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SAFETY ENGINEERING IN THE COMPRESSION OF GASES

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The purpose of this paper is to outline a few of the chief hazards that are associated with the compression of some of the gases in common use in industry. Among the gases considered are air, oxygen, nitrogen, argon, carbon dioxide, hydrogen, acetylene, ammonia, and chlorine. The preparation, utilization, storage, or transportation of the gases, except when some of these items may happen to have an important bearing upon the actual operation of compression, are not discussed. As to the mechanical strength of the apparatus that is used to effect the compression, the paper deals only with the things that are likely to happen even when the apparatus itself is strong enough to withstand the stresses that are thrown upon it in the course of its normal operation.

COMPRESSED air, the first of the gases to be considered, is used for many different purposes and at many different pressures, but so far as safety is concerned it is sufficient to distinguish two main problems. First, we have to deal with cases in which the ultimate pressure desired does not exceed, say, 200 lb. per sq. in.; and second, the special case in which the compression must be pushed to perhaps 3000 lb. per sq. in., for the production of liquid air.

2 When the ultimate pressure is not greater than 75 lb., the compression is usually effected in a single operation; but it would seem better to adopt two-stage compressions for pressures approaching or exceeding this limit. Three stages, at least, should be used for pressures in the neighborhood of 1000 lb., and to push the pressure from this point up to 3000 lb. a fourth stage or operation should be employed. It is advisable to use long-stroke com-

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pressors, with low piston speed, not only to avoid unnecessarily high temperatures, but also because less lubrication is needed.

3 Every now and then there is an explosion in connection with an air compressor, and the results are sometimes quite serious. Most of these explosions are probably associated more or less directly with the lubrication of the compressor cylinders, and with inefficient cooling of the air that is undergoing compression. In an ordinary compressor the temperature of the air rises considerably during the compression stroke, and it is of the utmost importance to keep this rise of temperature within reasonable bounds. A good deal can be accomplished in this direction by surrounding the cylinders with effective water jackets. The cooling water in these jackets should circulate actively and copiously, and thermometers should be provided to show the temperature at which the water is entering and leaving. To guard against stoppage of the flow of cooling water from any cause, it is also important to provide some positive means for showing that the circulation is free and plentiful at all times. It is advisable, for example, to have the discharge from each jacket located where it is plainly visible to the men working about the room.

4 It is not sufficient, however, to provide the compressor cylinders with water jackets. The air should be passed through a special cooler immediately after leaving the compressor and its temperature brought down near that of the surrounding atmosphere as quickly as practicable. Moreover, if the compression is effected in two or more stages, an intercooler between each stage and the next one should be provided, so that every cylinder will be supplied with air at a moderate and reasonable initial temperature. The use of efficient cooling devices tends not only to insure safety but also to lessen the cost of compression, because cooling reduces the pressure as well as the temperature.

5 In compressing air to moderate pressures the cylinders are lubricated with oil. Oil may also be used in the first stages of high-compression apparatus, though water is preferable for the final stages. The composition and physical characteristics of the oil should be carefully considered.

6 As a general rule, too much oil is used in lubricating the cylinders of air compressors. It takes considerable experience to determine just the right amount, and what is right with one machine or one grade of oil may not be right with another. In a

general way, however, it is safe to say that the lubrication is ample if the cylinder walls are always coated with a slight film of oil. It is often assumed that the explosions that sometimes occur in connection with air compressors are due to the ignition of oil vapor or of oily mist. It would be hard to justify this theory. Whenever a compressor cylinder discharges the air that it contains, the oily vapor or spray that is present is discharged at the same time, and it is hard to see how a quantity sufficient to produce a serious explosion could accumulate. Moreover there are comparatively few explosions in which the initial break is in the compressor cylinder. More commonly the first rupture occurs in the discharge pipe or the receiver, and trouble at these points can be minimized, and perhaps entirely avoided, by (1) quick and efficient cooling of the air, (2) thorough drainage of the oil that tends to collect in the piping and receiver, and (3) careful attention to the discharge valves on the compression apparatus. Considerable quantities of oil are likely to accumulate in the discharge pipe and the receiver, and if either of these bursts, a large amount of hot oily spray is likely to be discharged into the air, and this may take fire either spontaneously or from some external source, with a bad oil-vapor explosion as the result. Suitable traps and drains must be provided to prevent the accumulation of the oil, and in this way the oil hazard can be largely or wholly removed.

7 If the exhaust valves of the compression apparatus are leaky, then upon the return stroke more or less of the compressed and heated air will find its way back into the cylinder, so that the temperature of the air in the cylinder upon the next compression stroke will reach a much higher point than the designer of the apparatus intended. Carbonaceous deposits, produced by the carbonization of the lubricating oil, often collect in considerable quantity in and around the exhaust valves, and these may sometimes take fire, or they may prevent the valves from closing tightly. Exhaust valves should be carefully watched for such deposits, and should be kept as clean and tight as possible.

OXYGEN

8 Oxygen is compressed and shipped in vast quantities and is used in the greatest imaginable variety of ways. Before subjecting it to compression it is essential to know that the oxygen

is pure, and especially to know that it is not contaminated with any other substance with which it could combine, either during compression or in the course of subsequent handling. For example, if it is prepared by the fractional distillation of liquid air, it is important to know that the air that was subjected to liquefaction was free from smoke particles, from organic dust of any kind, and from coal gas, acetylene, and every other substance of an oxidizable nature. If the oxygen was produced by the electrolysis of water, it is equally essential to know that it is not contaminated by hydrogen. It is easy enough to insure purity in all these respects, but the importance of not neglecting the necessary testing, and the purification operations when these prove to be needed, cannot be over emphasized.

9 In handling compressed oxygen it is supremely important to prevent the gas from coming in contact with oil or grease either during the compression or while the oxygen is being stored, transported, or utilized; and in view of the fact that many exceedingly serious accidents have occurred in consequence of neglecting this principle, the author wishes to emphasize the hazard just as strongly as he can. When a man talks with appropriate earnestness about the danger of allowing compressed oxygen to come in contact with oil, grease, or other combustible organic materials, it is easy for the uninitiated to believe that he is inspired by unreasonable timidity, but this is not the case. Those who have followed the history of oxygen compression are well aware that many accidents have occurred under conditions that thoughtful and experienced men would not have considered to be at all likely to produce trouble. The use of even a slight trace of oil in the compressor is exceedingly hazardous, not only on account of the danger of immediate combustion, but also because some part of the oil is bound to go over with the compressed gas; this will collect in the tanks or cylinders used for storage purposes, and sooner or later serious results will surely follow. It is probably safe to say that most of the accidents that have occurred in connection with compressed oxygen have been due to lack of appreciation of the importance of this thing. The trouble is not confined, of course, to the mere combustion of the oil itself. The metal parts of the apparatus will burn freely as soon as they become sufficiently heated by the ignition of the oil or grease, and the consequences may transcend imagination.

10 The only absolutely safe thing to use for the lubrication of an oxygen-compressor cylinder is *pure water,* which should be introduced into the suction pipe in the form of a visible spray. Under special conditions it may happen that pure water is not sufficient, and in a case of this kind it may be permissible to dissolve a little soap in it; but soap should not be used when water will suffice, and it should *never* be used without first proving, by actual analysis, that the particular supply to be dissolved contains no uncombined (or unsaponified) oil or grease. The packings used on the compressor must also be entirely free from oil, grease, or graphite. Special packings, made for this express purpose, should be invariably employed.

11 The compression of oxygen is often, and perhaps usually, carried up to about 2000 lb. per sq. in., and it should be effected in not less than three stages. In speaking of the compression of air, the importance of prompt and effective *cooling* has been emphasized, and much greater attention should be paid to this point when compressing oxygen. The pump cylinders should be water-jacketed, the circulation of water should be positive and abundant, and the apparatus should be so designed that cessation or diminution of the flow of jacket water cannot escape immediate notice. The gas should also be passed through effective inter-coolers between each compression stage and the one next following; and *immediately* after leaving the last cylinder of the compressor it must be passed through a final cooler, and brought down to the temperature of the surrounding atmosphere.

12 It is exceedingly unwise to introduce oxygen into receivers of any kind, unless these receivers are known to be perfectly clean internally and wholly free from oil, grease, and other combustible substances. The author would like to see some kind of a regulation established forbidding every oxygen manufacturer to fill any tanks other than his own. This principle is already followed, it is believed, by some and perhaps all of the larger manufacturers, but unfortunately it is not followed by everybody. Moreover, oxygen should never be compressed into containers that have been used for other gases. When a cylinder or tank has been previously used for holding compressed gases other than oxygen, there is likely to be an accumulation of oil upon its inner surface, because oil may have been used for cylinder lubrication in connection with the compression of these other gases, and it is hard to remove such oil thoroughly enough to make the tank safe for oxygen.

NITROGEN

13 Nitrogen gas has a far narrower range of application in the arts than oxygen, yet it is compressed and shipped to a certain extent. This gas was used during the war in the recoil cylinders of certain types of guns, and it has also been used to a limited extent for blanketing combustible liquids and for supplying a neutral atmosphere for other purposes, where the presence of a gas with active chemical properties would be objectionable. At the present time compressed nitrogen is supplied mainly, it is believed, for filling incandescent electric lamps, and in connection with the manufacture of automobile tires. The gas itself is coming into use for the direct manufacture of ammonia, nitric acid, fertilizers, and other nitrogen compounds from the atmosphere; but chemical plants in which this kind of work is done usually prepare their own nitrogen and do not subject it to compression except as the process may require it to be under pressure.

14 Nitrogen forms four-fifths of the bulk of the atmosphere, and as it is nearly inert in its elemental form the precautions that are recommended in connection with the compression of air are also adequate when compressing nitrogen. It should be noted, however, that the nitrogen that is used for filling electric-lamp bulbs must be free from hydrocarbons, and this means that when the gas is to be employed for this purpose it is not permissible to use oil for lubricating the compressor cylinders. Water should be used instead. For certain reasons, in fact, it is best to avoid oil altogether and to lubricate with water in all cases. This does not mean, however, that there is any danger of direct chemical action between the oil and the nitrogen.

15 Nitrogen is usually compressed to about 2000 lb. per sq. in., and the compression should be performed in three stages.

ARGON

16 Argon, like helium and neon, has no chemical properties whatsoever. It forms no compounds and is absolutely inert under all circumstances. Hence it cannot produce fires or explosions. Moreover, it is not poisonous. It is obtained from liquid air, however, and when first separated from the air it is mingled with a large proportion of oxygen — the mixture usually containing

about 65 per cent of oxygen and 35 of argon. When it is handled in this state it must therefore be treated like oxygen; but after it has been freed from the admixed oxygen it may be compressed under the same conditions as nitrogen. For shipment it is usually compressed to a pressure of 1800 or 2000 lb. per sq. in., in three stages.

CARBON DIOXIDE

17 This gas is compressed in large quantities and is used for the most varied purposes. As is well known, it will neither burn nor support combustion, and the author does not recall any chemical dangers which are likely to be encountered in its compression. It is not especially poisonous, but when a considerable quantity of it is mixed with the air that the workmen have to breathe, it replaces the life-giving oxygen to a corresponding extent, and this may mean that the air is not fit for respiration. The effects of carbon dioxide in this way are sometimes very insidious, especially as the pure gas is without odor or color; and it is therefore evident that special care should be taken to provide free and copious ventilation at all times in buildings in which carbon dioxide may escape, by leakage or otherwise.

HYDROGEN

18 In connection with hydrogen and most of the other combustible gases (such as propane), the chief danger associated with compression probably consists in the likelihood of fire or explosion in case of leakage or of contamination with oxygen. If the hydrogen is prepared by the electrolysis of water, there is always a possibility that oxygen may be present in it in small amounts, and the gas should be carefully tested, either at short intervals or preferably by some continuous process, to make sure that the oxygen content is always well below 5 per cent. Small amounts of oxygen can be removed by passing the gas over palladium pumice, which causes the oxygen to combine in a quiet way with an equivalent quantity of hydrogen.

19 The danger of admixture with air or oxygen is not in any way restricted to hydrogen prepared by the electrolytic process. Air may leak into the suction pipe leading to the compressor, whatever the source of the hydrogen; and this, in fact, is

one of the hazards that must be watched most carefully in handling this gas. The suction line may be fitted with test cocks or drainage valves, and when this is the case it is exceedingly important to keep them closed except when they are opened for legitimate purposes and at proper times. It is believed, moreover, that all such cocks and valves should be kept locked, and that the keys should be in the keeping of some designated, responsible man. To guard further against trouble from this source and from accidental leakage, the whole operation should be conducted so that there will be a positive pressure in the suction line *at all times*. Care should also be taken that the gasometer does not stick and that its seams are kept absolutely tight.

20 It is important to consider the possibility of leakage outward as well as inward. Hydrogen is usually compressed to a pressure of 1800 or 2000 lb. per sq. in., and at high pressures a good deal of gas will escape through a small hole in a short time. If hydrogen gets out into the room and is allowed to collect there, a serious explosion is likely to result. Every discoverable source of ignition should be carefully considered and safeguarded. Rigorous measures should be taken to prevent the men from smoking or using matches or other sources of open flame. The artificial lighting should be provided by incandescent electric lamps enclosed in vapor-proof globes, and it is safest to mount these lamps outside of the windows, locating them so that they shine through the window glass into the interior. All electric wires should be run in closed conduits, and the fuses should invariably be outside of the region of possible danger. This applies also to switches, unless they are of a type which cannot produce an arc or flame. No electric motors should be used in rooms where hydrogen, propane, or any other combustible gas may escape in quantity, unless these motors are specially designed for this particular application, or else thoroughly ventilated by fresh, pure air from the outside of the building. And these various precautions should be observed not only where the hydrogen is compressed, but also wherever it is stored — either in gasometers or in cylinders. Finally, it is exceedingly important to provide abundant ventilation at all times to lessen the chance of fire or explosion in case the various other precautions prove inadequate.

21 Left-handed threads are extensively used for fittings that are to be employed in connection with hydrogen, the purpose being

to prevent the accidental connection of hydrogen lines or cylinders with pipe lines conveying other gases, and especially with those containing air or oxygen. It is to be regretted that in many plants the purpose of the left-handed thread is deliberately defeated by making use of devices known as "adapters." These are in effect right-and-left couplings, which are provided for the express purpose of making it possible to attach a cylinder with a left-handed thread to a pipe line having a right-handed thread.

ACETYLENE

22. No person should ever undertake to compress acetylene unless he fully understands the properties of the gas and knows exactly what it is permissible to do and what he must carefully avoid doing. This is not meant to imply that the compression of acetylene is a dangerous operation when it is performed under the direction of a properly qualified man, but is intended as a special note of warning to those who are tempted to compress the gas without first understanding its properties. Acetylene is an endothermic compound, and this formidable word has frightened a great many persons who do not understand its exact significance. It merely means that heat is absorbed (instead of emitted) when acetylene is formed from its constituent elements. Now it is well known that substances of this kind are likely to be more or less unstable under certain conditions, and acetylene is no exception to the rule; but the conditions under which the instability exists are well known, and it is only the man who does not understand them, or who is pleased to ignore them, who gets into trouble.

23 In compressing acetylene it is important to keep the temperature of the gas as low as practicable at all times. Expressed in more definite language, this means that the compression must be effected by a pump moving with a very low piston speed, and that it must be performed in not less than three stages. It also means that the pump cylinders should be kept as cool as practicable by a plentiful supply of water drawn from the coolest available source. The author cannot state any definite temperature at which the gas may become instable during the act of compression, and in fact it is doubtful if anyone knows what that temperature might be. The only thing that we can say is, that if the operation is conducted as here described, there is apparently no danger from

instability. It certainly is not safe, however, to *store* acetylene in otherwise empty cylinders, at the pressure at which the compressor pumps deliver it. There appears to be a time element involved here, and it is probable that a certain amount of polymerization gradually occurs in strongly compressed acetylene (except when it is stored in special receptacles containing suitable porous material charged with liquid acetone), so that in the course of time small quantities of other more sensitive substances are formed, which serve to lessen the stability. At all events, we know that acetylene should not be stored in an otherwise empty tank at a pressure of more than 15 lb. per sq. in. greater than the pressure of the atmosphere, and yet we know that explosions in the compression pumps, and in the delivery pipes leading from them, are exceedingly rare if the compression is effected as here described. In fact, the author knows of only one case of the sort, and this was precipitated by the breakage of a steel valve spring, which quite possibly struck a spark and thereby caused the development of a high temperature within the tiny space filled by the spark itself.

24 Oil may be used for lubricating the cylinders of acetylene-compressing pumps, but it should afterward be removed by passing the compressed gas through suitable separators as it leaves the compressor. And immediately upon leaving the oil separator the acetylene should be passed into the storage cylinders, which, as previously stated, must be filled with a special porous, solid material thoroughly impregnated by liquid acetone, which dissolves the acetylene and holds it safely in solution.

25 It should not be necessary to issue a warning against mixing other gases with acetylene in the storage tanks, or using acetylene storage cylinders for any purpose whatsoever, except for holding pure, unmixed acetylene (in addition to the safety filling).

ETHYL CHLORIDE, METHYL CHLORIDE, AND PROPANE

26 These gases are used to some extent as refrigerating agents, but it does not appear desirable to discuss their compression in any detail. They are all inflammable, and hence must be handled with due regard to the possibility of fire and explosion. Propane (like butane) does not require lubrication in the compressor cylinder, because the substance itself affords sufficient lubrication. It is necessary, however, to lubricate the stuffing box of the com-

pressor. There has been some difficulty in connection with the lubrication of cylinders in which the chlorides of ethyl and methyl are compressed. Castor oil has been used, but it is not very satisfactory. Glycerine is said to be much better, though still far from ideal. It is said that a new lubricant, consisting of ethylene and propylene glycol mixed with deflocculated graphite, and specially adapted to ethyl and methyl chlorides, and to propane, is now available.

27 In handling these and all other inflammable gases the various special precautions mentioned in connection with hydrogen should also be observed.

AMMONIA

28 Liquefied ammonia is used in immense quantities in connection with refrigerating machinery, and although it perhaps cannot be called a poisonous gas in the narrow sense of the term, it is easily capable of producing unconsciousness and death when it is present in the air in any considerable amount. Similar remarks apply to sulphur dioxide gas, which is also used in refrigerating machinery as well as in various other applications. Both of these gases are freely soluble in water, and it is recommended that in all rooms in which they are handled an overhead sprinkling system be provided that is capable of discharging large volumes of water into the room in case of the accidental liberation of excessive quantities of either gas. A considerable part of the liberated gas would be absorbed by the down-rushing water, and even though the air might not be rendered respirable in this way, something would surely be gained in the way of checking the spread of the gas to other rooms. It is certainly important to provide free and abundant ventilation and adequate means for quick exit in connection with any room in which either gas may suddenly be liberated in quantity. These simple and evident precautions are often wholly disregarded in laying out plants in which ammonia or sulphur dioxide are handled or used.

29 Ammonia gas is usually pronounced incombustible and incapable of being exploded when mixed with atmospheric air, but research and experience have shown that this is not altogether true. A mixture of ammonia gas and air can be exploded if it contains from 16 to 27 per cent of ammonia, and some of the explosions that have occurred in our big refrigerating plants subsequent to the

liberation of considerable quantities of ammonia may possibly have been due to the ignition of mixtures of this kind by means of the arc lamps which have in most cases been in use in rooms where these accidents have occurred. The limits given, while not guaranteed to be the exact ones within which the explosibility exists, are at least approximately correct.

30 In compressing ammonia another source of danger must be carefully considered. If the ammonia gas that is undergoing compression is allowed to become unduly hot, the ammonia that comes away from the compressor will contain a notable quantity of combustible gas that is distinctly different from ammonia. This may come in some measure from the decomposition of the oil that is used in lubricating the compressor cylinder, but it also contains free hydrogen, which appears to be produced by the actual dissociation (or breaking up) of the ammonia into its component gases, nitrogen and hydrogen. We used to think of ammonia as being exceedingly stable and incapable of dissociating in this way to any sensible extent, but we now know that such is not the case. Dissociation occurs even at moderate temperatures, and it is likely to become quite significant when the temperature is high. To guard against the development of combustible decomposition products from the lubricating oil, it is important to use a special kind of oil which experience has proved to be well adapted to work of this kind; and to keep the dissociation of the ammonia itself within as low a limit as practicable, it is important to keep the gas as cool as possible by methods already outlined in connection with other gases. Finally, to guard against vapor explosions in case ammonia gas should escape into the air in considerable quantity, it is important to take the same precautions against ignition sources that have been suggested in connection with hydrogen.

CHLORINE

31 Liquid chlorine is now shipped in vast quantities, for use in connection with bleaching, and for many other purposes. It has been greatly feared by the general public ever since it was used as a military gas in the war, but in time of peace this fear is hardly justifiable. Chlorine is exceedingly irritating, and it can produce unconsciousness and even death if inhaled in any considerable quantity. It has been well described as an "honest gas," however,

the phrase meaning that it has no treacherous qualities. We always know exactly what it will do. When the air on a battlefield was heavily charged with chlorine, there was no place to go in order to be rid of the gas; but in a manufacturing plant, or in a plant in which chlorine is compressed, immediate relief can be had, in case of leakage, by merely leaning out of an open window or going out of the room. It is not desired to underrate the dangers associated with handling liquid chlorine, yet it is only fair to say that they have been largely exaggerated. The gas is far from being like St. George's dragon, and it even has some redeeming features. If a cylinder or a tank containing liquid chlorine bursts or springs a leak, for example, the evaporation that takes place rapidly chills the liquid still remaining in the tank, so that the evolution of gas is quickly and automatically checked, though not wholly stopped. Abundant ventilation is important in a chlorine plant and special attention should be given to the exits, so that if the gas becomes accidentally liberated in considerable quantity the men can pass out into the open air as quickly and directly as possible.

32 Chlorine must be carefully dried before compression, because if it is moist it will corrode the pump, piping, and tanks. Perfectly dry chlorine, on the other hand, has practically no action upon iron. The drying is effected by passing the gas through towers filled with pumice wet with concentrated sulphuric acid. In liquefying the gas by means of a compression pump the main difficulty to be overcome is keeping the piston gas tight in the compression cylinder. A special form of packing is required for this purpose, and it should be designed and installed by some person who understands the necessities thoroughly. In one compression plant visited by the author there are seven sealing rings on the piston — six soft and hard packings of special chlorine-resisting material being used, while the middle space is filled with strong sulphuric acid which not only completes the seal but also serves to lubricate the cylinder. The pressure required in chlorine tanks is not high, as the vapor pressure of liquid chlorine is only about 120 lb. per sq. in., at 70 deg. fahr.; and even when a chlorine tank has been left standing in the sun for a considerable time, the pressure will hardly ever creep up as high as 160 lb. per sq. in. In liquefying this gas the compression is therefore performed in one operation. Tanks and other apparatus used in handling or storing

chlorine must be clean and free from all other substances — solid, liquid, or gaseous — with which the chlorine might combine.

33 In conclusion, there is one general suggestion relating to safety-valves which applies to all gases. Some engineers discourage the use of safety valves on gas-compressing apparatus, partly because the escape of gas through them is a source of waste, and partly because it creates a special hazard, when the gases are toxic or inflammable. But it is not necessary to liberate the escaping gas at or near the work place, and it can often be discharged where it will not constitute a hazard to property. Hence this objection is not altogether well founded. In fact, relief valves should be provided in all cases, and the discharge problem should be considered on its own merits in each individual plant. It is often, and perhaps usually, practicable to have the discharge delivered back into the piping system on the low-pressure side of the compressor, so that there is no economic loss, and no hazard to the men nor to property.

DISCUSSION

Frank Creelman. Acetylene, unlike the other gases considered in this paper, can be exploded without the addition of air or any other gas. This is caused when the temperature is raised sufficiently to cause it to decompose into its constituents, hydrogen and carbon. This decomposition is accompanied by a great evolution of heat which expands the hydrogen, thus causing an increase of pressure.

If the initial pressure of the acetylene is less than 30 lb. gage, and the gas is ignited by heating a spot in the metal container red hot or by introducing an electric spark into the gas inside of the container, only a small amount of the gas, that close to the ignition point, will decompose, and the heat evolved and the pressure caused by this heat will be relatively small, while if the initial pressure is much above the 30 lb. gage pressure the ignition will be propagated through the entire quantity of gas practically instantaneously with great evolution of heat and rapid and great rise of pressure; in fact it detonates.

Dissolving acetylene in acetone does not prevent the detonation of high-pressure acetylene, but if the container is entirely filled by a porous solid, the pores only containing the dissolved acetylene, the decomposition stated as above will be only local, that is, will not be propagated throughout the mass and no harm will result.

Care, however, must be taken to see that no large voids occur in the container, due either to carelessness in the original placing of the porous material in the container, or to its settling together later, thus leaving voids. If these voids are present the entire gas contents can be detonated.

The real advantage of dissolving acetylene in acetone is that with the proportions of porous material and acetone which is usually placed in the containers, a container holding the gas at any given pressure (say 150 lb. per sq. in.) will hold approximately ten times the amount of acetylene that the same container would hold of the gas (at the same pressure) alone without any porous material or acetone.

There is no evidence whatever that polymerization (cracking) takes place in stored acetylene at ordinary temperatures, even for long-time storage; all experience is to the contrary.

The writer has had many years' experience with compressed acetylene, and would like to say there is no evidence whatever of any such action; in fact, all of our experience is to the contrary, except possibly when the gas compound is compressed to such a high pressure as to be near the critical point of liquification. But no commercial concern today, with the knowledge they have, will attempt to compress gas up to any such point. The gas under these conditions is so very dangerous as to be not fit for any commercial use whatever.

Dr. Risteen also states that the storage of acetylene by this system is the only safe method of keeping it for long periods of time. That does not agree with practice. The dissolved acetylene system is not the only safe system of storing acetylene under pressure. Mr. Max Toltz devised a very safe system which was used extensively by two of our largest railway companies, for many years, with perfect safety from explosions. As a matter of fact, the writer's experience is that it is a little safer than the other.

Dr. Risteen says in compressing acetylene the speed of the pump should be very slow. That is not entirely necessary. In compressing acetylene the speed of the pump has no effect on the gas except in so far as it increases the temperature of the gas. This gas temperature is the limiting feature, so that if the gas is compressed in a sufficient number of efficiently cooled stages, with inter-coolers, also an after cooler (this last is very important) so that the gas temperature does not rise in the hottest spot above, say, 300 deg. fahr., the compressor can be run safely at any speed consistent with these requirements. A sufficient number of good thermometers should be located in the gas passages of the compressor at suitable points to enable the operator to keep track of the temperatures, so that he can shut down promptly before dangerous temperatures are reached.

The compressor should never be allowed to run unless the operator is in the compressor room.

Mayo D. Hersey. May I call attention to the fact that the Bureau of Mines is undertaking a series of investigations on oxygen explosions? That is being done at Pittsburgh. We are to make experiments to show the limiting temperatures and pressures, kind of oil, etc., which determine these explosions, quantitatively.

For our guidance, we shall be glad to be put in communication with all persons having experience with compressed oxygen explosions, particularly where lubricating oil was present, and it may be added that our survey, thus far, strongly corroborates the importance of the precautions suggested by Dr. Risteen.

E. P. Warner. The writer was particularly interested in what Dr. Risteen has said about the use of tetraethyl lead as a means of retarding detonation in acetylene tanks, because of its connection with the use of the same material in a very different field. The General Motors Research Corporation, after several years of work, has added tetraethyl lead as the latest stage in the development of an anti-knock compound for internal combustion engines. The addition of one cubic centimeter of this chemical to every gallon of gasolene is a practically absolute preventative of knock, even in high-compression engines under very unfavorable conditions, as was demonstrated by Mr. Midgley at last summer's meeting of the Society of Automotive Engineers. There is no doubt that the action in the retarding of the production of flame in the burning gasolene vapor mixture in the cylinder is exactly comparable to that in retarding the explosion in the acetylene cylinder.