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TECHNICAL AND ECONOMIC FEASIBILITY PLANNING FOR A SMALL IRON AND STEEL INDUSTRY

by

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SUMMARY

1. This paper sets out some of the factors to be considered when investigating the technical and economic feasibility of a small iron and steel industry.

2. The main points emphasised are -

(a) that the choice of a direct reduction process is not simple and that each case must be treated strictly on its merits;

(b) that the success of a projected iron and steel industry does not depend solely upon the availability of raw materials and techniques for processing them;

(c) that to ensure success it is necessary to consider the combined effects of technology and numerous economic and social factors such as size of market, labour skills, transport facilities and so on.

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New Zealand is a small country consisting of two major Islands, the North Island and South Island. The total area is approximately 110,000 square miles; the population is 2,500,000. Up till this year, New Zealand imported all its iron and steel requirements, approximately 350,000 tons per year. Last year a small merchant bar mill using local scrap arisings (about 50,000 - 60,000 tons per year) has commenced operations.

On the west coast of the North Island there are extensive deposits of titaniferous ironsands which contain the mineral titanomagnetite (Fe content 57% - 58%, TiO_2 8%). While New Zealand has very limited supplies of low sulphur coking coals, it has extensive supplies of sub-bituminous or lignite coals.

For over a hundred years several attempts were made to exploit these deposits; but they all failed because of the difficulties caused by the finely subdivided nature of the ore and the presence of the titanium (the ore contains 57-58% Fe, 8% TiO_2).

In 1960 the New Zealand Government established a Government Company, the New Zealand Steel Investigating Company, to investigate the technical and economic feasibility and desirability of a New Zealand iron and steel industry.

5. The Company was controlled by a Board of Directors, three of whom were Government officials, the other three being prominent businessmen. This joint effort of Government and private enterprise working together for the national good was found to be a very happy and effective arrangement. Each group brought to the task an outlook and experience not possessed by the other. The authors have little doubt that the generally favourable reception given by the Government and the people of New Zealand to the Company's report is in no small measure due to the fact that the report was unanimously recommended by both Government officials and highly reputable and successful businessmen.

6. The Company broke its task down into the main problems:-

a. to see if adequate reserves of the appropriate raw materials were available;

b. to ascertain if there were processes capable of reducing the ore commercially;

c. if the answers to the two questions above were satisfactory, to decide if an iron and steel industry would be economically feasible and desirable.

7. The Company believed that existing organizations in New Zealand were competent to assess the availability of the raw materials. The standard methods of geological reconnaissance, geophysical prospecting (particularly magnetic surveys), drilling, coring and chemical analysis and so on were adopted and will not be further discussed.

8. Because New Zealand has very small reserves of low-sulphur coking coals and also because of the titanium content of the ore, the conventional blast furnace could not be used.

9. Trials in 1949 had shown that direct cold charge smelting in an electric furnace would not be economic because the electricity consumption of about 2,500 kWh ton would cost about $15.00 per ton of pig iron.

10. Hence some form of direct reduction process, that is, a process other than blast furnace or direct cold charge electric smelting, would be required

11. Because New Zealand had no experience of direct reduction processes, it was quickly decided that the services of consultants would be required. To assist in the choice of consultants, three criteria were established:-

a. the consultant must, of course, be technically competent and have had experience in the field of direct reduction;

b. as far as possible the consultant should be free of any technical or financial interest in any specific direct reduction process;

c. that as far as possible the consultant had in his own organization all the necessary knowledge, skills and equipment for the purpose of the enquiry. It was felt that this requirement would make for quicker and easier collaboration between the company and the consultant.

12. Detailed study by the company and its consultant, the Battelle Memorial Institute, led to the conclusion that there were [illegible] direct reduction processes which seemed sufficiently well developed for possible use in New Zealand. It was arranged that the companies owning the processes should demonstrate the capabilities of their process using raw materials sent from New Zealand, with the trials to be observed and evaluated by representatives

of the Battelle Memorial Institute and of the investigating company. Before the trials commenced, the authors visited Japan where they were permitted to examine the only commercial plants currently processing titanomagnetite ironsands similar to our own.

13. While the authors cannot claim to be experts in any particular process, they have had the opportunity of examining closely the operation of six commercial plants using direct reduction processes, five of the plants being in Japan and one in Sweden. These six plants between them used four different types of process; the Krupp-Renn process, the Wiberg gaseous reduction process, cold charge electric pig-iron smelting and direct reduction processes using some combination of rotary kiln and electric pig-iron furnace. In addition, along with representatives from the Battelle Memorial Institute, they observed pilot plant trials by six different processes using New Zealand ironsands and coals. From this experience, supplemented by many profitable discussions with experts in several different countries, they venture to make the following observations.

14. Some direct reduction processes produce molten pig-iron (e.g. Strategic Udy or Elkem); others such as R-N produce sponge iron (or its equivalent) with or without some attempt to separate the gangue from the metallic iron before the steel-making process (usually an electric arc furnace). The steel-making process is usually more expensive when sponge-iron (or its equivalent), rather than molten pig-iron, is used as the charge to the steel furnace. Hence, if one wishes to compare the economics of a sponge-iron process with those of a hot-metal process for use in an integrated steel plant, one must take the cost comparison down to the billet or ingot stage, and not just compare the cost of production of metallic iron.

15. Neither the investigating company nor the Battelle Memorial Institute is aware of any successful commercial process which can reduce titaniferous ore comparable to New Zealand material by gaseous reduction. While there is no doubt that it is technically feasible to reduce ironsands by a gaseous process, the authors believe that, judging from the time taken to develop various direct reduction processes, it is likely to take several years' detailed investigation to prove the technical feasibility

of using a natural gas process for reducing New Zealand ironsand and to determine whether or not such a process would be commercially competitive. For example, there is even a notable lack of detailed information on the thermodynamics and kinetics of the Co-H_2-titanomagnetite reactions.

16. The authors are satisfied that the choice of a direct reduction process is not simple and that each case must be treated strictly on its merits. In other words, there is no single answer which can be expected to cover all possible situations. It is most unlikely that just one process will be the perfect answer to your problem or so superior that other processes can be ruled out without further detailed investigation.

17. In our own case, we originally believed that there were six processes which seemed more or less equally suitable for our conditions. But it required pilot plant trials to show conclusively that one had not yet been sufficiently developed for commercial operation, while two others in fact required more coking coal than would be available from domestic production.

18. The fact that a process is operating successfully in some other country using raw materials very similar to your own is no guarantee that that process is the best for your own conditions. Such items as the cost of labour, electricity, transport, interest on capital etc. might be so different in the two countries that some other process could be more economic in your case.

19. Because of the limitations of time and money, all the process proprietor can do in a normal type of pilot plant trial is to demonstrate the technical feasibility of his process and from the results of the trial and his general experience to give some reasonably firm estimate of the production costs for commercial operation. It is most unlikely that the trial will be able to determine optimum operating conditions. These limitations lead to at least four important practical considerations.

a. In making the choice of process, it is not sufficient to consider only the estimated costs that the process proprietor has given as a result of the trial. It is necessary to see that the scale-up effects from pilot plant operation to full scale operation have been reasonably calculated, neither too optimistically nor too conservatively

b. Some judgment should be made as to the extent to which one can expect to improve the performance of a particular process after some operational experience. For example, if in one process trial acceptable results were obtained quickly, while in another process trial, equally acceptable results were obtained only after considerable difficulty, one would
1 tend to select the first process.

c. Because it is most unlikely that pilot plant trials will provide optimum operating conditions for your own specific circumstances, you will have to determine these for yourself once your plant is in operation, should you wish to have as efficient industry as possible. This task will require the services of people well trained and skilled in metallurgy and operational research and possibly other disciplines as well.

d. The royalties or licence fees for some processes are based on well-established patent rights, others are based on 'know-how' and experience which cannot be patented. In the latter case, particularly, it is necessary to know well in advance what conditions of secrecy and technical security the process proprietor might wish to impose upon your operations. For this
1 reason, the authors would not favour the choice of a process subject to royalty or licence fees, unless it had a marked advantage over processes not subject to such conditions.

20. Apart from direct pig-iron electric smelting, there are at lease five processes either commercially processing titanomagnetite-ironsands or demonstrably capable of commercial operation. They all have one common feature, the use of a rotary kiln. In one of them, the whole process is carried out in the kiln; in another the reduction was originally carried out entirely in the kiln, but the process proprietors are now considering the possibility of enlarging the scope of their process by various
15 combinations of kiln pre-reduction followed by final smelting in an electric furnace. The other three all use a combination of rotary kiln and electric furnace. Fundamentally similar, they each try to do the same thing in somewhat different ways.

21. In these three similar processes, the major variations aro, as only to be expected, relatively few. The major difference is whether the ironsand is fed into the furnace in its original, finely subdivided form or after

it has been agglomerated, either by pelletizing or some form of sintering. Agglomeration in one form or another has certain advantages and disadvantages.

a. Agglomeration is another step in the process and costs money.

b. Offsetting this cost is the fact that agglomeration usually gives a better chance of achieving a higher degree of pre-reduction in the rotary kiln without running into the difficulties caused by sticking or ringing of the charge in the kiln which, if serious, leads to considerable maintenance costs and can involve the stoppage of the kiln.

c. Because of the possibility of achieving higher pre-reduction satisfactorily in the kiln, agglomeration can lead to economies in the use of electric power in the electric pig-iron furnaces.

d. Most experts believe that agglomeration leads to easier and more flexible operation of the electric furnace.

22. It is possible to feed raw sand into the kiln and, by very careful regulation of the temperature in the reduction zone, to ensure that the charge reduces and agglomerates in the kiln without ringing or sticking before it is discharged into the electric furnace. The authors believe that this process, though practicable, is so delicate that it should be attempted only by a master.

23. Speaking generally, the authors would say that if one wants ease and flexibility of operation and a high degree of pre-reduction and hence low electric power consumption, processes using some type of agglomeration are to be preferred. But the final decision depends on the relative prices of carbon and electricity and also to a marked extent on the reactivities of the coal and ore. The reactivity of the ore and the coal can be most important in the success of a direct reduction process. For a given size of kiln and electric furnace, the higher the reactivities of the raw materials, the higher the output per unit time and hence, all other things being equal, the cheaper the product, and conversely.

24. In our study no allowance was made for any possible recovery of titanium or vanadium in the iron or steel slags, as the information available about the profitability of attempting to recover these two possible by-products was inconclusive. The percentage of vanadium in the ironsand is about

0.4%. It would be difficult to raise the percentage of TiO_2 in the slag to more than 50%.

25. It is necessary to stress most emphatically that the success of a possible iron and steel industry does not depend only upon the availability of appropriate raw materials and techniques capable of processing them. Many other factors must be carefully considered, some of which are:-

a. Costs of transport of raw materials to the plant site and the cost of distributing the finished products to the market place. These costs have a major influence on the choice of the ore and coal deposits to be used, and on the choice of plant site. Under New Zealand conditions these costs could amount to about $15 per ton of finished product.

b. The size of market and range of products to be produced.

c. The availability of local labour and its productivity.

d. The availability and price of capital.

e. The permissible range of the selling prices of the finished products.

f. The optimum size of the plant or, perhaps, of the industry.

g. The supply and training of the necessary managerial and technical staff.

h. The necessity, if any, for the provision of housing and other social services such as schools or hospitals.

i. The availability and price of land suitable for present needs and sufficient for reasonable future expansion.

j. The need to observe public health regulations regarding air or water pollution.

k. The availability of adequate water supplies.

This list does not exhaust all the possible factors to be considered. As one or two examples will show, the chances of success depend upon a complex interaction of technical, economic and social factors.

26. Consider first the influence of transport costs on the choice of deposit. New Zealand has several titaniferous ironsand deposits suitable for an industry. They are easily mined by cheap open-cast methods and the upgrading of the ore by magnetic separators can be done relatively cheaply and easily. When mining, beneficiation and transport costs are all considered together, it turns out that in New Zealand a deposit containing

only 10% iron is much more attractive than another one containing 25% iron. The second richer deposit is in an isolated, relatively inaccessible location and its utilisation would require the establishment of a small township and the provision of expensive transport facilities and other services.

27. Another example of the transport problem was the necessity to decide whether the industry should be in the North or South Island. Until the New Zealand Government decided to install a cable to transmit electric power from the South Island to the North Island, it was thougnt that there might not be sufficient reserves of low-cost electricity in the North Island to safeguard the future expansion of an iron and steel industry. It was originally believed that the cost of transporting the ore from the North Island to the South by ore-carriers could offset the cost of bringing the finished products back to the North Island which accounts for about 70% of the New Zealand market for steel products. But careful calculation using linear programming techniques showed that this proposition was not nearly as economical as originally believed and that, to overcome the transport costs, electric power would have had to be supplied in the South Island at an impossibly low price.

28. In considering the size of market, it is not sufficient to consider just the total demand for steel. The following points must also be examined:-

a. The demand for various types of steel products and their size ranges or other significant characteristics; for example, the demand for pipe of sizes up to four inches in diameter, four to nine inches in diameter and over nine inches. The size of the pipe to be manufactured has considerable influence on the price of the pipe mill to be installed.

b. The likely rate of growth of demand. In our own case, after examining the trends over the last forty years and taking into account future possibilities of general industrial expansion in New Zealand, we believe that the demand for most steel products in New Zealand will rise at a rate of at least 4% per year. It must be noted, however, that various types of products will have different rates of growth of demand, plates and sheets having the highest and pipes the lowest under New Zealand conditions.

2 c. While the rate of growth of demand can be safely assumed to be not less than 4% per year, some account should be taken of possible fluctuations of demand from year to year. In our studies we assumed that the actual demand in any particular year could fall with equal probability within a range of 50,000 tons above or below the trend value. Because of these fluctuations, as well as for other reasons, it is necessary to have a reasonably accurate estimate of the break-even point of the proposed plant.

d. Much attention was given to the possible export of iron and steel products to earn overseas exchange and also to achieve economies of scale. However, because of uncertainties in the world market and because of conflicting opinions given to the investigating company, it was decided not to take exports into account.

29. The productivity of the local labour force plays a very important part in the production costs of an iron and steel industry. As many studies have shown, there are very real differences in output per man-hour between industries of the same type in different countries. When these studies were being made, New Zealand had no operational experience from which we could determine the productivity of a local industry.

30. To obtain realistic figures for operation in New Zealand, comparisons were made of labour productivities of such existing industries as the manufacture of cement, fertiliser and pulp and paper as found in New Zealand and other countries.

31. It must be remembered that the reasons for these differences in productivity are rarely simple in their totality. They result from a complex interaction of managerial skill and foresight, traditions of labour relationships, the
26. methods of wage negotiations, the general level of education, attitudes towards investment and the desire or need to keep abreast of technological innovation and other social institutional factors.

32. The availability of capital and its price, both loan and equity, can impose limitations in planning and implementation. For example, detailed calculations show that the production of sheet and plate in New Zealand by means of currently available mills would at best be very marginal for at least another ten years. But even if this were not the case, New

Zealand would find it very difficult to raise the initial capital for a fully-integrated industry making a very wide range of products. Because of this and the difficulty of finding all the necessary managerial and technical staff that would be required from the beginning, production of iron and steel in New Zealand for the next twelve years or so will be restricted to the possibilities of pig-iron for foundries, light and medium structurals, rails, wire rod, smaller sizes of pipe, merchant bar and such like. Furthermore, the restriction in range makes for less problems in the initial stages.

33. In order to assess profitability, it is necessary to know or to assess as accurately as possible the price at which the various products can be sold. Because New Zealand has had to import all her own iron and steel requirements, estimates of the return from gross sales were based on the average landed costs (c.i.f.) of steel products from Great Britain and Australia over the last three years, these two countries being our traditional suppliers for more than 70% of our needs. The investigating company recommended to the Government that the industry should be assured of the domestic market for its products for an initial period of, say seven years and thereafter should be given adequate protection against dumping.

34. Due attention having been given to the problems listed in paragraphs 25-31, one can proceed to calculate the optimum size of plant. It would take far too much space to go into the methods of calculation but an excellent account of the theory (which was modified to suit our requirements) has been given, for example, by Pierre Massé (i).

35. It turned out in our case that the optimum size of plant would be about 270,000 tons costing about $61,000,000 and that it would reach maximum capacity after 7 to 8 years' operation. But it was further noticed that by careful design the whole plant need not be built at once. A smaller plant costing about $38,500,000 could be designed to produce about 150,000 tons a year of a more limited range of products. Studies showed that the expansion could be financed largely from retained profits and depreciation after distribution of 50 per cent of tax paid profit. But it must be noted

(i) Massé, Pierre, Optimal Investment Decisions. First Edition, Prentice Hall, Inc; New Jersey (1962) that the choice of equipment and processes for the initial plant must be such that the envisaged expansion is both technically and financially practicable. All calculations were deliberately conservative.

36. It is one thing, however, to prepare plans; it is another thing to implement them according to expectation. The investigating company believes that if the correct initial decisions have been made, the two of the most important factors governing the long-term health and efficiency of an iron and steel industry, particularly in a developing country, are the quality and skill of the whole managerial and executive staff and the amount of research and development that the industry is prepared to undertake.

37. As far as New Zealand is concerned, research and development will be essential from the beginning if the industry is to flourish, for a New Zealand iron and steel industry will be, to a surprising extent, a unique industry. Some of the reasons for this are:-

a. at present the Japanese are the only people processing ironsands commercially;

b. ironsand concentrates in Japan and New Zealand are very similar, in some cases almost identical, but other New Zealand raw materials, particularly coal, are quite different.

c. the processing of ironsands in Japan is a small part of a large integrated industry obtaining most of its steel either from blast-furnace production or scrap. Because the situation in New Zealand will be the exact opposite, some of the Japanese techniques and developments will not be suitable for New Zealand.

38. Experience in other countries, e.g. Sweden and Canada, shows quite clearly that by judicious research and development quite small companies (by world standards) can develop new processes and techniques appropriate to their own circumstances, thus enabling them to compete profitably against much larger organisations.

39. This does not mean that a New Zealand industry will not depend to a large extent upon research and development done in other countries. It simply means that with a research and development programme of her own, she will not have the technical people able to assess the potential value of overseas developments, to see what modifications are required to adapt them to New Zealand conditions and to take advantage of them as quickly as possible. These reasons apply to all progressive steel companies, large and small.

40. The investigating company recommended that a New Zealand steel industry should devote about 1 per cent of sales to research and development.

41. For a country like New Zealand with no group of people experienced in the iron and steel industry, the problem of staff selection and staff training at all levels is a serious one. In the initial stages, much reliance will have to be placed on the services of consultants, but it is highly desirable that some of the local people, from the point of view of staff training and development, are able to work closely with the consultants. In this respect we owe a considerable debt of gratitude already to the Battelle Memorial Institute.

42. Other consultants will have to be engaged to design and supervise the erection of the plant and because of the lack of experienced people, the investigating company believes that a management contract should be arranged for about the first three years of the operation of the plant.

43. In order to obtain suitably trained staff as soon as possible the investigating company believes it to be essential that while the plant is being designed and erected, selected key technical and managerial staff should be sent for training in other countries. This training could be completed in time to enable them to return to New Zealand to work with the management contractors from the start of the operations and to take over the whole operation of the plant in a few years.

44. It is well known, of course, that a small steel industry in a small country is usually at an economic disadvantage. In the New Zealand case, however, there are three very important advantages which offset this handicap.

a. New Zealand is situated 1200 miles from her nearest steel supplier, Australia. All other steel suppliers, both actual and potential, are several thousand miles away. Thus, there is a considerable saving in transport costs.

b. The ore can be very cheaply mined from the surface and the beneficiation by means of magnetic separators is also quite straightforward and cheap.

c. Reference to figure 2 will show that the ore, the coal and the major market area (Auckland accounts for approximately 50% of the New Zealand demand for steel) are all within 75 miles of one another. Once again this means, that compared with most steel industries, there is an unusually favourable location of raw materials and market.

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Figures

FIGURES

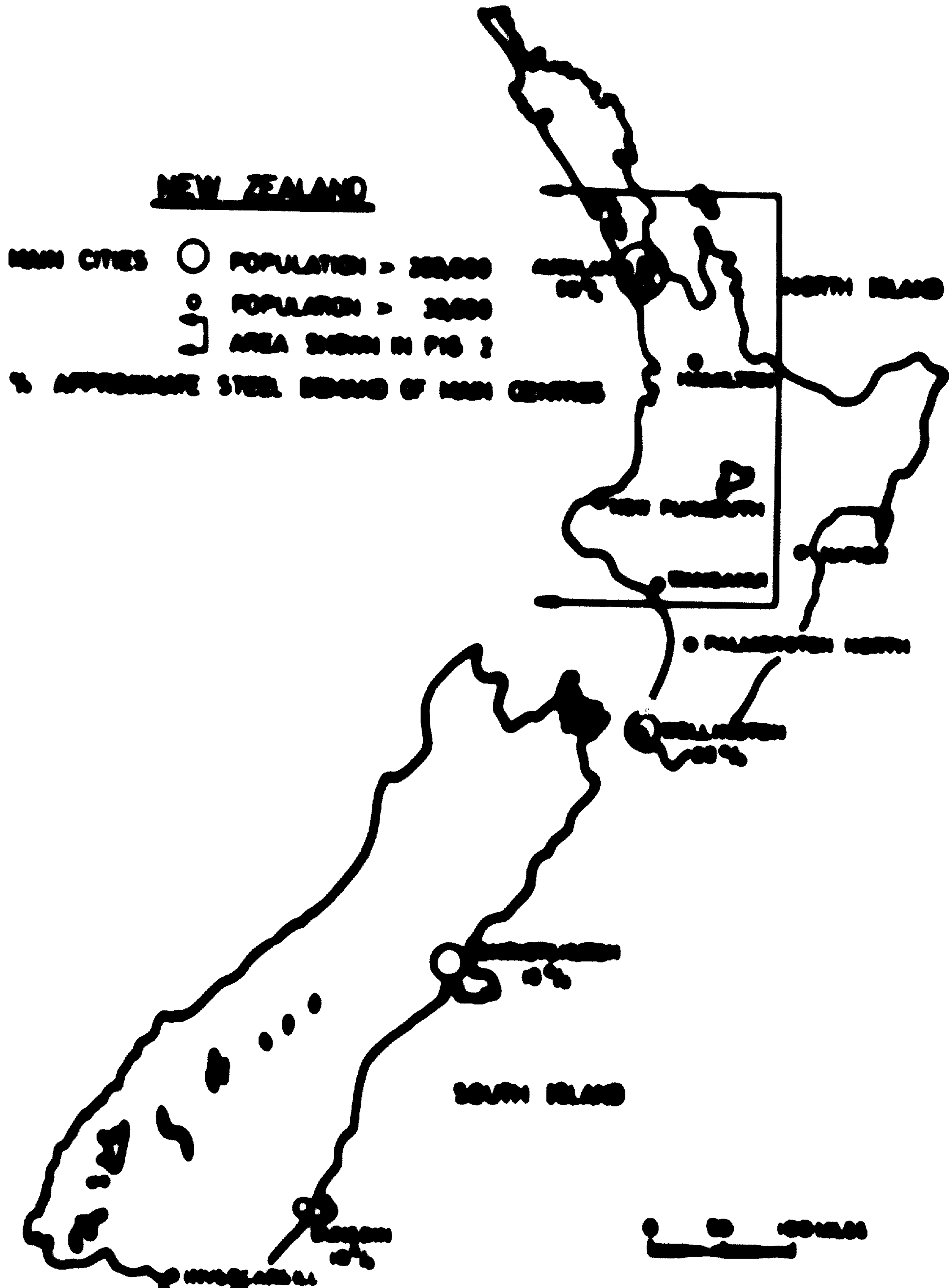
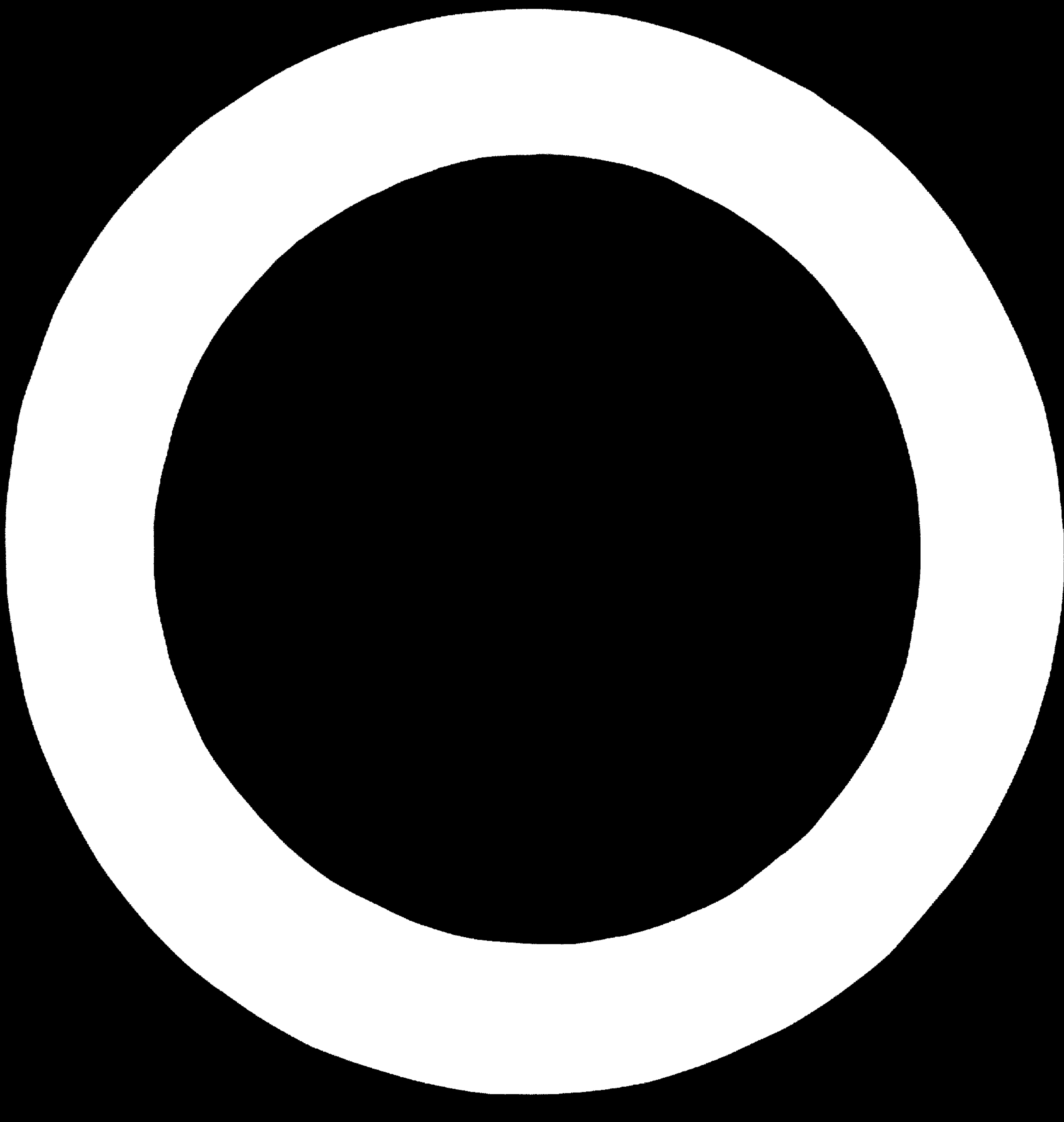

NEW ZEALAND
MAIN CITIES
POPULATION >
POPULATION >
AREA SHOWN IN FIG 2
NORTH ISLAND
SOUTH ISLAND

FIG. 1



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LOCALITY MAP

LEGEND

- Major ore deposits > 100 x 10^6 tons
- Minor ore deposits > 10 x 10^6 tons
- Major coalfields > 50 x 10^6 tons
- Minor coalfields < 50 x 10^6 tons
- Natural gas field
- Railways
- Limestone deposits

Auckland takes 50 % of total New Zealand steel demand

FIG. 2

22.3. 74