Some of the most important chemicals of all require so much expenditure in plant that the value of the output for a whole year, and in some cases for two years, would not equal the cost of the plant. This necessitates a calculation which is quite different from any other industry except agriculture. This is due partly to conditions which have always existed, and partly to the fact that consumers, have become more and more exacting in their specifications as to purity of commercial chemicals, rendering necessary much larger investments than formerly. I look upon this fact as being creditable both to the consumer and to the chemical manufacturer, and believe that it is a condition which will become more and more apparent in the future. In this connection reference should not be omitted to the changes in processes and plant rendered necessary by the advance of chemical science itself. I can think of no other industry in which a plant or process may become obsolete in such a short space of time. The Chemical Company with which I have been so closely associated since its beginning has very little in the way of plant to-day which was in existence ten years ago. This is not due solely to the effects of wear and tear, but to the fact that advances of knowledge have been so considerable and the requirements of users of chemicals so much more exacting than ten years ago that what would do then will not do at all to-day. I think this will be found to be the case—at any rate in a large degree—with all the other chemical manufacturers, and is, perhaps, not generally understood by the public at large, although it has such a serious bearing upon the cost of manufacture.

The chemical manufacturer of this country is fairly well situated for his supply of raw materials in certain respects, and not so well in others. It has been said that sulphuric acid is the "pig iron" of the chemical industry. The production of that article in this country is enormous, but, unfortunately, the raw materials are, to a very great extent, imported. A large sulphur deposit is being worked in Louisiana by most ingenious engineering methods, and sulphur is said to be produced at a very low cost. However this may be, the consumer of sulphur has not up to the present time had any benefit from the low cost, and I presume there is no good reason why he should have. The great bulk of sulphuric acid, however, is made from various ores containing sulphur, and, unfortunately, certain of these do not occur to any great extent in this country, particularly in the Eastern portion, where the production of sulphuric acid is the greatest. Spain furnishes the great bulk of iron pyrites used here—some cupreous and some non-cupreous; and this, in a large measure, is true of that used in Europe. If the war with Spain had been of longer duration, and had been a more serious affair, the industries of this country would have been brought to a very sharp realisation of this fact. Metallurgical processes are also responsible for much of the sulphur which is used in the manufacture of sulphuric acid, and are likely to become more important in this regard, particularly in the middle West and West. We already have a considerable tonnage from the zinc industry in which sulphuric acid is a by-product, and lately from two copper mines in Tennessee which are utilising the sulphur of their ores quite ingeniously, and, I hope, successfully. Anyone who can add a cheap source of supply of sulphuric acid to this country will be doing a public service and will deserve encouragement. It will thus be seen that, taken as a whole, so far as raw materials are concerned, including nitrate of soda, we have no advantage in situation for the production of this "pig iron" of chemistry.

The largest branch of the chemical industry of the United States is that engaged in the manufacture of artificial fertilisers. In these the chief elements are sulphuric acid, phosphate rock, potash, and ammoniates. Of phosphate rock we have plenty to last for a number of years, and I have no fears in that regard so far as our children are concerned. I am beginning to think that our grandchildren may have a good deal of anxiety regarding this absolute essential to the growth of all crops unless chemistry again comes to the rescue. The potash, as is well known, is mined in Germany, and I hope that nothing, diplomatic or otherwise, will interrupt its steady flow in our direction, as this essential has not been found in large available

quantities anywhere else in the world. Nitrogen we seem to have in increasing quantities, owing to the development of by-product coke ovens, tardy as this has been. It will, however, be a long time before we can feel assured of being able to fill the place of that most important source of nitrogen—nitrate of soda, the great deposits of which in Chili seem to be giving evidence that they are not limitless.

No important steps have yet been taken here to fix atmospheric nitrogen, although it is recognised that that source is absolutely necessary to the long-continued life of the race. With present knowledge, cheap electrical power is essential, and this is a problem not so easy of solution here as in Norway, due to the many industries able to outbid the chemist. The problem must be solved, however, and its difficulties make it all the more attractive.

The chemical industry of this country being so varied, I have thought best to confine my remarks to a very few of the economic aspects of the case. We have seen that it is not unduly assisted by the tariff; that it exists without price agreements or pools; that its production is about equal to the demand; that it labours under almost unique difficulties in cost of plant and changes made necessary by new conditions, and that as far as raw materials are concerned, it has nothing to boast of. In view of all this, the manufacturers have been equal to the demands upon them, which they have supplied without having to place values on the products which would act as a brake upon American industries in general. I think they will be found equal to the needs of the future, although all engaged in the industry realise the importance of many problems which are yet to be solved.

THE COLOUR INDUSTRY IN AMERICA.

BY HERMAN A. METZ.

RELATIONS BETWEEN THE METALLURGICAL AND CHEMICAL INDUSTRIES, WITH SPECIAL REFERENCE TO SULPHURIC ACID MANUFACTURE.

BY WALTER RENTON INGALLS.

The metallurgical industry may with some reason be called the predecessor of the chemical industry, not only historically, but also in the practice of the present day. When prehistoric man, emerging from the stone age, learned to make implements of iron and of bronze, he was utilising the discovery of some primitive metallurgist. In the middle ages, the alchemists seeking to produce gold became the fathers of chemistry, just as the astrologers were the earliest astronomers. In the history of every new country, our own included, one of the first branches of industry has been the production of metals. In almost all cases this has led, sooner or later, to the development of a chemical industry. This development has been natural, because without doubt the foundation of all chemical industry is the possession of sulphuric acid, and in the treatment of the largest class of ores the material for sulphuric acid is developed in the prosecution of metallurgical processes, conducted necessarily for the elimination of sulphur. We find in the operation of metallurgical works to-day a very large production of sulphuric acid which passes from those works into the chemical industry; and we may, therefore, rightly consider the metallurgist as the predecessor of the chemist, and the art of metallurgy as the trunk of a tree branching out into the wide expanse of modern industrial chemistry. Metallurgy is, in brief, the industrial chemistry of the metals.

Having drawn attention to sulphuric acid as the great link between metal production and chemical manufacture, I shall dwell chiefly upon this subject. It would be of value to all industries if we possessed up-to-date statistics of the production and consumption of sulphuric

acid, but unfortunately we have neither. I deduced from the census report for 1900 that the production of sulphuric acid in the United States at that time was equivalent to 1,034,659 tons of pure acid, and computed that of this production about 49 per cent. was employed for the treatment of phosphate rock, 19 per cent. for petroleum refining, 6.8 per cent. for pickling iron and steel, 3.5 per cent. for the manufacture of nitric acid, 2.9 per cent. for hydrochloric acid, 1.8 per cent. for mixed acids, 4.6 per cent. for alum and aluminium sulphate, 1.5 per cent. for copper sulphate, 4.6 per cent. for ammonium sulphate, and about 6.3 per cent. for other purposes, including ferrous sulphate, chrome products, magnesium sulphate, etc.

During the last ten years the production of sulphuric acid has greatly increased. Perhaps I should not be far out of the way if I should surmise that it has doubled itself. If this idea be correct, the value of our sulphuric acid product at the present time is exceeded only by that of seven or eight other mineral substances. I have no means of outlining the proportionate consumption of sulphuric acid at the present time, and with a feeling of shame that we have to go back ten years for such statistical data, I refer to those figures merely as indicative. However, they show aptly the closeness with which the mining, metallurgical, and chemical industries are linked, because after being supplied with the acid the chemists go to the miners for the phosphate rock, sodium nitrate, bauxite, salt, chrome ore, and a number of other mineral products.

A particularly noteworthy feature of our metallurgical and chemical industry is the increasing extent of the production of sulphuric acid recovered as a by-product. Although some of the pyrites concentrates coming from gold mills in Colorado and California have long been a source of sulphuric acid, the chief by-product acid in the United States until lately has been derived from zinc blende. The manufacture of acid from blende in the United States goes back to 1882 and was due to the initiative of Edward C. Hegeler, who died this year, leaving a name that will always be famous in the annals of zinc smelting. Thanks to him, this was a metallurgical and chemical development in which our country in no way lagged behind European practice. We not only began this manufacture of sulphuric acid about as early as in Europe, but from the beginning we used an advanced method of blende roasting. In 1900 our production of sulphuric acid from blende was estimated at 60,000 tons, basis 60° B. In 1909, judging from the ore consumption of the zinc smelters making sulphuric acid, and the average grade of the ore, their production must have been in the neighbourhood of 200,000 tons.

This is a production of sulphuric acid that is destined to increase largely during the next five years, for the reason that the supply of natural gas in Kansas is rapidly waning, and a great expansion of the zinc smelting business in the coal fields of Illinois is to be anticipated. Every new works to be erected in Illinois will comprise a sulphuric acid adjunct. Three works, one of them of very large size, have been erected in that State during the last five or six years, and at the present time the plans for several very large works are being prepared.

The most important recent contribution of metallurgists to the chemical industry has been the manufacture of sulphuric acid from the gas of pyritic smelting furnaces. In the so-called pyritic process of smelting cupiferous sulphides, but little carbonaceous fuel is employed, and the heat of combustion of the sulphur and iron of the ore is utilised for the smelting. The gases discharged by such furnaces are fairly high in sulphur dioxide, running up to 6 per cent., and it was early considered that they might be utilised for sulphuric acid manufacture. There were, however, many difficulties of a metallurgical and engineering character to be solved, difficulties of the kind that generally appear when it is undertaken to perform two dissimilar operations as a continuous process. A

furnace run for the best efficiency in ore smelting may not adjust itself naturally to the conditions of chambers and towers; and if adjustment be made to the latter, on the other hand, the primary process of ore smelting may suffer in efficiency. In this venture, moreover, the engineers were confronted by the process of adjusting to chambers and towers a pyrites burner, namely, the smelting furnace, of far greater size than had ever been previously employed in sulphuric acid manufacture; and the operation of chambers and towers with only a few burning units. These difficulties have been successfully solved, both at Copperhill and at Ducktown, and at the former place the Tennessee Copper Company will shortly be making 200,000 tons of tower acid per annum, while at the latter place the Ducktown Copper, Iron, and Sulphur Company is producing at the rate of about 60,000 tons per annum. This large production of acid, occurring in close proximity to one of the greatest phosphate fields of the United States, has had an important effect upon the fertiliser business and acid market.

Another recent development in sulphuric acid manufacture has been the increased utilisation of the cinder of non-cupiferous pyrites as iron ore. Up to the present time, this use is limited, but it is likely to increase. This, however, will be a case of utilising a by-product of sulphuric acid manufacture for metallurgical purposes, rather than the reverse. A similar condition obtains with respect to sulphuric acid manufacture on the Atlantic coast in general. Pyrites containing a small percentage of copper is imported in great quantities especially for its sulphur content, but because of the copper existing in the residue the latter is passed on to metallurgical works. This condition has led to the development on the seaboard of metallurgical works as adjuncts to sulphuric acid works, whereas in the interior the acid works are the adjuncts to metallurgical works. On the Atlantic coast the value possessed by sulphur is often troublesome to the metallurgist, who sometimes finds himself hard pressed to obtain the sulphur required to make his matte, which is necessarily the first step in his process. The sulphur of the matte is eventually wasted as sulphur dioxide discharged from the converters. If it were feasible to make sulphuric acid from the converter gases, the smelter might be allowed to have all the sulphur required, leaving it for recovery in a later stage of his process. Experiments upon the manufacture of sulphuric acid from converter gases have been made at Mansfeld, in Germany, and have shown, I believe, that under the conditions existing there, sulphuric acid can be made from such gases. So far as I am aware, however, no work in this direction has been done elsewhere. In fact, at our great smelting centres there is no incentive toward experimentation in that direction, because in general there is a superfluity of sulphur rather than a dearth. The disposal of this superfluous sulphur, in a harmless way, is indeed one of the greatest metallurgical problems of the day. A large number of our most important smelters live in constant fear of litigation and injunctions over their smoke nuisances, alleged or real. In our own environs the Orford Copper Company has had trouble of this kind, while the smelters in Tennessee, Utah, California, and Montana have been, or are now, in trouble. At the present time, the Federal Government is prosecuting a case against the Anaconda Copper Company. The Federal Government has told that Company that it ought to render its gas innocuous by making sulphuric acid out of it. Inasmuch, however, as the Washoe works alone discharges enough sulphur to make 1,400,000 tons of tower acid per annum, and is considerably over 1000 miles distant from any important market, it is not clear how acid manufacture could be conducted successfully under such conditions. It is evident, however, from the fact, that this works, producing about 25 per cent. of the blister copper of the United States, throws away so large a quantity of sulphur, that there is not likely to be any scarcity of sulphuric acid in the interior of the United States, when the demand may justify its manufacture.