Project management of an integrated iron- and steelworks during design, planning, and construction

M. D. J. BRISBY and A. R. PARISH

INTRODUCTION

MUCH HAS BEEN SAID, and many papers written, on the technical design problems associated with all branches of engineering involved in the building of a multi-million pound integrated steel plant. The object of this paper is not to add to their number, but rather to highlight the executive and management problems which arise in the course of the development and construction of this type of plant.

The cost of an integrated steel plant with a 1 m. ton output, will be about £100 m. In spending this money, many thousands of tons of materials, and thousands of people must be effectively deployed to ensure that the developer gets a return on his capital at the earliest possible moment. A project of this nature can be constructed in about three years, a formidable task when it is realized that it may involve moving 10 m. yd^3 of earth, placing 1 m. yd^3 of concrete, erecting 80 000 tons of structural steel, and installing and commissioning nearly £70 m. worth of plant.

The proportions of the total capital expenditure accounted for by the various types of engineering, excluding site purchase and working capital for a typical plant, are shown in Table I. These figures are indicative of costs on a site involving relatively low civil engineering expenditure. If, owing to external considerations, the location of the plant were on more difficult ground, the civil engineering costs could be double or even more. A typical build up of costs for such a site is given at Appendix A. It should be noticed that design, engineering, and management costs are shown as a separate item. Under certain types of contract this sum would apparently be absorbed into the quoted prices; it nevertheless exists, and will ultimately be paid by the developer.

In preparing an estimate, provision will, of course, be made for rising costs during the construction period and contingencies will be budgeted for realistically. It is evident that control must be kept over the spending of these vast sums of money to avoid extravagance and this can only be achieved by close supervision and continual review of the project at all stages from inception to completion. This paper examines the measures required to give this necessary supervision, and points out some of the many pitfalls awaiting the unwary developer.

The essence of a successful job is co-operation. A typical management team is outlined in the paper but it must be emphasized that everybody engaged in the project, be he client, consultant, or contractor, is of equal importance to the successful conclusion of the project.

The paper is divided into the following sections: planning; The team; cost control; design; inspection and progressing; construction; programmes; summary.

Planning

Any activity, large or small, can be carried out most effectively if it is performed in accordance with a plan established to make the best use of all available resources. This is a truism which cannot be over-emphasized, and is more than ever essential when vast sums of money, such as are involved in a modern integrated steelworks, are concerned.

Planning in this context must start from the moment the project is conceived. Preliminary work will consist of market and viability studies, investigations into the availability of finance and the period over which it will be forthcoming.

These studies will be proceeding concurrently, and will determine four things:

(i) that money can be raised for the project
(ii) that a site is available
(iii) that a specific type or types of plant are technically desirable
(iv) that certain combinations of plant will give an acceptable return on the expended capital.

It is necessary to give much detailed attention to the planning of the physical work to be done, since this will be affected by many opposing influences. For instance, the choice of a site may not be determined by physical considerations, as access to markets, availability of raw materials, availability of labour, proximity to existing plants, or sociological obligations in a particular area may outweigh the additional civil engineering cost involved in the use of a particular site.

Again, the completion date may be dictated by external considerations such as the pattern of markets, or the plant chosen may not be the cheapest initially, but may be more suitable for future expansion. A quick programme will ensure early returns on capital, but will cost money to achieve, and a project designed on a quick programme may lack refinements which could be included

SYNOPSIS

This paper examines problems encountered in the construction of a large integrated iron- and steelworks and offers appropriate solutions. The problems occur in all fields of engineering. Problems in accountancy also occur owing to the need for an early return on capital, which, in turn, necessitates as short a construction period as possible with consequently a very high rate of spending.

To control this expenditure the maximum pre-planning and programming of work must be maintained and this control demands leadership of a high order. The technical problems involved during the design and construction are considerable; no less important are the problems of co-ordination and co-operation between the professions and trades involved. A lack of this co-operation can cause disproportionate delay and cost increases. To overcome this, information must be made available early in the job and not change as the project progresses. Decisions must be taken rapidly and adhered to, and clear communications must be maintained between all the parties involved in any part of the work. SR78J

The authors are with W.S. Atkins and Partners, Consulting Engineers, London.

TABLE I Proportion of total capital expenditure devoted to various types of engineering

Civil engineering	£ 13 000 000	Site preparation, roads, railways, drainage, foundations
Structural engineering	£ 10 000 000	Process and ancillary buildings plant and services supporting structures
Plant engineering	£ 67 000 000	Mechanical and main electrical plant and services
Electrical distribution	£ 10 000 000	Main distribution and transforming equipment, plant cabling and wiring
Design, engineering, and management costs	£ 4 500 000	
Total	£ 104 500 000	

in a more leisurely one. Moreover, if a works is planned to be constructed quickly, and delays occur, it may well cost more than it would have if a longer programme had been established and maintained.

From the points mentioned, which are only a few of the many conflicting factors besetting the developer, it is obvious that great care must be taken to assess the dominant requirements for the project; only then can a rational decision be taken, and a programme of work produced. The more work done in the planning stage, the less modification will be required during construction : this is the key to a well run job.

THE TEAM

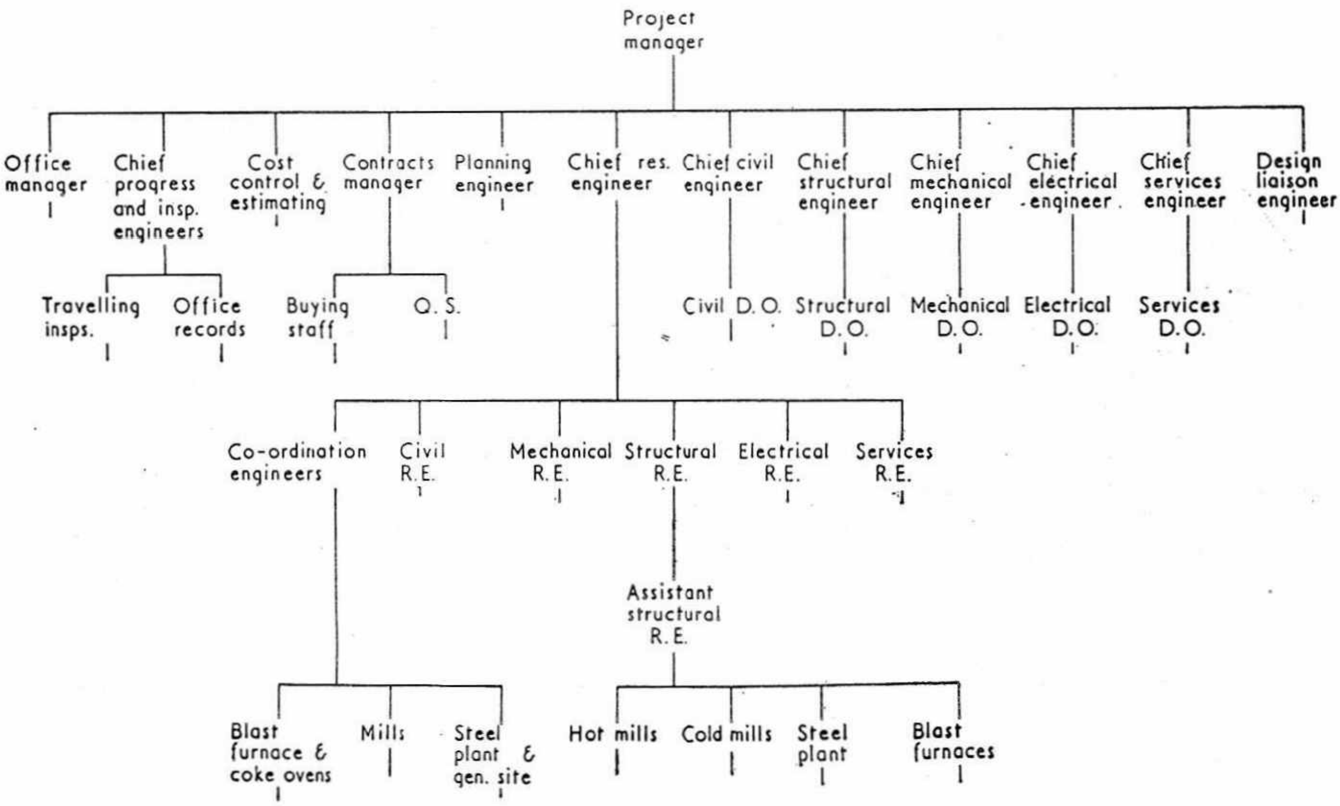
The construction of an integrated steelworks in some three years, at a cost of about £100 m. requires that a fully effective and integrated team be welded together in a short time. Even excluding the large number of people who will be working in manufacturers' drawing and design offices, the average number of staff working on the job over the three year period will be about 700, some in design offices and some on site. The composition of the team will vary as time goes on, with emphasis in the early stages on design office work and later on site supervision. The number will also vary, with a peak figure of well over 1 000 employed at the time when design and construction overlap. The site staff alone will number about 500.

To get this integrated team requires leadership of a very high order, since the whole success of the project, particularly as regards keeping to programme, depends on the ability of the senior staff to fire the team with their determination to succeed. On a job of this magnitude there are countless excuses for delay but it must be a point of pride for all levels of staff to use their ingenuity to overcome the difficulties.

The manager of the project carries the ultimate responsibility for the successful completion of the whole works and Fig. 1 shows in outline an organization which could be used for a typical project. No attempt has been made to show more than the basic ideas since a detailed arrangement must necessarily depend on the nature of the job. In Appendix B is shown a different, but equally workable organization chart.

During the design period the emphasis must be on liaison between the various design offices so that all necessary information is passed from one office to another. Co-ordination or liaison engineers should be appointed by the various design offices, as these men will be well informed on the needs of their departments. These men, at a later stage in the project, have the vital role of ensuring that construction drawings arrive on site at the required time and of seeing that the design offices reply quickly to questions from site.

For site supervision during construction it is essential that there be one man, the chief resident engineer, who has the whole responsibility for this work, so that the relative priorities for the various branches of engineering can be clearly defined. The chief resident engineer is likely to need the assistance of two or three co-ordination



1 *Skeletal management chart*

W. S. ATKINS & PARTNERS
CONSULTING ENGINEERS
158 VICTORIA STREET
WESTMINSTER. S.W.1

THE WEST OF ENGLAND IRON & STEEL Co. LTD.
CASTLE MILLS CONTRACT
PROJECT FINANCIAL CONTROL SHEET No. 15

REF. No. A199/MDJ/EOHT
DATE. 20/7/62
FORM. FC. 3

1 LEDGER CODE	2 DESCRIPTION	3 BROCHURE ESTIMATE AT 7 10 60	VARIATIONS AFFECTING CONTINGENCY: 4 UNFORESEEN WORKS APPROVED	5 OTHER VARIATIONS APPROVED	6 TO BE APPROVED	7 ALTERATIONS IN COST OF LABOUR AND MATERIALS	8 ESTIMATED FINAL COST	9 ORDER COMMITMENTS TO DATE	10 EXPENDITURE TO DATE
63/00	ROLLING MILLS	£	£	£	£	£	£	£	£
63/01	Stockyard	41,700		- 10,000		2,400	34,100	7,200	240
63/02	Stripping bay	331,440		- 60,000		2,500	273,940	117,040	43,800
63/03	Ingot preparation bay	260,400		- 28,000		2,400	234,800	148,440	31,300
63/04	Ingot storage bay	241,720		+ 46,800	+ 800	4,540	293,260	219,680	29,438
63/05	Soaking pit bay	2,013,200		- 42,800		38,400	2,008,800	1,626,000	621,128
63/06	Cogging mill bay	4,215,000		- 121,000	+ 30,000	100,400	4,224,400	3,800,576	1,730,168
63/07	Motor room 'A'	1,080,600		- 14,100		34,200	1,100,700	922,520	527,960
63/08	Billet mill bay	5,096,920		+ 204,520	+ 3,000	120,700	5,425,140	4,116,016	1,544,898
63/09	Motor room 'B'	1,392,800		+ 17,000		28,900	1,438,700	1,023,780	731,246
63/10	Warehouse no. 1	401,000		+ 8,900	+ 3,000	14,200	427,100	320,918	140,830
63/11	Warehouse no 2	2,654,000		- 40,000	+ 16,000	21,560	2,651,560	1,596,000	596,958
63/12	Roll shop no. 1	205,100		+ 40,500	+ 3,200	9,000	257,800	101,608	54,400
63/13	Bar mill stock bay	1,011,800		- 15,000		14,180	1,010,980	691,688	218,600
63/14	Heavy bar mill	2,849,200		+ 11,140	+ 4,000	71,880	2,936,220	2,228,040	641,680
63/15	Motor room 'C'	4,20,000		+ 2,000		21,600	443,600	281,000	160,968
63/16	Motor room 'D'	580,200		- 12,860	+ 37,000	28,680	633,020	276,080	66,986
63/17	Bar mill bay	1,202,000		+ 8,600		30,040	1,240,640	618,926	345,208
63/18	Research and test block	143,000		+ 8,360	+ 5,420	9,000	165,780	146,882	107,400
63/19	Tempering furnace bays	601,000		+ 40,400		6,100	647,500	593,206	215,448
63/20	Roll shop no. 2	312,900		- 4,764		4,308	312,444	216,880	80,106
63/21	Heat treatment bay	461,000		+ 10,360		10,180	481,540	387,000	110,726
63/22	Cogging mill welfare block	80,000		- 6,600		4,600	78,000	54,000	8,252
63/23	Billet mill welfare block	40,720		+ 3,080		1,000	44,800	36,000	8,000
63/24	Bar mill welfare block	24,360		+ 3,640		1,400	29,400	20,600	10,000
	ROLLING MILLS Sub-total	25,660,060		+ 49,576	+ 102,420	582,168	26,394,224	19,550,080	8,025,740
	Provision for engineering & other fees	910,000					910,000	910,000	530,882
	Sub-total	26,570,060		+ 49,576	+ 102,420	582,168	27,304,224	20,460,080	8,556,622
	Provision for contingencies	2,566,000		- 151,996			2,414,004		
	Provision for rising prices	1,200,000				- 582,168	617,832		
	TOTAL	30,336,060					30,336,060	20,460,080	8,556,622
	Less retention sums held								164,608
	GRAND TOTAL	30,336,060					30,336,060	29,460080	8,392,014

2 *Typical cost control sheet*

engineers who can perform this function in separate areas of the project.

To control the contractors it is necessary that all the supervision of, say, a structural contractor anywhere on the site be vested in one man, the structural resident engineer. If the supervision is divided on a geographical basis there will be conflicting interpretation of standards of quality and contract conditions, apart from pressures for concentration of effort in different areas, which will prevent efficient operation by the contractor. Each resident engineer will, however, need to have deputies whose responsibilities are for sections of the project.

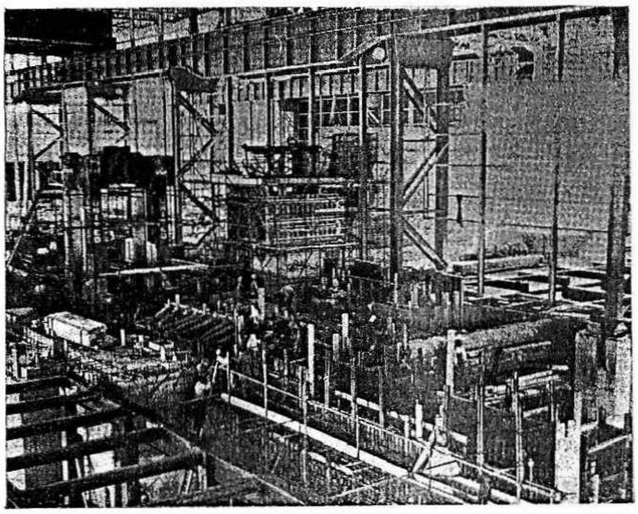
The functions of the chief progress engineer, the cost control and estimating section, the office manager, and the planning engineer will be clear from their titles. The contracts manager will handle the placing of orders and contract variations together with the general interpretation of conditions of contract ; he will also be the channel of day-to-day communication with quantity surveyors if they are engaged on the project.

It may well appear that the span of control of the project manager is too wide for effective management with 12 people responsible to him. The situation is made somewhat easier by the change of emphasis with time. In the beginning he will concentrate on design, later on construction work. The project manager will require a small, but effective, group of assistants.

The whole group of people, with diverse backgrounds and different technical interests, must function as a team with each man having an appreciation of his colleagues' difficulties. There is no place in such a team for the 'primadonna' because success depends so much on day-to-day informal contacts for achieving progress. Formal organization must exist for dealing with problems, but the informal contacts must be such that the vast majority of the difficulties are resolved before they become sufficiently important to be referred to the formal machinery. For all the senior positions there is no substitute for men with experience who can anticipate the problems and deal with them both correctly and swiftly.

COST CONTROL

It is clearly of great importance that the project should be constructed at a cost within the sum of money budgeted for the purpose, and to do this it is essential that there should be a system of cost control which, if costs are tending to get out of hand, will give warning sufficiently early for remedial action to be taken. This means that the cost control must be a forward-looking system operated by engineers of experience and vision and not a system of recording of cost events already passed. It must, however, be recognized that no system of paper-work can prevent overspending ; the system can only bring the situations as they developed to the attention of the project management whose duty it is to decide on the remedial action and implement it.



3 *Typical example of complex rolling mill foundations*

4 *Early stages of site levelling. Up to 10m.yd³ of spoil may have to be removed*

The first requirement for effective cost control is a realistic estimate, which should represent the expected cost of the job with an appropriate contingency allowance. To prepare such an estimate for a major scheme may well require three months of intensive effort, but this is time well spent. Subsequently the estimate will require continuous revision as design and construction proceeds, possibly with a formal re-estimate at six-monthly intervals.

In preparing estimates it is essential to have the co-operation of the engineering design staff so that they are aware of the amount of money allocated for their work, and are reasonably satisfied that it is sufficient.

As the design work and the letting of contracts proceeds some estimates will prove too generous and some insufficient; the project management must insist on being constantly advised on the position so that money can be re-allocated as required. The allocation of money in the original estimate is not to be regarded as final, and the best balanced works will not be obtained if one department is allowed to 'gold-plate' because the estimate is over-generous while another department is 'skimped' because the estimate has proved inadequate. Every estimate should include a contingency fund from which moneys can be drawn when needed and into which any surplus must be paid when available.

The cost control system should also be used to monitor the total payments made so that a financial progress indicator is available. This will be related to the predicted rate of call on capital which will have been prepared with the estimate. This information is invaluable to the accountant but its interpretation by the engineer requires care and experience to take account of terms of progress payment for plant and any delays implicit in the method of measurement and payment for civil and structural work (Fig. 2).

DESIGN

General

Since all steelworks projects are required to be completed in a hurry there are two fundamental problems affecting all design work, namely obtaining information, and the designer's tendency to strive after perfection.

All design work is based on information obtained from someone else, whether it be the structural engineer who needs to know the intended size of an overhead crane, or electrical engineer who requires mill motor ratings. Each design office therefore wants to get its own information as early as possible but, in order to have the maximum design time, the department will wish to pass on information to other people as late as possible. A design office programme adequately policed and carried out by experienced designers who can make intelligent guesses at missing data is the answer to this problem.

The second problem is that designers as a race are perfectionists. They are always sure that, given another two weeks, the present adequate design could be so greatly improved that they should be allowed the extra time. To allow this may be fatal to the programme and critical design office programme dates should remain sacrosanct.

Another point which requires careful watching is the piling of design margin on design margin, with consequent excessive costs. Consider the following case:

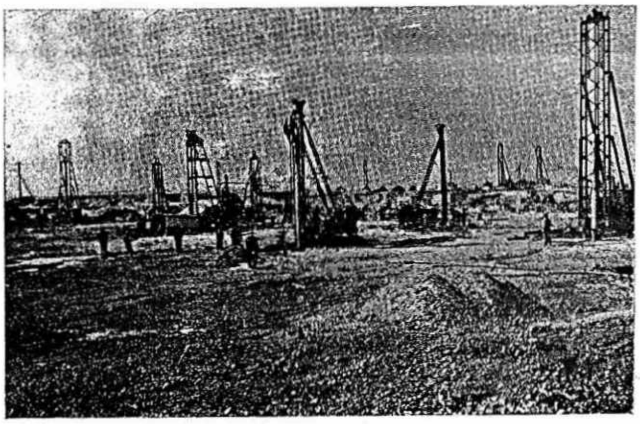
Furnace designer's estimate of water requirements	550 gal/min, 10 ft head
Figures passed to pump supplier after adding designer's 'safety margin'	600 gal/min, 12 ft head
Pump manufacturer has no standard pump for this duty and supplies one capable of	700 gal/min, 12 ft head
He asks motor manufacturer for motor rated	4 hp
This is a non-standard rating and the motor supplied is rated	5 hp

As a consequence all the electrical equipment will be designed for 5 hp full load whereas the real requirement is nearer 2½ hp.

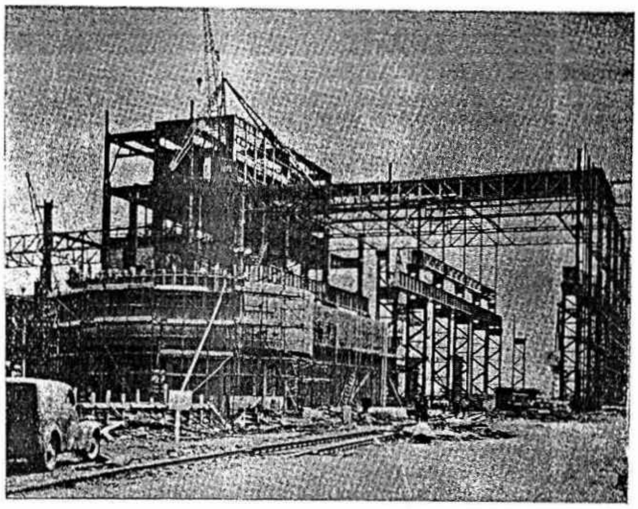
In the majority of cases the major part of design work will be carried out in offices remote from the site, whether they be the civil engineers' permanent offices or suppliers' work design offices. However, a small site drawing office capable of making rapid changes to issued drawings to conform to site requirements, or to undertake any small urgent designs, is a real necessity. Obviously the more remote the site from the main design offices the larger and more competent must be the site office staff.

Civil

In many cases, the first civil engineering responsibility will be that of assessing the relative merits of various sites. At the planning stage this will usually have to be done on the basis of existing geological data, any information available from other works carried out in the area,



5 *Corner of large steelworks site during piling operations, indicating amount of planning required to co-ordinate work of a large piling contract*



6 *LD converter building during construction. Supporting structure for the vessel is being erected concurrently with the building*

visual inspection of the site, and experience. A knowledge of the problems which are liable to affect the cost of site works is vital. It may also be possible to do preliminary ground surveys of possible sites, and if this is practicable it is well worth doing, as it gives a reliable picture of the geological hazards likely to be encountered. The importance of this assessment is shown in the figures for two plants recently constructed where in one case the civil engineering costs amounted to 15% of the total capital cost, and in the other 30%, a difference of some £15 m.

Once the site is determined, operational considerations will generally decide the plant layout, but a more detailed site investigation will frequently suggest layout modifications which will show considerable financial savings, as well as providing invaluable data to the civil engineer for his design work. The development of soil mechanics has reduced considerably the element of uncertainty in foundation design and the maximum use should always be made of advance knowledge gained in this way.

The civil designer will undoubtedly be asked at this stage for an estimate of the cost of the civil works, and it is he, rather than a professional estimator, who should produce it. This is because an estimator is usually unwilling to prepare figures until the basis for them is firmly established whereas the civil engineer is in a better position to produce budgetary estimate figures from his experience of the work, and knowledge of the problems likely to be encountered.

The main problem which always faces the designer at this stage is the difficulty of obtaining information. It is now that the technical details of the job will be determined, and the plant and structural engineers will not yet have settled their own designs, let alone their foundation requirements. These are likely to be the last items considered. At the same time, most of the civil engineering work must be done at site before the start of plant erection. It is therefore of vital importance to the civil engineer that he should receive the necessary information at the earliest possible moment. For this reason, all major decisions must be taken as early as possible and must remain unaltered unless there is a sound reason for them to be changed. It is from this point that the benefits of pre-planning the work become more and more apparent.

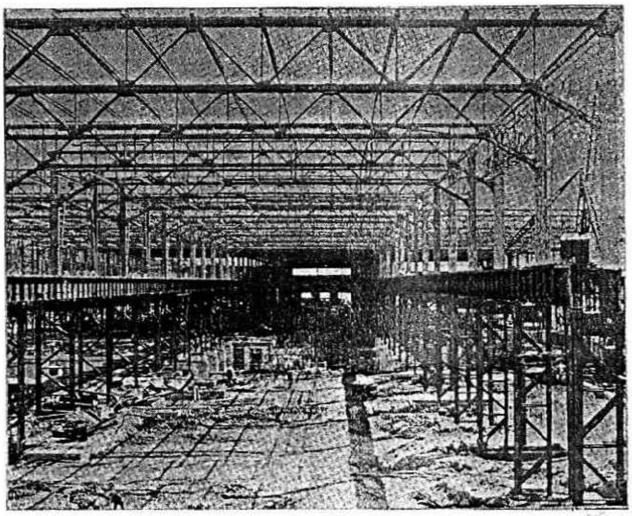
It frequently happens that, since the civil engineering work can be altered in detail right up to the moment the concrete is poured, late modifications are continually called for and incorporated in designs. This is bad for design office morale and is also expensive; the designer should be responsible for ensuring that the developer is aware of the costs in which he may be involved due to these late alterations. In a modern steelworks, the design of the foundations to support the plant is only a part of the problem. An additional part is the provision of tunnels and trenches for the increasingly complex network of pipes and cables required to operate the plant (*see* Fig. 3). Again, at the time when the civil designer starts to prepare his drawings, little final information is available regarding the precise routing of the services pipe and cable runs, and the closest co-ordination is required to ensure that when the time comes, the foundations are so designed as to give access for the services.

During the site investigation, the possibility of foundation settlement will have been determined. The civil designer must now agree with the plant and structural engineer what, if any, relative movement is acceptable, and design his work so that any movement will occur at points where it is permissible.

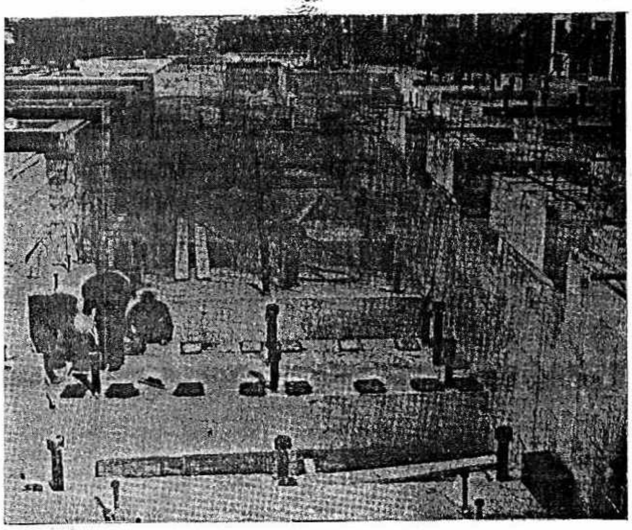
Structural

Until the structural engineer designs his outline building and calculates loads, the civil engineer cannot design his foundations. The structural engineer, however, cannot do his design until the parameters are outlined for him, particularly the plant layouts, and the capacities and heights of overhead cranes in the shops. In some cases he will be tied very intimately to the plant design, notably in LD steelmaking plants, where the structure is an integral part of the plant, but in most steelworks buildings the outline plant information will enable him to proceed with his design.

The structural department will be called upon to produce material ordering and design drawings for the structural contractor, as much of the material will have to be specially rolled, and will take a considerable time to assemble and fabricate. Both of these pressures tend to encourage the use of simple structural design, as the structure can be produced more quickly, and more important, any alterations which may be required in one area due to a revision in plant layout are not so likely to have repercussions elsewhere as they would with a more complex design. Together with this simplicity of design, it is advisable to let a contractor detail his own connections, as most major contractors have standard methods which they prefer to use: the engineer will, of course, check their adequacy for the imposed loads.



7 Building erection, plant installation, and plant foundation being carried out concurrently. Building is complete at far end of bay; EOT crane installed



8 Mill foundations being prepared to receive the stands. Levelling pads being grouted in foreground

In designing a building, it is essential to bear in mind the use for which it is intended. In a rolling mill, the mill housings will usually determine the maximum load to be lifted. In buildings such as a melting shop or foundry, however, there will be continual efforts made by the production staff to produce a quart out of a pint pot. The experienced structural engineer will steer a skilful course between the 'Scylla' of overdesign and the 'Charybdis' of following the design loads so carefully that he has to start strengthening as soon as the plant comes into operation.

In addition to these design points, the structural engineer is faced with a host of others. The buildings must be designed to minimise site erection time; they must be arranged so that erection can start where subsequent plant erection will take longest; they must be divisible into units which can be transported and lifted by the tackle which will be available; and they must be designed to give maximum access for maintenance, combined with a minimum maintenance requirement.

Plant

It will be evident from the figures given in Table I that process plant represents the largest item in the cost of a steelworks. All the other branches of engineering are there to serve the mechanical plant by supporting it, driving it, keeping the weather off it, keeping it cool, etc.

The starting point for plant layout and selection is a comprehensive process flow diagram which sets out the throughput of all materials and products. With this information, tentative selections can be made of the general types of plant to be used, but at this stage it is probably unwise to make rigid choices; further consideration must be given to the effect of one item of plant on another and of the way in which the plant items may be laid out in functional relationship to one another. This is the stage at which the engineers require proper guidance from the planners on the extent to which the plant should incorporate provision, which will inevitably add to the capital cost, for future expansion of output or change of product. It is also the time when careful thought should be given to arranging the plant so that more advanced techniques may be applied in the future without excessive costs; for example, if a mill will run initially under manual control it should be ensured that computer control could be added in the future.

These plant layouts will require consideration of all the known possible, and many apparently impossible, schemes before it is reasonably certain that the most appropriate layout has been evolved. This is a period of drawing, scrapping and re-drawing interspersed with consideration of the many ideas, useful and otherwise, put forward by engineering colleagues, manufacturers and production staffs. The appropriate techniques include cardboard cut-outs of plant items which allow modifications to layout to be investigated quickly, and if the problems are particularly complex, models should be employed. This process should not be unduly hurried because once settled, the effect of changing plant layouts can completely jeopardize both programme and estimate.

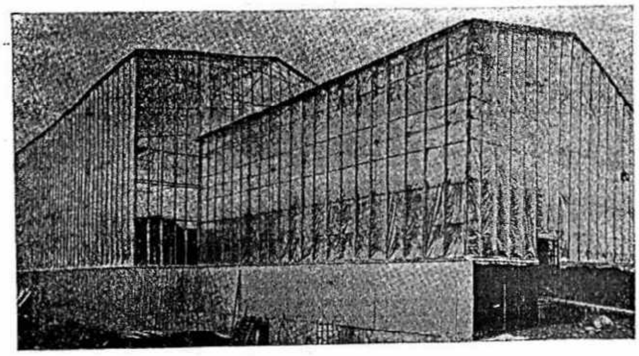
During this period it is vital that the operating staffs, metallurgists, and maintenance engineers have the opportunity to make their requirements known. They have a large fund of experience which should not go untapped.

For all this work the programme must allow sufficient time; heavy items such as steel plant, furnaces, and rolling mills are likely to be among the longest delivery items on the job and delays in putting such equipment on order will affect the completion date. Further, until the plant is on order neither final foundation requirements nor drive details will be known. There is the additional point that in many cases design work cannot begin on buildings until the manufacturer of the plant is selected.

Electrical

The electrical design falls into two quite separate parts: (*a*) plant engineering, and (*b*) power distribution. The extent and timing of electrical plant engineering will depend to a considerable extent on whether the electrical equipment is to be supplied by the mechanical plant contractor or whether there is to be a separate contract. If the former method is adopted the electrical engineer will specify the general types of equipment which he requires, but the mechanical plant contractor will be responsible for the ratings of motors, their suitability for the duty and so on. This relieves the electrical engineer of work, but to some extent he loses detailed control of the equipment which is to be supplied, and it costs more because the mechanical plant contractor requires a handling charge.

If electrical plant is bought under separate contract, and this is the preferable way, it is not possible to go



9 *Dry working conditions achieved by temporary structure clad in plastic sheet*

out to tender until after the mechanical plant has been ordered and motor ratings, speeds and duties, are known. Since electrical machinery and control gear involves long deliveries the ordering of the mechanical plant must not be delayed.

Continual contact is necessary with both mechanical and electrical plant suppliers to resolve the many detailed matters which require speedy settlement. At a later stage it becomes vital to obtain cable schedules from the electrical plant suppliers in sufficient time to enable plant wiring to be planned and the wiring work completed before the time for electrical commissioning tests.

The scope of the distribution engineering will depend on whether the waste heat/steam requirements balance is such that it is economic to generate electricity on the site. The inclusion of a power station will mean a considerable addition to the detailed engineering in dealing with both boiler and turbine houses. In other respects distribution engineering is relatively straightforward apart from the difficulties of assessing the probable loads at a sufficiently early date, and for this experience is invaluable. The over-riding consideration must always be continuity of supply, both because of the financial loss if a major plant item is shut down and because of the very real dangers if, for example, a pumped water supply fails ; these considerations lead to much more duplication of supplies than is the case with public systems.

An important item of distribution engineering is the temporary site system which has to be installed as soon as work begins on the site, and despite the hazards of excavation plant and mobile cranes this service has to be kept going until the permanent system can take over. So much contractors' plant is now electrically driven, including concrete batchers, compressors, vibrators, welders and the many types of hand tools, that failure of the electricity supply can have a very serious effect on the continuity of work and thus on progress. Temporary site lighting is also essential if, as is usual, extended hours are to be worked. However, the installation, the repeated modifications, and the continual maintenance results in a surprisingly large cost and a correspondingly large item in an estimate.

Mechanical services

The possibility of obtaining adequate supplies of water is one of the basic considerations in choosing a steelworks site and the reliable distribution of this water is a major task for the mechanical services designer. Obviously a failure of the water supply to a blast-furnace would be catastrophic and other steelworks plant would be severely damaged without water. Hence the whole design emphasis is on reliability, involving adequate storage in a near-by reservoir or other secure source, reserve storage in head tanks, and the probable use of ring mains for distribution.

The major design problem is the difficulty of obtaining reliable consumption figures from plant manufacturers before the system is fully designed and much therefore depends on the experience of the designer who must assess the likely demand, but so design the system that it is flexible enough to accept unexpected loads of reasonable size. Even when plant manufacturers' water consumption figures are available the design is not simple because of the need to decide just what demands will occur simultaneously, and the extent to which inflated demand figures have been given by plant builders.

The distribution of fuels (oil, town, or coke-oven gas, blast-furnace gas, natural gas, propane, etc.) will depend very much on the main iron and steelmaking processes selected, and the availability of surplus fuels ; thus each project will present its own problems. Steam distribution must depend upon the availability of surplus fuel, the extent to which waste heat can be used and the possibility of economic generation of electricity but such newly developed techniques as evaporative cooling will increase the possibilities of waste heat recovery. In all cases, however, simplicity and reliability will be the prime considerations, coupled with reasonable facility for extension as the plant develops.

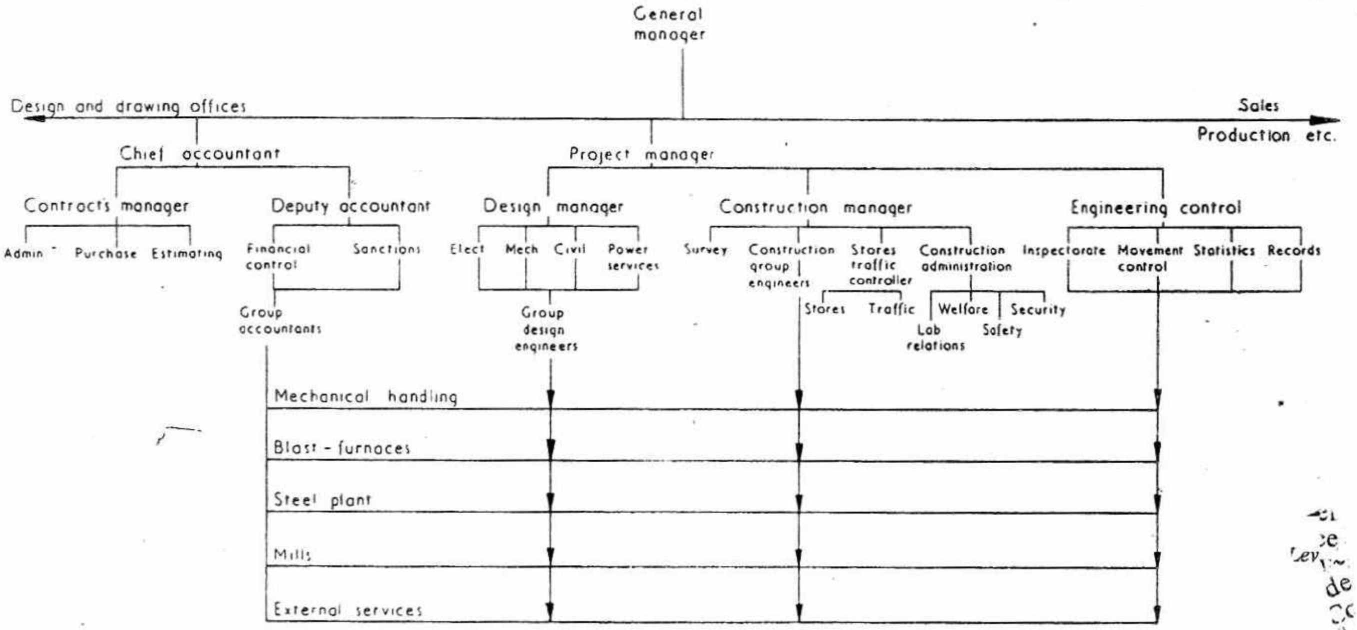
INSPECTION AND PROGRESS

Experience has shown that both inspection and progressing are essential to the successful completion of civil, structural, mechanical, and electrical work on this type of project. The inspecting engineer is responsible for maintaining the quality of all work while the progress engineer ensures that items produced off-site are available at the appropriate times to enable the commissioning date to be met.

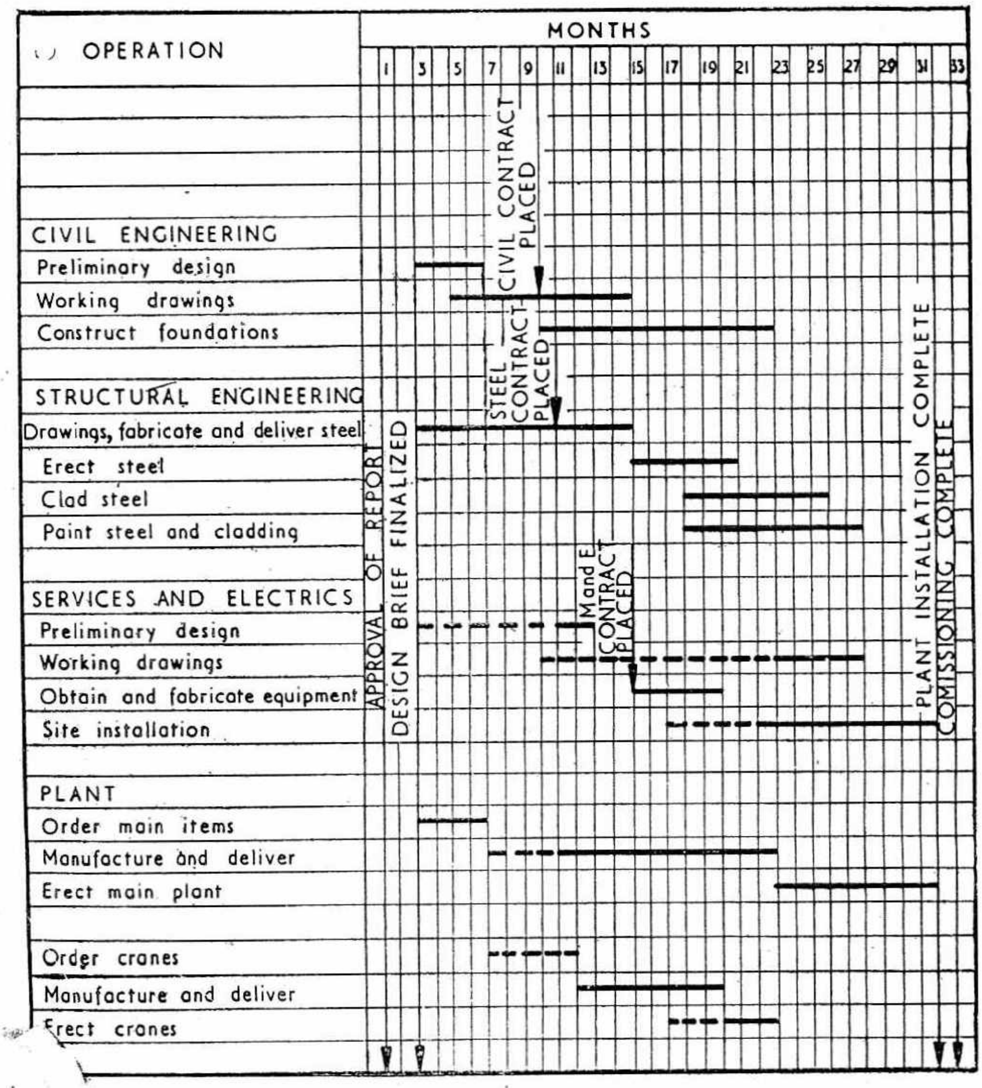
The methods and the extent of inspection are many and varied, depending on many factors, including the type of equipment, the experience of the past performance of the particular manufacturer, and the number of similar items being produced. The over-riding requirement is, of course, to ensure that in all respects the engineer's specification for manufacture is followed faithfully by the contractor. The inspecting engineer is not concerned with costs nor is he concerned with speed of production ; his only interest is in quality and performance.

On the construction site, all normal inspection work is undertaken by the staff responsible to the resident engineer but specialists may be seconded to the site for special techniques such as non-destructive testing by ultrasonics, X-rays, or gamma rays. Site inspection work includes :

Civil	Dimensional and positional accuracy of foundations and holding-down bolts and concrete quality
Structural	Line and level of structures, correctness of bolting, riveting or welding (using non-destructive techniques), visual checking of cladding, glazing, and painting
Services	Line and level of pipelines, weld inspection, pressure testing of pipelines, commissioning testing of pumps, compressors etc. ; visual inspection of all work
Mechanical	Visual checking of all items, commissioning and acceptance trials
Electrical	Visual quality checking and acceptance tests.



10 *Typical management organization chart for 1m. ton integrated steel plant*



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