one of difficulty; and it may be said that it has not yet been solved. The most serious effort yet made was the building of a granary on the banks of the Thames, known, we believe, as the Patent Ventilating Granary. This granary was referred to during the discussion by Mr. Percy Westmacott, so long the chief of the hydraulic department at Armstrong's. The patent ventilating arrangement consisted of a perforated tube running down the centre of each bin. This was provided with a movable stop or plug, and, by adjusting the height of the stop, a blast of air could be directed through the perforations of the tube into any part of the grain. The idea was of French origin, and, Mr. Westmacott said, more ingenious than practical, so that the granary was pulled down after a time. It is easy to understand that those parts of the grain which required most ventilation would form into hard lumps, into which the air would not penetrate. As a matter of fact it is found more advantageous to air the grain by giving it a constitutional over the carrying bands.

Prof. Hele Shaw's paper on his experimental engine and alternative centre-testing machine was one of great interest. The engine in question, which is described as a marine engine, though it has a large fly-wheel, is, we believe, the most elaborate from an experimental point of view, yet made. The question has been raised whether it is not too elaborate, so that satisfactory results will not be reached on any one point. That is a problem which remains to be proved by facts; for the engine has only just been erected. It is 150 horsepower, and is of the ordinary vertical three-cylinder three-stage compound type. The high-pressure and intermediate cylinders have cylindrical valves, and the low pressure has a flat valve. Each valve is worked by a different type of motion—namely, ordinary Stephenson link motion, Joy gear, and Hackworth gear. The cylinders are jacketed at sides and ends, and there are provisions in the way of connections for working in every possible manner, *i.e.* cylinders all jacketed, not jacketed at all, or any one or two jacketed. Any combination of cylinders can be worked, or any one cylinder alone. In addition to this the cranks are adjustable on their shaft, so that any combination can be got in this way; in short, the number of different combinations that are at command would require years to work through. There are the usual measuring tanks and other apparatus for quantitative tests. An excellent suggestion was made by Prof. Goodman during the discussion. He proposed that arrangements should be made for testing the students' knowledge by putting the engine into conditions not in accordance with proper design. For instance, he would have valve-rods or excentric rods of improper length, valves ill-set with improper lap or lead, leaky valves and pistons, and various other ills, to which engines are subject, purposely introduced. He would also provide a means of passing water into the cylinders. He would then have the student take diagrams from the engine, and leave him to determine the cause of the defect by the appearance of the cards. We hope Prof. Goodman will be able to follow up this useful suggestion in his own laboratory at Leeds. The alternative testing machine is a 100-ton single-lever machine of the Wicksteed type. The alteration in power is got by substituting one fulcrum for another a few inches distant. The mechanism by which this is done is ingenious, but the details would be difficult to explain without the aid of diagrams.

The last paper read at the meeting was that of Mr. Leader Williams. The author commenced by saying that 46½ million cubic yards had to be excavated in making the Manchester Ship Canal, and as only 17,000 men and 200 horses have been used there was evidently required a large power in the shape of mechanical appliances in order to get the work done in anything like reasonable time. Ninety-seven steam excavators and eight steam dredgers of large power have been employed; and the spoil has in most cases been taken a distance of several miles. For this work, and for the general purposes of construction, 173 locomotives and 6300 trucks and waggons have been used. The railways laid for the purpose amount to 228 miles of single line. The rate of excavation has varied from three-quarters of a million to 1½ million cubic yards per month. There are also employed on the works 124 steam-cranes, 192 portable and other steam-engines, and 212 steam-pumps. The coal consumed by the engines is about 10,000 tons a month. These figures will give some idea of the heroic proportions upon which large constructive works are carried out, and the capital required to start them. The whole plant of the Manchester Ship Canal has cost, we believe, close on a million sterling. The machines described in the

paper which were of greatest interest were the excavators. The chief of these is the now well-known "steam navy," made by Ruston and Proctor, of Lincoln. It first came prominently into notice during the construction of the Albert Docks, and is looked on as a standard tool wherever large excavating work is undertaken. It has the immense advantage of being able to work in any kind of soil, even including sandstone rock, if not very hard. It is only in hard rock that blasting has to be done as an auxiliary. The most interesting, or, perhaps, we should say the most novel machines are the French and German excavators, or land dredgers, which have been introduced into this country for the first time in connection with this work. These are on the same general principle as a floating ladder and bucket dredger of the common type. In place of the ladder and motive machinery being held by a floating hull, there is a small house mounted on wheels, and this runs on a line of rails on the summit of a bank. The ladder slopes outward from the side, reclining on the bank, which the buckets scrape away as they traverse, and deposit the spoil in waggons on the bank above. There are differences in detail between the French and German types, but in general principle they are alike. The German machine appears to us the better designed, but Mr. Leader Williams says the French excavator is of more substantial construction. The weight of these machines is from 70 to 80 tons, and under favourable conditions they have been known to excavate the enormous bulk of 2400 cubic yards in one working day. Mr. Williams's paper was not discussed, which is a fact to be regretted by engineers, as the subject is one which requires ventilation; but time was running short. After the usual votes of thanks, the sittings of the meeting were brought to a close.

We can only add a few words about the excursions. On the Tuesday there was a lunch on board the big White Star liner the *Majestic*, for one section of the members; whilst others visited the grain warehouse, described by Mr. Shapton in his paper, and the new overhead railway, which has been designed by Mr. Greathead, the Engineer of the City and South London Railway, and which runs along the line of docks. This railway is of steel and iron throughout, and possesses the novel advantage of forming a water-tight roof, under which the people of Liverpool will be able to walk on rainy days without getting wet. In the evening there was a *conversazione*, which, of course, was the social feature of the meeting. On Wednesday afternoon the members visited the new engineering laboratories which have been added to University College, Liverpool, where the engine and testing machine described in Prof. Hele-Shaw's paper were examined. On Thursday one party visited the Mersey Docks, the Mersey Tunnel, and Laird Bros.' ship-yard and engine works. At the latter there are several interesting vessels in progress, including the big battle ship *Royal Oak*, of 14,000 tons. Another party went to Horwich, and saw the fine locomotive works which have just been completed there by the Lancashire and Yorkshire Railway. These works have been beautifully planned and laid out under the superintendence of Mr. Aspinall. Although not so large as some other establishments of a similar kind, they may be taken as a model of design. Mr. Aspinall naturally had a unique opportunity with a clear field to work upon, and an accumulated experience at his command. Friday, the last day, was devoted wholly to the Manchester Ship Canal, the members being carried down the line of works in a special train, under the guidance of Mr. Leader Williams.

THE NEW GAS, CHLOROFLUORIDE OF PHOSPHORUS.

AS briefly announced in the report of the proceedings of the French Academy of Sciences, a note upon a new gaseous compound, containing phosphorus, fluorine, and chlorine, has just been presented by M. Moissan, on behalf of M. Poulenc. During the course of his work upon the fluorides of phosphorus, M. Moissan observed that, when phosphorus trifluoride was brought in contact with chlorine, the green colour of the latter at once disappeared, and there appeared to be formed a new and colourless gas. The gas thus formed has been prepared in considerable quantity by M. Poulenc, and its properties investigated. It appears to be directly formed by addition, according to the simple equation—

for the trifluoride of phosphorus and chlorine are found to react in equal volumes, and the combination is attended by a contraction of one-half. The new gas may therefore be considered as phosphorus chlorofluoride, PCl_2F_3 , the chlorine derivative of phosphoryl and thiophosphoryl fluoride, POF_3 and PSF_3 .

The most convenient mode of preparation is described as follows. Two flasks of equal capacity (about 500 c.c.) are taken, and filled respectively with phosphorus trifluoride and chlorine. They are connected together by a bent tube passing through the stoppers, and the flask containing the phosphorus trifluoride is further connected with a reservoir of mercury in such a manner that a gentle pressure may be placed upon the trifluoride, so as to gradually displace it over into the chlorine. The two flasks being of equal capacity, it is evident that, when the whole of the trifluoride has thus been transferred, the reaction is completed, the green colour of the contents of the other flask disappears, and the remaining gas is almost pure chlorofluoride. After allowing to stand a few days in contact with the mercury, in order to remove the last traces of chlorine, the gas is ready for examination.

Phosphorus chlorofluoride is a colourless incombustible gas, possessing a powerfully irritating odour. It is instantly absorbed and decomposed by water and by solutions of alkaline or alkaline earthy hydrates. A determination of its vapour-density gave the number 5.40, sufficiently near the theoretical density of a substance PCl_2F_3 (5.46). It is comparatively easily liquefied, a temperature of -8°C . being sufficient at ordinary pressures. It is dissociated at a temperature of 250°C . into gaseous pentafluoride and solid pentachloride of phosphorus. The induction spark effects the same decomposition.

Sulphur reacts with phosphorus chlorofluoride in a most interesting manner. The reaction commences about the melting-point of sulphur, 115°C ., and the products are chloride of sulphur and gaseous thiophosphoryl fluoride, PSF_3 . And here a most emphatic protest must be made against the manner in which many French chemists persistently ignore the work of the chemists of other countries. Thiophosphoryl fluoride, PSF_3 , was discovered and prepared three years ago in the Research Laboratory of the Royal College of Science, South Kensington, by Prof. Thorpe and Mr. J. W. Rodger; and a detailed account, illustrated by experiments, of the mode of preparation and properties of this remarkable gas, was laid before the Chemical Society and published in their Journal.¹ And yet, in the memoir just presented by M. Moissan, we find this compound, a description of which long ago found its way into the abstracts or *résumé* of most foreign journals, described as "un nouveau composé gazeux." Indeed, a considerable amount of unnecessary trouble appears to have been taken in order to ascertain the composition of this "new gas"—trouble which, as the compound is so readily recognizable by its extraordinary properties, might have been saved, if the author had taken the pains to look up the literature of the subject. It is high time that French chemists should look to their "prestige" in this respect, for, unfortunately, the present is by no means the only case which has within the last few months come before the notice of the writer of this note, in which compounds fully described and worked out by English chemists have been rediscovered and described as new by French authors.

When phosphorus chlorofluoride is passed over free phosphorus heated to 120° , it is decomposed with formation of phosphorus trifluoride, which passes away as gas, and phosphorus trichloride, which condenses in liquid drops. Metallic sodium, when slightly heated, appears to absorb the chlorofluoride entirely, while magnesium, aluminium, iron, nickel, lead, and tin, when heated to about 180° , attack the gas with formation of anhydrous chlorides and liberation of phosphorus trifluoride. Mercury attacks it very slowly at the ordinary temperature, but very rapidly at 180° , with formation likewise of a chloride of the metal and gaseous trifluoride of phosphorus. Hence, when purifying the gas from the last traces of chlorine, the mercury should not be agitated, but allowed to remain at rest, as agitation brings about a perceptible amount of decomposition.

Water reacts in two stages with phosphorus chlorofluoride. When a little aqueous vapour is admitted into the vessel inclosing the gas, phosphoryl fluoride and hydrochloric acid are formed in accordance with the equation—

When passed into water, however, the gas is completely

decomposed into phosphoric, hydrochloric, and hydrofluoric acids—

Ammonia gas reacts at the ordinary temperature with production of a white solid compound, readily soluble in water, which appears to be fluophosphamide, $\text{PF}_3(\text{NH}_2)_2$.

Phosphorus chlorofluoride is absorbed by absolute alcohol with production of a compound possessing a penetrating odour, and which burns with a bright flame bordered with green, and leaves a white residue of phosphoric acid. The nature of this compound has not yet been fully ascertained.

These properties of phosphorus chlorofluoride indicate that the gas is much less stable than the pentafluoride, and that the two atoms of chlorine possess a mobility which renders their removal a matter of considerable ease.

A. E. TUTTON.

PROF. MENDELEEFF ON THE VARIATION OF THE DENSITY OF WATER AT DIFFERENT TEMPERATURES.

THE last number of the Journal of the Russian Physical and Chemical Society (1891, No. 5) contains an important paper, by Prof. Mendeleeff, upon the variation of the density of water at different temperatures. In a work, published in 1884 and translated into English in the Journal of the Chemical Society, the Russian Professor proposed the formula $S_t = S_0(1 - kt)$ as a first approximation to a mode of expressing the expansion of liquids at a certain distance from the temperatures at which they change their state, and within the limits of accuracy attained in the present determinations. But he remarked that the expansion of water would require a separate formula, and he now proposes the formula

$$S_t = 1 - \frac{(t - 4)^2}{(A + t)(B - t)C},$$

which embodies, with sufficient accuracy, all that is yet known about changes in the density of water (S_t) within the limits of from -10° to $+200^\circ$. For all liquids save water, the increase of density with the increase of temperature, that is, the derived $\frac{ds}{dt}$, varies but little; it but slightly increases or slightly decreases with considerable changes of temperature; while for water, $\frac{ds}{dt}$ not only changes its sign

at $+4^\circ$, but very rapidly varies even at temperatures remote from zero, and even superior to 100° . After confirming the above by a few examples, Prof. Mendeleeff indicates the faint relations between his new formula for water and the general law of the expansion of liquids, by explaining the way in which he arrived at his new formula. He points out, moreover, that under the present state of the determinations of the density of water at various temperatures, it would be impossible to find exact figures for the constants A, B, and C, in the above formula, and that provisionally, and especially for temperatures between 0° and 40° , they may be taken as follows:— $A = 94.10$, $B = 703.51$, and $C = 1.90$.

Prof. Mendeleeff then goes on briefly to analyze the various corrections which ought to be taken into account in the determinations of the density of water; namely, the influence of pressure, the expansion of solids, and the measurements of temperature. All these being taken into account, it appears that the errors of the best determinations of densities attain several units in the fifth decimals, even at common temperatures. After many unsuccessful attempts at improving the current figures of densities by introducing into them several corrections, Prof. Mendeleeff abandoned the idea, and he now gives the authentic figures, as they were published by the investigators themselves, simply expressing all determinations in volumes for the sake of facilitating comparison. The figures published by Hallström (1823), Muncke (1828), Stampfer (1831), Despretz (1837), Pierre (1847), Kopp (1847), Plücker and Geissler (1852), Hagen (1855), Henrici (1864), Jolly (1864), Matthiessen (1865), Weidner (1866), and Rosetti (1869), are thus given in a first table. The figures, as they were corrected by Biot in 1811, Hallström in 1835, Miller in 1856, Rosetti in 1871, Volkmann in 1881, Mendeleeff in 1884, and Makaroff in 1891, are given in a second table.

The averages of the volumes of water derived from the original