

saturated and unsaturated hydrocarbons of the naphthenic or polynuclear type, and, to a limited extent, of paraffins and aromatic hydrocarbons.

The authors have made careful determinations of viscosity by a modified form of Ostwald apparatus, and discuss lubricating value in terms of this property and chemical composition. The desideratum for a lubricant appears to be low viscosity and good lubricating power, as the lubricant is concerned in the transformation of solid into liquid friction. On the other hand, the mysterious property known as "body"—that is, the power of maintaining a film (or film strength) between shaft and bearings—is a vital factor. This property of body seems to depend on surface tension, and is not necessarily dependent on viscosity, but appears to be connected with molecular weight. The possible iso-colloid nature of heavy oils in explaining high viscosity is considered, and the view is put forward that if this is the true nature of such oils, the film strength may depend upon the relation of the two phases present in the oil.

The following are some of the authors' general conclusions:—Paraffinoid oils, though highly stable, have little lubricating value, and the smaller the hydrogen content, the greater the viscosity and durability; it is the polynuclear naphthenes, especially the unsaturated components, which confer viscosity and film strength; the higher fractions of petroleum contain such unsaturated members, which, when removed, exhibit lower density, lower viscosity, higher molecular weight, and, generally, lower lubricating value.

It appears, then, that the true lubricant is an unsaturated compound possessing the characteristic attributes of such compounds, and this applies not only to hydrocarbons, but also to fatty oils, such as rape, castor, and olive oil; in other words, unsaturation is a feature of chemical activity which, in addition to colour, taste, smell, and physiological properties, manifests itself in lubricating value. Moreover, the colloidal condition of a good lubricant may also have to be taken into consideration.

The whole subject of liquid lubricants is an important one, and in the above brief summary the authors have brought forward a contribution of a highly suggestive character, which emphasises very clearly the necessity for further comprehensive and detailed study.

STATISTICAL METHODS APPLIED TO PRACTICAL PROBLEMS.

WE have received a copy of the presidential address delivered before the Indian Science Congress at Lahore in January last by Sir G. T. Walker, Director-General of Observatories, India (Calcutta: Thacker, Spink, and Co.). The bulk of the address is devoted to illustrating the application to important practical problems of statistical methods. Illustrations are given of the use of coefficients of correlation in connection with crop prediction, and also to show the extent of co-variation between the fever rate, population, cost of rice, cultivated area, and rainfall, so far as this can be determined by a first-degree regression equation computed from the data of twenty-five years.

An interesting point is the apparently close association between an increase of population and an increase of fever. Sir G. T. Walker observes that this "is so directly opposed to widely accepted medical ideas that for some months I did not treat it seriously. But on my informing Major McKendrick, of Kasauli, of it he urged me not to reject it lightly, and directed my attention to some analysis of his which would suggest an explanation. I have therefore examined the corre-

sponding relationship for all the ten provinces of India for which sufficient data are available, and have not found a single negative coefficient. The average value is +0.5. For those of you who are interested in sanitary matters I may briefly explain that the spread of malaria among men depends upon the meeting of healthy men with infected mosquitoes, and the spread among mosquitoes on the encounters between infected men and healthy mosquitoes; hence the relations are symmetrical from the mathematical, if not the æsthetic, point of view, and an increase in the number of men has essentially the same bad effect as an increase in the number of mosquitoes."

In view of the work which has been done upon the method of variate difference correlation during recent years, it would be of interest further to explore the association by the new method. Statisticians in this country will appreciate the concluding passage of Sir G. T. Walker's address:—"I hope that statistical methods may before long be recognised as essential for efficiency for the following reasons. First, a table of data covering, say, fifty years gives any intelligent man the same advantage as if he had carefully watched the conditions for fifty years and had a perfect memory; secondly, employing a draughtsman to plot these data will suggest relationships in a manner which would otherwise require profound study of the figures; and thirdly, employing a clerk to work out the correlation coefficients and regression equation will give him without effort trustworthy information about their relationships which will distinguish direct from indirect effects, and could be got in no other way."

METHODS OF GAS WARFARE.

THE issue of the Journal of the Washington Academy of Sciences for February 4 last includes a report of a lecture by Prof. S. J. M. Auld, of the British Military Mission, on "Methods of Gas Warfare," delivered before the Academy. Naturally in the lecture, which is here summarised, attention is confined to a description of what the Germans have been doing; nothing is said of the activities of the Entente Powers in this direction.

The first gas attack was made by the Germans in April, 1915, and the whole method of the war was changed. The attack was made, of course, against men who were entirely unprepared—absolutely unprotected. The Germans expected no immediate retaliation, as they had provided no protection for their own men. A clear and unobstructed gap in the lines was made, which was only closed by the Canadians, who rallied on the left and advanced, in part through the gas-cloud itself.

The method first used by the Germans is simple, but requires great preparation beforehand. A hole is dug in the bottom of the trench close underneath the parapet, and a gas cylinder is buried in the hole. It is then covered first with a quilt of moss containing potassium carbonate solution, and then with sand-bags. When the attack is to be made the sand-bags are taken off the cylinder, and each cylinder is connected with a lead pipe which is bent over the top of the parapet. A sand-bag is laid on the nozzle to prevent the back "kick" of the outrushing gas from throwing the pipe back into the trench.

The attackers must know the direction and velocity of the wind with certainty. Favourable conditions are limited practically to wind velocities between twelve and four miles an hour. A wind of more than twelve miles an hour disperses the gas-cloud very rapidly. An upward current of air is the worst foe of gas. If the trench line is very irregular it is likely that gas will flow into a portion of one's own trenches. The

Germans use a 40° angle of safety; that means that on a given straight portion of the front the wind direction must lie between the two directions which make angles of 40° with the neighbouring sections of the front. The most suitable type of country is where the ground slopes gently away from where the gas is being discharged. If the country is flat like that about Ypres, and the wind direction is right, there is little difficulty about making an attack. German gas attacks are made by two regiments of pioneers, with highly technical officers, including engineers, meteorologists, and chemists. The first attack was made with chlorine. If a gas attack is to be made with gas-clouds, the number of gases available is limited. The gas must be easily compressible, easily made in large quantities, and should be considerably heavier than air. If to this is added the necessity of its being very toxic and of low chemical reactivity, the choice is practically reduced to two gases: chlorine and phosgene. Pure chlorine did not satisfy quite all the requirements, as it is very active chemically and therefore easily absorbed.

The first protection was primitive. It consisted largely of respirators made by women in England in response to an appeal by Lord Kitchener. Then came the helmet made of a flannel bag soaked in thiosulphate and carbonate, with a mica window in it. A modified form of this device with different chemicals is still used in the British Army as a reserve protection. The outcome of attempts to counteract the effects of phosgene was a helmet saturated with sodium phenate. The concentration of gases when used in a cloud is small, and 1 to 1000 by volume is relatively very strong. The helmet easily gave protection against phosgene at a normal concentration of 1 part in 10,000.

The element of surprise came in an attack by night. The meteorological conditions are much better at night than during the day. The best two hours out of the twenty-four, when steady and downward currents exist, are the hour between sunset and dark and the hour between dawn and sunrise. Gas attacks have therefore been frequently made just in the gloaming or early morning, between lights. This took away one of the easy methods of spotting gas, that of seeing it, and we had to depend upon the hissing noises made by the escaping gas, and upon the sense of smell.

Another element of surprise was the sending out of more than one cloud in an attack. After the first cloud the men would think it was all over, but ten minutes or half an hour later there would come another cloud on exactly the same front. Efforts were also made to effect surprise by silencing the gas. But silencers reduced the rate of escape so greatly that the loss of efficiency from low concentration more than made up for the gain in suddenness. Another method was to mix the gas up with smoke, or to alternate gas and smoke, so that it would be difficult to tell where the gas began and the smoke ended.

There was a long search for materials that would absorb phosgene. The substance now used very extensively is hexamethylenetetramine (urotropine), $(\text{CH}_2)_6\text{N}_4$, which reacts very rapidly with phosgene. Used in conjunction with sodium phenate, it will protect against phosgene at a concentration of 1:1000 for a considerable period. An excess of sodium hydroxide is used with the sodium phenate, and a valve is provided in the helmet for the escape of exhaled air.

A high concentration for a gas-cloud is 1 part in 1000, whereas concentrations of 2 or 3 per cent. can be met by respirators depending on chemical reactivity. One such respirator is a box of chemicals connected by a flexible tube with a face-piece fitting around the contours of the face, and provided with a mouthpiece and a nose-piece. As regards the chemicals used there is

no secret, for the Germans have many of the same things. Active absorbent charcoal is one of the main reliances, and is a suggestion that we owe to the Russians. Wood charcoal was used in one of their devices and was effective, but most of the Russian soldiers had no protection at all. We wanted to protect against chlorine, acids and acid-forming gases, phosgene, etc., and at one time were fearful of meeting large quantities of hydrocyanic (prussic) acid (HCN). The three things that then seemed most important were:—(1) Chlorine and phosgene; (2) prussic acid; (3) lachrymators. Charcoal and alkaline permanganate will protect against nearly everything used, even up to concentrations of 10 per cent. for short periods.

As regards the future of the gas-cloud, it may be looked upon as almost finished. The case is different with gas shells. The gas shells are the most important of all methods of using gas on the Western front, and are still in course of development. The enemy started using them soon after the first cloud attack. He began with the celebrated "tear" shells. The original tear shells contained almost pure xylol bromide or benzyl bromide, made by brominating the higher fractions of coal-tar distillates. The German did his bromination rather badly. It should be done carefully or much dibromide is produced, which is solid and inactive. Some of the shells contained as much as 20 per cent. dibromide, enough to make the liquid paste and inactive.

When the Germans started using highly poisonous shells, the substance used was trichloromethyl-chloroformate, but not in great strength.

The use of gas out of a projectile has a number of advantages over its use in a gas-cloud. First, it is not so dependent on the wind. Secondly, the gunners have their ordinary job of shelling, and there is no such elaborate and unwelcome organisation to put into the front trenches as is necessary for the cloud. Thirdly, the targets are picked with all the accuracy of artillery fire. Fourthly, the gas shells succeed with targets that are not accessible to high explosives or to gas-clouds.

Among the effective materials used by the Germans for gas shells were mono- and tri-chloromethyl-chloroformate. Prussic acid never appeared; the Germans rate it lower than phosgene in toxicity, and reports concerning it were obviously meant merely to produce fear and distract the provisions for protection.

During the last months of 1917 the actual materials and the tactics used by the Germans have undergone a complete change.

One substance used for the method of simultaneously harassing and seriously injuring was dichlorodiethylsulphide (mustard gas). It has a distinctive smell, rather like garlic than mustard.

Up to the present time there has been no material brought out on either side that can be depended on to go through the other fellow's respirator. The casualties are due to surprise or to lack of training in the use of masks. The mask must be put on and adjusted within six seconds, which requires a considerable amount of preliminary training, if it is to be done under field conditions.

Among other surprises on the part of the Germans were phenylcarbylamine chloride, a lachrymator, and diphenylchloroarsine, or "sneezing gas." The latter is mixed in with high-explosive shells, or with other gas shells, or with shrapnel.

As regards the future of gas shells, it should be emphasised that the "gas shell" is not necessarily a gas shell at all, but a liquid or solid shell, and it opens up the whole sphere of organic chemistry to be drawn upon for materials. The material placed inside the shell is transformed into vapour or fine droplets by the explosion, and a proper adjustment between the bursting

charge and the poisonous substance is necessary. Both sides are busy trying to find something that the others have not used, and both are trying to find a "colourless, odourless, and invisible" gas that is highly poisonous. It is within the realm of possibilities that the war will be finished, literally, in the chemical laboratory.

The following compounds have been used by the Germans in gas-clouds or in shells:—

1. Allyl-*iso*-thiocyanate (allyl mustard oil), $C_3H_5.NCS$ (shell).
2. Benzyl bromide, $C_6H_5.CH_2Br$ (shell).
3. Bromo-acetone, $CH_2Br.CO.CH_3$ (hand grenades).
4. Bromated methylethyl-ketone (bromo-ketone) $CH_2Br.CO.C_2H_5$ or $CH_3.CO.CHBr.CH_3$ (shell). Di-bromo-ketone, $CH_3.CO.CHBr.CH_2Br$ (shell).
5. Bromine, Br_2 (hand grenades).
6. Chloro-acetone, $CH_2Cl.CO.CH_3$ (hand grenades).
7. Chlorine, Cl_2 (cloud).
8. Chloromethyl-chloroformate (palite), $CICOO.CH_2.Cl$ (shell).
9. Nitrotrichloromethane (chloropicrin or nitro-chloroform), CCl_3NO_2 (shell).
10. Chlorosulphonic acid, $SO_3.H.Cl$ (hand grenades and "smoke pots").
11. Dichlorodiethylsulphide (mustard gas), $(CH_2Cl.CH_2)_2S$ (shell).
12. Dimethyl sulphate, $(CH_3)_2SO_4$ (hand grenades).
13. Diphenylchloro-arsine, $(C_6H_5)_2AsCl$ (shell).
14. Dichloromethyl ether, $(CH_2Cl)_2O$ (shell).
15. Methylchlorosulphonate, CH_3ClSO_3 (hand grenades).
16. Phenylcarbylamine chloride, $C_6H_5N.CCl_2$ (shell).
17. Phosgene (carbonyl chloride), $COCl_2$ (cloud and shell).
18. Sulphur trioxide, SO_3 (hand grenades and shell).
19. Trichloromethyl - chloroformate (diphosgene, superpalite), $CICOO.CCl_3$ (shell).
20. Xylyl bromide (tolyl bromide), $CH_3.C_6H_4.CH_2Br$ (shell).

CRYSTALS OBTAINED FROM GLASS FURNACES.

MR. G. V. WILSON has studied the materials obtained from glass furnaces of the tank type making bottle glass, where, by a rupture of the tank, the glass has flowed out and has been allowed to crystallise slowly, and he described his results to the Society of Glass Technology on April 17. He finds that crystals of wollastonite form in great numbers, partly arranged in spherulitic groups of long diverging crystalline fibres, partly as separate rod-shaped crystals with well-defined faces. Tridymite occurs also in flat hexagonal plates, very thin, but showing the polarisation in sectors which is so characteristic of this mineral. He has also observed quartz as double hexagonal pyramids in places where veins of glass have eaten their way into the bricks which make the walls of the tank; and manganese augite, of purplish-brown colour, only in parts of the glass where an excess of manganese oxide has existed through imperfect mixing of the ingredients of the batch.

Fragments of limestone, probably in part magnesian, occurred in the glass, imperfectly dissolved and showing recrystallisation through contact alteration and admixture with silica and other elements of the glass. These have a granular crystalline structure except where veins of glass penetrate into them. The new minerals produced are wollastonite, augite (golden-yellow, in small prisms), melilite, and probably a silicate of lime ($3CaO, 2SiO_2$).

The vault of the furnace consists of firebrick, and

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is covered with a fused glassy layer, from which stalactites hang down, and drops of molten matter must have been falling into the glass below. The zone of altered brick is about an inch thick, and two layers can be detected in it—an outer glassy stalactitic layer containing much corundum and a little sillimanite in a glassy matrix, and an inner white layer looking very like white porcelain to the naked eye. This inner layer is richly charged with sillimanite needles.

The external surface of glass pots also contains very well formed crystals of sillimanite and sometimes also magnetite and corundum. The inner surface of old glass pots often shows much sillimanite embedded in clear glass, and where the cooling has been slow. Biotite and oligoclase also make their appearance.

Mr. Wilson regards as important the presence of volatile fluxes, such as soda, given off by the heated glass. These combine with the alumina and silica of the clay, forming glassy alkali-alumina-silicates which are comparatively fusible, and serve as a medium in which corundum, sillimanite, and other minerals are crystallised. The corrosion of the glass pots is due largely to the action of this alkali-alumina-silicate melt eating its way deeper and deeper into the clay.

THE CARNEGIE INSTITUTION OF WASHINGTON.

THE Year Book for 1917 of the Carnegie Institution of Washington has now reached us in its complete form. Attention has already been directed to the report of the president of the institution with which the Year Book, which was published previously separately, opens, and the opportunity provided by the receipt of the complete volume may be taken to refer to the financial records of the institution. During the year ending October 31, 1917, the total financial receipts of the institution reached 285,120*l.*; of this amount 220,100*l.* represented interest on endowment, 20,100*l.* interest on deposits in banks, and 35,000*l.* amounts derived from miscellaneous sources. The total of the yearly incomes of the institution since its foundation in 1902 amounts to 2,886,665*l.*

The income of 1917 was expended in the manner shown in the following table:—

	£
Investment in bonds	101,100
Large projects	139,160
Minor and special projects	19,500
Publications	12,600
Administration	9,800
Total	282,160

The departments of investigation to which the larger grants were made by the trustees of the institution are shown below:—

	£
Botanical research	8,686
Embryology	6,954
Experimental evolution	11,386
Geophysical laboratory	20,302
Historical research	7,090
Marine biology	3,980
Meridian astronomy	6,231
Nutrition laboratory	9,227
Publications	2,280
Solar observatory	35,509
Terrestrial magnetism	28,441
Total	140,086

The publication of twenty-five volumes was authorised during the year at a cost of 13,000*l.*