ber of samples to be collected, in widely separated schools perhaps on the same day, that it would be necessary to depend upon some other method than one relying upon the use of a hand pump in conjunction with a gas meter. The limited time per day (school hours) available for collecting samples and the transportation of apparatus were factors of supreme importance.

After many conferences, in which the entire staff took part, Messrs. Wallace and Tiernan, Engineers,

New York City, who also had a representative present, supplied us with an apparatus, which we think should be described for the benefit of those members of the Society interested in atmospheric hygiene.

The principle of the apparatus depends upon measuring volume by time. The apparatus includes an exhaust pump of the friction type run by a $1\frac{1}{2}$ horse power motor and a measuring apparatus of compact and ingenious design. This apparatus, placed be-

tween the pump and the sampling filter, consists of an air chamber, the inlet of which is connected with the two ends of a U-tube, graduated on its distal arm. The opening of this distal arm is so reduced that the pressure at the mouth of the proximal arm is registered by a rise of the liquid in the distal arm. The whole apparatus is enclosed in an oak box fourteen inches by twelve inches, air being drawn in through an opening at the top and forced out through an opening in the side. The upper opening is fitted with a small steel cup with a rubber stopper inside, having a hole large enough to fit the constricted end of the sugar or sand filter. At the base of the cup, an extension passes through the wooden cover and screws on to the suction chamber of the machine.

The apparatus as first made was designed to draw through about three-quarters of a cubic foot of air per minute. With the resistance due to the sand or sugar, however, the time required was about three minutes per one cubic foot. The pump when first tested proved to be too noisy, so the apparatus was placed within a second box lined with felt and a muffler attached to the exhaust. This reduced the noise to a minimum. Teachers in whose classrooms we operated, were consulted, and no objections were offered to the noise made by the apparatus during class hours.

The accuracy of obtaining dust and bacteria samples by means of this form of apparatus was compared with the hand pump and meter method and approximately similar results were obtained. A further check was made by running the electrically driven pump and measuring the flow by means of standard gas meters. Both the electrical pump and the gas meters were tested and standardized by the manufacturers.

The amounts of air taken for samples for bacteria and dust with this machine were usually three feet and two feet, duplicate determinations always being made. The official methods of the Public Health Association were used in making counts of bacteria and studying the character of the dust collected.

The apparatus might be used extensively in studying the air of factories and other places where occupational diseases are to be investigated.

COLLEGE OF THE CITY OF NEW YORK

ADDRESSES

RECENT DEVELOPMENTS IN COMMERCIAL EXPLOSIVES¹

E. A. LESUEUR

The last few years have seen a great development in the use of safer explosives than were previously commercially available or even believed to be possible. It is my purpose to take a brief general view of the trend of development, to deal with some particularity with an explosive of rather unique character with which I have had much experience, and incidentally to outline certain advantages and disadvantages of the new types.

The most striking feature among the changes occurring in the field is the almost omnipresence of nitrate of ammonia. Although a salt of a hypothetical metal it breaks down into a

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gaseous mixture containing a surplus of free oxygen and no solid residue whatever and, insofar, is therefore peculiarly suited to employment in explosives. Unfortunately it is very hygroscopic and of deplorably low specific gravity so that but a comparatively small weight can be packed into a given cavity. On the other hand, its adaptability, within the above limitations, is remarkably wide and we find it associated with almost every ingredient known to explosives manufacture, and especially with nitroglycerin. So wide is the present market for this material for use in explosives that practically the entire output of the gigantic Norwegian Atmospheric Nitrate works is now delivered in the form of nitrate of ammonia, and further important developments in the cheap manufacture of this important compound are to be looked for in the very near future.

Perchlorates, and especially perchlorate of ammonia, have

numerous advocates among the inventors, but so far do not appear to have entered the market to any very great extent. Perchlorate of ammonia is obviously, from its chemical formula (NH_4ClO_4), well adapted to act as an explosive itself and at the same time provide three atoms of excess oxygen to combine with additional material. Aside from any other considerations, it possesses the serious defect of liberating considerable hydrochloric acid or a mixture of the same with chlorine. The use of certain powdered metals in the mixture serves very largely to eliminate both of the above gases.

A most profound impression has been made in the explosives trade of late years by the nitro derivatives of toluol, and especially by the various commercial mixtures of di- and trinitrotoluol now on the market. The cheddites (practically mixtures of the nitrotoluols with chlorate of soda and a vegetable oil, preferably castor oil) have achieved considerable well earned popularity, and the flood of current patent applications for explosives containing trinitrotoluol reminds one of nothing so much as of that which occurred some ten years ago for acetylene generators. Bearing in mind that trinitrotoluol possesses certain of the properties, so far as explosive effects go, of nitroglycerine itself; that it withstands water and is not affected by cold, and that it can be handled with absolute safety until blended with other materials that may increase its sensitiveness, it is not difficult to understand the enthusiasm with which it has been received by amateurs as well as by others in the explosives field. Aside from any admixture with other materials it forms, in the refined condition, an explosive of quite ideal properties for use in shells, torpedoes, mines and the like. In spite of its fierce and terrific disruptive energy, and of an enormous speed of detonation, it is a safer material to handle, transport and store than, for instance, ordinary calcium carbide. And, notwithstanding its inert behavior, it can be depended on absolutely to explode completely when exposed, in a suitable physical condition, to detonation from an adequate primer. Several European governments are now making extensive use of this intensely interesting compound. Owing to the fact that its constitution ($\text{C}_7\text{H}_5\text{N}_3\text{O}_6$) presents too little oxygen completely to combine with the carbon contents even to the monoxide form, the result of explosion is the formation of a cloud of carbon particles which will presumably have advantages in warfare both through marking the position of a shell at the instant of explosion and in obscuring the enemy's vision.

The liquid nitrotoluols are also finding an important use in connection with nitroglycerine. They greatly lower the freezing point of the latter, contribute their quota to the explosive effect, and render the resulting explosive much safer than before.

In addition to the above compounds and many others (including the nitronaphthalenes, benzenes and xylols) the old stand-by, chlorate of potash, holds its own as a prime constituent of modern disruptive powders. It may be worth while to glance for a moment at the extraordinary thermo-chemistry of the chlorates and perchlorates, the same having a vital bearing on the matters of energy developed, sensitiveness and stability of certain explosive mixtures containing them.

Chlorate of potash disengages heat energy to the extent of 93,800 calories per kilogram molecule on formation from its elements, but potassium chloride disengages 105,700 calories, or 11,900 more than the chlorate. The addition of three atoms of oxygen to the chloride is accompanied by the absorption of energy to this latter extent, the formation reaction being endothermic. Perchlorate contains one-third as much oxygen again as chlorate, but, instead of the addition being accompanied by a further absorption of heat, there is actually a disengagement of energy, accompanying the entry of this lone atom, of far more (19,900 calories altogether) than the entire amount absorbed when the first three atoms were added. Chlorate stands ready

to fall to pieces on scant provocation and, in doing so, gives up not only three atoms of active oxygen to any combustible in the neighborhood, but 11,900 calories per kilo molecule as well. Perchlorate, on the other hand, in spite of its higher degree of oxygenation, requires more energy to drag it to pieces than does the chloride itself, and, in consequence, forms a less sensitive and less energetic constituent for an explosive than the less oxygenated chlorate.

In the light of the above, and especially in view of the fact that the besetting trouble with most modern chlorate explosives is lack rather than excess of sensitiveness, it will be seen that plain chlorate presents certain large advantages over perchlorate for many explosives. This will help to explain the fact that, although modern electrochemical methods enable the ready production of perchlorates, the latter have not, as stated above, so far become serious competitors in the field of commercial explosives.

To illustrate the remarkable extent to which the desensitizing of at least one chlorate explosive has been carried without destroying its practical usefulness I will now cite the case of an explosive developed by me some seven years ago which has been in somewhat wide-spread practical use since that time.

In manufacturing this powder 5 parts of paraffine wax are melted and 4 of ground sulfur and 22 of nitrate of soda stirred into it; the mixture is allowed to cool and is then grained. The resulting material is called "mineral base." In spite of containing an oxidizing agent and combustibles it is completely inexplosive technically. It is finished to explosive by dusting 8 parts (to the above 31 of base) of powdered chlorate of potash over the grains. The final material possesses a number of interesting features. Due to an extremely low speed of detonation it develops its power in a way peculiarly available for the requirements of many large applications such as heavy rock work, clearing land of stumps and the like; and, owing to the said low speed of detonation, its high effectiveness for these purposes, even compared with explosives possessing decidedly greater energy content, is quite surprising. Its insensitiveness is such that it withstands the impact of a steel tipped service rifle bullet fired from the regular service rifle with a standard charge behind it without response of any kind; although, due to its property of going out after being set fire to when the flame causing ignition is removed, it is possible that incipient ignition occurs during the passage of the bullet. If packed hard it is impossible to explode it by any means whatever. On the other hand, loaded loose, it is an absolutely sure fire with a No. 6 detonator even when unconfined, and, for work in earth, as in removing stumps, it is necessary to bear in mind that confinement may be negligible. When well confined in large shots in solid rock, and especially if detonated with a stick of dynamite, it will withstand any reasonable amount of packing and still give a sure fire. From its composition it will be obvious that it is non-freezing, and, indeed, owing to the paraffine wax incorporated in it becoming harder with increasing cold, it loses its porosity through being pressed into holes less readily cold than otherwise. With regard to stability, it withstands the International Stability Test (75° C. for 48 hours) with indifference, whether with moisture added or not, and some millions of pounds have been used during the past seven years, and in some cases excesses over requirements have been stored by contractors in badly constructed magazines, occasionally for years, and there has never been any sign of heating or decomposition, incipient or otherwise.

The very low chlorate content and the fact that all the other materials are used in their crude commercial condition, together with the extremely simple process of manufacture, render the cost of this powder exceptionally low. It is known under the name of R. R. Virite. A blast containing 600 fifty pound cases was fired on the Canadian National Transcontinental Railway

work on the Quebec-New Brunswick border, near Notre Dame du Lac, some years ago, and the two largest blasts at Prince Rupert, the Pacific Coast terminal of the Grand Trunk Pacific, 3500 miles from Notre Dame du Lac, were also shot with it, the charges containing respectively, 1010 and 1000 fifty pound cases of the explosive. Aside from the technical importance of these blasts the spectacular effect is quite indescribable. To give an idea I may say that in the one of these shots that I witnessed the mass of broken rock that had mounted in the air about three seconds after explosion occurred, and which looked like nothing so much as a vast and spreading black tree, contained, to state it in units that will make it sound as impressive as possible, about 175,000,000 pounds. Reference to the efficiency of virite in agricultural work is contained in *Bulletin* No. 134, entitled "Land Clearing," issued from the University of Minnesota by Prof. A. J. McGuire, Superintendent of the North Central Experiment Station.

With reference to the property which this explosive, in common with very many others, has of being more difficult to explode as its porosity diminishes, I wish to point out a certain important corollary which exists in a case where the insensitiveness when closely packed reaches the point it does in a case such as the one under discussion. If compressed forcibly to a specific gravity of about 1.45 it has been found impossible to explode by any amount of detonation, no matter what the degree of confinement. This in spite of the fact that a certain small amount of local combustion occurs where the material is in direct contact with the detonator. The superficially paradoxical situation confronts us that the only condition in which the material can be exploded by hammering between hard surfaces is one in which it becomes insensitive to detonation from another explosive. By this is meant that, in order to cause explosion of the powder by hammering, it has to be packed to a maximum density before the pinching between hard surfaces necessary to cause explosion occurs. Of course what happens when the material is hammered on an anvil is that any excess over what can be pinched down to the thickness of thin paper between hammer and anvil is forced aside and only the trifling amount of powder actually so pinched goes off, and it has hitherto been found impossible by any degree of practicable impact to communicate explosion from the quantity so pinched to the rest of the mass of powder. The importance of this peculiarity in securing freedom from accidents in any case other than where the powder is exposed to detonation from another explosive will be obvious.

If we consider what is the fundamental difference between the blow of a hammer and that of a detonator we see at once why a mass of the explosive which refuses to transmit detonation, however powerful (within the enormous upper limit experimented with) when in a dense (non-porous) condition—why such material may be readily exploded when in a porous condition by a detonator although a blow from a hammer can have only a local effect. The point is that, in the former case, the blow is struck so quickly that the explosive is hammered between the products of explosion of the detonator and, if I may so express it, its own inertia, without having time for its porosity to be interfered with. The passage of a bullet exposes it to the same kind of a blow against its own inertia, but the swiftest bullet is so far inferior in speed to the velocity of the products of explosion of a detonator that it falls short, in the case of a powder of the class under discussion, of producing an explosion. There is also, of course, the essentially important feature, in the case of explosion by a detonator, of exposure to vastly greater heat than from the friction of a bullet or impact of a hammer.

The well compressed material behaves, as previously stated, in a completely inert fashion to attempts to detonate it, but mere crumbling restores it to the explosive condition. It would seem as though a technical division on the lines of classification according to safety might well be adopted to embrace explosives

that require outside detonation from another explosive in order to set them off.

I must not close without making reference to liquid oxygen as a constituent of explosives. Modern methods exist for producing this element in a state of high technical purity in the liquid form at a cost extremely low compared with its cost in the combined form in any of the chemicals employed in the explosives trade, so that completely smokeless and fumeless mixtures equal to 75 per cent dynamite can be made at a cost of about 2 cents per pound. As regards safety, explosives containing liquid oxygen stand in a class by themselves in one particular, *i. e.*, in the fact that, should a shot be missed for any reason, the charge presently becomes inexplosive through volatilization. Of course this is merely the merit which accompanies the greatest defect of these explosives. They must be used within a few minutes of being compounded. Nevertheless this is by no means the absolutely prohibitive feature that might be expected, owing to two considerations, one the numerous gigantic individual blasts that are necessary on certain heavy construction works (the time required for the charge to evaporate being comparatively long in such cases) and the other the fact that the addition of the liquid oxygen to the combustible portion of the charge may be made the last thing before firing. I am rather firmly of the opinion that in the heaviest construction works of the future, especially where the so-called "coyote" shooting can be employed, liquid oxygen will play an important part.

This paper is intended to deal with accomplished facts in explosives development and there is no occasion at present to do more than refer briefly to the hopes of the nitroglycerine manufacturers that in synthetically prepared glycol may be found the solution of their bondage to the fluctuation of the corn and cotton seed crops. The production of glycerine depends considerably on the abundance or otherwise of pork and of cotton seed oil and the former depends largely on the corn supply. The stearine candle industry, another feeder to the high explosives maker, is not in a healthy condition, and altogether the situation of the dynamite manufacturers is not so completely free from anxiety in the matter of their glycerine supply as they might wish.

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EXPERIMENTS WITH SMALL ANIMALS AND CARBON MONOXIDE¹

By GEORGE A. BURRELL AND FRANK M. SEIBERT

The usefulness of small animals in detecting vitiated air in mines is well established. The Bureau of Mines and others have much information on this subject, but in order to make this paper brief, accounts of their practical use or of accidents because they have not been used will not be given here. Time can be devoted, if so desired, to this phase of the subject in the discussion.

The Bureau has experimented with most of the more common small animals, such as canaries, guinea pigs, rabbits, chickens, dogs, mice and pigeons, and finds that canaries or mice are the most suitable for the work. Of the two the Bureau finds canaries to be the most sensitive. They were used in England before their acceptance in this country, presumably in places on the continent also. Their usefulness in husbanding the resources of breathing apparatus is of great importance.

An additional reason for the use of canaries lies in the fact that they are generally easily obtainable, and become pets of the men who have them. If handled intelligently in rescue operations, they seldom die as a result of their exposure to carbon monoxide.

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