upon the mismanagement of many mines, the unbusinesslike methods employed, and the lack of co-operation and combination amongst mine-owners. He further directs attention to another drawback, of which all engaged in the management of metal mines in this country are only too well aware, in the following words:—"Labour in the non-ferrous mines has in the past been paid on rather a low level, the wages have been, moreover, in many cases the reward for part-time service, many employees having small farms of their own or being habituated to dual occupations. The system is utterly pernicious, and involves great waste of the men's time and energy in going to and from the scenes of respective work, and entails poor efficiency all round. It has endured from time immemorial, and any change that may be brought about now can only be very gradually effected."

This criticism upon the labour conditions is perfectly sound, and will be endorsed by everyone who knows the system of working, especially in our lead and zinc mines. It is evident that with impoverished deposits, poor management, and inefficient labour the outlook for the non-ferrous metal-mining industry is not a very bright one. There are, however, a number of other difficulties to be contended with; perhaps the most serious is the question of taxation. It is clearly pointed out that "mines are, at best, wasting assets," and that "in all mines earning profits the amounts distributed to proprietors as dividends or profits consist not only of income, but include the return of capital as well. . . . To tax mining profits on this basis is to tax capital as well as income, and to differentiate unfairly against persons who invest in mines." Furthermore, the present system of taxation discourages the formation of a reserve fund to meet the inevitable fluctuations of mining, and as the report says: "Reserve funds so derived should not be taxed. Similarly, the tax-gatherer should not levy toll upon sums spent out of profits in development." Sir Lionel Phillips does not go on to draw the inevitable inference that the unhappy state of the metal-mining industry has to a large extent been brought about by this injudicious system of taxation; it is, however, clear enough that the discouragement of development must tend to leave mines impoverished or exhausted, since it prevents the discovery of new deposits or shoots of ore. It is hopeless to expect a sound policy of management when the accumulation of a reserve fund, which should form the basis of such a policy, is mulcted in taxes. Sir Lionel Phillips does not think that compulsion could be applied to force mining companies to set aside each year out of profits sums estimated as sufficient to redeem their capital; in France, however, the building up of a "legal reserve" is obligatory, and the system appears to work quite satisfactorily.

There is very much in this report that will repay careful perusal, and stress may well be laid upon the recommendations which urge the formation of a Mines Department for the United Kingdom, this Department having for its object the study and encouragement of the home mineral industry. The report is careful to point out that nothing more than advice and assistance is required from a Government Department; as the Controller says: "That there has been too little interference by Government in the past will be generally admitted. That there can well be too much interference is equally obvious. . . . Government cannot, I believe, undertake any industrial work as efficiently as individuals whose material well-being depends upon the result. The nationalisation of mines would, therefore, be disadvantageous to the country. . . . In most industrial enterprises, and certainly in mines, there is an element of hazard which fortune-seekers are willing and are bound to take, but which the Government ought not to, and permanent officials never would, take." There is no doubt that these opinions would receive the unanimous endorsement of all mining engineers experienced in the direction of British mining enterprises, and it is to be hoped that the Government of the country will give heed to the findings of the Controller of this important Department of national industry.

H. LOUIS.

SUPERSATURATION AND TURBINE THEORY.[1]

IT has become of late years increasingly obvious that the equilibrium state of saturation, assumed as the basis of the theory of the steam-engine, does not apply accurately to the case of rapid expansion, especially in turbines. Steam in rapid expansion does not even begin to condense until its temperature has fallen far below the saturation limit. This fact has been familiar for many years as a general property of vapours called supersaturation, but it was not realised until recently that it might produce effects which could not be ignored in practice. Many authorities (*e.g.* Prof. Rateau, "Flow of Steam," 1905) held that there was no appreciable retard in the condensation even in a steam-nozzle where the expansion reaches the limit of rapidity. On the other hand, Callendar and Nicolson (Proc. Inst. C.E., 1897) found experimental evidence of supersaturation in the cylinder of a reciprocating engine at comparatively low speeds. Assuming that the adiabatic of supersaturated steam was simply a continuation of that of superheated steam, they calculated that a loss of 20 per cent. of available heat-drop would result at low pressures if there were no condensation; but as there was known to be a limit to the state of supersaturation they estimated that the actual loss due to this cause would not exceed 5 per cent. to 10 per cent. in practice, depending on the range and rapidity of expansion.

The first definite measurement of the supersaturation limit was obtained by Mr. C. T. R. Wilson (Phil. Trans. R.S., 1897) by expanding water vapour mixed with air at 20° C. It was found that the mixture could be expanded in the absence of dust or other nuclei without any con-

[1] "A New Theory of the Steam Turbine." By Harold Medway Martin. Reprinted from *Engineering*, vol. cvi. Pp. 22+folding diagram.

densation occurring until the density of the vapour was about eight times that of saturation at the lower temperature, but that beyond this point the condensation was so dense as to suggest that a natural limit of supersaturation had been reached. Experiments on steam-jets by Barus and others suggested a similar limit for steam at high temperatures free from air, though the precise ratio of density required could not be directly obtained from such experiments. Taking the density ratio given by Wilson as the limit of supersaturation, the discharge through a nozzle was calculated by Callendar (Proc. Inst. Mech. Eng., January, 1915), and shown to afford a reasonable explanation of well-known anomalies.

Admitting the supersaturation limit thus defined, the discharge through a nozzle comes out about 5 per cent. greater than that given by the older view, and agrees much better with the results of experiment. The available heat-drop to the supersaturation limit is about 5 per cent. less, involving a corresponding loss of work. So far the result is definite, depending only on the limit assumed and the equation of the adiabatic, which is fairly certain. Beyond this point the loss must depend on the rate of expansion, but it is still possible to calculate an upper and a lower limit. The maximum heat-drop is obtained by assuming that, when once condensation has started, the temperature follows the ordinary saturation limit in isentropic expansion, in which case there is no further loss of available heat-drop. On the other hand, assuming that the temperature cannot fall appreciably below the supersaturation limit, however rapid the expansion, the maximum *loss* is obtained by assuming that the temperature follows the supersaturation limit, in which case the loss continually increases with increase of entropy, but reaches a nearly constant percentage, about 8 per cent., of the total heat-drop at low pressures.

In the work before us the author adopts a slightly different definition of the supersaturation limit. Instead of taking a simple ratio of densities as proposed by Wilson, he assumes that the effective radius of the supersaturation nucleus remains constant at different temperatures. In the absence of experimental evidence at high temperatures, it is scarcely possible to decide between the two assumptions, except that the first is the simpler in application. The two corresponding curves for the supersaturation limit agree so closely at pressures between 1 lb. and 15 lb. that they give practically identical results when applied to any turbine problem. Now that one of the leading exponents of turbine theory has set the example we may confidently expect that other useful applications of the supersaturation hypothesis will follow, and that more accurate determinations of the limit will be made in the near future.

The "New Theory" gives an example of one such application of great practical interest—namely, the effect of superheat in improving the efficiency, which confirms the hypothesis of supersaturation, and throws light on the probable state of the steam in an actual turbine by comparing theory with experiment.

According to the older theory of isentropic expansion of saturated steam, the effect of a moderate degree of superheat in improving the relative efficiency of a turbine should be practically negligible, whereas even the earliest experiments in this direction showed that the improvement was strongly marked. The improvement was generally attributed to elimination of friction due to the presence of water (Stodola, "Steam Turbines," p. 137), but Osborne Reynolds showed this explanation to be unsatisfactory. The supersaturation theory of expansion requires that the improvement should be most marked in the early stages of superheat, owing to the reduction of supersaturation losses, which diminish most rapidly with the first rise of temperature. The most trustworthy and recent experimental results on the improvement due to superheat are probably those given by the correction curves of Baumann (Journ. Inst. Elect. Eng., 1911), which are generally regarded as accurately representing the case of the modern high-speed turbine.

Mr. Martin shows that these results can be satisfactorily explained on the supersaturation hypothesis provided that we are prepared to admit that the temperature of the steam, after condensation has set in, remains much nearer the supersaturation than the saturation limit, dividing the interval in the ratio 1 to 4. His method, involving the estimation of reheat factors, may appear indirect, but tends, if anything, to exaggerate the effect of superheat in reducing the supersaturation losses. The present writer has made many similar calculations, which corroborate Mr. Martin's, and tend to show that the temperature of the steam must be very near the supersaturation limit in the later stages of expansion in a high-speed turbine. A result so strongly at variance with the generally accepted theory cannot fail to act as a stimulus to further research on the effects of supersaturation, and may lead to appreciable improvements in design when proper account is taken of these essential physical properties of steam.

H. L. CALLENDAR.

THE EPIDEMIOLOGY OF PHTHISIS.[1]

TUBERCULOSIS, and particularly pulmonary tuberculosis (phthisis, or consumption of the lungs), still remains one of the health problems of the age. The Medical Research Committee has, therefore, been well advised to institute an inquiry into the epidemiology of phthisis in Great Britain and Ireland, of which this report by Dr. John Brownlee is the outcome.

The present investigation is a statistical analysis of the Registrar-General's returns of mortality, mainly for the five decades 1851–60 to 1891–1900, for the constituent countries as a whole and also for certain districts of them. By this means remarkable differences are brought out respecting the age at which the maximum death-rate from phthisis occurs in different localities. If we take the deaths of males from phthisis in England and

[1] An Investigation into the Epidemiology of Phthisis in Great Britain and Ireland. Medical Research Committee, Special Report Series, No. 18.