must* do so, from the fact, heretofore quoted, that a charge near the top of a hole filled with sand *instantly* explodes a charge at the bottom. The intensely hot gas percolates through the sand.

Seam blasts.—Again, nitro-glycerine has been tried in seam blasts, but the results were very unsatisfactory, not seeming to nearly equal powder. It is probable that in the larger fissure of a seam blast filled with sand a large quantity of the gas escapes.

Mixture of nitro-glycerin and powder.—In Europe, charges of powder moistened with nitro-glycerin are used in seam blasts, it is said, with excellent effect. I have not yet had the opportunity of verifying this by actual experiment.

Must be confined.—An air-tight tamping is desirable; or a block of wood, nearly filling the hole, may with advantage be placed on the top of the oil.

Should be used in cartridges.—Secondly, it is not practically safe to pour the oil into a hole, as it is so seldom that holes of any depth are for their whole depth water-tight.

Danger from holes leaking.—Besides the danger of losing part of the charge, the escape of any oil that may trickle through an aperture to some distant basin, is a source of future danger. At least one serious accident has occurred from this cause.

Cartridges employed.—Cartridges of tin, rubber bags, paper cylinders soaked in paraffine, and animals' entrails, have been successfully employed.

To be distributed.—Third. I am of the opinion that the charge may frequently be distributed to great advantage, and except for the purpose of securing more tamping, and consequent confinement, it is not desirable that the charge should be in one mass at the bottom of the hole, but better in several cartridges at various points of the hole.

Cost of nitro-glycerin and powder.—Nitro-glycerin costs contractors through the country an average of $1.60 per pound. Five pounds of powder costs about 80 cents.

Apparent economy of use.—Hence, if one pound of nitro-glycerin represents the effective force of but five pounds of powder, and the labor of using either be the same, it is obvious that powder is much more economical than nitro-glycerin. In fact, many who have used both, declare in favor of powder. With due deference to their much larger experience, I cannot but believe that their judgment has been based upon an indiscreet, not to say irrational, use of the oil. It is of course almost impossible to establish, except by long and judicious experience, the exact relative effectiveness of the two, but it does not seem too much to announce that one pound of oil, properly used, may represent seven pounds of powder. But allowing that one pound of oil represents but five pounds of powder—

Real economy in using N. G.—1st. The labor in preparing for one volume of oil certainly need not be one-third as great as in preparing for the equivalent of powder.

2nd. It is conceded that it shatters and breaks up rock, when powder overthrows large masses, which require subsequent additional labor and blasting to reduce to transportable dimensions.

3rd. It breaks at or below the bottom of the hole, shattering downward or outward. The natural deductions need hardly be followed to their logical conclusions.

Why N. G. has not been universally adopted.—But nitro-glycerin certainly has not hitherto been generally adopted for blasting purposes in the United States. The principal obstacles opposing its more general use have, doubtless, been the following, to which I particularly invite your attention :

Difficulty of obtaining it.—First. The cost, and the extreme difficulty of obtaining the article in quantities sufficient for experimental purposes.

Danger of storing.—Second. Being generally necessary to purchase it in large bulk, it is required to store it in the vicinity of the locality where used—when it either deteriorates, or becomes excessively dangerous to handle.

Popular prejudices.—Third. Public sentiment almost forbids its transportation by any ordinary route of travel, and its storage near human habitations or routes of possible travel. Popularly, it is regarded as a material excessively sensitive—liable to explode with the slightest shock, or even to explode spontaneously, or from mere change of temperature.

Has been misused.—Fourth. It has been recklessly condemned by ignorant contractors after a very limited use of the oil, in a very irrational manner.

To these objections I would respectfully suggest that a careful consideration of the care, cost, and safety of its production, as before described, may naturally lead to the conclusion that most of these obstacles may be relieved.

Can be produced cheaply.—To the first and second objections, it may be stated that, when more generally adopted, it can be produced at a cost not to exceed the cost of the nominal equivalent of gunpowder, and the outlay required to prepare for its manufacture would be very inconsiderable when any amount may be required.

New oil much better than old.—I have made the statement that nitro-glycerin, when long stored, *deteriorates*. My authority for this statement is in the fact, that many pounds of oil, recently produced by the process described, and many pounds of oil obtained elsewhere, and long stored, have been used, under precisely similar circumstances, on the Boston, Hartford, and Erie Railroad, and in every case the effect produced by the first-mentioned oil has been astonishingly greater than that produced by the latter.

The inference is unavoidable: either nitro-glycerin deteriorates greatly when long stored in metal vessels, *or* the blasting oil sold by a well-known company is not the nitro-glycerin produced by the process described, and does not possess its qualities.

Prejudices not unfounded.—The unfortunate popular prejudices regarding this material are not unfounded. Notwithstanding its limited use in this country, already many terrible accidents have attested to its fearful power. While these may in part be attributed to gross recklessness in its treatment, they still seem to indicate that the material possesses a degree of sensitiveness not consistent with the statements hereinbefore made.

I believe I am right, however, in stating that every accident that has yet occurred, has been with oil that had been long packed in tin vessels.

Why old oil is dangerous.—Chemical experts thave conceded that nitro-glycerin can, and does, decompose; but I am not aware that any one has satisfactorily determined what the result of such decomposition may be. Mr. Mobray, an accomplished chemist, and extensive manufacturer of nitro-glycerin, declares that it does *not* decompose, *provided* that every particle of free acid be removed from it.

Cannot be made free from acid.—But this I believe to be nearly, or quite impossible. Minute globules of acid become enveloped in larger globules of oil of the same specific gravity, and owing to their peculiar cohesiveness, before described, there is no certainty that all these globules come in contact with the water in which the oil is washed. We have placed oil already repeatedly washed in a vessel containing a strong alkaline solution, and it was frequently stirred therein. For a day or two, the water did not lose its alkaline character, but after several days it became decidedly acid.

Tin vessels dangerous.—Hence, when placed in tin vessels, what acid thus exists may be locked up in the centre of the mass, but by slow movement particles may at length come in contact with the metal. If no other decomposition occurs, may not the bubbles of mixed hydrogen and oxygen gas, and perhaps nitrous acid gas, that may be formed, be a sufficient cause for the extreme sensitiveness to explosion being then developed? At all events, whatever may be the cause, it is quite certain that under these circumstances, something is frequently produced which, however minute in quantity, is all-sufficient to produce dire results.

Should never be transported.—This being undeniable, I would respectfully submit to your judgment that popular sentiment need not be outraged by the transportation of this material; life need not be risked by its storage in large quantities, since it can nearly always be easily and cheaply manufactured in the immediate vicinity of the locality where it is to be used.

It is to be remembered also that there are reasons for believing that the *value* of the material thus newly produced *may* be greater than that of oil that has been stored.

The process of manufacture is so simple, the formulæ so few and arbitrary, that a chemical expert is not required, but any reliable and intelligent laborer may be instructed in one day to manufacture it successfully.

To the fourth objection it may be said, that, though unfortunate that ignorant experiment may in its results lead us to false conclusions, yet all popular improvements pass through similar ordeals. There seems to be no cure to the prejudices thus created, except in the fact that it will eventually be submitted to the experimentation of more intelligent and more careful men, who will, at least, develop its greater value, or give us more reliable data upon which to determine its value as compared to powder or other explosives.