

physics to ensure yields and technical figures beyond our present attainment, though it must be confessed that the present younger generation makes up in carelessness and indifference for any superiority in learning it may possess over its fathers.

Much of the chemical process-work is classed as light work, though certain operations, such as furnace work, involve heavy physical effort. The current practice is to divide the day into three shifts of eight hours, the shifts being relieved at 6 a.m., 2 p.m., and 10 p.m. The shifts change about at the week-ends, two of them usually working an extra half-shift, whilst the third shift has the week-end off. The former practice of running twelve-hour shifts with a full twenty-four hours' work at the week-end passed away finally at the instance of the Chemical Trade Joint Industrial Council, and, it is hoped, will never return.

Experience has shown that change in the shift does much to break down any monotony in the work; the men profit to the full from the daylight periods when they are off work, and most of them keep allotments or have other outdoor hobbies. In works where careful statistics of sickness are kept, there is no evidence that the shift men are better or worse in health than the day men. The week's holiday with pay which has long been a custom in the chemical industry—generally coupled with some condition as to good time-keeping—is also a factor in promoting the health of the employees.

Industrial fatigue is also reduced by another factor, namely, that in the course of a period of years in an old-established works most of the jobs on a chemical plant become filled by men who are temperamentally fitted for the particular work, the less suitable either throwing up the work themselves or being weeded out by the management. The vagaries of the plant provide as much or as little excitement in the daily routine as the worker prefers, so that the feeling of monotony—due so often to un congenial employment—does not arise. Moreover, it is only under very abnormal conditions, such as prevailed during the latter stages of the war, that the plants are run at such intensity as to cause actual overstrain of the workers.

The avoidance of the effects of industrial fatigue in such cases where repetition work does occur, as, for example, in packing into small tins, is not very difficult if ordinary common sense, plus a little science, be used. Long hours or prolonged periods without a rest are to be avoided, and good lighting and ventilation are especially necessary when chemicals are handled. The time at which juveniles start work should not be so early as to prevent them from obtaining a proper breakfast. The rest periods of a few minutes, so frequently advocated, are of doubtful utility, as the worker will take them of his or her own accord if the need be felt. When a process involves more than one operation worked by a team, a change-round should be made periodically.

Work requiring greater care, *i.e.*, more use of the intelligence, cannot be done as piecework, but must be paid for as daywork, a reasonable standard of quality and output being required. In a well-managed works with a large number of employees, workers will be specially selected for this purpose, and they will be found usually to represent a slightly better class socially, and to have had a better education than the mass of the workers. Under these conditions carelessness, the outward expression of industrial fatigue, will occur but rarely. As a general rule, repetition work of all kinds is better performed by girls than by boys; the whole nature and outlook of the latter is essentially foreign to such work, which for them is largely to be regarded as a blind-alley occupation, once the lesson of discipline and co-ordinated movement to be learnt from it has been acquired.

It is perhaps desirable to emphasise that to-day, owing to the short hours of employment and the general disinclination of the worker to exert himself, genuine industrial fatigue is very rare. A noticeable effect of the reduced hours in industry has been the tendency to undertake a second job and to misuse the increased leisure period; on its introduction individual workers exhibited greater fatigue and kept worse time than before.

The chemical industry, like other industries, has its occupational diseases, but the precautions necessary to minimise the risk of these, and to alleviate their effect, are, generally speaking, well-understood and properly enforced.

## THE MANUFACTURE OF TNT DURING THE WAR.\*

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The manufacture of TNT by the Ministry of Munitions affords a fascinating illustration of the evolution of a typical laboratory preparation in organic chemistry into a fully-fledged manufacturing process, yielding in its final stages over 1000 tons per week of the finished product. This evolution hinged very largely on a detailed physico-chemical study of the processes of nitration and purification. Thus, whilst on a small scale trinitration may be carried through in one operation and the finished product separated in a solid form, this method is extremely wasteful as a manufacturing process, since the acid used for nitration must be able to absorb all the water set free in the various stages and yet at the end be strong enough to effect the complete trinitration of the compound. This can only be done by the use of oleum, and it was largely to avoid this that the two-stage process of nitration was worked out. Again, when nitration has been completed, the mere precipitation of the finished product by drastic dilution with water is a crude and wasteful operation which could not be maintained in large-scale manufacture.

The actual process adopted was an ingenious device of nitration in two (or even three) stages, a conspicuous feature being the use of the less nitrated material, both to extract the more highly nitrated products from the waste acids and to utilise in the most effective way the nitric acid which they contained. Thus, in the first stage, toluene, or Borneo petroleum containing toluene, was used to extract the nitric acid and any partially nitrated toluene from waste acids resulting from "mononitration," after diluting to about 25 per cent. of water and cooling to 30° C.; this operation, which gave a product containing about 50 per cent. of MNT (commonly referred to as " $\frac{1}{2}$ NT"), was regarded as essentially an extraction rather than a nitration. In the second stage the " $\frac{1}{2}$ NT" was nitrated to about " $\frac{1}{3}$ NT" at about 50° C., the actual nitration being carried beyond the stage of mononitration in order to relieve the final stage of trinitration from some of the dilution consequent upon the introduction of a second nitro-group. For this nominal "mononitration" of toluene, the waste acid from "trinitration" was used, after diluting somewhat to precipitate the TNT and adding more nitric acid, *e.g.*, by using dilute nitric acid instead of water to effect the precipitation of the TNT. The final trinitration is by far the most difficult operation; the " $\frac{1}{3}$ NT" resulting from

\* Technical Records of Explosives Supply, 1915-1918. No. 2. Manufacture of Trinitrotoluene (TNT) and its Intermediate Products. Pp. 116. Ministry of Munitions and Department of Scientific and Industrial Research. (London: H.M. Stationery Office, 1920.) Price 17s. 6d. net.

the nominal "mononitration" was dissolved in 100 per cent. sulphuric acid and nitrated by adding mixed acid below 70° C., keeping for three hours at 70° C., and then heating to 110° C. during one hour and maintaining at this temperature for two hours more. After cooling to 80° C. only, so as to maintain the product as a liquid, the acid would retain in solution up to 30 or 40 per cent. of TNT. To return this to the earlier stages of nitration would be wasteful, and dilution to 15 per cent. of water was found to precipitate most of the TNT, whilst leaving the waste acids strong enough to effect the "mononitration." As already explained, the original detoxication of the waste acids by extraction with toluene became merged in a process of "mononitration" of toluene, which in its turn had already been partially nitrated in the same way at an earlier stage in the process.

The actual process of nitration is essentially an interrupted counter-current system. The ideal process is a real counter-current system in which toluene flows in at one end and escapes as TNT at the other, whilst mixed acid flows in the reverse direction and emerges as waste acid, stripped of all its nitric acid and carrying away with it all the water produced in the successive stages of nitration. It is of interest to know that this continuous process was actually developed, at least to the stage of converting MNT into TNT, and that it gave an almost miraculous production, a plant designed to produce 100 tons giving the amazing output of 500 tons per week. Under such conditions the chief problem to be faced was the supply of materials to satisfy the immense capacity of the plant.

During the mononitration of toluene about 4 per cent. of the hydrocarbon is converted into *m*-nitrotoluene, and on further nitration can only yield the less stable isomers of the symmetrical 2:4:6-trinitrotoluene. These, with imperfectly nitrated material, gave an impure product, the essential constituent of which (a quaternary eutectic of three isomeric forms of TNT with DNT) remained liquid at atmospheric temperatures. This liquid eutectic, when TNT was used alone or mixed with only an equal weight of ammonium nitrate, was liable to ooze through the screw-threads of a shell and was a fertile cause of premature explosions. Purification of the crude TNT was, therefore, an urgent necessity, although it involved a considerable loss of material. It was found that whereas crude TNT was liable to froth when mixed in the molten state with ammonium nitrate containing pyridine or thiocyanate, no frothing took place when the TNT was purified. The purification can be effected by crystallising out dinitrotoluene, but this is undesirable as it disturbs the normal course of nitration. Various methods involving the use of solvents were developed, many of them highly ingenious, *e.g.*, melting the TNT with a little phenol, and removing the impurities with the phenol in the form of a liquid eutectic by centrifuging after slow crystallisation, washing finally with water on the centrifuge to remove the phenol. Washing the coarsely crystalline "toffee" by grinding with alcohol was actually used on a very large scale in spite of the very serious fire-risk that it involved—a risk which fortunately never developed into a liability. But a final method of purifying was reached by making use of the mobility of one of the nitro-groups in the unsymmetrical TNT's, which could be replaced by a sulphonic group  $-\text{SO}_3\text{ONa}$ , merely by warming with sodium sulphite, thereby removing the two most important impurities in a form in which they were soluble in water. This process had the great advantage that it carried no fire-risk and could be carried on safely and conveniently as a part of the normal process of nitration, instead of being removed for safety to a distant factory, with all the disadvantages of transport, rehandling and repacking. It also removed practically none of the symmetrical

TNT, not even the amount required to form the eutectic; the DNT was also left, but by giving increased care to the trinitration, this had already been reduced to very small proportions. This process could even be applied to recover some TNT from the residue of the alcohol-purification process, by removing the unsymmetrical isomers, giving a mixture of DNT and TNT which could be worked up again as raw material for the ordinary process of trinitration.

It may be asserted, with little fear of contradiction, that the nitration of an aromatic compound has never before been studied in such detail as in the present publication; it constitutes a record of unique value, if only as showing how much can be done to effect economy and to promote smooth working when industry is able to mobilise all the resources of science to assist in the solution of its problems.

## SOCIETY OF CHEMICAL INDUSTRY.

### MEETINGS OF COUNCIL.

Meetings of the Council were held on November 11 and December 9, the Hon. Treasurer, Mr. E. V. Evans, presiding. At the former meeting a vote of sympathy was passed to Mrs. John Spiller, on the death of her husband (*cf.* J., 1921, 460 n), and a letter was read from Dr. Ruttan, in which he expressed the hope that he would be in England in May next and be able to visit some of the Local Sections. The Council decided that the chief duty of the General Purposes Committee was to consider matters which arose between two meetings of Council and which required immediate attention. On the subject of co-operation with the Chemical Society (*cf.* J., 1921, 139 n), letters were read from the Local Sections conveying practically unanimous approval of the proposals of the Chemical Society which had been recommended to them by the Council. Messrs. J. L. Baker and F. H. Carr were appointed to serve upon a standing committee on the Standardisation of Scientific Glassware to be set up by the National Physical Laboratory; and Mr. W. F. Reid was nominated to represent the Society upon the General Committee of the British Empire Exhibition, 1923, pending the acceptance of Dr. Ruttan.

At the December meeting the Council approved of the projected institution of a General Council of the Canadian Local Sections to promote and safeguard the interests of the Society in the Dominion and to consider questions that may arise regarding Federal and Provincial legislation. On the report of the Publications Committee, it was agreed that various books and periodicals located at headquarters, which were not required for the use of the Staff, should be offered to the Chemical Society and to those Local Sections which possess a library. It was also resolved that the first Messel Memorial Lecture should be delivered in Glasgow on the occasion of the next Annual Meeting; that the (first) medal to be presented to the lecturer should, if practicable, be made from the platinum of the platinum dish bequeathed to the Society by Dr. Messel; and that Prof. H. E. Armstrong be asked to give the lecture. Prof. Armstrong has since accepted the invitation. The next award of the Society's Medal has been deferred until 1923.

Fifty-six candidates have been elected members of the Society since October last; of this number 35 are resident in the United Kingdom, 7 in the Dominions Overseas, 7 in the United States, and 7 in other countries.