SOME ASPECTS OF PILOT PLANT RESEARCH AND DEVELOPMENT IN IRON AND STEEL INDUSTRY (*)

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Students of ferrous metallurgy appear unanimous in their opinion that major revolutions are taking place in the technology of iron and steel production whilst the essence of basic reactions and fundamentals involved remains unchanged. Apart from the physical enlargement of smelting units proper and scaling up of ancillary equipment, some of the major advances currently under application relate to raw-materials processing and prepared burdens such as, sizing, classification, concentrating, agglomeration, sintering etc. which have to-day become bywords to increased productivity and reduced operational costs. Similarly important technical developments are taking place in iron blast furnace operations, steel-making technology, continuous casting technique and in related fields. These industrial developments are the products of laboratory scale researches followed by comprehensive investigations on pilot plant scale trials. The importance of such pilot plant trials has been recognised the world over. In this short paper, some of these pilot plant scale investigations will be highlighted including some current technical developments in the technology of iron and steel production in different steel producing countries of the world.

Sinter:

Work on sinter, self-fluxing sinter and super-fluxing sinter for iron blast furnace has been going on at different research centres in several countries, such as at British Iron and Steel Research Association in U.K., I.R.S.I.D. in France, Tsnirchermet (Central Scientific Research Institute of Ferrous Metallurgy) and Steel Institute in U.S.S.R. etc. Work in Russia has related to the production of high quality fluxed sinter with a basicity of 1.4 (CaO/SiO_2) with a tolerance of $\pm$ 0.07. Hot sinter has been favoured. Work at B.I.S.R.A. in the U.K. on sinter technology has been very comprehensive. It has attacked on a pilot plant scale - several aspects of sintering including trials on the production of super-fluxing sinter with a ratio of $\frac{CaO + MgO}{SiO_2 + Al_2O_3} = 1.67$. Studies in this

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connection on what are termed 'flame front' and 'heat front' and their matching or mismatching determine the quality and operating efficiency of sinter production.

Extensive pilot plant trials on flue dust and ore briquetting have been done at the Humboldt Works of Klockner-Humboldt Deutz A.G. at Koln and such pilot scale results have been industrially adopted at the Works of Holsch-Westfalenhuette A.G. at Dortmund. At this plant good results have been obtained with pure flue dust briquettes and still better are the results with mix-type briquettes. These mix-type briquettes were composed of 75% flue dust and 25% open hearth slags whilst additions of other ferrous materials were also made to mix type briquettes such as fine grained iron ore concentrate together with flue dust. Binders used for briquetting have been investigated on pilot plant scale such as, Bitumens, cement, sulphite lye, lime hydrate clay, bentonites etc. Such trials are some of the best examples of pilot plant trials in the use of fines for iron production.

Work on gas sintering on pilot plant scale has been conducted at the Dzerzhinsku Works in U.S.S.R. and has shown in high reducibility of sinter. Work on sinter research is also under active progress at I.R.S.I.D. Likewise, extensive pilot plant scale investigations have been undertaken on agglomeration, pelletising, production of self-fluxing pellets at Minnesota (Pickands Mather and Co.) and at other centres in the U.S.A., at Lurgi in West Germany and in other countries including Russia and China. Applied aspects of the sinter and assessments of compositional limits for its optimum quality and reducibility have been investigated at the National Metallurgical Laboratory. Work on more fundamental aspects of sinter technology with Indian raw materials has now been projected particularly on pilot plant scale.

Iron-making:

In the field of iron-making, the scope of pilot plant research and development is practically unlimited. Extensive work on its many diverse fields is in progress in several countries including direct reduction processes based on fluidized bed technique or packing technique besides diverse sponge iron processes; low-shaft iron smelting methods based on the use of non-metallurgical fuels and ore fines etc. Work on flame smelting with fluidized bed technique at British Iron and Steel Research Association in the U.K. is outstanding. Pilot plant investigations on smelting of iron in low-shaft furnaces at Liege, in West Germany at Troisdorf (Klockner-HumboldtDeutz A.G.) by the D.H.N.; in East Germany at Calbe have been now summarised in several publications and offer wide scope for investigation into the use of fines, development of briquetting techniques and the use of non-metallurgical fuels including lignite coke.

The international Low-shaft furnace at Liege was set up to investigate whether unprepared fine iron ores could be smelted economically without the use of sinter installation. It was observed that ore and coke must be of the same average grain size of about 1/2" whilst below $\frac{1}{4}$" or $\frac{1}{8}$" caused highly irregular furnace operations; the burden baked together to form a roof and hollow below it. The explosive breaking of the roof apart from causing bad reduction and dislocating the furnace operation caused heavy dust loss (200 - 400 kg per ton of iron) - the iron made was cold, low in carbon and high in sulphur and the slag high in iron content. Efforts were made to utilise dust-forming minette ores without sieving and sintering but uniform operation with a satisfactory iron composition and low dust loss resulted only when finest ore fractions had been screened off. In the European background of raw materials for iron production, the objective was not achieved because the run-of-the-mine ore could not be satisfactorily used whilst it was established that even for the low shaft furnace, screening off and agglomeration of fines were desirable. The tests also established that mechanically low grade coke or even low-bitumen coal could be advantageously used in a low shaft furnace which operated well with sinter load and pelletized charge. Current Pilot plant work on the subject underway at the National Metallurgical Laboratory in India on low-shaft furnace smelting of Indian iron ores by the use of non-coking coals based on briquetted as also non-briquetted charge is progressing steadily.

In Russia, pilot plant investigations are conducted on a massive scale at their integrated iron and steel research plant at Tula which has two blast furnaces, one of 335 cu.m. and the other of 930 cu.m. employed for investigation on iron and ferro-manganese production trials. On the small furnace, it has been reported by a recent British delegation that the production of ferro-manganese has been doubled by using 32% oxygen in the air-blast at a temperature of 950 deg.C. and the coke rate thereby reduced from 2.3 - 1.75 tons per ton of alloy. Although it has been also claimed that 25% increase in pig iron production had been obtained with 25 - 26 percentage oxygen in the blast, there are disclaimers from other parts of the world on the relative value of oxygen enrichment of air-blast for iron production in respect of difficulties experienced in furnace operations, such as persistent hangings and scaffelding consequent upon the drop of temperature in upper stack portions of the furnace etc. It has also been stated that coke rate is not improved for iron production consequent on oxygen enrichment of air blast. The cause of burden hanging and irregularities from oxygen enrichment of air-blast has been explained to be due to (1) reduction in the combustion zone volume, especially its depth, impeding descent of the stock, (2) increased pressure of gases on the burden from below following an increase in gas volume with rise in combustion temperature (3) intensification of gas movement along with walls (4) reduction in gas penetrability of the burden following evaporation of silicon oxides

(SiO, SiO_2) etc. These effects are attributed to rise in temperatures in the combustion zone and to intensity of heat exchange process therein, which in turn cause a displacement of temperature zones and thermo-chemical processes including reduction into lower levels of the furnace.

The lack of any coke economy in the case of oxygen enriched blast is also explained by the displacement of the temperature zones of the furnace downwards. A reduction in the zone of indirect reduction of ferrous oxide to iron causes additional consumption of fuel which mitigates against any economy obtained by greater concentration of reducing medium, by raising the smelting intensity and reducing the sensible heat carried by the outgoing gases. Improvements in the blast furnace process through oxygen enrichment of air blast are directed towards the useful utilisation of the excess heat in the furnace hearth and improving the heat state of the furnace stack. This is being attempted by (1) injections of dissociated gases into the hearth, (2) charging hot self-fluxing sinter in the furnace, and (3) improving the gas permeability of the stock through better raw materials' preparation. Dissociation in the hearth of the furnace of water vapour or carbon dioxide permits reduction of temperature in the combustion zone, transfer of heat to the upper lying areas, and increase in the concentration of the reducing medium through hydrogen and carbon monoxide that results. Whilst these factors may lead to better furnace operations, no appreciable reduction in the coke rate can be expected. For more effective may be the injection of gases such as natural gas, hydro-carbon gases, coke oven gas and even the clean blast furnace gas itself.

Work at the International Low-Shaft furnace at Liege (Belgium) is reported to be directed towards the injection of oil and hydro-carbons in the hearth zone of the furnace with the object of reducing coke consumption and increasing productivity. In the case of International Low Shaft Furnace also, oxygen blast enrichment to the extent of 28% appeared to cause no improvement of the coke reduction or even of the dust losses. On the other hand, it even gave increased coke rate per ton for low silicon irons. This can also be explained on the basis that blast enrichment would be useful if top temperature of the furnace was high.

In this connection, comprehensive successful trials are also being conducted at Yahagi Iron Works in Japan on oxygen enrichment of air blast in the blast furnace. The unique feature in this case is that the blast is not preheated at all while its oxygen content is raised to over 50%; the furnace is of low-shaft type although not strictly operating as a conventional Low Shaft Furnace, with a daily production capacity of 50 tons per day. It is producing high silicon malleable grades of foundry iron containing about 0.1% phosphorus. At the same time, a part of the clean blast furnace gas is fed back into the hearth area of the furnace. This low-shaft furnace has a 2.5 m. hearth diameter with 6 m. height of shaft with carbon lining at the hearth and eight tuyeres of 40 mm diameter.

The clean blast furnace gas analysing in this case, CO - 60%, CO_2 - 10%, H_2 - 2% and rest nitrogen with a calorific value of 2000 K calories per cu.m. is fed back into the furnace to the extent of 30% of the total furnace gas volume evolved. The furnace gas volume liberated is about 2500 cu.m. per ton of iron made. The furnace top temperature in this case runs to 300 deg. C. The air-blast pressure is 3 metres W.C. The consumption of oxygen of over 99% purity was reported to be 500 - 1000 cu.m. per ton of iron made. The coke rate was 1.2 tons per ton of iron. The limestone consumed was 500 kgms per ton of iron (silica content of limestone was 1%). The furnace operated on 100% sinter charge containing Fe - 60%, Cu - 0.3%, SiO_2 - 11% and sulphur - 0.5 - 0.7%. The sinter did not contain any limestone and was made up of 90 kgms of coke breeze per ton of sinter of a mesh size of 70 - 80% below 100 mesh. The furnace produced about 54000 tons of iron a year evolving 38000 x 10^3 cu.m. of gas from which ammonia is recovered for making ammonium sulphate ($(NH_4)2\ SO_4$), lactum, nylon, methyl, Acrylate and Viniyl chloride in a synthetic chemical engineering plant. The ammonia equivalent of the gas was 90 kgms per ton of iron made. The above trials are being conducted basically on pilot plant scale and their industrial scale implementation may be a logical step thereof. A plant in France is also experimenting on a pilot plant scale on the injection of oil or natural gas into a blast furnace. It has been said that by injection of oil some saving of coke is obtained along with increased productivity but these factors have yet to be balanced against the additional costs and complications of the process involved.

Steel-Making:

Likewise extensive pilot plant trials have been conducted on different steel making processes in various parts of the world and are to-day well-known.

Whilst the original L-D oxygen process of steel making has proved exceedingly successful in the low phosphorus pig irons, the problem of refining high phosphorus irons by a method involving almost concurrent removal of phosphorus and carbon without excessive iron loss in the slag has been more difficult.

The Austrians have extended the phosphorus range of pig irons amenable to L-D oxygen treatment to some extent by the use of fluxes (flourspar or bauxite); fluorspar seems to have been most successful, but its use clearly has disadvantages when it is required to produce a saleable phosphoric slag. French workers (I.R.S.I.D.) have, succeeded in modifying the L-D procedure by injecting a suspension of lime into the oxygen lance and have developed the O.L.P. process whilst the Belgiums have developed what is known as O.C.P. process - these new developments are still in active pilot plant stages or at best can be said to be on the threshold to industrial scale implementation chiefly in the country of their origin.

In Sweden, Professor Bo Kalling and his co-workers at Domnarvet have investigated the subject somewhat differently. In their Kaldo process, a large inclined rotating vessel ensures mechanical mixing of slag and metal whilst oxygen is injected through a water cooled lance, but at velocities lower than that of the L-D process, so that the oxygen jet does not penetrate the slag blanket, with the result that reactions are then essentially slag/metal rather than gas/metal. Kaldo process claims nitrogen contents of 0.002% in the steel with oxygen purities of 96 - 97%, based on the advantage of avoiding direct contact between the oxygen stream and the metal and in this respect the process is more similar to other hearth than converter processes.

The principle of rotation has also been used by Graf and his co-workers in the Rotor process Huttenwerk at Oberhausen in Germany as a means of preserving the refractory lining by continually keeping it out of the very high temperature zones above the metal bath than as a means of mixing the metal and slag. In the Rotor process, the requisite mixing of slag and metal is ensured by using two lances, one oxygen lance is used above the bath surface and the other below it. It has been claimed by the Rotor process developed since 1955 that any grade of open hearth steel can be made. From this pilot plant operation, claim has further been advanced that the cost of these steels is lower than those of Siemens-Martin. Working at full capacity of the plant the cost of steel was estimated to be 50 - 60% that of Siemens-Martin steels. Two Rotor steel works have recently started operating. (Ilseder Hutte, Peine, Deutschland, and South African Iron and Steel Industrial Corporation Ltd., - Iscor - Vanderbijlpark, South Africa). It is to be noted that Ilseder Hutte charges a pig iron containing 2.2% P and 1.5% Mn. In the Iscor-Werke, a low phosphorus and low sulphur pig iron is charged and only ore is used as cooling agent. Rotor process is also planned to be employed on industrial scale in France. In the U.K., the use of oxygen roof lances in the Steel Company of Wales open hearths is well-known. In America, the work in this respect of Halley at Inland Steel, has shown that it is possible to make steel in an 'Open hearth' using oxygen alone, without any external source of heat. Of course, the classical open hearth furnace is not a proper vessel for this purpose - a circular tilting vessel with removable roof has been indicated. Also in Britain, the tendency seems to favour the big electric arc furnaces for steel making.

<u>Basic air side-blown converter steel-making:</u>

Whilst on the subject of converter steel making, reference may be made to basic air side-blown converter steel-making technique for refining low or medium phosphoric irons. However whilst published records for a side-blown acid lined converter what is known as Tropenas converter for refining non-phosphoric irons are abundant, there appears, as far as known, no record of a process depending upon air surface blowing in a basic vessel using conventional fluxes such as lime. Whilst some work in this field has been done by Sims and Toy in the U.S.A. employing basic irons containing phosphorus contents of 0.2 - 0.4% which is too high for acid Bessemer or Tropenas side-blown converter and too low for Thomas basic converter process. And yet, the basic air-side blown converter steel-making method is to-day in full industrial scale use in China using low or medium phosphoric basic irons.

The conversion of pig iron into steel on a small scale is widely practised in China in 'side-blown converters'. These converters are essentially 'basic lined' with one or two sets of tuyeres fixed at suitable positions at the 'hot metal-slag interface' following what is known as 'keep-slag process'. While the theory of the side-blown converter method steel making may have been well known, its industrial use, on a mass scale, has been adopted, it is believed, only in China. The technique of steel making in side-blown converters has been developed to include the elimination of metalloids, such as phosphorus, most effectively and also to satisfactory extent that of sulphur. The technique is based essentially on making slag of the requisite quality, composition and characteristics, which is retained in the converter prior to hot metal additions and of subsequent suitable 'slag-making' through additions of fluxes so as to secure adequate removal of phosphorus and of sulphur satisfactorily. The side-blown converters are lined with tarred dolomite refractories. In a typical plant, the pig iron analysed silicon 1%, phosphorus 0.3%, sulphur 0.1% and manganese 0.8%. The converters range in capacity from ½ tons upwards and 35 tons capacity converters are being put up. The air blast volume for a small converter is of the order of 120 cu.m. per minute surface blown at 0.3 atmosphere pressure. More than 1/3rd of the basic oxidising slag is retained in the converter prior to hot metal additions by the mouth bridge technique. The converter is kept in 3 different positions during blowing and the angle of tilt is varied to allow the tuyeres to be submerged or be clear of the bath depending upon the particular reactions required. For example, for effecting decarburization, the tuyeres would be kept submerged. The first slag usually contains 25% FeO. Two sets of tuyeres promote better combustion and permit high temperatures. Thus the combination of this high temperature, high FeO content and high CaO content or rather its availability favour the removal of phosphorus concurrently with carbon and manganese oxidation. It was also stated that with high FeO in slag of 25% or over, operating at a high temperature with adequate basicity, sulphur removal in side-blown converter also effectively takes place. Although strongly oxidizing conditions existing in a side-blown converter are not favourable for sulphur removal, it has been shown that highly basic slag operating at high temperatures can effect sulphur removal in the early parts of the blow even under highly oxidizing conditions. It may be that with 2 sets of tuyeres in a basic side-blown converter, conditions are similar to that of L.D oxygen converter with the highly oxidising slag already in the converter following the 'keep-slag' technique. This optimum combination ensures de-phosphorisation and also prevention in many cases of abnormal nitrogen pick up in the steel melt. Typical Chinese converter slag analyses are as follows:

	MnO	FeO	P_2O_5	S	SiO_2	CaO	MgO	Al_2O_3
Slag I	2.50	9.70	6.50	0.80	9.97	59.05	5.53	1.50
Slag II	2.53	11.95	9.20	1.20	11.40	49.43	11.28	2.20

The Chinese allow the refractory lining to be cut down thereby increasing the converter capacity from 3 to 5 tons per blow even though the life of the converter is thereby reduced. Some further typical data may be of interest. 6% lime is added to a ton of steel made in a converter blow. Some mill-scale is added to cool the bath if required at times. No flourspar is normally added to the bath. 14 kgms of FeSi is added per ton of steel made containing 45% Si, made in the blast furnace and is much less expensive than superior FeSi. The life of the converter lining is 50 - 60 blows. The nitrogen of the steel made is reported to be as low as 0.003. In some case 0.0084% nitrogen content is not reported to be good for deep drawing quality. In a 5 ton vessel, there are 8 tuyere holes. The steel melt is bottom poured to yield 100 kgm ingots - 45-55 in number per cast. The progress of the blow is as follows:

Total blowing time - 20 minutes

0 - 6 minutes - 40% of Mn and 70% Si are oxidised away.

6 to 20 minutes - 40% of balance Mn, requisite carbon and phosphorus are removed.

20% of the manganese is retained in the melt.

There are one to two blowers per converter. The converter top is detachable. Single or double slagging operations are employed depending upon the sulphur and phosphorus content of the pig iron being refined.

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Reference to side-blown basic converter steel making technique naturally brings to mind allied aspects of pilot plant investigations relating to steel-making. For instance, in U.S.S.R. pilot plant scale research into steel making is in progress relating to open hearth furnaces, mixers, soaking pits and on a model open hearth furnace made of perspex similar to units established in the U.K. at B.I.S.R.A. and at Swinden laboratories. At Tula in Russia considerable work has been done on different blowing positions for converters for a variety of iron compositions and refractories including oxygen, steam oxygen and CO_2 and oxygen mixtures with top and bottom blowing. According to the Russians, oxygen top blowing processes would grow but the final shape of the converter may undergo considerable change.

Likewise, at the Swinden laboratories in the U.K., pilot plant models of steel-making and reheating furnaces are employed for studies into flow patterns of gases, such as one fifth scale model of an open hearth steel furnace and a pusher type reheating furnace. These pilot plants are valuable tools of research investigations, for studies into heat transfer at operating temperatures and aerodynamic studies in open hearth furnaces. The importance of studies into life of open hearth roof is well established to-day. The aerodynamics of turbulent jets is to-day under active Pilot Plant studies since at high temperatures the combustion is determined by mixing and the resulting velocity of combustion and flame length. Although the steel furnace roof accounts for approximately 5 percent of the total cost of the refractories used in steelmaking, the roof life defines the time lost between major shut-downs. The silica roof is kept at a temperature close to its melting point during its life and is subjected to continuous attack by molten iron oxide flying particles. It must maintain its sprung-arch shape and lend itself to repair or removal whenever there is any risk of collapse. The more a furnace is pushed, the greater is the load on silica roofs. The temperature at which the silica brick starts to drop is a good test for its wear - the higher the dripping temperature, less the wear. Pilot plant studies have helped in the drive for greater output consistent with adequate roof lives. Continuous measurement of roof temperature was once considered hopeless, but to-day many steel plants have all their furnaces equipped with roof pyrometers and several make use of automatic roof temperature - fuel flow linkage. Unfortunately the fact that the control point on a roof does not exceed a maximum safe temperature of, say 1,650 deg.C., does not mean that other parts are equally well treated. Extensive furnace trials and aerodynamic studies, both in the laboratory and works, have shown that certain designs, for example, the single-uptake, used in conjection with correct steam/oil ratio to give optimum flame length, can reduce such peak temperature differences. Great benefit has been obtained in these furnace trials, which necessitated simultaneous measurements by as many as thirty different investigators, achieved by close co-operation with research teams from the British Coal Utilisation Research Association, the British Iron and Steel Research Association, and more recently the Fuel Technology and Chemical Engineering Department of the University of Sheffield. The new science of furnace design, based on the study of turbulent mixing, flow pattern and the dynamics of liquid iron oxide droplets in gas streams, has caused improvements to be successfully predicted from such changes as burners movement. New development such as the use of moving air curtains for the protection of refractories from flux-laden gases, are being investigated.

Models of steel-melting and reheating furnaces are among the Pilot plant equipment installed at the Swinden laboratories of the United Steel Companies Limited in U.K. These include one-fifth scale models of an open-hearth steel furnace and of a pusher-type reheating furnace, and a 47 ft. long flame tunnel. The pilot plants will be used for research investigations into such problems as heat transfer at operating temperatures and the desirability or otherwise of recirculation in open-hearth furnaces. Likewise, work at the Bureau of Mines in U.S.A. has been related to steel making techniques in an experimental open hearth furnace.

An experimental blast furnace and the pebble stoves, are used by the Bureau of Mines to obtain possible greater efficiency and economy in iron-making. Iron-bearing materials not now used in producing pig iron also are evaluated in this equipment.

Work at the United States Steel Corporation has demonstrated a process called Nu-Iron or Fluidized for making iron out of iron ores by using gas instead of high grade coke when finely divided iron ore particles are suspended in a vessel by a rising stream of hot hydrogen or carbon monoxide gas. This gas reacts with the ore to produce iron. Because of its suitability for finely divided ores and because it does not require high grade coke, the Fluidized Reduction Process holds considerable promise for future iron making operations. Pilot plant investigations are being continued to obtain information for designing a semi-commercial plan. Similarly Burke has obtained a Patent on Flash Steel Process wherein pellets of sintered ore float down through a upward rising stream of gas producing molten steel one percent carbon steel. Further studies to investigate the fluid dynamics of the system have been undertaken at the U.S. Bureau of Mines Experimental Station at Pittsburgh as a co-operative project.

Similar work on fluidized reduction of iron ore to produce steel by what is termed Flame smelting is under active investigation on Pilot Plant scale at the British Iron and Steel Research Association in England. Some of the other Pilot Plants work at B.I.S.R.A. relate to radio-active tracer investigations in the blast furnace hearth, set up for the automatic measurement of blast furnace stack pressures, etc. Work on different fields of iron and steel metallurgy is under progress at several international centres such as I.R.S.I.D. in France, C.N.R.M. in Belgium, Max Plank Institute in Germany etc. The United States Steel Corporation at its South Works in Chicago is pursuing active Pilot Plant investigational work under steel mill conditions of research results obtained at their U.S. Steel Research Centre at Monroeville. Such pilot scale investigations have related to T. V. aided experimental open Hearth Model, instrumented to study the effects of heats at different point and flame changes by means of T.V. The model, a one-twelfth scale replica of a 300 ton commercial open-hearth furnace does not melt any steel. To isolate combustion effects from the heat generating effects in steel making, the furnace was built with a rectangular tank occupying the position of the metallurgical charge. Flowing water through this tank absorbs heat from the opposing flame of burning oil which corresponds to the heat that is absorbed by the molten steel in an open hearth furnace and which is measured. Work on basic oxygen steel making in which flames are directed to an exhaust system for gas recovery rather than led into air is also being pursued. Similar work on gas recovery from exhaust gases of L.D oxygen converter is under active pursuit at the Pilot Plant station of I.R.S.I.D. at Metz and at the Pilot Plant establishment of Krupps at Essen in West Germany. Further pilot plant scale work at U.S. Steel applied Research

Laboratory relates to exploring the full potential of the oxygen steel-making process. Various aspects of this process are under investigation at their South Works in an experimental 8-ton furnace to determine operational characteristics, yields for different iron compositions, flux needs, effect of steel scrap additions etc. Considerable scope for development work exists for the production of high carbon steels of uniform analyses of successive melts employing the above process. Likewise, work is underway on consumable-electrode vacuum melting capable of producing up to 32 in. dia ingots weighing over 20,000 lbs. of bearing steels, high temperature stainless steels, ultra high strength alloy steels for missiles and jet aircraft, rotor and other types of special steels.

Similarly comprehensive pilot plant investigations are being systematically pursued at different world centres on various aspects of making, casting, processing and shaping of steels. Most countries owe their present metallurgical industrial stature to such pilot plant investigations. The pilot plant installation relating to continuous casting of steel in U.S.S.R. at Tula is an excellent example of such progress and this subject has been fully covered by a recent British delegation to U.S.S.R. in their Report.

The scope of pilot plant investigation in mechanical metallurgy such as rolling, wire drawing, extension is vast indeed. Some ideas of the breadth of such work may be gauged from the work of international body (E.C.S.C.) to trace possible differences between old and modern rolling mills of sheet, bar and wire. Starting from open hearth steel and from normal or improved basic Bessemer steels, sheet, bar and wire were hot rolled in 13 rolling mills. Following by an investigation into their mechanical and metallurgical qualities.

The scope for pilot plant investigations in diverse phases of technology of iron and steel-making, casting, fabrication etc. is so vast that it not only defies one's imagination but also can defy one's resources and funds. It is not over-statement that results to be expected out of such laboratory and pilot plant scale research and development can apart from effecting distinct improvements in the existing techniques may also revolutionize the technology and story of iron and steel-making in years to come.

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