CAST IRON
in
BUILDING

By the same author

BUILDING FOR THE PEOPLE

CAST IRON
in
BUILDING

by

RICHARD SHEPPARD
F.R.I.B.A.

With an
Introduction by

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R. S.

INTRODUCTION

By J. G. PEARCE, M.Sc., M.I.Mech.E., M.I.E.E., F.Inst.P.

Few subjects excite more interest and discussion than building materials and equipment, notably those used in housing. It is, therefore, particularly appropriate that this informed account should have been prepared of a material whose applications, despite a long tradition of usage associated with craftsmanship in the highest degree, have so often been ignored, so much so that the average user is seldom, if ever, aware of its nature and ubiquity. This volume is specifically intended for those interested in the building uses of cast iron, in the hope that the anonymity of this material will speedily become a thing of the past. Such a book, although intended for users of cast iron, is in effect directed to members of the community in general, for it is virtually impossible under the conditions of modern civilization to avoid the use of iron castings in some form or other.

The versatility of cast iron and the great array of finishes it now receives frequently prevent it from being recognized; while many people are under the false impression that this once universally used structural material, noted for its strength and fireproof qualities, has been supplanted by other materials. A brief consideration of the size of the industry shows how this view is misleading and erroneous.

Since the Industrial Revolution first created a demand for iron castings, the output has grown more than a hundredfold, and in the United Kingdom it is now about 2½ million tons per annum—measured as unmachined and unfinished castings. They are made in approximately 1,750 establishments, widely distributed throughout the country, and which differ markedly in both type and size of product. The number of persons employed and the output of each foundry is, therefore, highly variable, but the total directly engaged in the industry exceeds 100,000. If the employment in ancillary industries occupied in the manufacture of materials and equipment for the foundry industry is added to the previous figure, those persons and their dependents constitute probably one per cent of our population.

Readers of this book will, however, be more directly interested in the proportion engaged in the manufacture of castings for the building industry. The output of iron castings comprises those used for building and domestic purposes and those required by the engineering and allied industries. The former may be conveniently divided into two parts. One constitutes what is termed the light castings industry which—among many items—produces rainwater pipes and gutters, sanitary ware, baths, stoves, grates, cookers for gas, electricity and solid fuel, radiators and hot water or steam pipes, hollow-ware, telephone and pillar-boxes, kiosks, and municipal castings. Under pre-war conditions this comprised about one-sixth of the total output of iron castings. The remaining part includes castings heavier in section, such as those used in public works and civil engineering practice: pipes, tunnel segments, shelters, lamp and electric standards, road and traffic furniture, including signs, nameplates, milestones, bollards, kerbs, road setts, etc. In this second category pipes form a most important part and make an essential contribution to civilized life in conveying water, gas and sewage. This section also represents about one-sixth of the total output, and both categories furnish an important part of our export trade under normal conditions. Thus, the two sides of building and domestic uses are responsible for about one-third of the total output of cast iron. The accumulated and intensified consumer demand at home and abroad following the second world war may well result in building and domestic castings reaching an output of 40 or even 50 per cent of an expanded total production.

An industry of this magnitude not only performs an important public service but constitutes an essential link in the country's industrial structure. I therefore commend this book, the first modern work to be written exclusively on the building uses of cast iron. It should be welcomed not only by all interested in the applications of cast iron but by those engaged in the industry itself, for it gives a true picture of its historical origin and traditions as well as of its current practice, and there can be few who will fail to be stimulated and inspired by the remarkable work of the craftsmen of earlier days. Furthermore, the book reveals something of which few even in the industry are aware, namely the very fine artistic work still being done in this country, which displays all the qualities of design and craftsmanship that for generations enabled us to lead the world. This craftsmanship is internationally recognized as being a major contribution made by this country to the foundry art, and to-day more examples of its highest expression are to be found than is commonly supposed.

The illustrations in this book support the hope that the use of cast iron for sculptural, decorative and memorial purposes may be widened. Some deplore the effect of so-called mass production methods on craftsmanship. That view is not shared by the writer, for it appears to be based on an exaggerated idea of the proportion of craftsmen in the community during the Middle Ages. In addition, it is a matter of experience that where production is mechanized, the proportion of craftsmen employed is either maintained or increased. Those who find anything to deplore in mass production would observe with satisfaction the output of decorative castings—an obvious outlet for craftsmanship of the very highest order. The material lends itself admirably to such production, and with a demand arising from cultivated taste, satisfied by skill in design and workmanship, this country could equal in volume—as well as in quality—the work of continental foundries.

As Director of the British Cast Iron Research Association, I am particularly interested in this matter, because in 1944 the Association, with the co-operation of the British Ironfounders Association, formed a Building Uses Department for the purpose of supplying authoritative and impartial information to architects, builders, surveyors, industrial designers, students, local authorities, public utility companies, and so forth. Late in 1944, this department organized an exhibition to display the scope and variety of the applications of cast iron in building. The scientific and technical activities of the Association are concerned with ensuring, among other things, adequate technical properties for a given application, but in building and domestic use the additional factor of form is important—partly by reason of the product being in many cases continually visible, and partly because good design is an expression of fitness for function. For this reason design lies much deeper than external form, although it ultimately governs that form. The proposals announced by the Board of Trade in December 1944, for the creation of a Council of Industrial Design should direct more attention to the operation of design than it has hitherto received. The final product should integrate technical quality and suitability, fitness for purpose or function, with ease and economy of manufacture. None of these factors can without harm be isolated from the total synthesis.

Section One

EARLY BUILDING USES OF CAST IRON

HUMPHRY DAVY disclosed a deep comprehension of a relationship between science and art, when he wrote these words:

"The contemplation of the laws of the universe is connected with an immediate tranquil exaltation of mind, and pure mental enjoyment. The perception of truth is almost as simple a feeling as the perception of beauty; and the genius of Newton, of Shakespeare, of Michael Angelo, and of Handel are not very remote in character from each other. Imagination, as well as reason, is necessary to perfection in the philosophical mind. A rapidity of combination, a power of perceiving analogies, and of comparing them by facts, is the creative source of discovery. Discrimination and delicacy of sensation, so important in physical research, are other words for taste; and the love of nature is the same passion, as the love of the magnificent, the sublime and the beautiful."[1]

An instance of the significance of those words could be found in the development of cast iron during the closing decades of the eighteenth century and the first half of the nineteenth. The improvement in the manufacturing processes of cast iron between 1750 and 1850 was accompanied by adventurous experiments into the possibilities of using the material in engineering and architecture, which stimulated and sustained further developments in production. Although to-day we are equipped with a greater range of materials and with a more precise knowledge of their use, we have not always shown ourselves so eager as the late Georgians and early Victorians to take advantage of their possibilities in the arts of peace. Metallurgy is no longer limited to a study of the extractive processes; it extends to the investigation and measurement, in advance, of the properties, capacity and precise nature of metals and their alloys. Though rapid progress has been made in metallurgical research, particularly with alloys, the application of new knowledge to

[1] Quoted in *The Romantics*, an anthology by Geoffrey Grigson.

building methods is less immediate and dramatic than in the early nineteenth century. Perhaps this is because any new development has now to face more intense competition, from a considerable variety of established materials and methods. But for whatever reason, the process of adopting a new material is prolonged and slow by comparison with the sudden illumination of the problems of nineteenth-century designers by the introduction of cast iron.

The history of the development of cast iron in this period is also the history of Britain's transformation from an agricultural to a machine economy; and in architecture from the spacious and stately perspectives of Wood and Repton to the crowded industrial areas of Birmingham and Manchester. Seen thus it discloses a most exciting glimpse of our national development. It is a microcosm of the social, economic, and technical changes which characterize the epoch, not only in this country but, in varying degrees, in most of western Europe and the new world. The applications of cast iron which were then developed still endure, and if it is no longer the only structural metal available in quantity it is still the best for certain purposes.

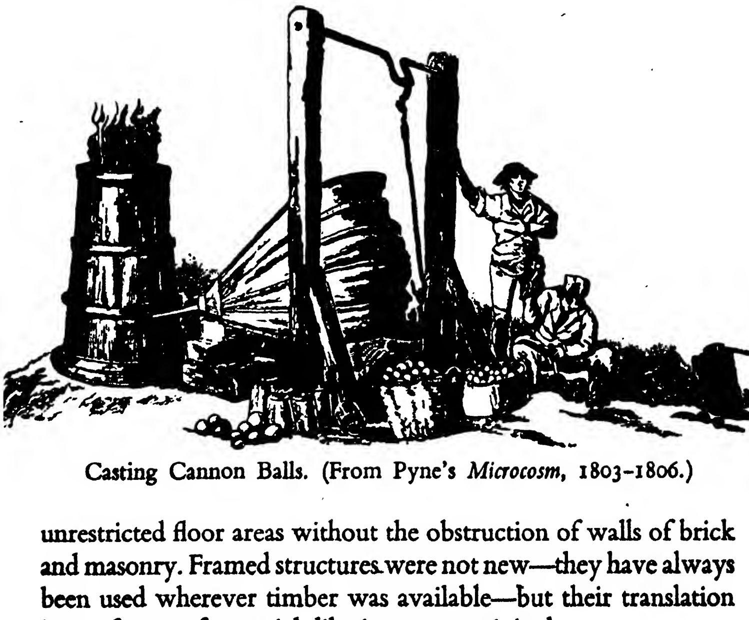
The geographical distribution of the manufacture of cast iron is related to the development of the deep coal seams. Throughout medieval times and up to the eighteenth century, iron was smelted by means of charcoal. It was manufactured in the forests and woods, where both ore and fuel were located. Thus the early centres of the industry were widely distributed, in keeping with a rural economy, and were to be found in Sussex and the Forest of Dean. With the developing industry of the eighteenth century, the demand for iron increased to such an extent that steps had to be taken to limit the consumption of timber for smelting as the shortage was threatening to imperil supplies for shipbuilding. With the industrial development of the steam engine in the latter half of the eighteenth century, improved methods for exploiting coal seams were found, thus providing smelters with a more substantial supply of fuel. Coal had been used for iron-working since the early seventeenth century in some areas, notably Coalbrookdale in Shropshire. Gradually the iron industry became linked with coal, and subsequently with coke; more foundries were established; new uses for the material were developed. The effect of this was to concentrate the growing industry in areas where coal and the means of transport (at this stage, the canal) were available. This transference and expansion of the industry were accompanied by a movement of population to these new areas. The early smelting furnaces at Coalbrookdale, and others in Scotland, particularly in the county of Stirling, began the industrial revolution.

There is a parallel between that transference of industry and conditions to-day. Our local supplies, both of coal and iron ore, are diminishing and we are being forced increasingly to rely upon other sources. In the late nineteenth century blast furnaces came to be located close to some of our big ports where supplies of iron ore entered from Sweden, Spain, and North Africa. The development of Middlesbrough and later of Dagenham exemplifies this tendency. But perhaps as important to the industry as reduced supplies of indigenous high grade ores is the increased cost of coal. It may be that during the next decades industry will seek fresh locations and generally adopt new methods of producing and fabricating materials.

With the development of coke as a fuel, large-scale methods of production became possible. Up to 1750 the average annual production of cast iron in this country did not exceed 20,000 tons, and it was therefore only used in small pieces and in small quantities—for bolts and wheels, and cannon balls. But when the steam engine ceased to be a merely static power-producing device, used for pumping, and became mobile, the "iron horse" on land was followed inevitably by the iron ship at sea. But iron was the basic factor: upon its production and fabrication Britain's century of industrial leadership was founded. The Iron Age, already three thousand years old, had reached a period of stupendous achievement.

Just as cast iron made possible the steam power unit, so it made possible the construction of the multi-storey cotton mills of

Wigan and Preston. Here, from 1800 onwards, cast iron began to be used in the building industry in an entirely new and revolutionary way. Until then its application to building had been confined to small forgings and castings, and the utmost structural use contemplated was for the chains round the base of the dome of St. Paul's. The nineteenth-century manufacturer, faced with the need of housing his machines and his operatives, hit upon the use of cast iron to form columns and beams, which gave him



Casting Cannon Balls. (From Pyne's *Microcosm*, 1803–1806.)

unrestricted floor areas without the obstruction of walls of brick and masonry. Framed structures were not new—they have always been used wherever timber was available—but their translation into a fireproof material, like iron, was original.

The new idea, once realized, was adopted enthusiastically, and in 1824 William Wilkins used cast iron beams in the construction of the roofs in the University College, London, and in the National Gallery. These pioneers showed far more enterprise and adventure in building than we do to-day; even in recent years there have been architects who were unwilling to use steel in their buildings for fear that the material might not be permanent. (It is a curious reflection upon Humphry Davy's views that a century of scientific research should apparently have fomented such distrust for science.)

Cast iron was quickly adopted in many forms of building and engineering. The history of bridge building in the last decades of the eighteenth century and the first half of the nineteenth is a record of progressive development in the use of cast iron. Samuel Smiles in his *Lives of the Engineers* records that almost to the end of the eighteenth century the Italians and French were pioneers in engineering, and were fully aware of the value of cast iron, and made many attempts to use it for bridge building; but they failed partly because the early founders were unable to cast large masses of iron, and because the metal then cost far more than stone or timber. The first attempt to build a cast iron bridge was made at Lyons in 1755. One of the arches was actually put together in the builder's yard; but the project was abandoned because of the expense. A little later, some English iron-masters were discussing the possibility of an iron bridge across the Severn near Broseley. "It was proposed to substitute a bridge in place of the ferry which then connected the two banks of the river," Smiles tells us, "and Mr. John Wilkinson, who had, as some thought, an extravagant but, as results had proved, a truly prophetic, appreciation of the extensive uses to which iron might be applied, strongly urged that the structure should be of that material. Everybody knew of Mr. Wilkinson's hobby, and of his prognostication that the time would come when we should live in houses of iron, and even navigate the seas in ships of iron. When he insisted upon an iron bridge being built at Coalbrookdale, people said he was 'iron-mad.' But as he was a powerful man in his day—'the great iron-master' he was called—his suggestion could not be dismissed without consideration; and the Bridge Company, which had been formed, determined to take the opinion of Mr. Pritchard, of Shrewsbury, on the subject. The architect's opinion was favourable to the suggestion of the iron-master; and he was requested to supply a design of an iron bridge, which was eventually adopted. The work was erected,

The first iron bridge at Coalbrookdale, Shropshire, designed by Thomas Farnoll Pritchard. It was constructed by John Wilkinson and Abraham Darby, and cast and erected in 1779 by the Coalbrookdale Company. This should be compared with the design of the Buildwas Bridge, shown on page 22. (From the *Lives of the Engineers*, by Samuel Smiles.)

under contract, by Messrs. Reynolds and Darby, iron-masters at Coalbrookdale, in the year 1779. The bridge has only one semi-circular arch of 100 feet span, each of the great ribs consisting of two pieces only. Though it was on the whole a bold design, and well executed, the error was committed of treating the arch as one of equilibrium. There also seems to have been some defect in the abutments, which were forced inwards by the pressure of the earth behind them, and the iron arch was thus partially fractured and raised in the middle. Nevertheless, the first cast iron bridge ever erected proved a very serviceable structure, and it remains so to this day."[1]

The next English designer of an iron bridge was Tom Paine, author of *The Rights of Man*. When he was living in America, Paine had suggested building a cast iron bridge with a span of 400 feet over the Schuylkill. Smiles relates that "he came to England to take out a patent for his invention[2] and to order a bridge after his plan, the materials of which were manufactured at the Rotherham Ironworks. They were delivered in London, and fitted together on a bowling-green at Paddington. But the French Revolution breaking out, Paine hastened to Paris to join the 'Friends of Man,' leaving his bridge in the hands of his creditors. His democratic associates having incarcerated him in the Luxembourg prison, he lay there for eleven months, but finally escaped to America. In the meantime the materials had been purchased for erection over the river Wear, at Sunderland, where the second iron bridge in England was erected after a design by Mr. T. Wilson in the year 1796."

The span of this bridge was 236 feet, with a rise of 34 feet, with the springing point 95 feet above the river bed.

Thomas Telford built his first iron bridge over the Severn at Buildwas, midway between Shrewsbury and Bridgenorth. Telford had examined the Coalbrookdale bridge in great detail, and had observed certain structural defects. Although aware of its deficiencies, he appreciated its merits, and determined to make the bridge at Buildwas of cast iron. He decided to use only one arch, to allow the largest water-way.

"He had some difficulty in inducing the Coalbrookdale ironmasters, who undertook the casting of the material, to depart from the plan of the earlier structure," Smiles tells us, "but he persisted in his own design, which was eventually carried out. It consisted of a single arch of 130 feet span, the segment of a very large circle, calculated to resist that tendency of the abut-

[1] *Lives of the Engineers*, by Samuel Smiles. "The Life of Thomas Telford," Chap. VII, Vol. II (1862).

[2] Specification of Patents, No. 1667, A.D. 1788.

ments to slide inwards which had been the defect of the Coalbrookdale bridge; the flat arch being itself sustained and strengthened by an outer ribbed one on each side, springing lower than the former and also rising higher, somewhat after the manner of timber-trussing. Although the span of the new bridge was 30 feet wider than the Coalbrookdale bridge, it contained

The first iron bridge designed by Thomas Telford, which crossed the Severn at Buildwas, midway between Shrewsbury and Bridgenorth. This bridge was cast at Coalbrookdale in 1796. Its total cost was £6,034 13s. 3d.

(From the *Lives of the Engineers*, by Samuel Smiles.)

less than half the quantity of iron; Buildwas bridge containing 173, whereas the other contained 378 tons. The new structure was, besides, extremely elegant in form; and when the centres were struck, the arch and abutments stood perfectly firm. . . ."

The total cost of the Buildwas bridge was £6,034 13s. 3d. In 1795 Telford had advocated an iron aqueduct for the Shrewsbury Canal, "on a principle entirely new," and which he was "endeavouring to establish with regard to the application of iron."[1] This iron aqueduct when cast and fixed effected a considerable economy in masonry and earthwork.

"The uses of cast iron in canal construction became more obvious with every year's successive experience; and Telford was accustomed to introduce it in many cases where formerly only timber or stone had been employed. On the Ellesmere, and afterwards on the Caledonian Canal, he introduced cast iron lock-gates, which were found to answer admirably, being more durable than timber, and not liable like it to shrink and expand with alternate dryness and wet. The turnbridges which he introduced upon his canals, instead of the old drawbridges, were also of cast iron; and in some cases even the locks were of the same material. Thus, on a part of the Ellesmere Canal opposite Beeston Castle, in Cheshire, where a couple of locks, together rising 17 feet, having been built on a stratum of quicksand, were repeatedly undermined, the idea of constructing the entire locks of cast iron was suggested; and this extraordinary application of the new material was successfully accomplished, with entirely satisfactory results."[2]

Telford's boldest design was unfortunately never carried out; and it was owing to the difficulty of constructing the approaches that London was deprived of a cast iron bridge that would have crossed the Thames on a single arch of not less than 600 feet span. This design was prepared in 1801, when the replacement of Old London Bridge had become an urgent necessity.

Smiles describes the bridge as one of the boldest of Telford's projects. "He proposed by his one arch to provide a clear headway of 65 feet above high water. The arch was to consist of seven cast iron ribs, in segments as large as possible, and they were to be connected by diagonal cross-bracing, disposed in such a manner that any part of the ribs and braces could be taken out and replaced without injury to the stability of the bridge or interruption to the traffic over it. The roadway was to be 45 feet wide in the centre, increasing to double that width

[1] Letter to Mr. Andrew Little, Langholm, dated Shrewsbury, March 18, 1795.

[2] Samuel Smiles, *opus cit.*

at the abutments. It was to contain 6,500 tons of iron, and the cost of the whole was to be £262,289." Smiles goes on to say: "The originality of the design was greatly admired, though there were many who received with incredulity the proposal of bridging the Thames by a single arch, and it was sarcastically said of Telford that he might as well think of 'setting the Thames on fire.' Before any outlay was incurred in its construction, it was determined to submit the design to the most

Thomas Telford's design for spanning the Thames by one arch, to consist of seven cast iron ribs. The clearance allowed was 65 feet above high water level. The bridge was to contain 6,500 tons of iron, and its cost was estimated at £262,289. (From the *Lives of the Engineers*, by Samuel Smiles.)

eminent scientific and practical men of the day; after which evidence was taken at great length before a Select Committee which sat on the subject. Amongst those examined on the occasion were the venerable James Watt of Birmingham, Mr. John Rennie, Professor Hutton of Woolwich, Professors Playfair and Robison of Edinburgh, Mr. Jessop, Mr. Southern, and Dr. Maskelyne. There was a considerable diversity of opinion amongst the witnesses, as might have been expected; for experience was as yet very limited as to the resistance of cast iron to extension and compression."

Apparently the Committee concluded that the construction of the bridge was practicable and safe; the preliminary works were started; but the design was abandoned, owing "to the difficulty of constructing the approaches with such a headway, which would have involved the formation of extensive inclined planes from the adjoining streets, and thereby led to serious inconvenience, and depreciation of much valuable property on both sides of the river."[1]

Beginning with the Coalbrookdale bridge where a single span arch is formed by castings which make an open structure and act like voussoirs, progress in design was rapid until 1850 when Stephenson designed the Menai Bridge with tubular castings. Although Bessemer developed his process for the manufacture of steel in 1855, some years were to elapse before it was universally used to replace cast or wrought iron for heavy structural purposes. As late as 1878 when Eiffel built his tower, the use of steel was still uncommon, for "the highest building in the world" was designed in wrought iron.

The great exhibition of 1851 was housed in the first large-scale prefabricated structure, and cast iron was the material used for the prefabricated units. This huge building of glass and iron, standardized and mass-produced, symbolizes the revolution achieved by applying industrial methods to building. With the exception of the smaller glazing bars, the whole of the structural frame of this building was of cast iron and Paxton exploited to the full the lightness and strength which its use allowed. He was not, however, a pioneer. From 1820 onwards cast iron had been used for similar types of construction, and the Palm House at Kew, designed by Decimus Burton, indicates by its exquisite and delicate detailing that considerable experience must have already been gained in handling the material. It was also used in the new railway stations, in banks and offices and for churches. In 1834 the Ecclesiastical Commissioners recommended that cast iron should be used in a number of useful ways in conjunction with the Gothic style. They wanted ten thousand new churches

[1] Samuel Smiles, *opus cit.*

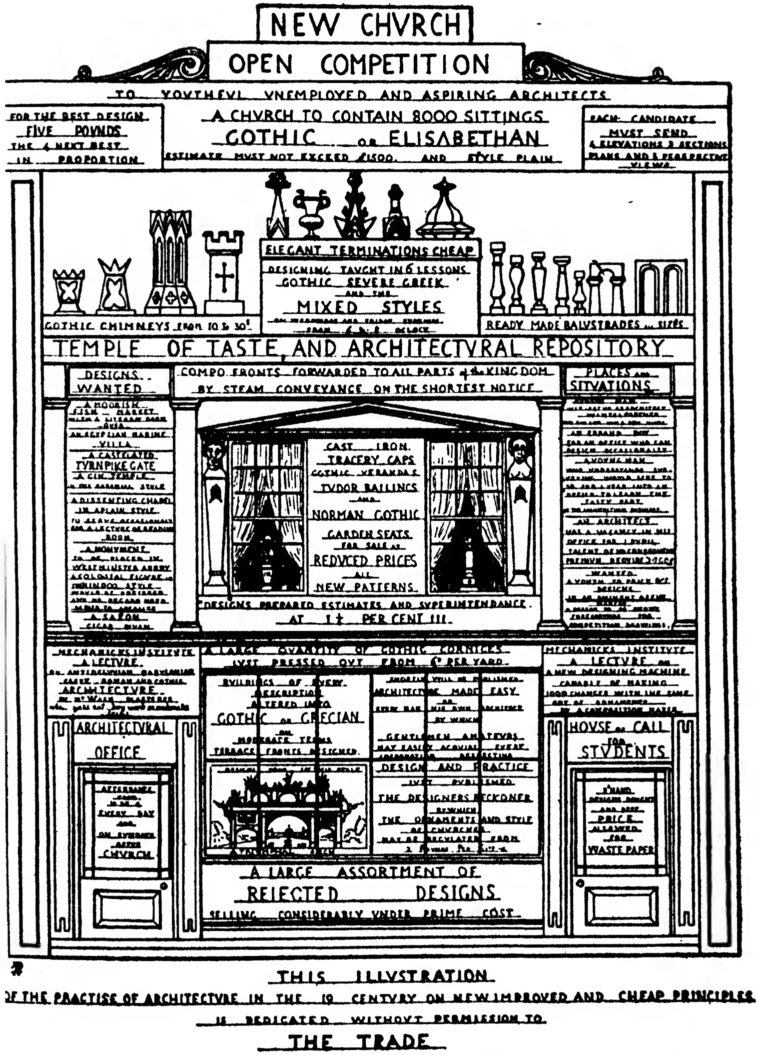
to serve the new industrial and residential areas that were spreading all over the country. The Commissioners enumerated the positions, where "with elegance and propriety" cast iron could be employed: for columns, where the capitals and mouldings supported the balconies, and for the crockets and finials which surmounted gable and verge.

The Ecclesiastical Commissioners, it will be seen, realized at once that the peculiar characteristics of cast iron—the fact that it can be poured and moulded—would give great advantages in the building of these ten thousand churches.

Pugin in his famous book of *Contrasts*[1] mercilessly guyed the ideas of the Commissioners in a plate which he entitled "New Church, Open Competition," and he dealt even more caustically with the misuse of cast iron in two lectures which he delivered at St. Marie's, Oscott, and which subsequently appeared in book form. These lectures were on "The True Principles of Pointed or Christian Architecture," and Pugin listed some of the absurd things that were being made in cast iron. Grates, he pointed out, were not unfrequently made to represent diminutive fronts of castellated or ecclesiastical buildings with turrets, loopholes, windows and doorways, all in a space of 40 inches.

"The fender is a sort of embattled parapet, with a lodge-gate at each end; the end of the poker is a sharp pointed finial; and at the summit of the tongs is a saint. It is impossible to enumerate half the absurdities of modern metal-workers; but all these proceed from the false notion of *disguising* instead of *beautifying* articles of utility. How many objects of ordinary use are rendered monstrous and ridiculous simply because the artist, instead of seeking the *most convenient form*, and *then decorating it*, has embodied some extravagance *to conceal the real purpose for which the article has been made!* If a clock is required, it is not unusual to cast a Roman warrior in a flying chariot, round one of the wheels of which, on close inspection, the hours may be described; or the whole front of a cathedral church reduced to a few inches in

[1] *Contrasts, or a Parallel between the Architecture of the 15th and 19th centuries*, by A. Welby Pugin, was published by the author in May 1836.



Pugin's gibe at the Ecclesiastical Commissioners is condensed in this page from his famous book of *Contrasts*, published in 1836.

height, with the clock-face occupying the position of a magnificent rose window. Surely the inventor of this patent clock-case could never have reflected that according to the scale on which the edifice was reduced, his clock would be about two hundred feet in circumference; and that such a monster of a dial would crush the proportions of almost any building that could be raised. But this is nothing when compared to what we see continually produced from those inexhaustible mines of bad taste, Birmingham and Sheffield: staircase turrets for inkstands, monumental crosses for light-shades, gable ends hung on handles for door-porters, and four doorways and a cluster of pillars to support a French lamp; while a pair of *pinnacles* supporting an arch is called a Gothic-pattern scraper, and a wiry compound of quatrefoils and fan tracery an abbey garden-seat. Neither relative scale, form, purpose, nor unity of style, is ever considered by those who design these abominations; if they only introduce a quatrefoil or an acute arch, be the outline and style of the article ever so modern and debased, it is at once denominated and sold as Gothic."

Contemporary developments in plastics, and in the non-ferrous metal alloys, have perhaps made us oblivious of the extent of cast iron used in building to-day. Over a century ago the Ecclesiastical Commissioners certainly had fewer claims upon their attention; but, as Pugin suggests, designers in the thirties and forties of the last century took the application of this material to fantastic lengths. Cast iron crockets may seem a curious fancy but they are nothing to the decorative castings in which the early nineteenth-century foundry designers delighted to indulge. Magnificent bisons, shaggy with cast iron hair and horns, street fountains, garden chairs with the whole fauna and flora of classical mythology to sit on, were some of the minor perversions of taste in that period. Great skill was needed for these intricate castings; it was misdirected skill.

In the latter part of the nineteenth century there were more rational and less complex applications of cast iron. The heavy engineering industry began to develop the material for its own purposes, and it is in this branch of industry that some of the most productive investigations are being made to-day. The alloying of cast iron with nickel, copper, molybdenum, chromium and other elements has resulted in the development of certain mechanically strong and hard irons which have widened the application of the material. Such irons are used whenever heavy duty work or high resistance to shock is demanded, such as in heavy castings for steam engines and turbines, petrol and oil engines, bed plates and anvil blocks. Motor car manufacture provides many examples of its use: cylinder blocks, heads, liners, piston rings are generally made in the material. A modern car contains some thirty components made in cast or malleable cast iron.

In the building industry the use of cast iron for framing purposes has almost been eliminated. Its structural capacity was and is considerable: during the second world war its powers of endurance have been severely tested. Many of the old warehouses in the City of London which survived complete collapse during the blitz were found to have cast iron columns which resisted fire and water better than steel. (See plates 8 and 9.)

We tend to think of cast iron as being mainly used for positions where great strength or fineness of appearance are unnecessary—for gutters, drain pipes, and all the external accessories of drainage and plumbing which sprawl casually over our buildings (and our bye-laws). Such things represent a practical and most advantageous use of the low corrosion rate of cast iron, but they have led to a general disregard of its uses in other directions. Between the eighteenth-century fire-back with its delicately reeded pattern, and the efficiency of purpose and line displayed by the modern heat-storage cooker, lies a prolific period of experiment and research into surface finishes and textures. These have developed from the original painted or black leaded finishes, and now include not only enamels and synthetic resins, but also the use of sprayed metal in finely divided form which change the surface character of the material so drastically that its real nature is not always recognized. The Palm House at

Kew is painted but the panels below the bay windows of the new Adelphi Building are sprayed with aluminium in such a way that the lighter metal is forced into the surface of the cast iron of which the panels are made. (See plates 14 and 15.)

While Victorian designers and manufacturers exploited the material to the limits of their ingenuity it is possible that we have not begun to explore its application in modern building technique. Some of the illustrations in this book indicate what could be done. Unfortunately there have been few opportunities in recent years for contemporary designers to exploit to the full the possibilities which modern methods of casting and surface finishing present. The development of cast iron has been partly stultified by the ease with which its dominant characteristics may be diverted to the production of features and motives for which the material was never intended. Because it is possible to cast sheep's heads and Corinthian columns it does not follow that it is necessary or desirable to do so, and as such extravagant features are so insistent upon attention, the real quality of cast iron has often been lost and prejudices against it have accumulated as a result of past misuse.

Section Two

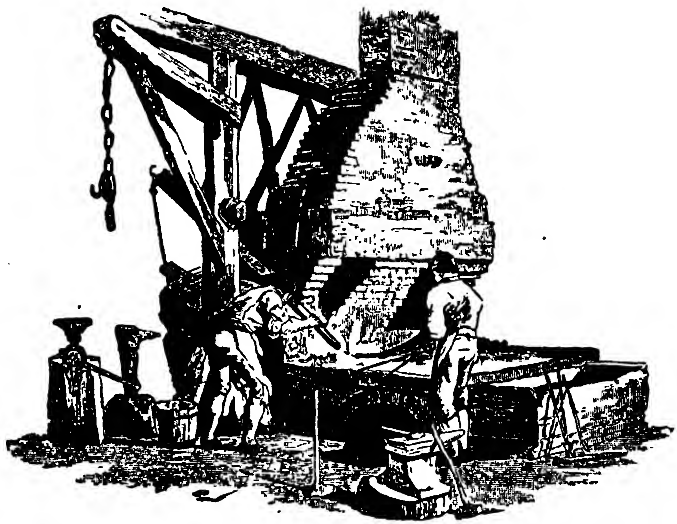
PRODUCTION, VARIETIES AND PROPERTIES OF IRON

DURING the last twenty to thirty years the scientific investigation and testing of materials has increased control over building technique. The modern architect must possess an extensive knowledge, not only of the properties of the materials he employs, but also, if he is to use them effectively, of the way they are produced and fabricated. This is no new development; at all times, good designers have had an extensive acquaintance with their materials and the craft processes associated with them. The architecture of the seventeenth and eighteenth centuries was informed and inspired by such knowledge: the charm and dignity of buildings in that period are derived from it, and whether a plaster ceiling, a wrought iron balcony or some other feature, arouses our admiration, we can discern in its character the influence of the designer's masterly understanding of the materials which have enabled him to exercise his taste for good proportion and elegant decoration. This traditional approach was lost in the nineteenth century, and the architect, bewildered by an abundance of strange materials, by industrial, economic and social developments which he found difficult to understand, abandoned his proper study of materials and took refuge in stylistic revivals. His successors to-day realize that despite the greatly increased equipment now available, real comprehension of the characteristics of the materials which are components both of civilization and of buildings, is essential. It was just possible in the Victorian epoch to ignore industrial growth and technique; to-day it is impossible. It is just possible to design a building without using any of the materials which have been developed since the eighteenth century, but it is difficult—though this might not be suspected from the appearance of much domestic architecture.

All metals are the result of a series of processes of reduction from the original ore and refinement of the first product, and this applies broadly to both ferrous and non-ferrous metals. In this respect the production and fabrication of cast iron, nearly as old historically as that of copper or tin, can be taken as typical. A great variety of types and qualities exists, arising either from the character of the raw material or from modifications in manufacture. Different needs may thus secure an appropriate grade or quality of cast iron.

In Section One the range of cast iron products was indicated, and it is obvious that it is not essential for the material always to have the same characteristics. A rainwater gutter, for instance, which is not stressed and where corrosion is the principal problem encountered, need not have the same strength or finish as the cast iron needed for a crank shaft which is subjected to alternating stresses. The article itself will of necessity determine such differences in quality, which arise from differences in manufacture. In the manufacture of a cast iron gutter the principal need is for the material to spread rapidly and evenly in the mould over a large superficial area. But in the crank shaft the metal must consolidate itself evenly in the mould in order to secure a uniform strength throughout the cross section in any direction, and must cool in such a manner that secondary stresses are not set up inside it during the process.

The production of iron in small quantities was carried out by a process known to many primitive peoples, and subsequently termed the *direct process* because it yielded iron straight from the ore. In a simple hearth, oxides of iron occurring on the surface of the earth can be reduced by means of charcoal fuel with the aid of air blast from a simple bellows. The resulting piece of metal, which had been pasty but not molten under the heat applied to it, was comparatively pure as iron, but contaminated with slag and earthy matter. As the demand for the precious metal rose, appliances and bellows were increased in capacity and improvement, and the higher temperatures obtained resulted in the iron dissolving some carbon from the fuel. Its melting point was thereby lowered, and instead of being a pasty mass, it became fluid, wholly or in part, and the molten metal could readily be separated from the impurities, and could, as was afterwards discovered, be solidified into any desired shape and size. Thus, cast iron was discovered, essentially an alloy of iron and carbon, and there is little doubt that the mode of its production has been discovered, lost, and rediscovered many times by different peoples. Since the cast iron may form also a



An early iron foundry. (From Pyne's *Microcosm*, 1803–1806.)

starting point for a further series of refining operations, this process became the *indirect process* universally used to-day through the whole world. From the simple hearth the blast furnace evolved, the product of which, known as pig iron, being the raw material of the iron-founder, yielding castings by simple re-melting.

The ores of iron, chiefly oxides or carbonates of iron, are widely distributed throughout the surface of the earth, and in varying concentrations with respect to the iron itself. Generally speaking, ore which contains less than 20 per cent of iron is uneconomic in manufacture, and some may contain as much as

80 per cent. The modern blast furnace, which may produce as much as 1,000 tons of pig iron in twenty-four hours, is charged with appropriate proportions of ore, limestone and coke fuel, and during its descent through the stack of the furnace, temperatures as high as 1,800° C. may be reached by the combustion of the fuel in the blast of heated air supplied through the tuyeres. The ores are reduced and the molten metal falls to the bottom or hearth of the furnace, covered by a layer of slag which is derived from the combination between the limestone and the impurities in the ordinary ore. Blast furnace gas is a most important by-product of the process. The molten metal is tapped off at intervals into pig beds, and the solidified pig iron forms an article of commerce. Alternatively, for the manufacture of steel, the molten metal may be transferred immediately to begin its further process of refining, for the pig iron, relatively pure as it is, still contains a number of elements other than iron, notably manganese, sulphur, silicon. Certain ores yield pig irons containing phosphorus, while others are comparatively free from this element. In England, the native resources of low phosphorus iron, particularly the haematites, are now greatly reduced, and much of our pig iron is made from the phosphoric ores of the Midlands.

Metallurgically, pig iron is essentially a cast iron which is an alloy of iron and carbon. The amount of carbon in cast iron averages about 3 per cent; and varies over a range of about 1·5 per cent to 4·5 per cent. In the absence of other elements, this carbon would be present wholly as carbide of iron, in which case the metal, whether pig iron or cast iron, is white, hard and brittle. In the cast form, white iron is the starting point for the production of malleable cast iron, through a process of annealing by means of which the metal may be obtained with as much as 20 per cent elongation on the gauge length of a standard test bar. In addition, white iron finds a number of industrial uses on account of its great resistance to wear and abrasion, and in a number of cases it is found convenient to obtain the wear-resisting properties of the white iron with the strength and toughness of grey iron in the one casting, and the ploughshare is a familiar example. The majority of iron castings, however, are grey in fracture and machinable, and in order to achieve this result it is necessary to have in the iron certain so-called graphitizing elements, of which the most widely used is silicon. In this case, the carbon exists in two forms, part being combined as mentioned above, and the remainder is deposited in the form of graphite flakes, microscopically visible. While, theoretically, the amount of carbon in cast iron, including both the combined and graphite forms, may range from 1·5 per cent to 4·5 per cent, in the majority of iron castings, the range is comparatively narrow, between 2·8 per cent and 3·5 per cent, and indeed, for the majority of castings used in building, between 3 per cent and 3·5 per cent. The difference between iron and steel consists in the fact that steel has a lower carbon content than iron, and the carbon is wholly in the combined form. In steels, the carbon content is below 1·5 per cent, and generally considerably below this figure. In structural steel, the carbon content is usually of the order of 0·2 per cent, and is higher for steels used for tools, gears and the like. The difference between steel and cast iron is therefore wholly one of the amount of carbon present, and of the elements which determine whether in cast iron the carbon shall be mainly combined or mainly free, as graphite.

The iron derived from the direct process mentioned consists of grains of relatively pure iron, known metallurgically as ferrite, and the nearest modern commercial approach to this structure is that of ordinary wrought iron, which can be forged and hammered. When carbon is present, in small quantities, as carbide of iron, the cementite of the metallurgist, the carbide does not appear in the massive form, but is present as microscopically fine laminations alternating with laminations of pure iron or ferrite, this duplex or sandwich-like structure forming grains of material known metallurgically as pearlite, which is harder and stronger but less ductile than ferrite. The larger part of the structure of ordinary cast iron consists of grains of pearlite, the remainder being ferritic, the whole matrix being broken as described, by flakes of graphite. It is possible, by a simple heat treatment, to convert the grains of pearlite completely to ferrite, the carbon from the carbide of iron thus broken down being deposited on the existing flakes. In this form, the metal is softer and more easily machinable, and this process is applied to-day to many industrial castings.

Other structures are now practicable as the result of modern metallurgical research, although the aggregate of castings made of these structures is still comparatively small. Nevertheless, there may be at any time a demand for these materials for building and domestic castings, on account of special properties which they possess. The pearlitic structure mentioned forms at a temperature of about 740° C., and above this temperature more of the carbon is in solution, and the condition is then spoken of metallurgically as austenitic. By certain alloy additions, notably nickel and copper, it is practicable to lower the temperature at which this transformation takes place in the process of cooling the molten metal to the solid state, and if sufficient quantities are used, the temperature is lowered to something below atmospheric temperature with the result that the resulting iron is austenitic in the cold state. It has certain properties which mark it distinctly from ordinary pearlitic grey iron, notably a relatively high resistance to corrosion and heat, non-magnetic properties, a lower thermal conductivity, and a higher thermal expansion than ordinary grey iron. The austenitic irons are also relatively more ductile, and have excellent resistance to shock and wear, in spite of their comparative softness. If the amount of alloy addition referred to is diminished, an intermediate martensitic structure may be produced, which is intensely hard, and finds application for its abrasion-resisting properties. The austenitic and martensitic irons are usually known as "special duty" cast irons, while those irons generally used for their mechanical strength are known as "high duty" cast irons.[1]

The most recent development in the alloyed field is that of

[1] Further information on these may be obtained from the reports issued by the High Duty Cast Irons Research Committee of the Institution of Mechanical Engineers, in 1938, 1941 (two) and 1943.

acicular cast irons, an alloy cast iron in which molybdenum is an essential constituent, with nickel and copper. These irons have high resistance to stress, and particularly to shock. They are commercially made to tensile strengths of the order of 35 to 45 tons per square inch, and are about three times as tough on shock test as the best high duty irons hitherto made. The quality of high duty irons may be judged from the properties required in B.S.I. Specification 786–1938, in which four grades of material are covered. Ordinary grey irons are dealt with in B.S.I. Specification 321, two grades being covered.

Finally, reference should be made to the high silicon cast irons, containing about 15 per cent silicon, the best ferrous metal known for resistance to corrosion, particularly acid corrosion, although unfortunately rather hard and brittle; and to the high chromium cast irons, containing about 30 per cent chromium, which offer perhaps the best combination known in the cast iron field for combined resistance to heat and corrosion, particularly against sulphurous gases.

Generally speaking, the properties of all types of cast iron which are used in the building industry may be summarized quite simply. Since the material is very seldom used in highly stressed positions, since its weakness in tension and shear as compared with steel make it less suitable, its structural qualities are often ignored. But its strength is quite sufficient for the majority of loads which are encountered in buildings of two or three storeys, and in view of its greater resistance to corrosion and to the fact that it is less easily deformed by heat than steel it is difficult to know why it should have been abandoned.

It will be seen that where extreme stresses are being met, cast iron does compare very favourably with steel for certain purposes. The accompanying table gives a comparison between tubular cast iron sections, which have been centrifugally spun, and similar sections cast in sand. The lack of ductility seems scarcely sufficient in itself to account for the universal disuse of iron for framing purposes.

TENSILE STRENGTH

Tensile strength determined by cutting rings 1 in. wide from standard pipes and breaking these as a link in a standard testing machine. For test the ring is supported between knife edges at opposite ends of a diameter.

SPUN PIPES

Calculated tensile strength, tons per square inch

Nominal Diameter	2 in.	3 in.	4 in.	6 in.	8 in.	10 in.	12 in.
	21·52	20·75	19·82	18·03	17·82	16·14	15·45

SAND CAST PIPES

Calculated tensile strength, tons per square inch

Nominal Diameter	4 in.	6 in.	8 in.	10 in.	12 in.
	11·95	11·55	12·55	11·80	12·08

MODULUS OF ELASTICITY

Average figures: modulus of elasticity are:—

	lbs. per square inch
Cast Iron, spun pipe	16,000,000
Cast Iron from sand cast pipe	14,200,000

Ductility is valuable when there is risk of overstressing; but when loads are kept within the safety limit, it loses its significance.

The uses to which the material is put have always depended upon its special casting properties which enable it to be poured in the molten state into a variety of most intricate moulds. This has meant that its use has been chiefly developed where stress is not present.

Section Three

THE CASTING OF IRON

METALS may be fashioned in many different ways; but with inconsiderable exceptions they start their life in the cast form. Thereafter they may be used in the cast form by simple remelting processes, or alternatively, they may be made suitable for treatment in other ways: forging, rolling, drawing, pressing or extrusion. Casting is one of the oldest known methods of forming metal objects. Bronze Age man, when he arranged his little pile of charcoal, soon found that all the metals which he knew, copper, lead, tin, and eventually gold and silver, could be cast, and he gradually discovered uses most appropriate to their different properties. Owing to the higher temperatures involved in smelting iron, which could not easily be reached by crude ovens, its development had to await the invention of more efficient furnaces. But the principal methods of metal working, of alloying and tempering, and of casting, were evolved in Ancient Egypt and Chaldea.

Subsequent progress has been concerned largely with the development of more efficient techniques both of production and working—with improved applications rather than with new principles. There are revolutionary innovations—the use of metals in powder form for moulding is one—but in general metals are still used in ways which the Bronze Age metal worker would recognize.

Casting as a process is of great antiquity, although iron was not cast on a large scale until the eighteenth century. The methods used for casting iron which were then evolved were developed further—particularly in regard to size—in the nineteenth century, and have remained relatively unchanged ever since. Other methods, like die casting or the more recently introduced injection moulding, are variations of the original technique; they are used in different ways and for different purposes, and the cast iron industry has been little affected by them. Die casting gives a very high degree of accuracy and uniformity of strength; it is a quick and economical process within certain limits of size.

The building industry does not work to such fine limits that small tolerances are inadmissable, and the castings used in building are usually of a fair size—stoves and downpipes, for instance. The majority of castings are non-structural and do not require a high degree of strength. A good surface is of more importance than a uniform degree of strength and the presence of minute imperfections in the cross section will not cause so much difficulty as inequalities of the surface. The essential requirement in making a casting is a pattern of similar size and shape, around which the moulding material may be rammed in boxes which permit the mould to be separated so that the pattern may be withdrawn. Most patterns are made of wood, but for quantity production, metal patterns are frequently used.

Various types of moulding material are used in casting to-day, and of these sand is by far the most common. Sand moulding became universal in England and Scotland towards the end of the seventeenth century, and sand has certain definite advantages over other moulding materials. It is easy to work to the required shape; the texture is so fine that very delicate surface treatment may be obtained. The possibility of compacting it into given shapes is due to the presence of clay, either natural or, in the case of so-called synthetic sands, artificially added. The porosity of sand allows the air contained in the mould to escape when the iron is poured into it, thus avoiding air pockets and bubbles in the final casting; and the gases given off by the iron in cooling inside the mould can also escape. Moulds made of other materials, such as cement or metal, are used extensively, but the use of sand is universal.

The sand is worked into the required shape in a moulding box, usually of iron or steel, and every large foundry has numbers of these boxes, of different sizes and types. Before the sand can be poured into the box it has to be treated. The United Kingdom is particularly rich in clay-bonded sand deposits suitable for moulding for iron castings; but sands required for core making, and in certain cases for mould making, are drawn from special areas, such as Southport or Leighton Buzzard. These are silica sands, like seashore sands, and are specially bonded with clay or organic binders.

Two distinct tendencies may be observed in iron-founding practice to-day. There are the traditional methods by which every casting is treated as a cycle complete in itself; even when a casting is standardized each foundryman accumulates round him his own materials and tools, his own sand and casting boxes, and sets about his work. This method depends upon the skill and speed of the individual craftsman. Nineteenth-century production in quantity was based upon an effort to speed up the craftsman; twentieth-century mass-production seeks to replace him with improved mechanical and automatic devices. The sequence of tasks which go to the manufacture of one article are split up and distributed among a number of operatives, who are assisted as far as possible by machines. This process has only in recent years made much progress in iron-founding, for the individual craftsman has long remained the basis of the industry. In certain directions contemporary mass-production methods have been successfully applied.

In a foundry organized on traditional lines the iron-founder pours his own sand into the moulding box and tamps it down. With the continuous process the sand is fed automatically into a series of boxes which reach and leave a moulding machine by means of a conveyor belt. The conveyor carries the mould to the cupola where the molten iron is poured into the box; the box is carried on by the belt, cooling as it goes, and the casting is broken out of the box which passes again into the cycle.

Although few foundries have been equipped in this way, this form of production demonstrates how effectively modern methods may be introduced to accelerate a traditional technique. Even the method of using the sand is improved, for it is operated in a continuous cycle.

While the large bulk of iron castings, and particularly castings for the building industry, are made in greensand—that is, prepared, moist sand—certain castings are frequently made in moulds which are completely dried in an oven before pouring. In this state the sand is much stronger. Other castings of cylindrical shape are swept in loam, a plaster mixture which can also be hardened by baking.

The process of mould making is one of those apparently simple operations which are really deceptive. The complexity of the process depends upon the article: a cylindrical or rectangular casting presents no difficulty so far as the operation of moulding is concerned. But the modern iron-founder has to be able to make castings of a complexity undreamed of in the eighteenth century. Not merely curved hollow castings in three dimensions—like a boiler back—but castings with an intricate series of compartments and apertures which require the insertion of a number of separate sand cores during the setting up of the complete mould. It is thus apparent that the simplest mould is formed of, first, the metal box, in which the sand is packed, and which gives it sufficient strength to resist the metal during the pouring process. Secondly, the sand is packed and this may have to be shaped in a number of ways, and with a number of sections or inserts, according to the complexity of the article. Lastly, the mould is closed by the top of the casting box. Generally, the mould is made in two halves which are brought together to make the complete casting; this facilitates the withdrawal of the patterns dealing with the casting process—a point which must always be considered in designing a casting. This description applies to the production of solid castings; when hollow castings or shells are required, it is necessary to insert in the mould a part, also made of sand, known as a core. Core making is a well-recognized branch of the foundry art. As cores are usually small, and are completely surrounded by molten metal, they must be harder and stronger than the mould itself.

Before the mould can be run with molten iron certain precautions have to be taken. First of all the mould must be of a shape that will allow the metal to run easily through it; in a big casting or one containing a large quantity of metal this sometimes presents difficulties. The mould must also allow air and gases to escape without injury to the casting. Each mould has in consequence at least two apertures; one, for entry, is used for pouring the metal, while the other acts as a vent and a channel for exit. They are usually placed as far apart as practicable. In a big mould, or in one which has a number of sections, more apertures of both kinds are necessary, and in this matter the skill of the foundryman in judging the run of the metal comes into play.

The next stage of the process is the running of the metal into the moulds. Metal running is a highly skilled technique, and the foundryman has the same importance in iron running as the blower in glass manufacture. A good foundryman needs many years of experience, and even then he will probably have specialized in pouring one type of casting only. A change in size and thickness of the casting may require a different method of running. Similarly, the temperature of the metal has also to be considered in relation to the type of casting and also to the alloy employed. This demands considerable judgment.

The method of metal running depends upon the size of the casting and foundry practice. In the traditional process the travelling ladle is employed; the molten iron is tapped from the cupola and wheeled to the moulds where it is poured by means of a hand-shank, filled from the ladle, into the completed moulds. The number of moulds which can be filled from a single ladle depends naturally upon the size of the castings. In the mass-production process the ladle is kept at the required temperature and tapped automatically as the moulds pass underneath. Whatever the method employed the actual pouring of the molten iron is the crucial process and demands skill and judgment from the craftsman. If the metal is poured too rapidly extreme pressure is likely to be set up, and with rapid cooling this results in an uneven deposit of metal in the mould, and causes flaws and weakness in the casting. The metal has to run evenly and continuously if air bubbles and pockets are to be avoided; it is for this reason that in a large mould more than one pouring inlet is made.

Section Four

FINISHES AND SURFACE TREATMENT OF IRON

A GREAT many finishes have been successfully applied to cast iron in recent years. Potentially, the designer has tremendous resources in non-corrosive finishes and colour and texture, although they have not been thoroughly and consistently exploited. The taste of the Victorian period still hangs like a pall over cast iron design—a pall of blacklead so far as finish is concerned, relieved only by the verdant greens and browns used by the seaside surveyor. We have to go back to the end of the eighteenth century to see colour boldly applied to cast iron and only now are we emerging from the period of protective camouflage which followed the death of George IV.

The decline in taste which continued through the reign of Queen Victoria can be studied in the evolution of English watering places. While most of them date from the middle of the last century, they had an aristocratic origin in modish Brighton, where the Prince Regent's fanciful little palace, the Pavilion, was enlivened by gaily-painted cast iron columns and other ornamental features. His architect, John Nash, understood this medium and some of the designs are as fantastic as they are delicate, and the iron is gilded and lacquered in a gay profusion of colour. All the decorative antics performed in cast iron in the Pavilion, under the direction of a master designer, were used less happily by the makers of seaside promenade shelters and bandstands. These erections were placed at regular intervals along the seaside promenade. Green and brown were considered the most durable colours, and while the eye was delighted by the freshness of the one, the sense of decorum was soothed by the other, and these shades became universal. These colours have become traditional, and these early examples of prefabrication in cast iron have been submerged at intervals beneath them ever since. The design of some of these shelters is as ingenious as it is elaborate, and they deserve a better surface treatment. In the future some seaside surveyor, more than usually gifted, may recognize that his shelters no longer correspond with contemporary ideas of design, and may become adventurous with form and colour, allied with modern technique and surface finishes. If and when this happy event occurs, it will be found that paint, as well as blacking, represents only a small section of available surface finishes. Some of these treatments are not confined to the application of a protective skin—although it is still the most common form—but they reduce corrosion by means of alloying and by chemical modifications in the metal surface. Iron is more resistant than other ferrous metals to corrosion in all its forms—which was one of the reasons why Victorian manufacturers adopted it for the seaside shelter and the pier. Corrosion is a primary defect of all ferrous metals, and much research has been conducted in seeking to overcome it, though no spectacular results are likely which would give permanent freedom from corrosion under all circumstances. Some of the methods give hope of an eventual solution to the problem, and certainly enhance the appearance of the metal.

Surface finishes also serve other purposes: many of them are resistant to abrasion, and give the metal a smooth, easily-cleaned surface so that utility is associated with decorative qualities. For this reason cast iron is popular and practical for fireplaces and cooking equipment.

It would be easy to classify the various types of finish under three main headings: those in which a surface finish is obtained by modifying the surface of the iron itself so that a form is obtained more resistant to wear or corrosion, as in oxide or phosphate coatings; those in which a permanent and continuous skin is applied, as in the use of sprayed metal or vitreous enamel; and thirdly those in which a non-permanent or transparent skin is applied, as in paints and varnishes. A close examination of the effects obtained, however, shows that the categories are not sharply defined, and the finishes fade insensibly from one group to another. Again, finishes are used for both decorative and utilitarian purposes, but in these respects also the categories are not mutually exclusive; the ordinary cast iron bath is treated with vitreous enamel to give a very agreeable finish, but it has also to resist the wear associated with use, and the various types of cleaning materials, some of which are very drastic in their action. Hence the enamel requires to resist alkaline attack from soap, wear from use and the action of household cleansers, and heat from hot water.

A very well-tried process largely used on kitchen coppers and pans for corrosion prevention is known as the barffing or bower-barffing process. By heating the article to be treated to an appropriate temperature and admitting steam to the furnace, the outer skin of the metal can be converted to the black magnetic oxide of iron which is a continuous layer capable of withstanding wear and ordinary hazards of use. The conversion of the surface of the iron to a phosphate also yields a black corrosion-resistant coating developed originally in this country as coslettising, but subsequently carried further in the United States as "parkerizing," and, when these coatings became used increasingly as a base for paint, as bonderizing.

One of the simplest of the familiar finishing processes is hot-dipping, that is, the dipping of the article to be coated in a bath of molten metal, a layer of which adheres to and alloys to some extent with the base iron. Both tin and zinc are commonly used on cast iron, the former where the metal is required to come into contact with food products, and the latter when resistance to corrosion is required. From the nature of the process, hot-dipped coatings are relatively thick. The process of zinc dipping is usually known as galvanizing. During the second world war improvements were made in the technique of hot-dipped coatings for cast iron. Although by metallic hot-dipping processes a certain amount of alloying between the molten metal and base metal takes place, another type of finishing process aims at forming an effective coating by an alloying action with a metal not applied in the molten state. The process is broadly known as cementation, although strictly this should be retained only for the alloying of carbon with a ferrous base, as in converting iron to steel by contact with charcoal, or, in more recent times, as in case-hardening low-carbon steel. For special purposes both cast iron and steel can be given a very hard surface coat by nitriding in ammonia gas, resulting in the formation in the surface of nitrides which confer great hardness. Cyanide hardening can also be used. Ferrous metals can be surface treated by heating in zinc powder (sherardizing), giving an iron-zinc alloy in the surface, and by heating in aluminium powder (calorizing). The former is usually used for corrosion resistance, and the latter for heat resistance. Chromium and silicon can also be applied in this way.

Electroplating is also a method by which a protective coating may be applied, and in practice cast iron can be used as a base for the deposition of iron itself, copper, nickel, tin, zinc and chromium. Combinations of these processes can be used. For example, an electro-plated deposit may be a useful preliminary to a thicker hot-dipped coating.

In recent years metal spraying has undergone considerable developments. Metal to form the coating is fed in the form of wire into a pistol in which the wire is melted by a gas flame and atomized in an air blast, which serves to make the spray impinge on the metal to be treated. Sprayed coatings are usually of the lower melting point metals or alloys.

Vitreous enamel is essentially a glass or porcelain distributed over the metal in the form of a thin uniform coating which may be in a very wide range of colours. The coating is thus not only decorative but may also need to meet technical requirements with respect to heat resistance, acid or alkali resistance and wear resistance. The raw enamel or frit is made by grinding and fusing together various refractory and mineral oxides and other compounds and fluxes; the product is quenched in water, breaking up into small opaque particles.

Two methods of applying this enamel are in common use, the older or dry process and the wet process. The dry process is widely used for baths and sanitary ware. The frit is ground to a fine powder with opacifiers or oxides to give colour, and is applied as a dry powder to the surface to be treated. The article is then put into a furnace and heated so that the frit melts and runs over the whole area, forming a uniform coat. (See plates 5 and 6.)

In the wet process, the frit is ground with opacifying and colouring agents, and a water suspension made which can be applied either by dipping therein the article to be treated or by a spray. The enamel coating is then fired at a rather lower temperature than in the dry process. More than one coating may be applied in either process, and for some work only one coat is required. Vitreous enamel can be applied either to cast iron or to sheet iron (low in carbon) or steel. The modern acid resistant enamels represent a considerable technical achievement since they are more difficult to make and to apply than the older types of enamels.

One of the most widely used coating processes consists in the application by hot-dipping of a bituminous coating of asphaltic or coal-tar origin, which is frequently specified as Dr. Angus Smith's solution. As modern research has modified and improved both the material and the technique considerably, the name is now misleading. These bituminous coatings are of great value in protecting cast iron pipes against corrosive attack, and in special cases pipes can be lined with concrete applied by the centrifugal process, similar to that used in casting the pipe itself. An enormous amount of research has been carried out in recent years on soil corrosion in the United States, in Holland and in this country.

Paints and varnishes are used as protective coatings with definite decorative value, and, being organic in character, differ materially from those so far discussed. The technology of these materials is too vast to permit more than passing reference, but in recent years considerable improvements have been made both in the materials themselves and in the technique of their application to structures. Metallic paints, as aluminium paint, may be advantageous in some cases. Temporary protection against corrosion of ferrous parts in storage may be obtained by the use of lanolin, dissolved in a suitable solvent. It is easy to apply and remove, and prevents corrosion very satisfactorily. Where tanks and containers carry water likely to cause corrosion, a small amount of potassium or sodium dichromate will inhibit corrosion.

In some cases it may be desirable to have recourse to a modification of the base metal so that corrosion resistance is obtained without any superficial treatment. Reference has already been made to the austenitic irons, which are much more resistant to corrosion than ordinary grey iron. The degree of protection varies enormously according to conditions, but it may be taken as two to two hundred times that of good grey iron. The first cost of these irons, however, is likely to limit their application. Niresist and Nicrosilal are well-known examples. Similarly, in building and domestic applications the high silicon irons and high chromium irons are not likely to find considerable use, but in special cases this may be advantageously considered.

These finishes demonstrate the fallacy of the popular idea that cast iron always looks solid, dark and heavy. Cast iron has suffered from association with the debased taste of the nineteenth century, which, as John Gloag says in *The Missing Technician*, "advanced year by year into a deeper and darker jungle of complicated decoration. To the public, cast iron became identified with the more repellent branches of housework; the blackleading of the kitchen range and the parlour grate was inevitably associated with a material that for three-quarters of a century had been used for coal-burning appliances without any consideration being given to labour-saving."[1]

The housewife has some excuse for her aversion to anything obviously labelled cast iron. Millions of women must have spent millions of days blackleading kitchen stoves and fireplace surrounds, and it comes as a shock to them that their light-coloured, gleaming heat-storage cooker is cast from the familiar

[1] *The Missing Technician in Industrial Production*, by John Gloag. (George Allen & Unwin Ltd., 1944.) Chapter IX, p. 96.

material: architects have also been deceived and many have mistaken the panels on the bays of the new Adelphi Building for an aluminium casting. Good design and modern, easily-cleaned finishes could overcome the prejudices generations of misuse have implanted.

Section Five

CAST IRON IN BUILDING

WHEN the iron ship *Great Eastern* was built at Millwall in 1858 she was a wonder of the world, for she had a screw as well as paddles, a displacement of 32,160 tons, a speed of 13 knots, and engines of 11,000 horse-power. But how many people would choose her to-day for an Atlantic crossing if she were still in service, and her owners in advertising for passengers used as their principal inducement the fact that she was built in 1858? Such an attitude of mind in respect of a ship is unthinkable. A modern luxury liner pays its cost in six or seven years, and is in the shipbreakers' hands in twenty. The structure of a liner or an aeroplane is as complete and as up to date as science can make it; the cost of its equipment is a secondary factor: safety and efficiency come first. But when static structures are considered, a complete change of approach to the problem of finance and planning is apparent. A stubborn parsimony characterizes the attitude of those who commission buildings, whether they represent private, municipal or state enterprise.

In most buildings the physical envelope is ruthlessly conditioned by cost. Every architect and engineer knows that the efficiency in heat and sound insulation, in ventilation and lighting, of innumerable structures is reduced because the people who find the initial finance are unwilling to spend money on such essential things. They are façade-minded, and their buildings are handicapped from birth. Many buildings are even obsolete before they are completed. Very many of the houses of this country are hundreds of years old, and this is considered a great attraction by just those people who would fiercely condemn a similar attitude towards ships or vehicles. Industrial and commercial buildings are often financed on a fifteen-year expectation of life; they are occupied and used for four or six times this period. It is a great pity that buildings do not sink when obsolete.

An affection for obsolescence, sometimes sentimental, sometimes mean, has retarded the progress of building and has warped the development of structural materials. In this respect cast iron has suffered more than other materials owing to the flexibility of the casting process. It has not been allowed to develop in a straightforward fashion as a material with certain aptitudes and advantages, but has often been used as a cheap substitute for something more expensive and precious. This attitude still persists and is exemplified by the panels of large office buildings, where it is given a bronze or aluminium finish. The ease with which cast iron can simulate other materials, and its comparative cheapness of production are conflicting merits, and they obscured its development in the nineteenth century. As Pugin and the Ecclesiastical Commissioners suggested in the eighteen thirties—from different points of view as we have seen in Section One—the Gothic revivalists failed to appreciate that the form of medieval architecture depended upon a method of stone construction and saw in cast iron the means of cheaply furnishing a church, with the surface embellishments of Gothic character. The seaside surveyor, early in the present century, discovered in cast iron a material which could set in permanent form the intricate gaiety of design associated with the plaster domes and porticos of the Paris exhibition of 1900.

These and other perverted forms have wearied our eyes and hardened our prejudices to such an extent that we are only content to admit the existence of cast iron when it is confined to drains and brackets. It is not a material to be taken seriously, to be accorded any attention by the experienced designer, but only to be used in building in positions where it is useful, not for its own merits, but because nothing else is so cheap and convenient. This attitude is justified neither by the history of the material nor by its present capabilities. It has a wider application in building than is generally recognized; it has uses and virtues which an objective survey will inevitably reveal. It is obviously impossible to describe all the uses which the building industry finds for cast iron; some are important and interesting both in a technical and aesthetic sense, while others are merely ingenious and useful means to an end.

A method of classification which distinguishes the significant from the trivial is essential if the applications of the casting process are to be understood and the potentialities of the metal in contemporary building technique enlarged and improved. In a previous section different methods of moulding were described; but it is impossible to classify the uses of cast iron on this basis as the methods often overlap. Moreover there is little variation in the fundamentals of the casting process and the quality of the iron used for the building industry does not vary over wide limits; in mechanical engineering by contrast, iron alloys, often specially treated, are extensively employed. In this way cast iron differs from other materials, such as glass, where the method of manufacture determines the function of a particular type of glass in a building. A classification for cast iron based upon the different methods of manufacture is thus impossible to achieve, and one has been adopted which rests upon the divisions which the building industry itself makes as a matter of convenience, into structural and semi-structural uses in connection with the envelope of a building, and into building components and appliances which are built into, or fixed inside, the envelope.

This classification has the merit of being convenient even though it is neither scientific nor distinctive. For instance, from the structural aspect there is a difference between a cast iron column and the same iron cast in the form of a boiler; but considered in terms of the use of cast iron it becomes simply a question of the stress set up in the members. Nearly all castings are stressed in some degree or another, and to differentiate between one set up by the direct loading and one set up by pressure, as with the boiler, is to ignore the basis of comparison which lies in the physical characteristics of the iron. This is one of the difficulties in connection with the classification adopted: by concentrating on the function of a member it may also obscure the method by which the member is made. But as this book is primarily concerned with applications rather than with technique, the arrangement has the merits of familiarity and convenience.

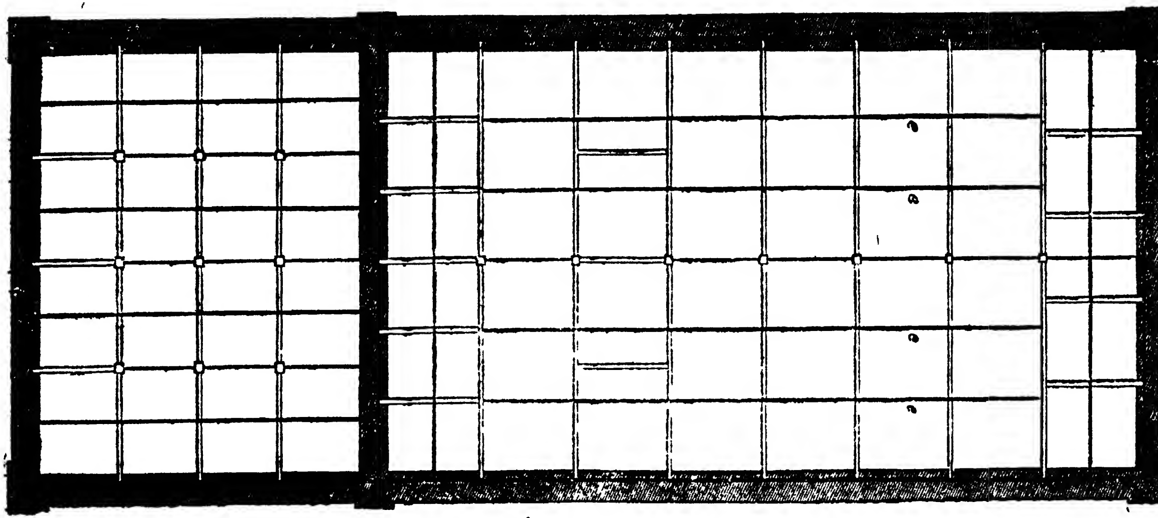
(*a*) *Structural Uses of Cast Iron.*

In considering the structural uses of iron, it should be remembered that those characteristics which make its use possible in this direction are also taken into account when it is used in other ways. The term *structural* is taken to mean that the iron is being used for the primary framing of a building, for the main beams and columns and other members which transmit the weight of a building to the subsoil; or for floors and other positions where it has to take a direct, superimposed loading. This was once the most exciting and vital field for the use of iron; engineers and designers competed with each other to press the application of iron to its ultimate limits. Huge spans, ingenious connections, economical sections were developed and exploited right up to 1870. (As we have seen in Section One, Thomas Telford as early as 1801 was considering the relatively gigantic span of 600 feet for his London Bridge design.) But since the 'seventies its use in these directions has substantially declined; the introduction of the Bessemer process for the mass conversion of steel in 1856 partially accounts for this; steel is more ductile and can withstand considerable deformation before the elastic limit is reached, and it is equally strong in tension and compression. These characteristics which have made the use of steel universal in the construction of framed buildings are not possessed by iron, and it has in consequence been largely displaced for this purpose.

Yet it is difficult to account for the complete exclusion of cast iron. There are certain functions for which it is as well suited as steel, and it is probably more simple to erect, if the skill is available. It is possible that the use of steel has become so much a matter of course, a thing taken for granted, that we seldom consider any alternatives for structural purposes. This is to be deplored if aesthetic possibilities as well as exactitude in the selection of the appropriate materials are ignored. As the aim of design is to satisfy the structural requirements of a building as exactly and precisely as possible, and in such a manner as to emphasize aesthetic qualities, legitimate opportunities for using cast iron have been wasted. Perhaps the inner truth of the matter is that with the introduction of steel, cast iron became associated with a phase of life and an attitude to design for which all sympathy was lacking, and the material was too closely bound up with a period that was over and done with for any reprieve to be possible. But the reasons for the disuse of cast iron are complex and have never been adequately investigated from the designer's point of view. The decline occurred and seems to have been inevitable, yet much has been lost as a result. From consideration of the physical characteristics and the methods of casting the material it is apparent that mere lack of ductility, of comparative weakness in tension, are insufficient in themselves to account for the decline in structural use. The engineers of the early part of the nineteenth century, with their arched forms of construction, had shown the way in which, in the compressive strength of iron, for instance, structures could be developed for long life, which combined economy in maintenance with low initial cost.

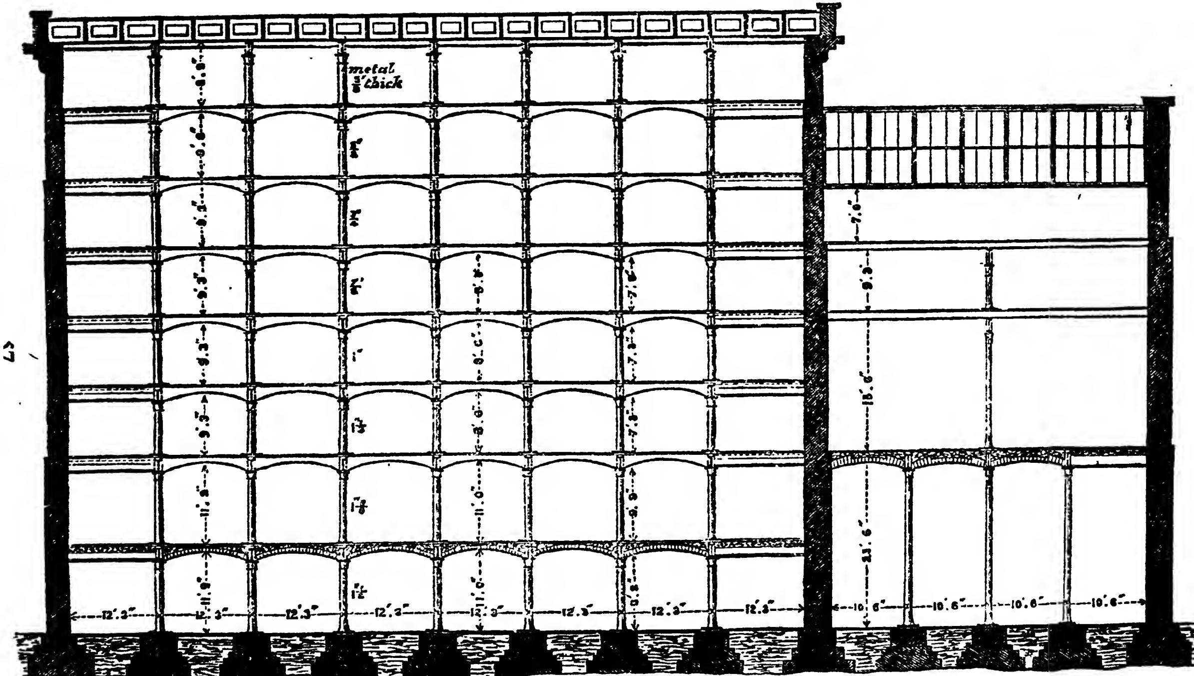
Certainly a comparison of the physical characteristics of iron and mild steel of the quality normally used in building construction does not suggest the virtual obsolescence of iron which has in fact occurred. It becomes apparent that under certain conditions of loading and restraint the performance of iron is equal to steel. But it is equally evident that for multi-floored framed structure with spans of the order of 20 feet to 24 feet, iron is unsuitable; though this particular type of structure has achieved a part of its popularity from the fact that designers have been accustomed to think in such terms.

Whether iron will be widely used again will not depend upon its treatment at the hands of a few gifted designers who know how to exploit its possibilities. Primarily its use will depend, as always, upon the question of cost. If iron can once again show itself cheaper and more convenient than other materials for those uses to which it is particularly suited, then it



Scale $\frac{1}{24}$ inch = 1 foot.

This is a plan of an eight-storey building about 150 feet long and 58 feet wide. Wrought iron beams are supported by a single row of cast iron columns down the centre of the main building, with three rows in the lower floor of the cistern house, which is shown on the plan above at the left. This building was designed as a sugar refinery for Bewley Moss & Company by William Fairbairn, C.E. These illustrations are taken from his book on *The Application of Cast and Wrought Iron to Building Purposes* published by Longman, Green, Longman, Robert and Green (3rd edition), 1864.



Scale $\frac{1}{24}$ inch = 1 foot.

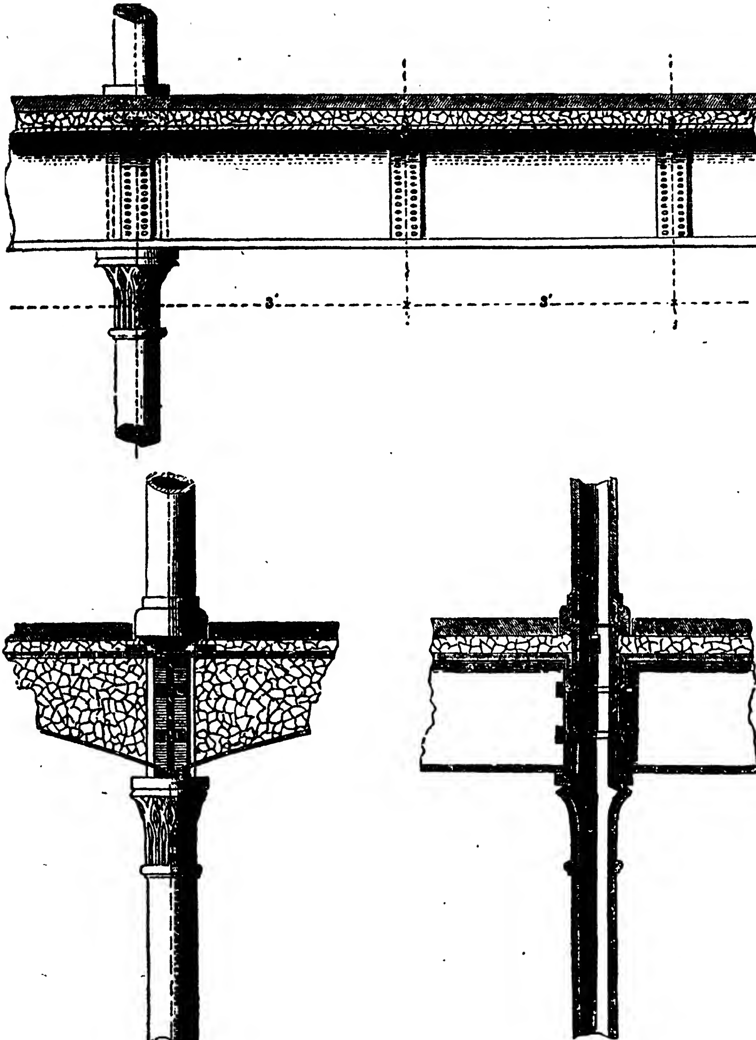
A section through the eight-storey sugar refinery. The plan is shown on the opposite page. (From *The Application of Cast and Wrought Iron to Building Purposes*, by William Fairbairn.)

could recover a measure of its former popularity. The designer has to work in terms of strength/cost ratio, and this ratio must be considered, in terms of the individual structure.

The ultimate strength in tension varies over a wide range, from about 10 to 40 tons per square inch. Cast iron is often tested in transverse, by centrally loading a test bar end-supported, as in an ordinary beam. Both the breaking load and deflection at fracture can then be taken, and the deflection figure is an important indication of toughness. By the ordinary beam formula used by engineers the breaking load can be calculated in pounds or tons per square inch of section, and this is usually 1·8 to 2 times the ultimate tensile stress of the same material. The compression stress at failure is usually about four times the ultimate tensile stress, while shear and torsional strengths are about 1·2 times the ultimate tensile stress. Malleable cast iron can be made with elongations on the gauge length of a standard test piece of 5 to 25 per cent. There is little change in tensile strength (and frequently a slight increase) as the temperature of the test rises up to about 450° C., and after that a gradual decline. Under fatigue conditions (that is, of alternations of stress from tension to compression, or bending or twisting, from one direction to another direction, continually repeated, as in many moving parts), cast irons behave very well, and will withstand under alternating stress conditions the relatively high figure of 40 to 50 per cent of the ultimate tensile stress without failure. They are relatively insensitive to what engineers call "stress-raisers," that is, to notches or section changes involved in the use of screw threads, keyways, oil holes and the like. The figures for tensile and compressive strength assume that the loading is truly axial.

The hardness of cast iron measured by the Brinell test varies over a wide range. Completely annealed and hence very soft castings may be as low as 120, while white irons may reach 500, and the martensitic irons 450 to 700. By surface treatments a hardness of 1,000 may be reached. Ordinary grey iron castings as used in building may range from 160 to 210.

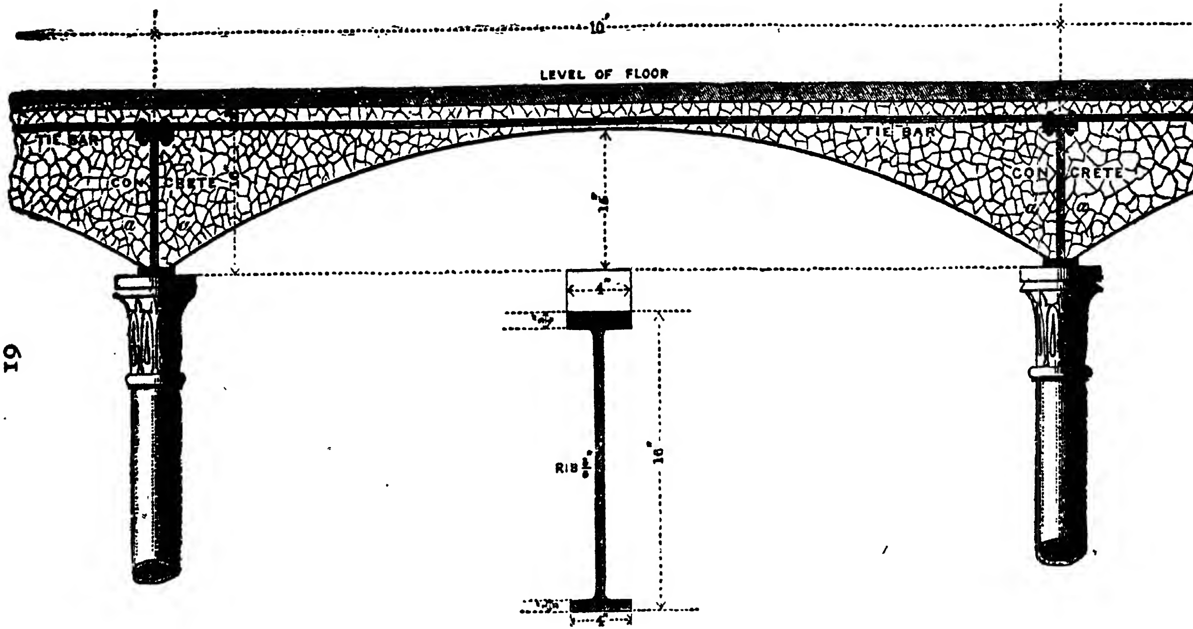
From these facts it is apparent that the strength of iron in



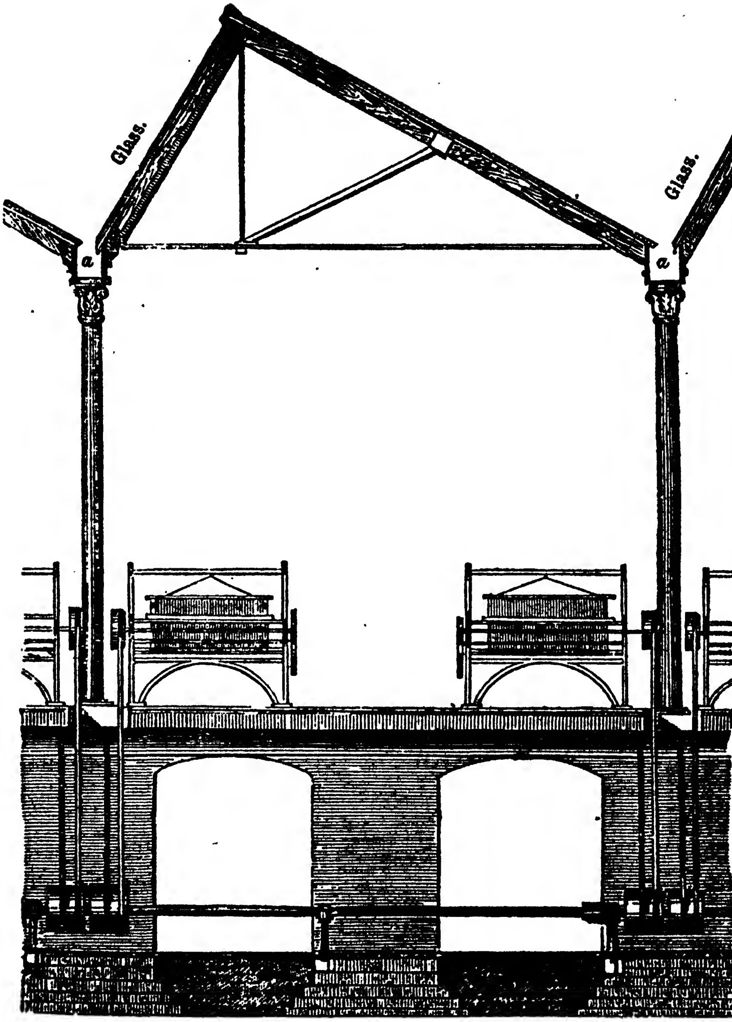
The association of wrought iron plates and beams with vertical columns of cast iron represented common building practice in the construction of warehouses during the nineteenth century, and these drawings are reproduced from Part 3 of *The Application of Cast and Wrought Iron to Building Purposes*, by William Fairbairn, which deals with the construction of fire-proof warehouses.

compression is directly affected by axial loading to a greater extent than steel. The importance of symmetrical loading on cast iron columns is shown by the fact that the majority of the column types cast are circular in plan. Any eccentricity, if it were sufficiently large, would cause collapse in the walls of such a column owing to the shear and tensional stress set up. Incidentally, the City of London blitz revealed how well cast iron columns stood up to the test of heating and rapid cooling imposed by fire, and such columns usually displayed less distortion than steel members of the same length and area. This experience does suggest that cast iron may prove to be very safe and economic in three storey buildings with a comparatively high floor load. The factory and the warehouse with a row of cast iron columns in the centre supporting longitudinal or transverse beams represents a most economical building type and facilitates good lighting conditions. It might well be considered as a standard for buildings of this type in the future, as we shall need large numbers of them, and in the shortest possible time, and we must standardize the structural frames as well as the dimensions that govern our building materials if we are to get the maximum production. Cast iron is particularly suitable for standardization; a pattern automatically standardizes an article. If we decide that a certain type of building—a class room, factory, a warehouse or storage unit—can be adapted to a standard set of dimensions then we are in a position to standardize the framing components of which it is made, and cast iron would be suitable for this purpose.

There are two further advantages conferred by the moulding process. Steel can be rolled in almost any section that seems likely to be useful, but the rolling process is necessarily limited in sectional outline. In cast iron any type of section which is desired may be easily and inexpensively cast; the patterns are not so expensive nor so permanent as the rolling machinery. Cast iron can therefore be precisely adapted to the particular stresses which are to be encountered. Furthermore, the process of casting gives the designer an additional asset. Steel sections, where they are



This shows an arch with the haunches filled with concrete between the head of the columns and the wrought iron beams. (From *The Application of Cast and Wrought Iron to Building Purposes*, by William Fairbairn.)



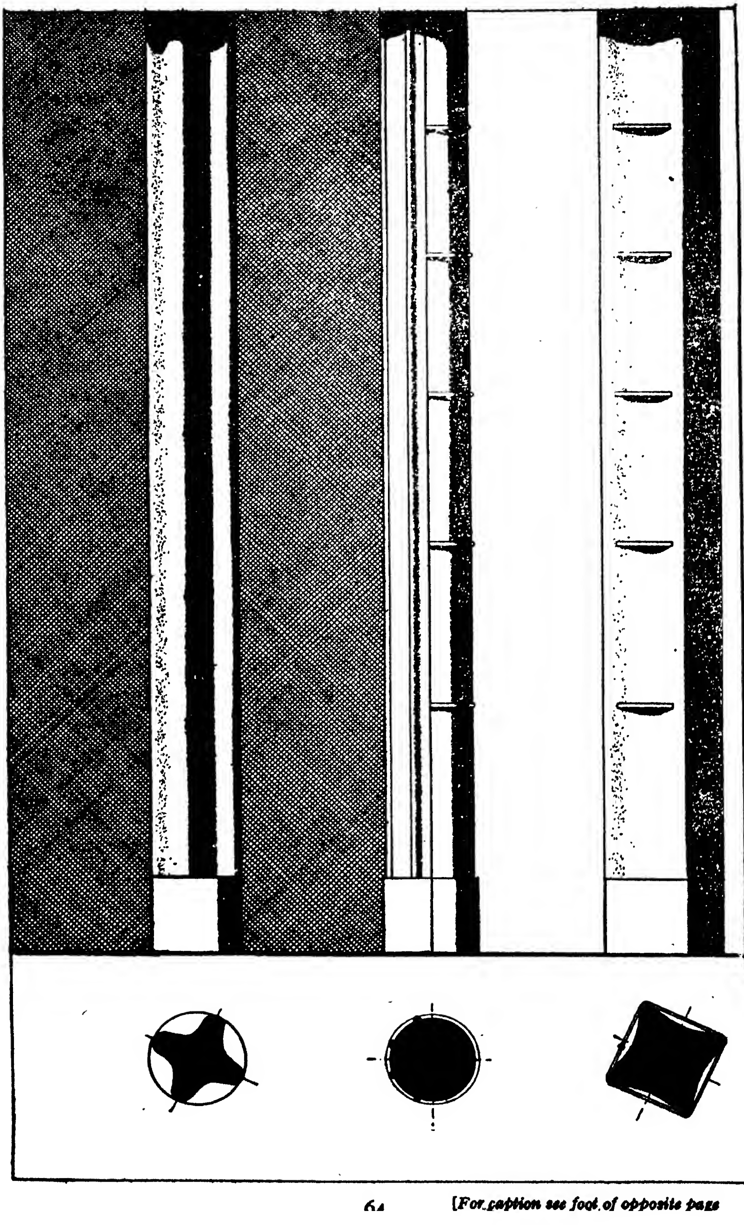
A section through a weaving shed, showing cast iron columns which support cast iron gutters. The dimensions of these gutters allow them to form entablatures for the columns, and they also act as supports for the reception of the roofs which extend from east to west and in the same direction as the gutters. (From *The Application of Cast and Wrought Iron to Building Purposes*, by William Fairbairn.)

to be exposed, are limited by the rolling process. But with cast iron we can, glancing back to the Pavilion at Brighton, mould the column sections to give vertical or horizontal accents where we require a row of isolated supports. Mendelssohn and Chermayeff in the library of their lovely pavilion at Bexhill used as columns a double steel angle section, and by this means accentuated the grace and slenderness of the structure. Cast iron can be used in this way, and can be developed over a wider range of accents than was possible in this example.

The Eiffel Tower was constructed of wrought iron in 1889—thirty years after the Bessemer process was evolved. Steel had come into general use in industry before 1870: Eiffel may have been influenced in his choice of wrought iron, because its resistance to atmospheric corrosion was better than steel.

The resistance of cast iron to corrosion, which has been further improved by some of the recent developments in alloying, has encouraged its use for seaside piers and pavilions since the eighteen sixties. Iron has a high degree of resistance to the sea atmosphere and to the direct action of sea water, and the columns and superstructure of many of our existing piers are of iron. Most of our piers are highly characteristic and have a genius of design all their own; they were the Victorian equivalent of the folk festival, and the quality of their decoration is expressive; it is bold, coarse and vigorous. The iron is used flamboyantly in panels and columns and crockets and gables, for windows and doors, for turnstiles and slot machines. Buried under the paint and obscured by later accretions the social investigator can discover a record of the habits, characteristics and amusements of mid-Victorian England. A design by the author is illustrated which gives an idea of what could be done to cater for traditional requirements while adapting the structure to contemporary form. The pier includes a marine aquarium, a concert hall, an open-air dance hall, and a planetarium.

Iron is used in such seaside shelters usually in the form of a frame to which panels of iron are bolted; occasionally in the smaller buildings the frame is omitted and the panels themselves



[For caption see foot of opposite page

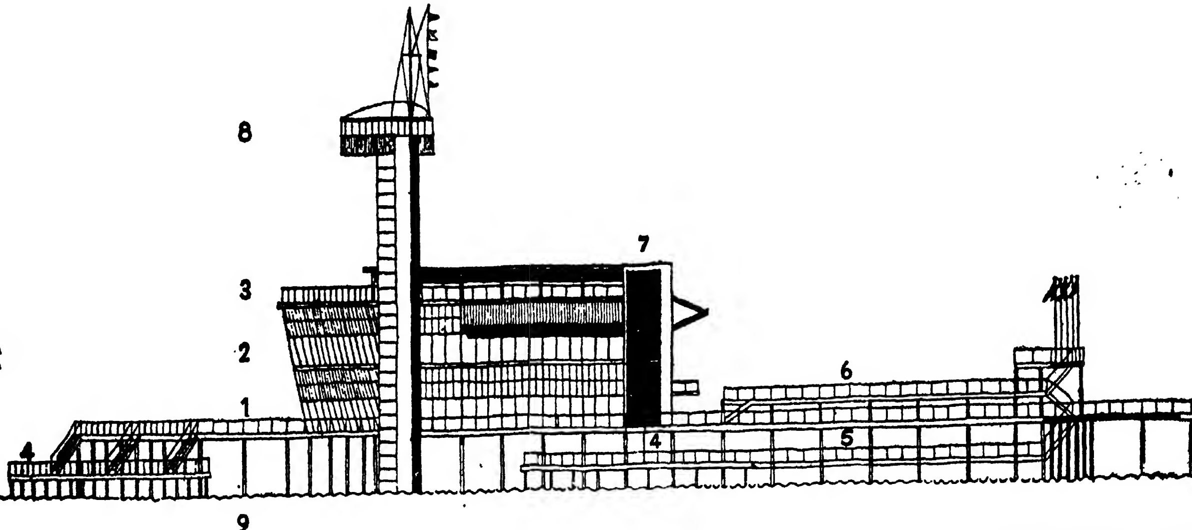
are moulded to take the stresses involved. These structures display considerable ingenuity not merely in the elaboration of design but in the methods which were adopted for jointing and fixing the units. The G.P.O. telephone kiosk is of the same order of building, and the construction of the latter shown on plates 32 and 33 should be compared with that of the kiosk on plate 34. Except in the case of the piers, the spans involved in these structures are always small, and the cast iron frames are of a solid tubular or cruciform section.

At some time in the early years of the nineteenth century a cast iron lock house was built at No. 1 Lock, Tipton Green, Staffordshire. It had walls of flanged cast iron units, one storey high, bolted together. The outside was painted, and the inside finished with lath and plaster.[1]

These instances emphasize some of the characteristics of cast iron in framed structure. The units are either hollow or solid. Beams are usually solid and the low tensile strength leads to a section with deep web and heavy flanges, and of a greater cross section area than a steel section of equivalent strength. Hollow sections can be made either vertically or horizontally, and in recent years the method of manufacture without the use of cores has been perfected. In this method the mould is spun and the

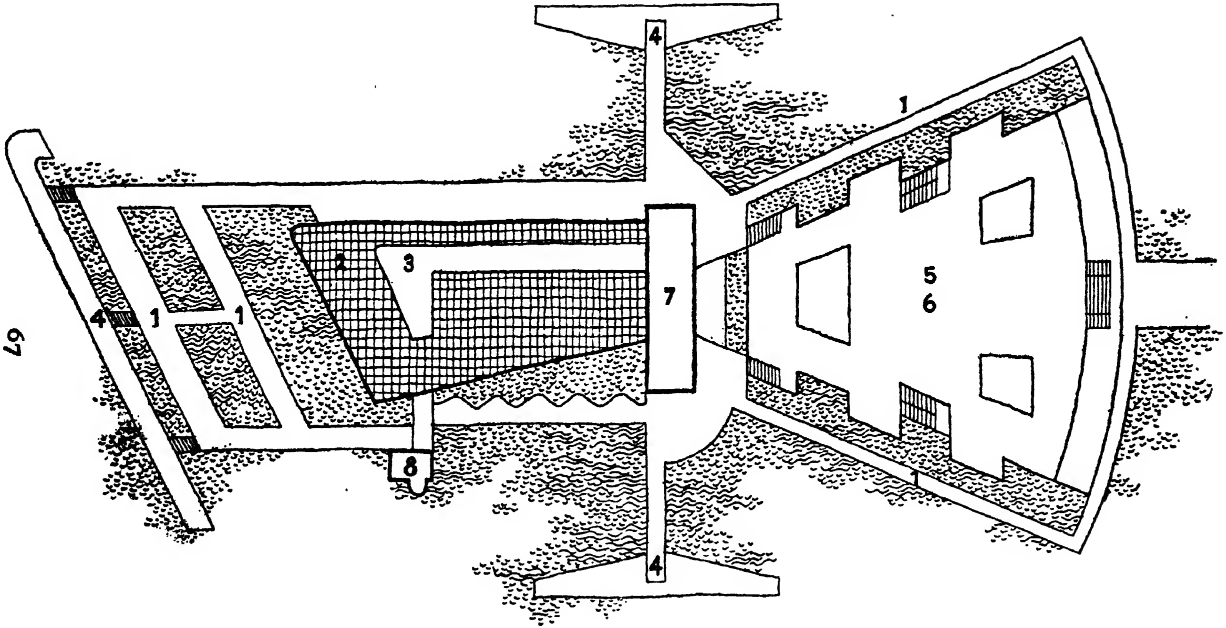
[1] In an article published in the *Birmingham Gazette*, December 6, 1924, the house was described in detail, and a tribute to its comfort was recorded. The occupants at that date were interviewed, and stated that the house was: "As dry as a bone; as warm and cosy in winter as anybody could wish, and cool in summer."

Caption for illustration on page 64]
Iron can be cast to give emphasis or decorative quality to individual parts of a design. Here are three iron columns, cast to give a suggestion of slenderness or solidity. Each column has the same diameter; that on the left is cruciform in section and the shadowing shows the effect of slenderness and lightness which is obtained. The left hand section of the central column shows another variation of a vertical effect, while the right hand half gives horizontal emphasis in the form of astragals. The column on the right has a square section with slightly concave faces which are emphasized by horizontal ribs.

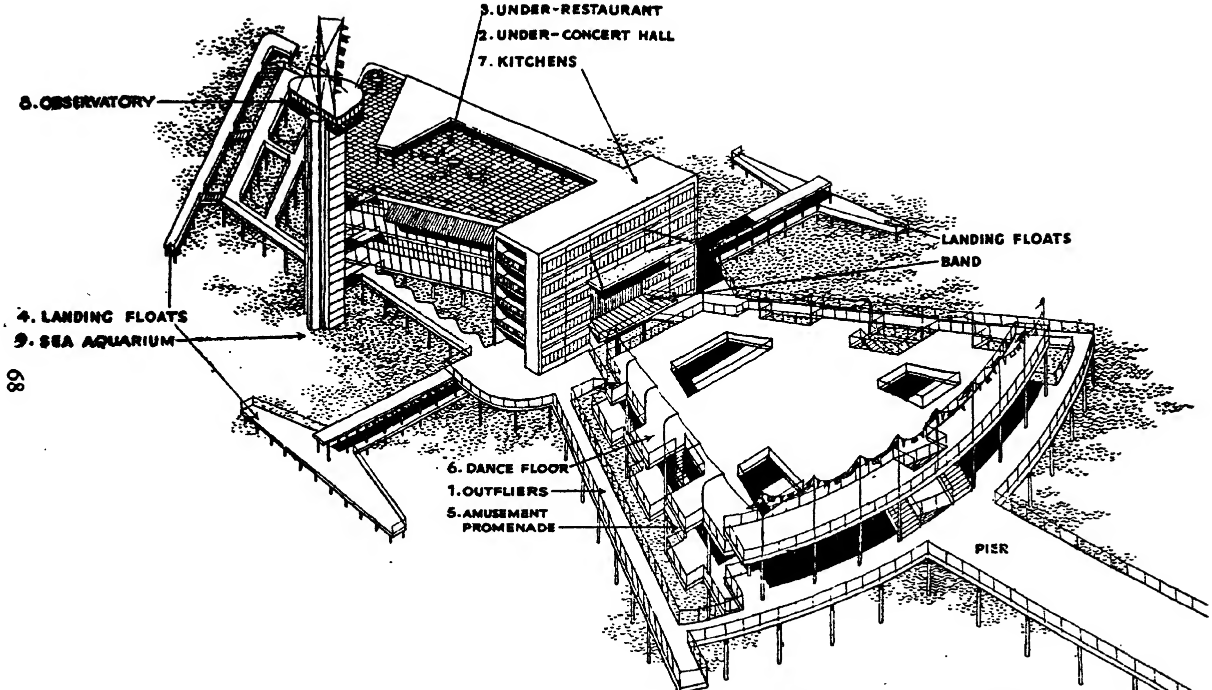


Design for a pier at a popular seaside resort. The elevation is shown above. The key to the figures, both of the elevation and the plan, shown on the opposite page, is as follows:

1. Outfliers
2. Under-Concert Hall
3. Under-Restaurant
4. Landing Floats
5. Under-Amusement Promenade
6. Dance Floor
7. Kitchens
8. Observatory
9. Sea Aquarium



Design for a pier at a popular seaside resort, plan. (The perspective view of this design is shown on the next page.)



Perspective view of design for a pier at a popular seaside resort (The elevation is shown on page 66 and the plan on page 67.)

molten metal forms the wall of the casting by centrifugal action. By this process pipes are now made up to 2 feet in diameter, and 16 feet in length, both in sand moulds (sand spun pipes) and in metal moulds (metal spun pipes). The same process is applied to cylinder liners for the motor industry.

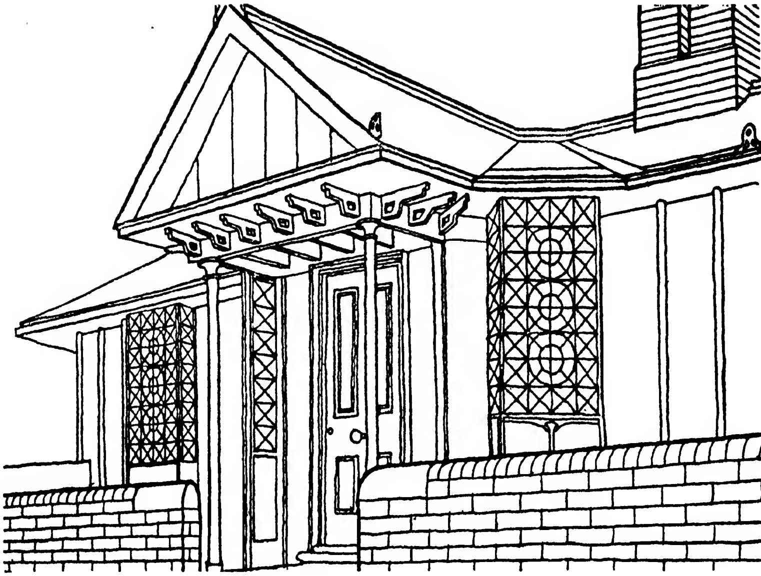
The spun process although more expensive ensures a uniform cross section and an even consolidation of the metal. Consequently it results in greater structural precision, and is increasingly used in manufacture.

These definite advantages are to be gained by the use of cast iron, particularly in buildings of a composite construction. The ease with which standardized brackets and heads can be fixed makes it possible to use iron columns in combination with beams of concrete and timber; the cap can be sweated on to the column and so designed to give axial loading. This form of construction was widely employed, and many examples are to be seen in railway stations and warehouses dating from the mid-nineteenth century. They were often of weird and wonderful patterns, but a more rational design has been produced in recent years which allows a simple connection between column and beam to be made.

The use of solid columns or struts is naturally much more restricted. In relation to their weight the slenderness ratio is low, and they are therefore more economic when the load is large and their length short. Nevertheless cast iron when used in this way gives a very slender and graceful appearance, which is strikingly apparent when such columns are used to support the reinforced concrete canopies. (See page 64.) The repetition of such columns along a façade forms a contrast to the horizontal emphasis given by monolithic reinforced concrete construction and creates an impression of lightness and grace.

Cast iron is also used to form the bases of columns and stanchions in framed structures where the loads are not large—in practice buildings of a permanent construction not exceeding three storeys in height. Such bases are formed of flat plates which are sweated on to the column, and the concrete cast over them. In larger buildings, where a grillage is being used, a more elaborate base with brackets and cleats is required. A considerable amount of investigation has been carried out to test the resistance of irons to vibration and impact. Such research has a specific application in mechanical engineering, and irons with these resistant properties are mainly used as bases for machinery. It is often necessary to provide bases which will withstand stresses of this sort, particularly with air compression machinery, lift motors, and other equipment.

There are many uses for cast iron in connection with the structural frames of buildings. Many of them are unimportant and not widely employed. Sometimes they include uses which, however valuable in themselves, hold little interest for the designer. The escape stair is an instance. If it is necessary, it should form part of the building, but unfortunately many of our buildings are a compromise between obsolescence and economy, and the escape stair trailing down the back symbolizes architectural inadequacy. It often means that the building to which it clings was erected for some other purpose and was adapted to its present use, or that it was so badly planned in the first instance that the safety of the occupants had to be ensured by means of another and unconsidered stair. The number of these escape stairs in hospitals, boarding houses, hotels and schools indicates a high proportion of buildings which are obsolete. Generally these stairs are seldom worth a second glance and the architect can scarcely be blamed for lack of interest in their design. But the treads and the landing, unlike the rest of the structure, often form a design of great interest and technical ingenuity. They are cast in flat sections and their beauty lies in the varied relief which is obtained by the open design which minimizes the weight. Cast iron has often been used in this way to forge galleries and floor decks and in the nineteenth century by Labrouste in the construction of the galleries in the Bibliothèque Nationale in Paris. It is a lovely and characteristic use of the material and exploits the facility for casting a complex form; moreover, it does not exclude light and can be designed to give a sense of spatial unity.

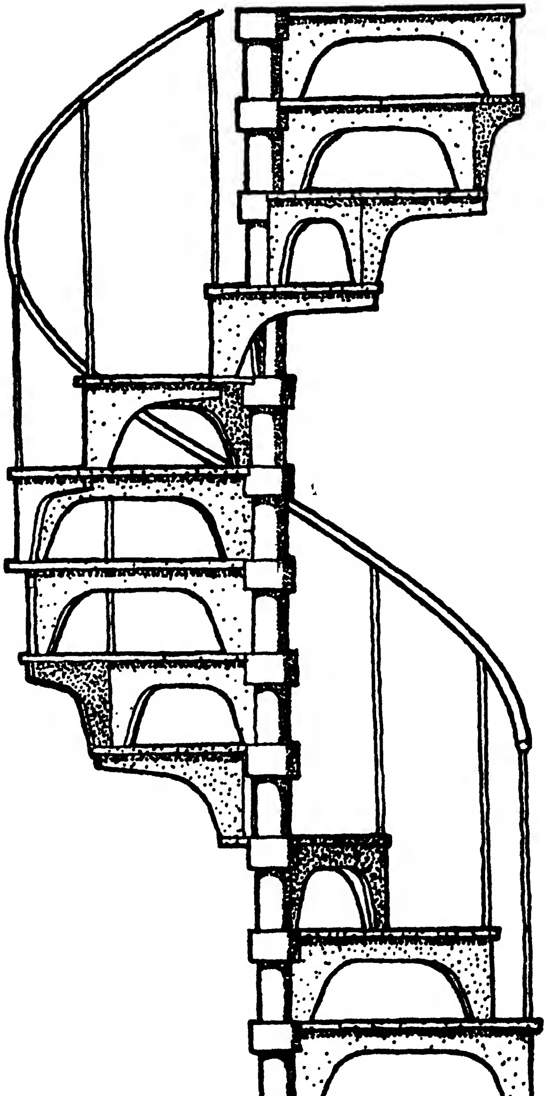


A cast iron lock house built at number 1 lock Tipton Green, Staffordshire, during the early nineteenth century. This drawing is based on a photograph which was published in the *Birmingham Gazette*, December 6, 1924.

The few examples described in this section show the character and possibilities of cast iron when it is used for structural purposes, and demonstrate that iron is both economic and flexible as a structural material, and that there is a range inside which it is a most practical and effective material.

(*b*) *Semi-Structural Uses of Cast Iron.*

Under this heading are included applications of iron which are not used as primary elements in a load-bearing frame, but which may be exposed to secondary stresses. The units made withstand considerable stress either through their own weight of through their use as supporting or stiffening members, but



A spiral stairway in cast iron. It is a characteristic use of the material, and exploits the facility for casting a complex form.

they have no direct share in the transmission of structural loading to the ground. Such uses include the inter-locking structural panels which are used, sometimes in combination with a frame, to form shelters, telephone kiosks, and structures of the type considered earlier in this section. External facings to panel walls, door and window frames come within this category. That miscellaneous group of castings which embraces anything from tram standards to pillar boxes, and is generally known as road furniture, has also been included. It is true that such things are not subjected to conditions that occur in buildings, although a tram standard may endure considerable variation in stress due to the action of the wind and to the load of the cable. The difficulties encountered in casting a pillar box and a facing to a panel wall are similar, and as both are used externally the corrosion factor has to be considered.

Commercially road furniture is one of the most important fields for the use of cast iron. The first essential in the design of panels and other large units is stiffness and rigidity; these factors are necessary in manufacture, transport and erection, and they also improve the efficiency of the unit structurally, provided that its weight is not correspondingly increased. This principle is best exemplified by reference to one of the bollards in Hyde Park, London. Although these are of recent date, they were designed by the Office of Works to harmonize with Decimus Burton's screen at Hyde Park Corner, and with the magnificent lay-out of the Park. The elaborate and dignified design is suitable for mass-repetition in a mould, and it uses the almost sculptural possibilities inherent in the moulding process. The mouldings and the heraldic devices so convolute the iron section that they increase its strength and give it great rigidity, and the sculptural quality of the bollard is enhanced.

It is evident that a flat plate of cast iron, rectangular in shape and of a uniform thickness, will not have the same degree of transverse strength and stiffness as one of the same weight and dimensions, but with a ribbed section. This increase of strength is given by the disposition of the ribs, which are deeper than the thickness of a plate of uniform thickness. The key to successful design in cast iron lies in securing the maximum strength from a given weight of metal, and the design of the mould must always be considered in these dimensions.

The total superficial area of the casting has a direct relationship to its thickness. The stresses set up in cooling when withdrawing a panel from the mould have been mentioned previously. Theoretically, although there is no limit to the size of a casting, the stresses set up in cooling and withdrawal have an important effect in determining the maximum thickness of castings, and particularly in varying thicknesses of the same castings. Very large castings have been made—like the window frame shown in plate 20, whose chief recommendation is its size, which is 24 feet by 36 feet. This is probably the largest casting in point of superficial area ever made in this country. Generally, the superficial area of castings of the panel type is limited to 50 or 60 square feet; larger sizes are possible, but the cost increases steeply above this limit owing to the care necessary in casting. Workshop, transport and site handling are also factors which have to be considered.

It will be obvious that foundry and manufacturing considerations rather than design calculations determine the minimum thickness of flat panels. Where no superimposed weight is allowed for and uniform support assumed, the minimum thickness may be taken as follows:

Dimensions	*Area*	*Thickness*
Feet	*Square feet*	*Inches*
2 by 2	4	$\frac{1}{8}$
2 by 4	8	$\frac{3}{16}$
3 by 6	18	$\frac{1}{4}$
4 by 8	32	$\frac{3}{8}$
5 by 10	50	$\frac{1}{2}$

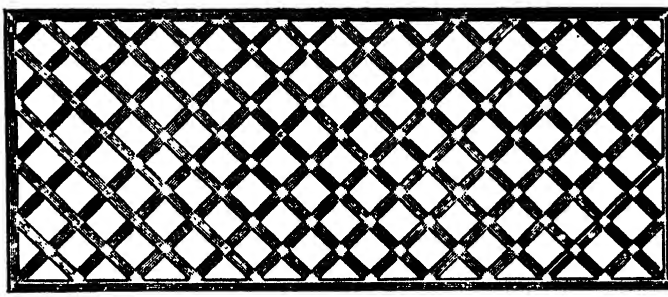
This gives a rough guide to the size and weight of such panels, and ribbing or other moulded detail will generally increase their strength.

Iron can be cast within very close limits of size. Naturally a fine tolerance demands excellent pattern making and stringent control in the manufacture of the mould and in pouring; but for building purposes fine tolerances such as those required in engineering are not necessary. With grey iron, cast in the normal way, very fine detailing and modelling of the surface is possible.

Cast iron has many advantages for non-structural purposes. Obviously the repetition of single units whether elaborately modelled or plain, is one of them. The panels used on such buildings as Bush House or Selfridge's, apart from the character of their design, must give an iron-founder solid and lasting satisfaction. Once the mould has been produced he has only to keep on pouring in the iron. Moreover, the range of such castings is wide. They can be used to form series of panels between the windows as well as the sub-frames themselves. Although in both uses they are not subject to primary stressing, there may be a considerable amount of lateral thrust. Bronze windows may be inset in these, panels and lugs can be cast on them to facilitate fixing to the structural wall. This is the method used for the wall panels at the new Adelphi Building. (See plate 15.) Iron panels may be backed with brick or concrete, as the chemicals contained in these materials do not affect the iron and there are many methods of fixing. Slots are sometimes cast in the back panel clamped to the brickwork in such a way that the effects of any settlement in the structure are not transmitted to the panel. The top and bottom edges of the panel are often rebated to the cills and heads of the windows and the joints caulked or grouted with cement or mastic. Thus the whole external facing, the window frames and panel walls of a modern commercial building, can be made of cast iron; the iron is often bronze finished or sprayed with aluminium as on the Adelphi Building. The same technique could be extended to provide a panel infilling for school classrooms.

The use of cast iron in the panels of framed buildings dates back to the beginning of the nineteenth century. Sigfried

Giedion in his book *Space, Time and Architecture*,[1] illustrates some fine examples of such panels from St. Louis, which they appear to have reached by being freighted down the Mississippi during the early days of American river steamboat traffic. On this side of the Atlantic they have also been used extensively, particularly in office and store construction. In the nineteenth century the panels were cast with classic mouldings round the edge, and although this helps to stiffen the iron panel it avoids the problem —which we have still not solved—of finding a surface treatment in keeping with the material. Like the crockets of the Gothic



A cast iron grating with a 2-in. mesh.

Revival churches, the illusion that the panels were of stone was further heightened by the use of stone paints and slurries. To-day metallic sprays and paints are used in the same way, and the appearance of such panels is often more characteristic of drawn bronze than of an iron casting.

Panels thus employed may be sub-divided into three principal types, according to their design. It is seldom that any one of these is used independently of the other, but this sub-division serves to distinguish the characteristics common to all these units.

1. Pattern casting, in which the metal is of a uniform thickness, relieved either by mouldings or by surface patterns of no great depth. This is perhaps the most common type of panel,

[1] Oxford University Press, 1941.

but it has not generally been handled very successfully. The chequer pattern which is sometimes found on manhole covers is more in keeping with the material, but for some reason continuous surface patterns of this sort have been little used.

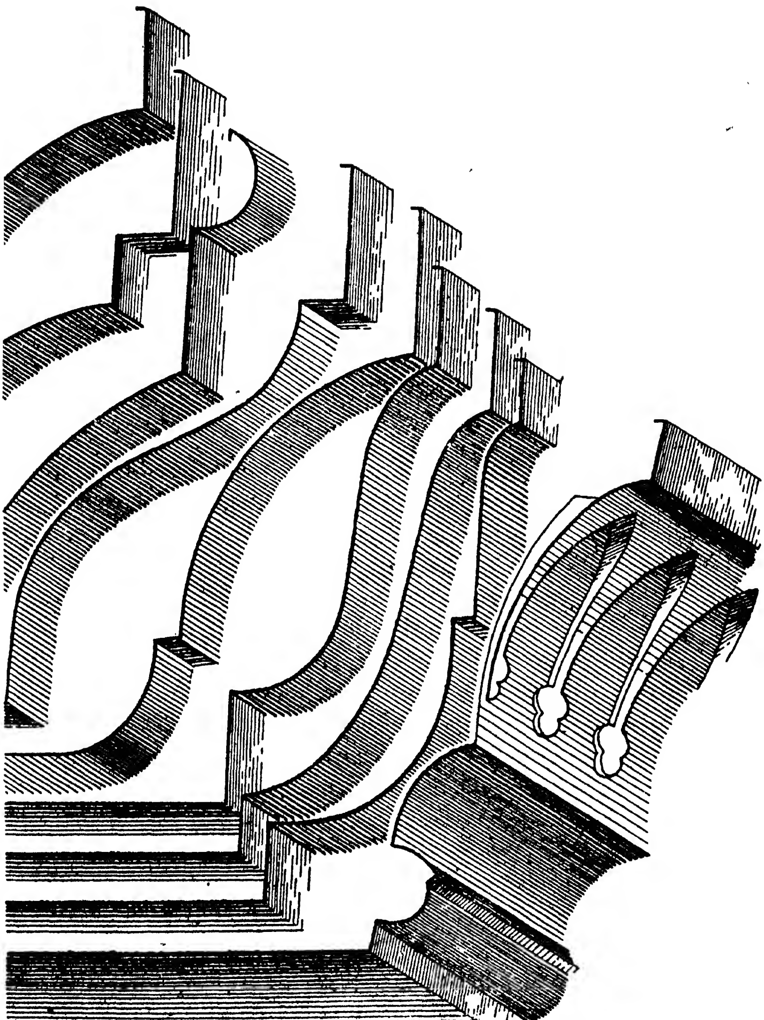
2. Castings in which the metal is not of a uniform thickness and can be considered as being moulded rather than relieved by pattern. This type of panel uses the metal in a logical way, and it can be curved in any dimension. This type has not been extensively used, due partly to the persistence of the classic tradition for commercial buildings, and partly to an unwillingness to experiment in form. (Plate 15.) In the new Adelphi Building, the moulded quality of the design is very evident, and the panels are curved in two dimensions and give a good indication of the possibilities of the material.

3. Sculptural relief has also been extensively used, and this again is practical and legitimate. The initial design must be carefully considered so that it does not create difficulties in the pouring and in the withdrawal of the mould. The sculpture should be more in the nature of bas-relief, and should not be undercut. Its position in the panel as well as its comparative size and weight must also be considered so as to avoid unnecessary stresses in cooling. (Plate 16.)

In point of mere numbers, the G.P.O. telephone kiosk must be the most successful piece of pre-fabrication ever designed. The latest pattern consists of four panels and a roof unit which are rebated and interlocking and fixed by bolting. The panels themselves vary as sides and door are made for glazing, while the rear unit is solid. To overcome the weakness of castings incorporating such a large opening, the door and window units are formed with curved projections which raise them in front of the panel. For the same reason vertical reeding is used in the corner sections. The design of small structures of this type calls for a very close study of their individual requirements. The G.P.O. kiosk is an example of the close approximation of means to ends, and if iron is applied to a great range, a corresponding study of detailed requirements must be made. If the number of structural components can be reduced to a minimum, and the panels themselves standardized so that they are interchangeable, then it is possible to manufacture a range of such units which can be adapted for different uses. It would enable standard panels to be produced, with a number of different finishes, and would allow definite scope for individuality in the treatment of each type. The dimensional standards of these units—electric sub-stations, transport shelters, kiosks, police boxes, fire alarms and ambulance boxes—as well as their assembly, would form a productive study in technique.

(*c*) *Building Components.*

Included under this classification are such things as window frames and porches, gutters and gates, drain pipes and manhole covers, which are fixed or built into a structure, and all components necessary to complete a structure and to ensure its maintenance in good order. For many of these purposes the use of iron has become traditional and for drain pipes and gutters it has long been the only material which is both cheap and durable. For others the changing basis of building technique makes it likely that its use will be extended, and such things as window frames and porches are likely to be made in cast iron to an increasing extent owing to the fact that the building craftsman is becoming an expensive luxury, that costs have risen rapidly since the war, and mass-production represents the only hope of getting homes in sufficient quantities and at a low cost. Many of these products, moreover, were first fabricated in the last century, and although the designs have been modified in course of time, some of them require to be re-designed to bring them into line with modern requirements. The industry is very much alive to the importance of overcoming the prejudices which arose in the latter part of the nineteenth century. As John Gloag puts it in *The Missing Technician*: ". . . the mishandling of the material between the middle years of the last century and the nineteen twenties, has caused many people to regard it as hopelessly old fashioned, a view that is soon corrected by knowledge of the



These sections of cast iron gutters indicate what a considerable variety of form was available. For drain pipes and gutters cast iron has long been the only material which is both cheap and durable.

progressive improvements in the qualities and capacity of cast iron achieved by contemporary research."[1]

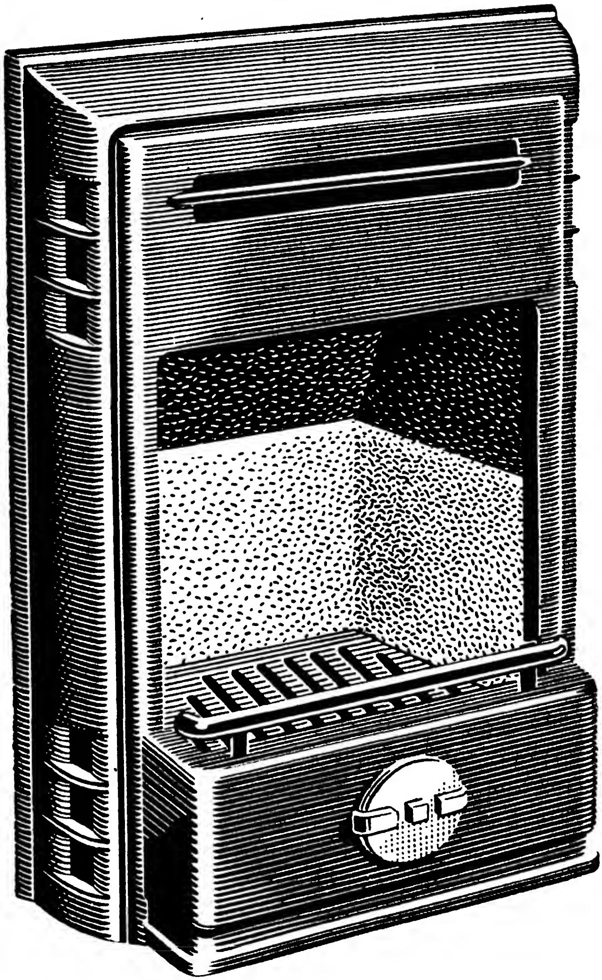
In building equipment, much of this work has already been carried out; one has only to look at some of the designs for post-war fireplaces and stoves to realize what can be done by good designers.

It is often held that the design of an efficient and good-looking article rests upon three factors.

1. An exact determination of function.
2. The selection of the material whose physical characteristics most nearly approximate to the requirements of the article as determined by the first process.
3. Its manufacture in terms of both the preceding phases and its economic production.

These three assumptions represent what might now be called the behaviourist school of design since the intention of the designer is discounted. This theory, while only partly true, certainly does establish a factual basis for design. It is difficult to go far wrong on this basis, but the ability of the individual designer cannot be written off by implication over the whole range of industrial design. A Georgian railing or balustrade satisfies all the conditions. (Plate 31.) Another example equally efficient in function, material use and manufacture dates from the mid-nineteenth century, and shows that the fourth qualification—the intention in the designer—can ruin even a soundly made object. (Plate 41.) Cast iron has suffered severely from the intention of designers in the past; fitness for function and material is insufficient by itself; an article can be efficient without being beautiful, and there is no point in pretending that good design can come about simply by the operation of mechanistic processes. The design of components in cast iron for the building industry illustrates this comprehensively and finally. The production of most building components does not require a high degree of accuracy or of strength, and consequently the main

[1] Chapter IX, "Old Materials with New Properties," page 98.



A modern cast iron projector heating unit which fulfils the three requirements of design. 1. An exact determination of function. 2. The selection of the material whose physical characteristics most nearly approximate to the requirements of the article as determined by the first process. 3. Its manufacture in terms of both the preceding phases and its economic production.

problem from the manufacturers' point of view has been the ease and rapidity with which they can be produced. A high degree of finish is not always required either, and normally a casting is used as it comes from the mould, as it will have some form of decorative finish added. Components may be classified according to the degree of finish which their purpose requires.

1. Sewage and Surface Water Components. These range from the common backyard downpipe to elaborate, air-tight manholes with upwards of a score of connections, or to the main sewers and sewage works. Castings for this purpose are not ground or buffed, and their finish consists of a non-corrosive surface which is usually carried out by impregnation of the metal under heat with a tar or bituminous finish. Ventilators and air bricks are also included under this heading. Most of the service and drainage components are buried and forgotten. Insurance statistics prove how rarely any fault or defect which arises is attributable to the use of cast iron; particularly when it is remembered that practically all our drainage installations are of cast iron and a big proportion of the public sewers are of the same material. It is, in fact, the bread and butter occupation of a particular branch of the cast iron industry that caters for the building trade. But while the production of such castings is interesting from a technical point of view—in the coring of the moulds for downpipes for instance—they are not of great interest to the designer.

2. In the second category come those applications where a finer finish is necessary and which may necessitate grinding or polishing. Different types of surface finish are also required, and these, as already stated, determine to a large extent the degree of grinding and polishing necessary. Generally where these are used externally and are to be painted, the cast finish is sufficient, but the possibilities latent in the various finishes discussed earlier have scarcely been tried. There is always an inclination, particularly in a material which lends itself to use on a large scale, to think that a large unit is necessarily more convenient since it requires less fixing than a number of small ones. This is not always

correct, and even when fixing is taken into account the small unit may be more economic. Some of the disadvantages of very large units, both in casting and transport, have already been mentioned, but there are other reasons which support this view and are worth consideration. It is, of course, perfectly easy to cast a soil pipe in 18 foot lengths rather than in 6 foot ones. But the danger of damage before erection is increased, and if it does occur the cost of replacement is trebled. Secondly, the erection of the shorter lengths allows considerable latitude in dimensions and tolerance and makes the unit considerably easier to handle both in erection and replacement. Another instance of this is furnished by the erection of walls and roofs in prefabricated housing: with many systems it is perfectly possible to prefabricate a wall or roof entire in one unit. But site experience has shown that even with elaborate plant larger sizes are more difficult to handle than small. It is often advisable therefore in designing such units as handrails and hoods to sub-divide them into units which can be easily man-handled, and more easily and economically manufactured.

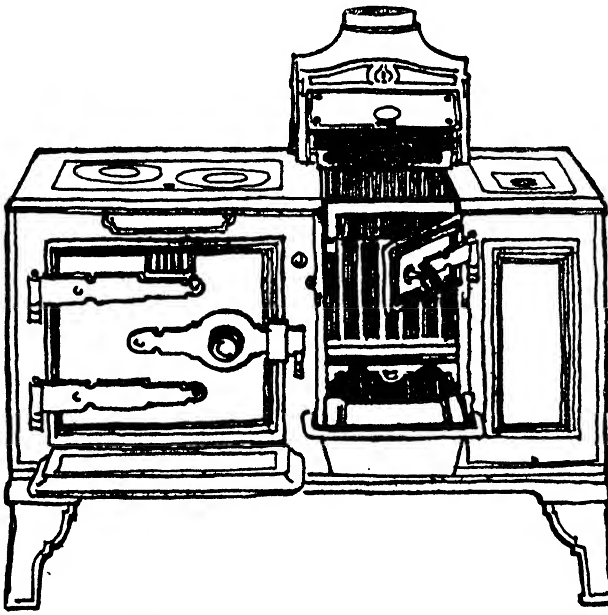
(*d*) *Building Equipment.*

A list of some of the appliances covered by this heading shows the extent and importance of this category. It would include heating and hot water installations, radiators and boilers, gas and electric as well as solid fuel burning fires, kitchen equipment like cookers of all types, boilers and refrigerators, laundry equipment; also bedsteads, turnstiles and school desks. The suitability of the material for a whole range of smaller castings is immediately demonstrated by any large hotel kitchen. Practically all the equipment, irrespective of its cost, will be made from cast iron. It is in this field that the new kinds of surface finish are likely to increase the use of the material; just as the blacklead finish aroused prejudice against it.

The fireplace was perhaps the earliest application of cast iron to be made: it is not affected by the heat generated, it retains its original appearance almost indefinitely and is not easily damaged or broken. In most appliances cast iron is used not independently, but in conjunction with other materials. A gas cooker may have its external panels of cast iron, but inside will be found aluminium reflectors and chromium-plated taps and fittings.

Apart from the casting process, which enables elaborate patterns to be easily and quickly followed, iron has the enormous advantage of providing a good base for finishes. Sheet steel will take stove enamel well, but its subsequent life depends upon the rigidity of the metal as well as upon the continuity of the enamel. A cast iron panel is unlikely to bend and deflect in the same way as a steel sheet. Stove enamel is therefore likely to be more durable on cast iron and will withstand the intensive wear to which it is subjected in a kitchen. The building equipment mentioned at the beginning of this sub-section shows that the great advantage of iron lies in the facility with which complicated castings can be made, which would require expensive working if carried out by other methods. The top of the gas cooker or the body of an electric fire are forms which can only be cheaply produced by moulding. By comparison with a cylinder head or other types of casting required in the mechanical industry they are quite simple.

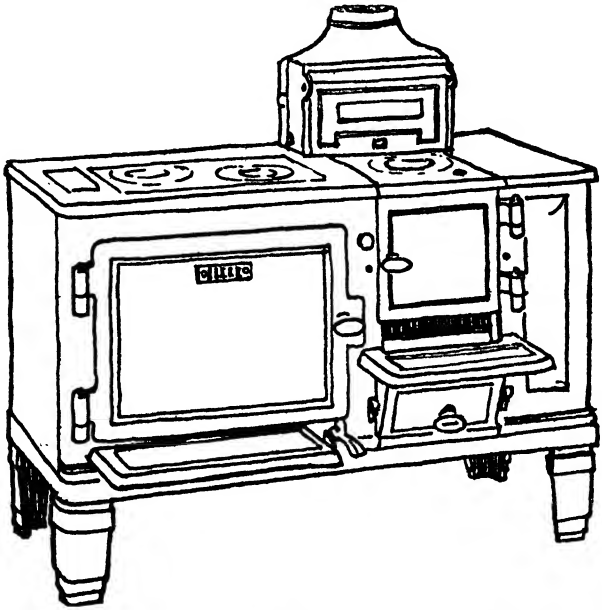
In all these applications cast iron shows an extraordinary continuity in use. The type of fuel may change, from the coal and wood ranges of the eighteenth century to electric cookers; the surface materials may develop from blacklead to enamel, and there may be a corresponding improvement in the convenience of the cooker. In fact the ordinary kitchen stove forms one of the most interesting studies in the relation of technology to purpose. Many of the articles we use every day, the telephone and the radio set, for instance, have been developed in the last twenty-five to forty years; there was no previous tradition of form which directed their shape and appearance. It is true that the "horseless carriage" conception retarded the design of the motor car for some years, but even here the effect was only temporary. In kitchen equipment, however, the adoption of gas and electricity for heating is as fundamental a change as the adoption of the internal combustion engine. The cycle of development in the solid fuel type of burner is of great technical interest. The kitchen range which was intended to be built in was



Three stages in the design of a solid fuel cooker and water heater. First, there is the pre-1914 model in cast iron with a blacklead finish.

a formidable appliance. A great fire which cooked by main heat and strength rather than by cunning, or by comprehending the process of combustion, was the prominent feature. It was embellished by some charming mouldings, an extensive area of reeding, and quite a selection of heraldry and zoological scenes. By 1860 the design had become stabilized. The iron has a blacklead finish. Blackleading accompanied the innumerable maids in the Victorian home.

The next development was to make the fire smaller and the range more efficient. There was a small water jacket, not linked to any circulating system, but the hot water could be drawn off by a tap; on the opposite side was a small oven. The draught could be controlled by a damper, but individual control of either

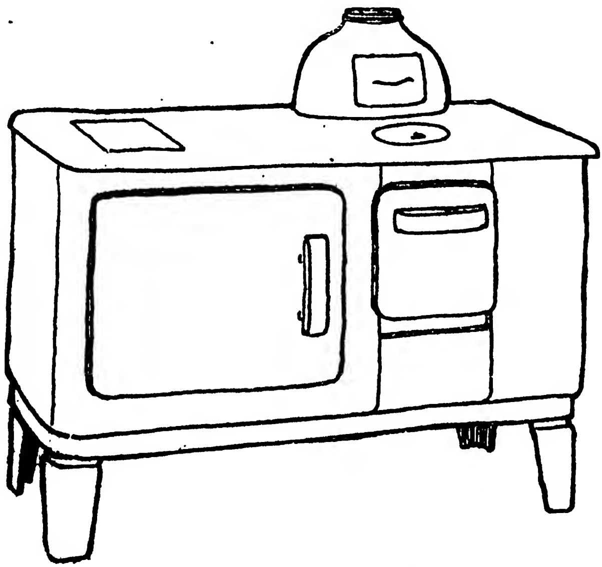


This is the next stage, a simplified version produced in the period between the wars. This has an enamel finish.

the oven or the water heater was not possible. It was awkward to clean, expensive in fuel and inefficient in operation.

Compare this model with one dating from 1920. The same features remain and the greatest improvement is that the main draught can be controlled so that either the boiler or the oven receive most of the heat. The finish has been improved—areas are tiled, sections can be stove enamelled. Blackleading still remains in parts, and the total amount of work has not been substantially reduced. Moreover, there are knobs, projecting hinges and handles, all of them liable to be easily damaged or knocked off.

The modern solid fuel cooker has been transformed. Its surface is entirely enamelled. It is easy to clean, durable and pleasant



Here is a contemporary design by Grey Wornum, F.R.I.B.A. The legitimate and improved descendant of the ancestral models shown on page 85 and opposite.

to look at. All the projections, the knobs and knicknacks have been cleaned up; the unnecessary ones eliminated or automatically controlled, and the essential ones countersunk and given heat-resisting handles. Any part can be easily replaced. It is efficient, for its fuel consumption is low and it is so arranged that heat can be generated quickly or it can be stored. It is equally economical for grilling a chop or for cooking porridge.

Technically it is easier to manufacture and assemble. The size of units has not increased, but they are similar in design. The elimination of so many trimmings makes assembly a simple process.

The evolution of this appliance has been considered at some length because it admirably illustrates a threefold development: (1) The improvement of the article as a cooking appliance; it is a better cooker, it is more convenient in the house. (2) It is more efficient and economical. (3) It is easier to manufacture, to standardize and produce; it is simpler, cleaner in operation, it is better looking and better made. Thus it represents a unified technical development—and a development which has evolved in one material over a century and a half. This does not necessarily make it a better article. If other materials had been equally efficient, as well as being cheaper, they would have been used. But it does enable the course of design over this period to be traced in a precise form which would not be possible if other materials had been found more suitable.

In this way the development of cast iron for various uses, from structural applications to small domestic appliances, is unique. Aluminium and zinc alloy castings have been produced by the die-casting process in the last thirty or forty years, and have been used in the equipment of cars and aeroplanes, and this has been paralleled more recently in the manufacture of plastics. Highly efficient, well-designed articles have been produced, and where they offer a better standard of performance or other advantages—like the low heat conductivity of certain kinds of plastics which has led to their use for switches and taps in cookers—they have been adopted. The only criterion in the long run is efficiency in performance, and the persistence of the casting process is due to no sentimental feeling for iron, but solely to the inherent qualities of the material and the ease with which the changes and variations in design can be made.

The modern heat storage cooker was taken as an example of this process of what might be called natural selection, but it applies to many other articles as well in all the four categories under which the applications of iron have been classified. It is true that it is more marked in the sphere of domestic appliances

—fireplaces and stoves, to cookers and boilers—than in the structural uses which have been considered. The reason for this is that it is seldom worth while to standardize the large units; they are not used in the same way, and the demand is not so copious or steady that it becomes worth while to preserve the special patterns in the foundries. But the number of domestic appliances make it worth while to develop a foundry for their production and little else, and to maintain this production at a uniform level.

When mass-production on this scale is undertaken it pays the iron-founder to obtain the best designs he can. Mass-production entails standard patterns, and once these have been made and production started, variations are expensive. Moreover, the public soon become aware of the comparative merits of appliances which are in daily use. The housewife with memories of pre-war labour-saving propaganda to sharpen her judgment, knows precisely what she wants in her kitchen, though she is less able to judge the merits of units which she does not personally use. It is for this reason, perhaps, that the design of kitchen equipment has made comparatively rapid progress. But with the demand which will be made on the industry in the future it seems likely that other uses will be rapidly developed and lead to improvements in design and in finish. This development belongs to the future, and its trends can only be properly appreciated in relation to the building industry.

Section Six

TRENDS IN BUILDING

BUILDING methods have altered slowly in the century and a half that has elapsed since cast iron was first used as a constructional material. Such changes as have occurred are principally due to alterations in the organization of the industry and to the methods used in the manufacture of materials. In principle and in general practice, methods of building are still what they were in the eighteenth century. Materials are available in larger units, and though sheets of one sort and another are so widely used that they have become as familiar as traditional materials, the traditional materials are still in favour, and still extensively used, in the same way and by the same trades as in the past. Cement is produced in enormous quantities, and its quality has been improved and standardized by modern methods of production; but it is generally puddled up into concrete on the site and shovelled into position; bricks, although manufactured by machinery in most cases, are placed into position by hand. Methods of construction which eliminate some of the mess and waste of time involved by ordinary building methods have been used for emergencies, but they are not yet perfect or popular. The building industry, like the cast iron industry, is individualistic in character and diversified in method, but it may have to yield a good deal of ground in the future to prefabricated and standardized methods of building. Both industries have, in fact, many features in common; each relies mainly on craft organization, and in each the stability of tradition rests upon numbers of local firms.

The cast iron industry is facing up to its problem. Developments in the design and production of cast iron will have an immediate effect upon building procedure just as the large-scale tendencies and trends to be observed in the building industry—like prefabrication—will in turn affect the position of cast iron components.

A study of the first Report of the Standards Committee

Ministry of Works, 1944, shows that the process of standardization is being largely applied throughout the building industry. British Standards Specifications are concerned with three aspects:—

1. The quality of materials or products.
2. Sizes and dimensions.
3. Workmanship.

Forty years ago there were no standards in the building industry. The unfortunate architect was forced, in his specification, to name the place from which a material was obtained, what quality he expected, how it was to be prepared, and how it was to be used. Usually he obtained a sample and hoped that the rest would conform to it. With the application of these standards to building products he can save himself a lot of trouble; he can write that magic phrase "in accordance with B.S.S.," and he no longer relies on hope. During the war the Standards Committee of the M.O.W. has suggested the production to new British Standards of every material and product used by the building industry. A uniform quality of material is thus imposed on the manufacturers while leaving room for individual ingenuity in production. But perhaps the most important development lies in fixing standard dimensions for equipment and components. It is proposed to adopt standard dimensions for a range of manufactured articles, in particular those used in house building, from cookers to cupboards. Manufacturers will be absolved from the game of guessing the popularity of a given size or from producing articles in the hope that they will suit the conditions in which they will be used; they will be able to arrange for the mass-production of components and appliances to the sizes laid down, knowing that these articles will be used in the majority of buildings, because such standardization will make them cheap and interchangeable.

The sizes, as well as the quality and performance of cast iron stoves, for instance, will be laid down, and standardization will probably result in the elimination of a number of different types.

Of course, non-standard articles will still be produced to meet individual requirements, but they are likely to be more expensive. The production of a standard metal window has cheapened its cost, made the job of the architect in co-ordinating it with other products easier, and given an assured standard of performance. It is not suitable for every set of conditions, and non-standard windows are usually obtainable; similar conditions of use and demand are likely to occur with cast iron products.

The extension of standardization is certain to have a marked effect upon the cast iron industry. Already machinery for the mass-production of certain units has been laid down in many foundries, and the war has accelerated this development. But one of the obstacles in the way of this tendency before the war was the fact that demand was variable and the range enormous. If the demand is constant for a given article—say a bath or boiler—then it will pay to instal the necessary plant. The industry has been prepared for this situation, and standardization will increase production and thus help to avoid a shortage of building components.

It is often argued that a reduction in the range of universal products will restrict the freedom of choice of the individual and result in stagnation and monotony of design. With a material like cast iron, where the range of surface finishes, texture and colour can vary within wide limits, monotony of appearance is unlikely to occur. The freedom of individual choice presumably follows an assumption of efficiency in a given set of conditions. But if building components are produced to a set standard of performance and the conditions under which they are used is similarly restricted by the conditions inside the building industry as a whole, then this criticism loses force. Moreover, if large scale production is to be started and a large sum laid out on plant, the individual manufacturer is much more likely to take care that his product is the best which can be designed. So long as he is producing many different designs, it does not much matter if one is not as perfect as it might be, nor does it necessarily pay him to employ the best designers. But if he is going to produce a smaller range of articles for a long period he will be more likely to ensure that his design is as efficient and attractive as possible. In the cast iron industry this process is already apparent, and the design of cast iron products is being improved and extended.

The mass-production of materials and components has proceeded for a long time. But latterly it has been extended to include not only the raw materials of assembly like bricks and mortar and plaster, but complete building units—plumbing installations, roof trusses, and sectionalized constructional units as well. Moreover, the tendency towards concentration, towards the assembly of small components into single large units, has also proceeded as in other industries. From the manufacturers' point of view it has certain advantages, while for the builder erection is simplified. It is not likely that this process can be applied largely to cast iron owing to the limitations in weight and strength, but it has occurred in other industries. The production of complete building units and the elimination of site work has obvious advantages which have been so often put forward that it is unnecessary to repeat them.

Prefabrication of schools and dwellings is to be tried out in solving the immense building problems of the next ten years. There can therefore be no doubt as to the technical efficiency of factory-produced buildings or to their production in quantity. Such houses embody new techniques in the use of materials and in their methods of assembly.

In some types of prefabricated building the equipment and components are similar to those used in orthodox methods of construction. In all there is a field for the use of cast iron. This development increases rather than diminishes the extent to which cast iron will be used. Timber shortage, the scarcity of building craftsmen, will lead to the fabrication of many units at present constructed on the site. Prefabrication demands precision and simplicity of assembly, and the casting process seems to fit this programme very aptly.

Prefabrication is still in leading strings, and is tied to our conception of a house based upon traditional methods of construction. When the opportunities offered by prefabrication have had time to be absorbed, maybe we shall explore a new field of possibilities in materials and form. But we have not yet begun, and most of the experiments which have been made so far are disappointing in appearance if not in construction. This is not unnatural, as the solution of the technical problem is the main preoccupation of the designer. It is only since the first world war that prefabrication has been seriously considered and commercial development begun. In twenty odd years it has been carried to the point that satisfactory houses can be built by using methods which have never been applied to building before. In the future it may be expected that some of these systems which have been successfully applied to houses will be pushed further and applied to other types of building. Schools and offices, factories and welfare buildings, all seem to offer opportunities.

Some prefabricated cast iron houses were erected in Glasgow in the early nineteen-twenties. The cast iron panels which formed facing units were amongst the earliest examples of prefabrication at that period. These houses have proved economical in maintenance, and demonstrate the suitability of the material for such purposes.

It is difficult to foresee the extent to which prefabrication will be applied to buildings in the future; the process of standardization and the factory production of components has steadily increased for some years. It is probable that the present period is one of transition, so far as building technique is concerned, from the laborious methods of handcraft to the precision of machine construction. In this development cast iron will have a definite part to play. It has been developed for panel construction, and the industry has gained experience in forms of interlocking panels and their fixing. The industry is paying close attention to such methods, not only as they affect the structure, but also in the installation and design of equipment. Improvements are being made in the quality of the iron by the use of alloys which will enable it to be cast in thinner sections, and in other methods of stiffening both panels and sections to reduce the weight. Similarly the development of joints which do not require caulking by hand and which remain weathertight, and of connections which can be clipped or locked into position, and so avoid bolting, are being investigated.

A great deal of work has been carried out, particularly since 1939, in the iron and steel industry as a whole, to find methods of making joints entirely waterproof and of protecting delicate metal surfaces against corrosion. These methods may be applied commercially in the future, and may perhaps assume the same importance as metal spraying. The search for a self-facing metal of good appearance, which is completely resistant to all atmospheric forms of corrosion, has for years been the hope alike of manufacturers and designers: we seem to be approaching a time when it may cease to be a hope deferred. Cast iron may be one of the most effective fulfilments.

INDEX

[Numbers in italics refer to figures in text on pages indicated.]

THE PLATES

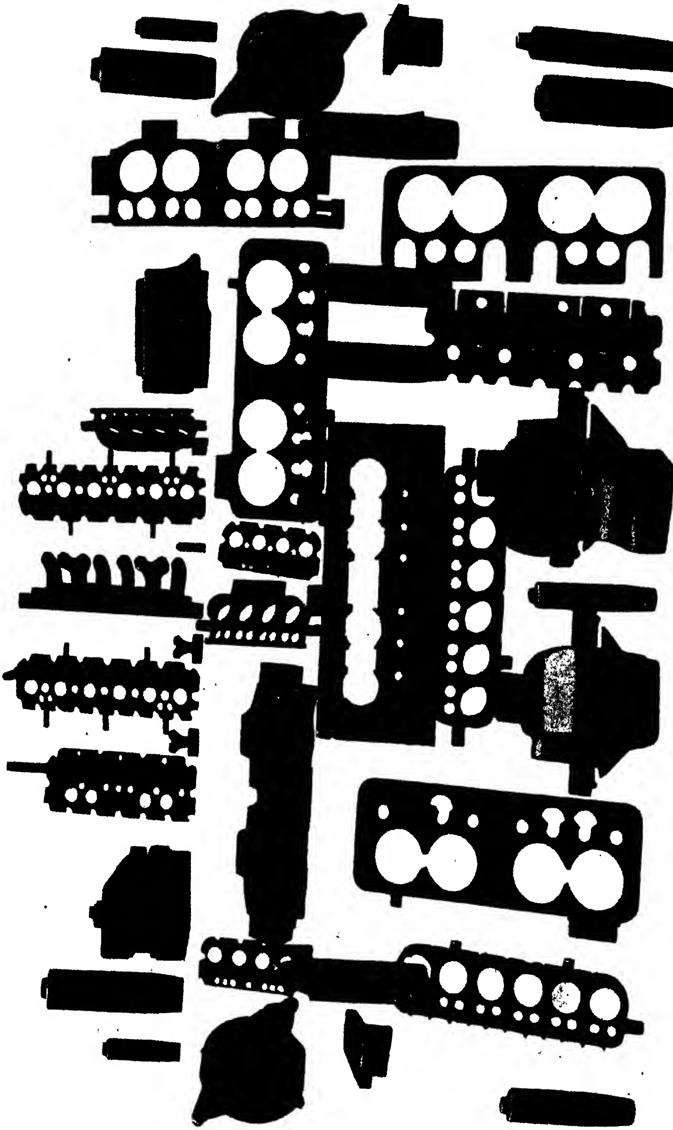
1 TO 48

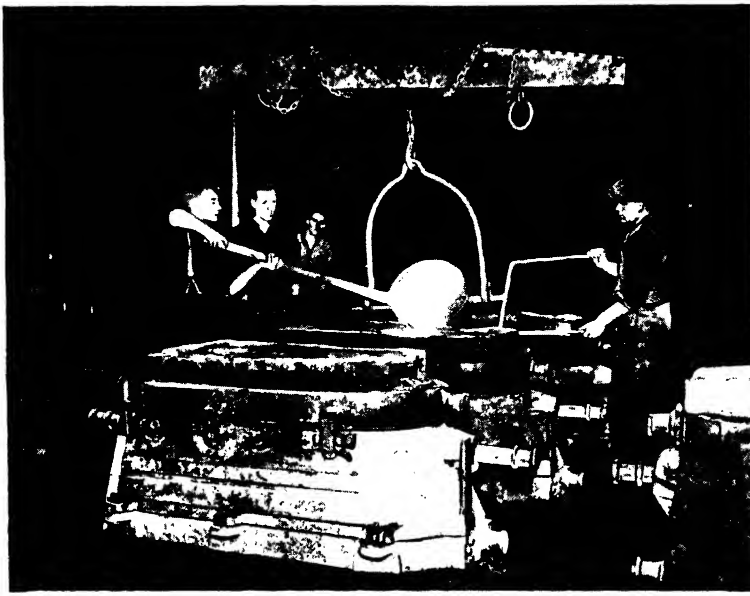
The plates are grouped to illustrate, firstly, some aspects of the production of cast iron and some of the processes used for finishes. The use of the material in building structure, and for building details, large and small, follows, and then a section is given to independent structures. Finally some miscellaneous examples of casting are shown, including work executed in the late eighteenth and nineteenth centuries.

PLATE I.—Mechanization in a modern foundry. This shows the sand plant, push-plate conveyor, sand hoppers, casting runway and mould conveyor.

PLATE 2.—Curved boiler back castings, just removed from the mould.

PLATE 3.—On the opposite plate a group of motor cylinder bonded cores are shown.





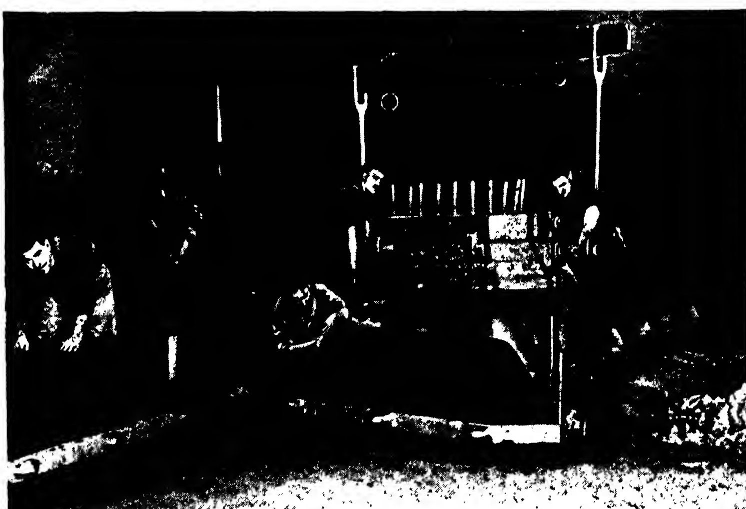


PLATE 4.—*Above:* Pouring iron into a mould in bath manufacture.
Below: The bath turned out from the mould.

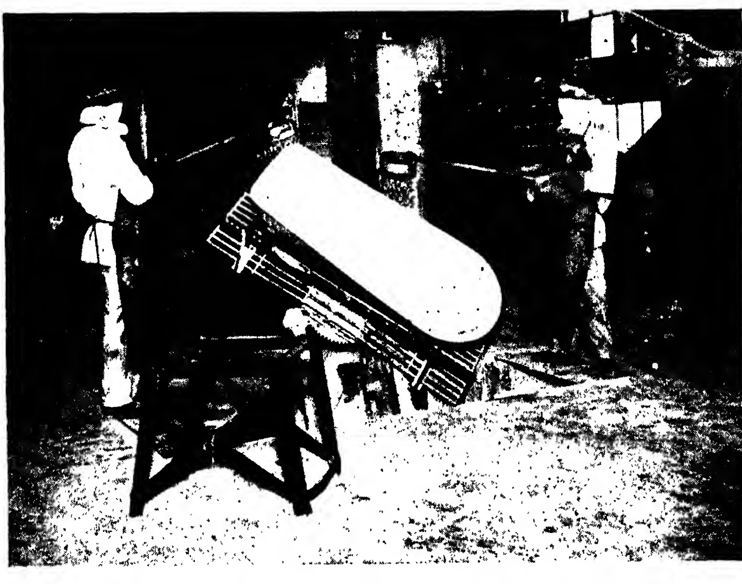


PLATE 5.—*Above:* Placing the bath in the muffle before the enamel is dusted on the surface. (Photograph by the *Weekly Scotsman*.)
Below: Dusting enamel on the bath, in the form of powder.

:. 6.—Finishes for cast iron. *Above, left:* Porcelain white enamel. *Above, right:* Organic paint finish in colour. *Below:* Processed vitreous enamel finish.

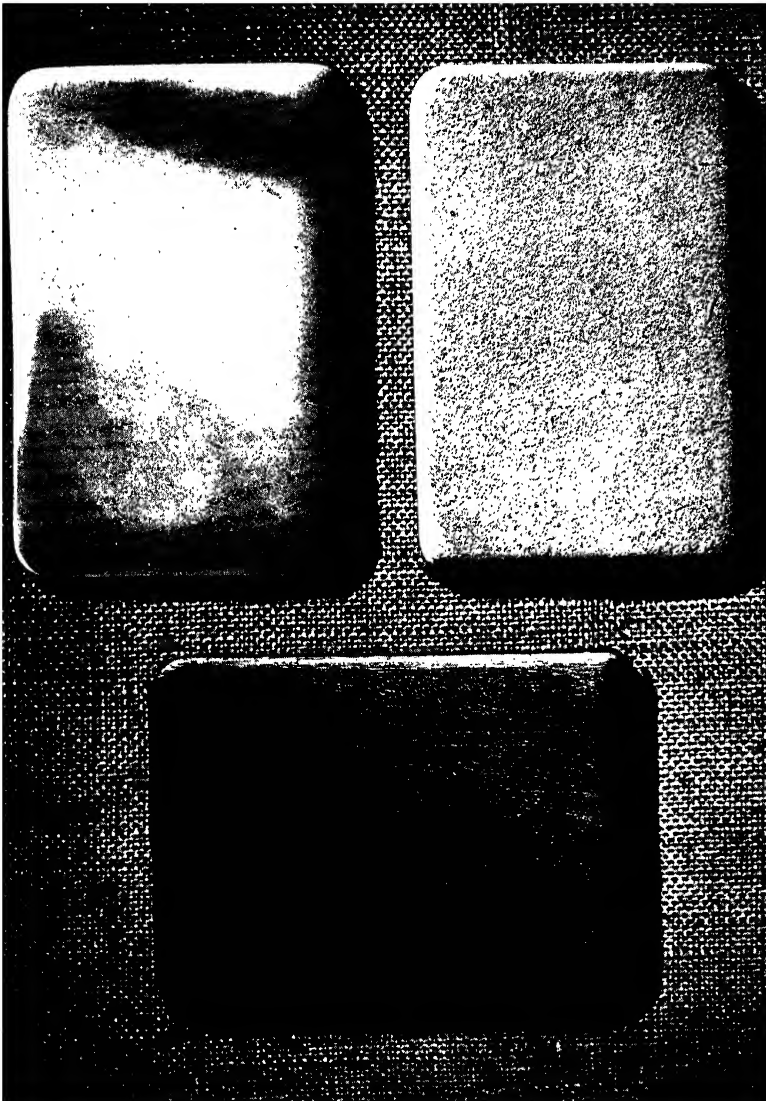


PLATE 7.—Finishes for cast iron. *Above, left:* Nickel-plated surface. *Above, right:* Surface sprayed with aluminium. *Below:* Parkerised finish.

TE 8—Cast iron columns used in the internal structure of a building erected about 2 This was *The Swan with Two Necks*, in Gresham Street, London, damaged in air raids

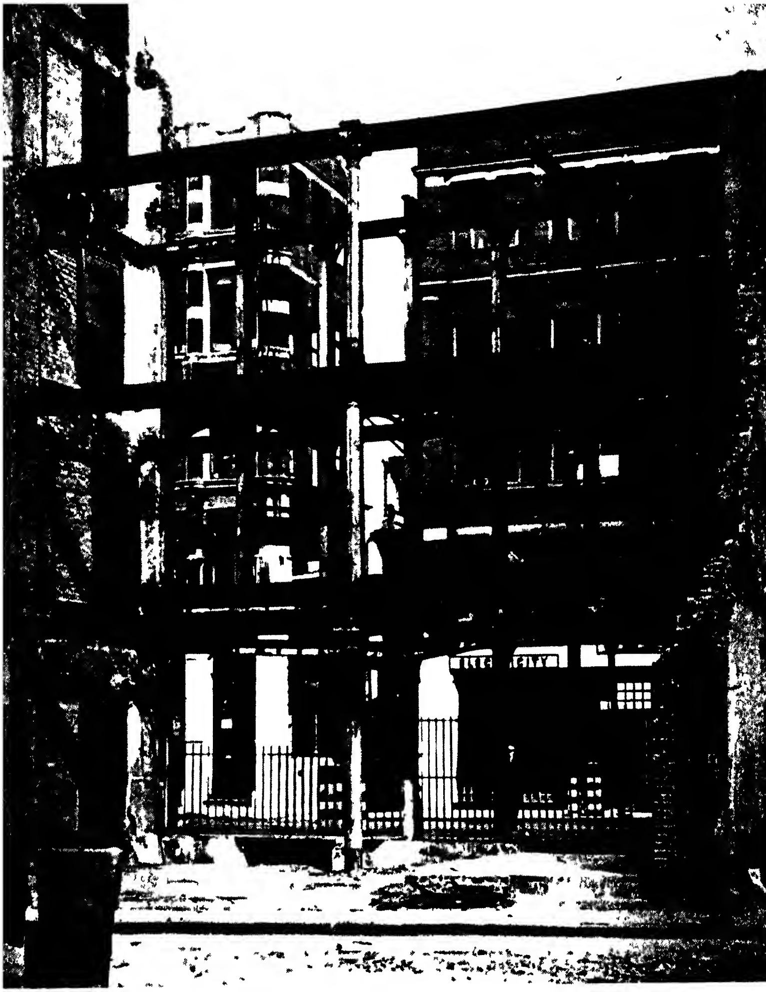


PLATE 9.—An all-iron structure, built about 1870 in Old Street, Finsbury, London. Air raid damage again discloses the use of cast iron columns as vertical members. The structure recalls the technique set forth in William Fairbairn's book, from which some drawings are reproduced on pages 56 to 62.

(The photographs above and opposite are reproduced by courtesy of The National Buildings Record.)

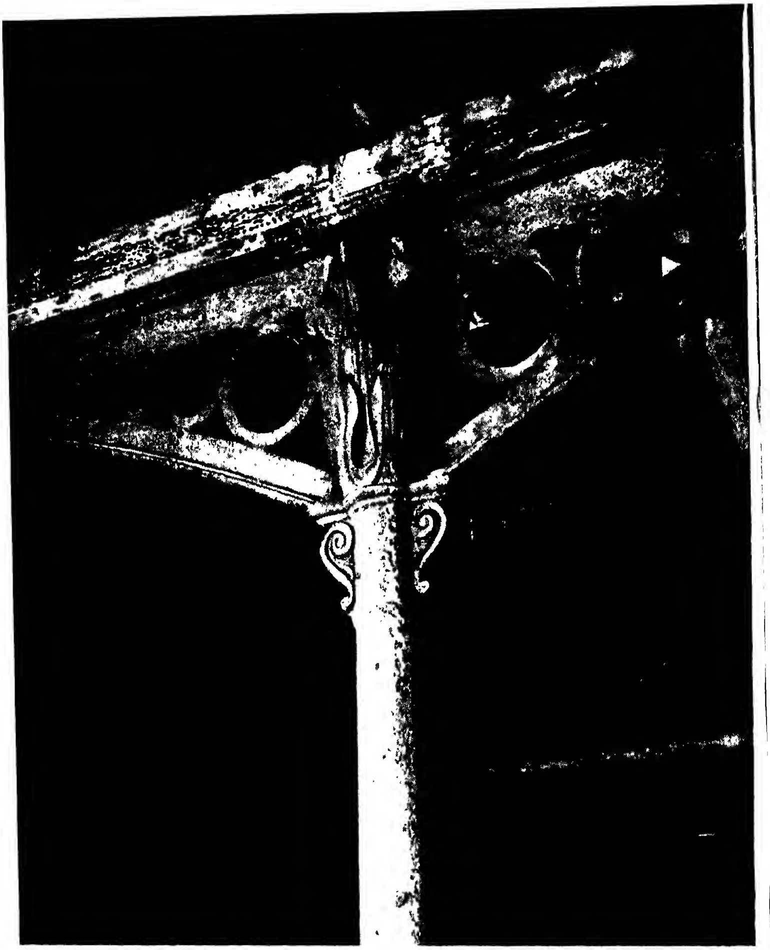
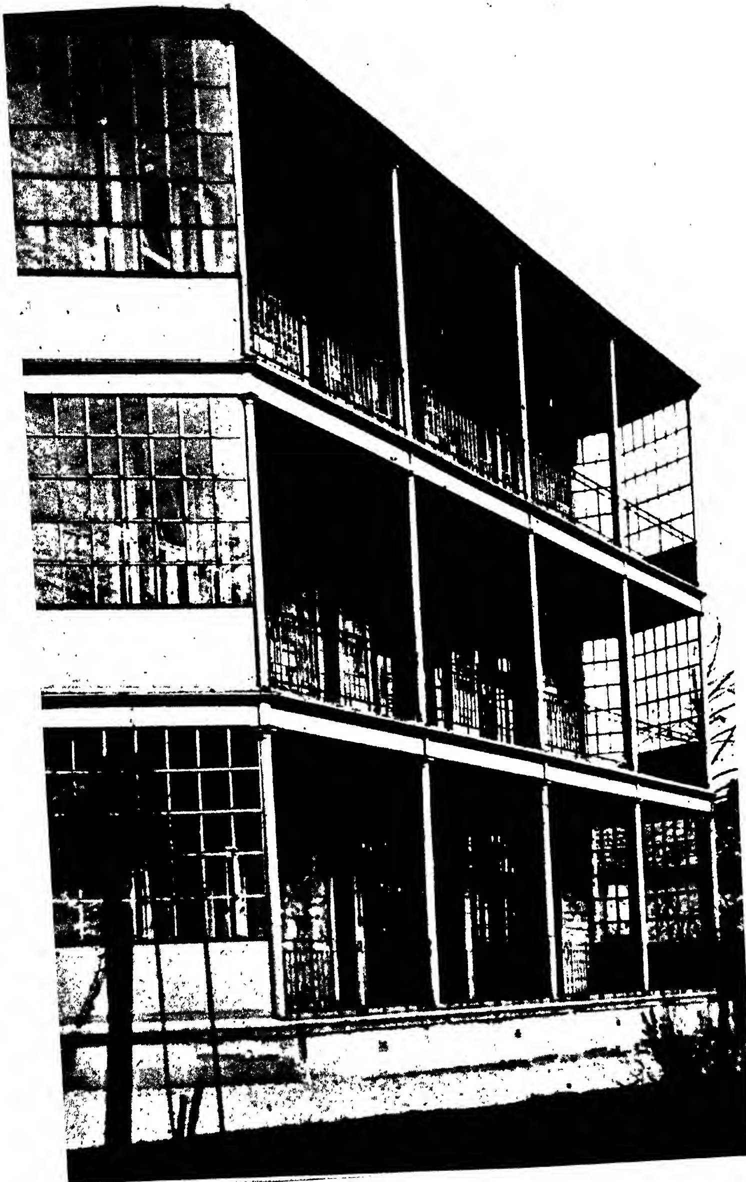


PLATE 10.—A cast iron column at the Nine Elms Goods Depot, near Vauxhall, London. Here again the operation of Fairbairn's technique is demonstrated. (See page 59.) (Photograph reproduced by courtesy of *The Builder*.)

PLATE 11.—The interior of the Palm House at Kew Gardens, designed by Decimus Burton and Richard Turner. Begun in 1844, this structure was an example of the use of cast iron and glass units. (Reproduced by courtesy of the *Architectural Press*, from *Glass in Architecture and Decoration*, by Raymond McGrath and A. C. Frost.)



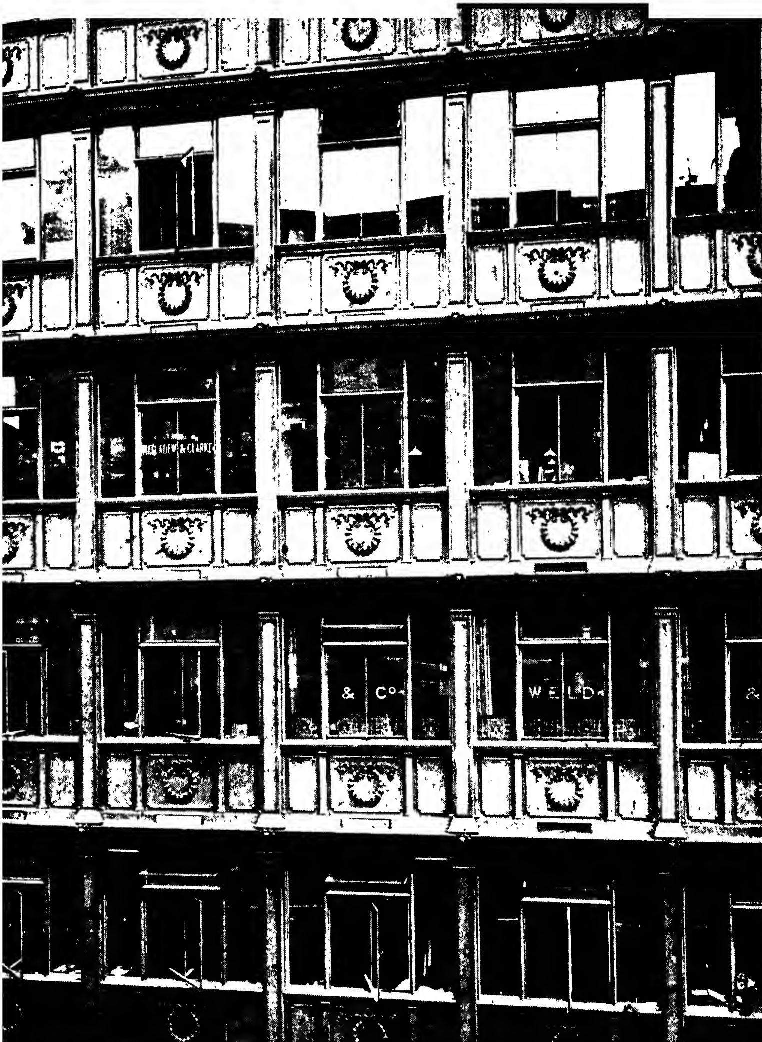


PLATE 13.—The Cotton Exchange at Liverpool, faced with panels of cast iron.

Opposite (PLATE 12): Sun balconies and verandah of cast iron and mild-steel construction at Broomhill Homes. Architects: J. M. Monro and Son, AA.R.I.B.A.

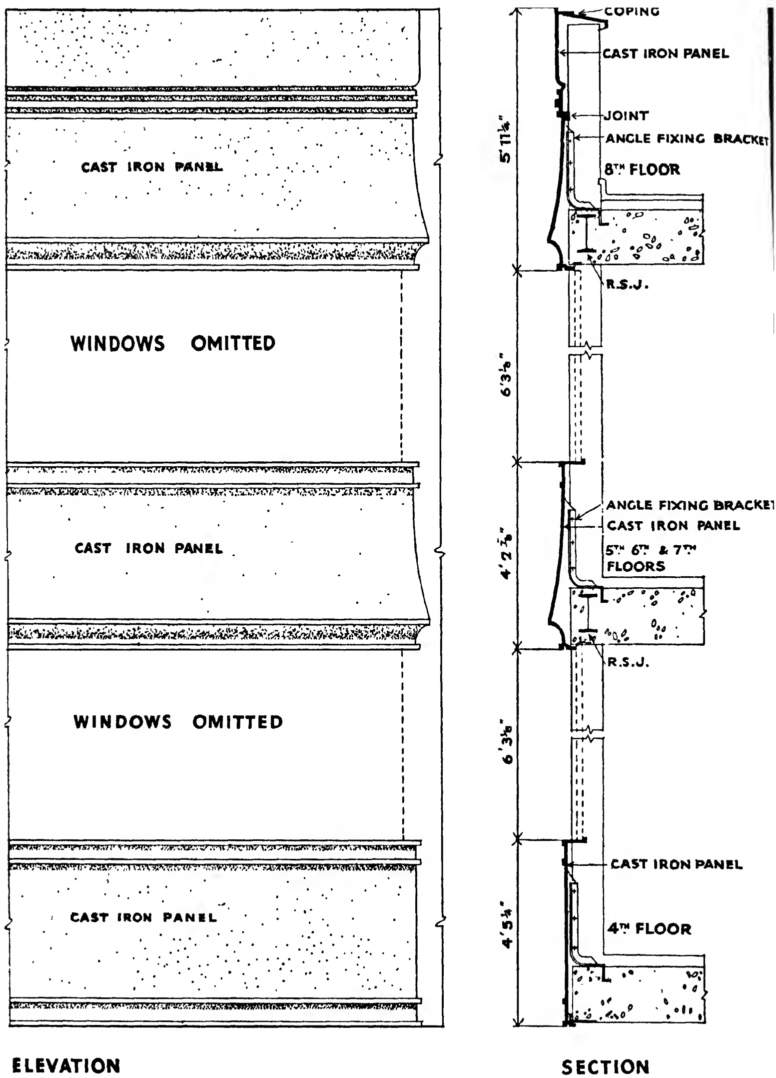


PLATE 14.—Details of the cast iron window bays in the new Adelphi building on the Embankment, London. (See opposite.)

PLATE 15.—The cast iron window bays of the new Adelphi building, London. The external finish is aluminium paint, sprayed on. Details are shown on the plate opposite. Architects: Stanley Hamp, F.R.I.B.A. (Collcutt and Hamp).

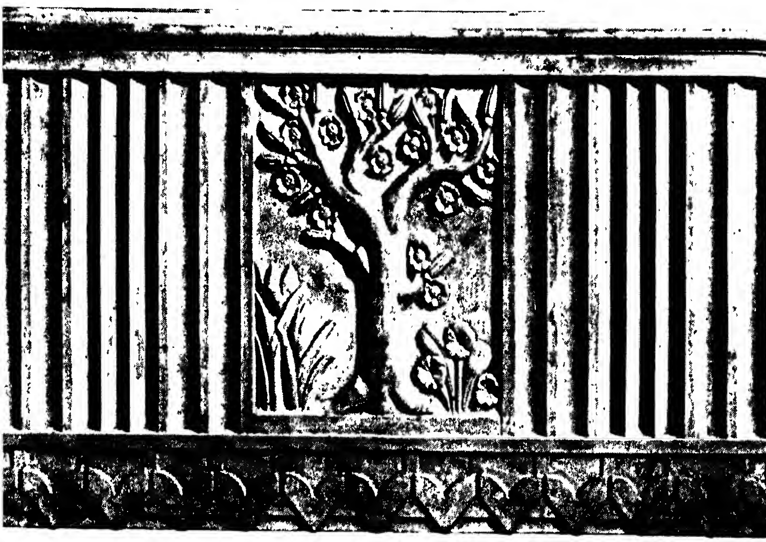


PLATE 16.—Cast iron window breast panel for Lothian House, Edinburgh. Architect: Stewart Kaye, A.R.I.B.A. Sculptor: Pilkington Jackson. The association of cast iron panels with metal framed windows is shown on Plate 13 and opposite: in both examples, as well as above, the decorative possibilities of the material have been appreciated and used with restraint.

PLATE 17.—Cast iron window breast panels on the façade of a building in d'Arblay Street, London, W.C.1. Architects: Abbot and Dickens.

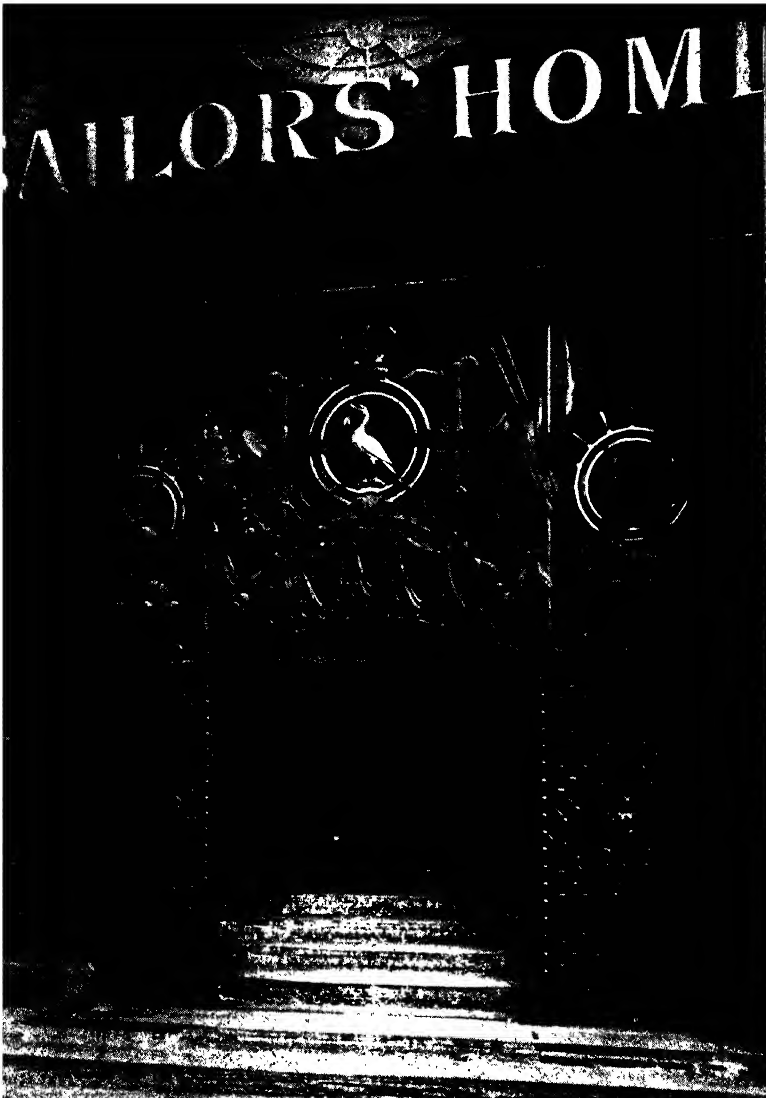


PLATE 19.—Decorative cast iron work on the entrance gate of the Sailors' Home, Liverpool. (Reproduced by courtesy of the National Buildings Record.)

PLATE 18.—*Opposite* Cast iron doors, overdoor and architrave at Broströmia House, Gothenburg, Sweden.

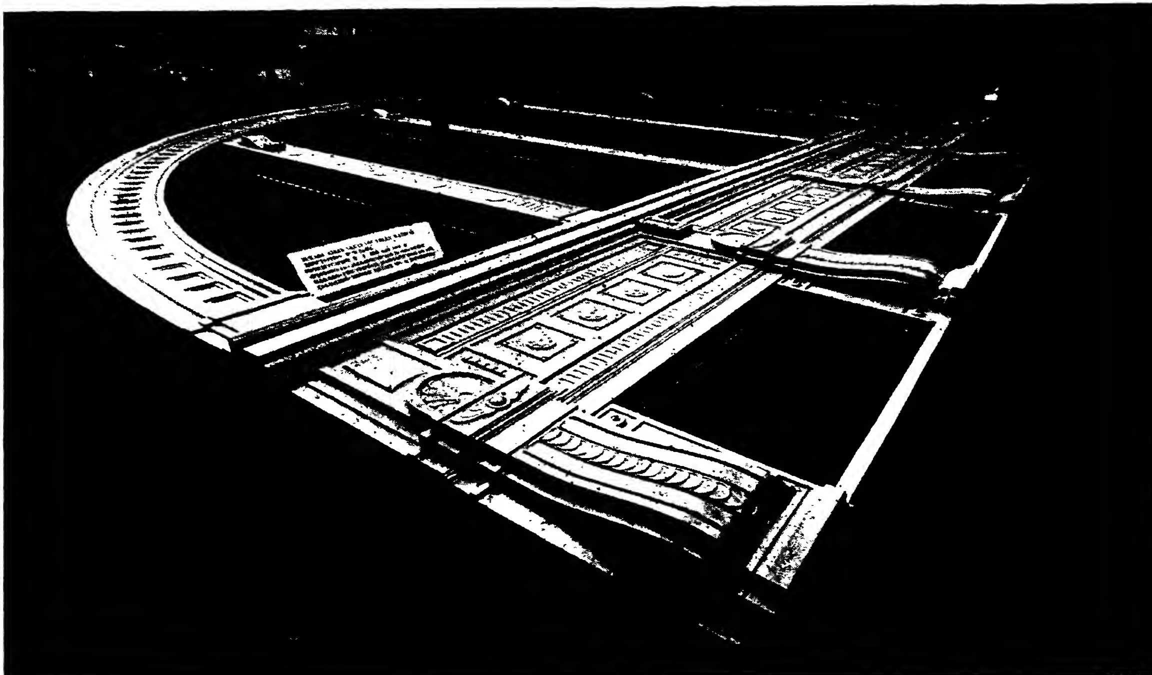


PLATE 20.—This large casting, 60 ft. wide by 43 ft. high, consists of a window surround, mullions and panels for the Plaza Constitucion Station, Great Southern Railway, Buenos Ayres.

Plate 21.—Cast iron columns supporting the ceiling of the kitchen in the Royal Pavilion, Brighton. The columns terminate in leaves made of copper. (Reproduced by courtesy of the Brighton Art Gallery.)

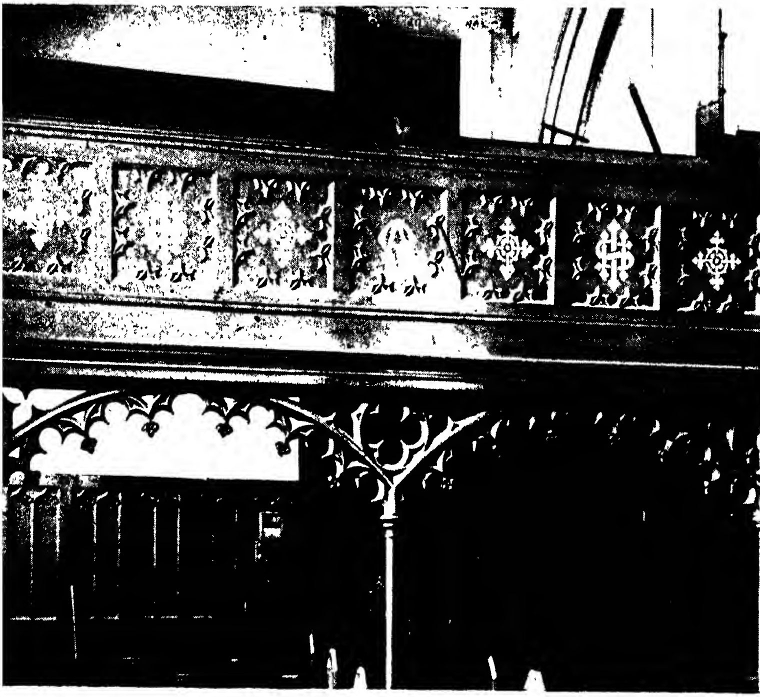


PLATE 22.—Cast iron arches supporting the gallery front of St. George's Church, Birmingham. (Reproduced by courtesy of the National Buildings Record.)

PLATE 23.—Decorative cast iron balusters at the De Grey Rooms, York. (Reproduced by courtesy of the National Buildings Record.)

PLATE 24.—Cast iron balustrade on the staircase of St. Andrew's Halls, Glasgow.

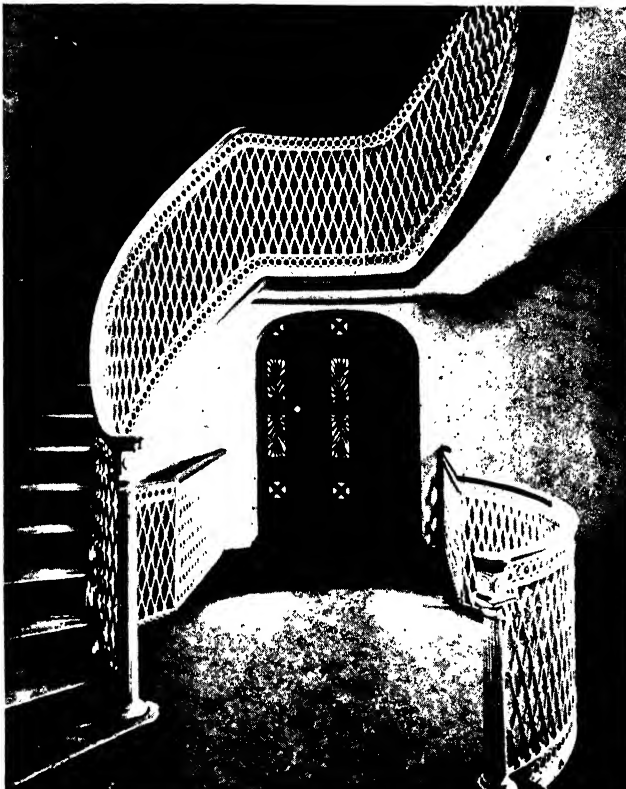
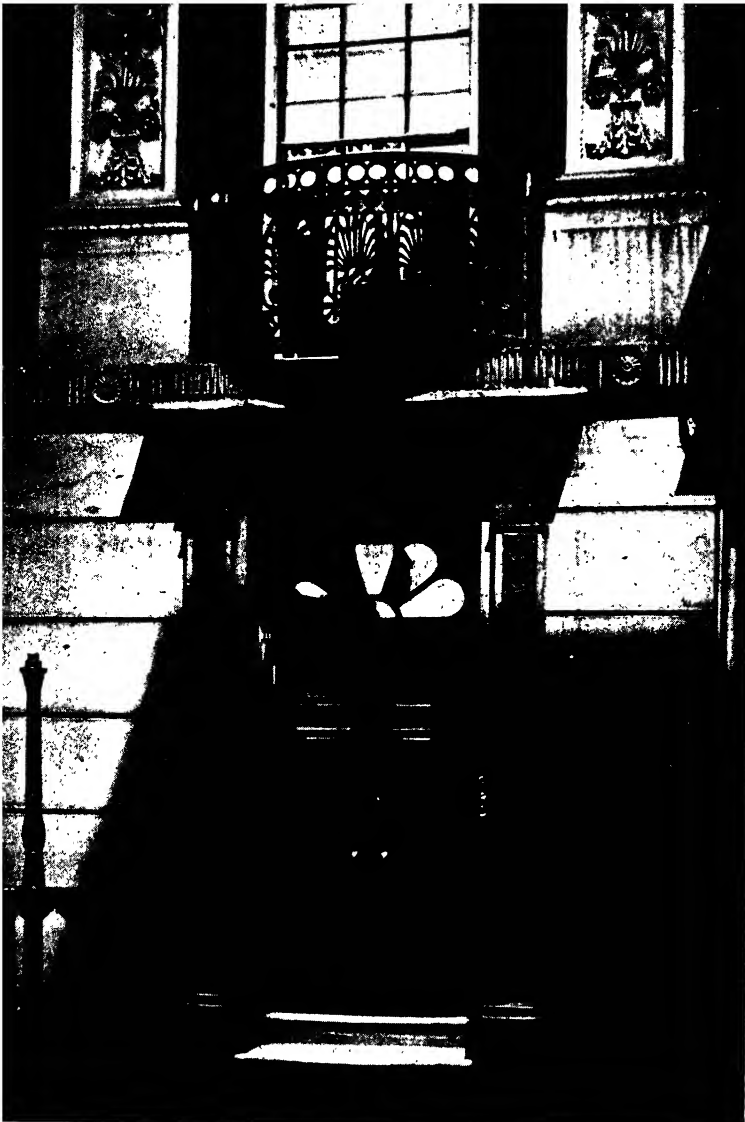


PLATE 25.—Cast iron staircase of the Students' Union, Liverpool University. Designed by Professor Sir Charles Reilly, F.R.I.B.A.

PLATE 26.—Late Georgian example of cast iron work on balcony.
(Reproduced by courtesy of F. R. Yerbury.)

PLATE 27.—Early nineteenth-century cast iron balcony railing.
(Reproduced by courtesy of F. R. Yerbury.)



-ATE 28.—Cast iron balcony on a house in the Adelphi, London, designed by Robert Adam. (Reproduced by courtesy of F. R. Yerbury.)

PLATE 29.—Cast iron railings and gate posts in Surrey Street, Norwich. (Reproduced by courtesy of the National Buildings Record.)

PLATE 30.—Cast iron bollard in Hyde Park, London. Here is an example of the decorative treatment of a casting giving additional structural strength, as well as lightening the general appearance.

PLATE 31.—*Above:* Cast iron railings surrounding the Inner Temple Library, London.

Right: Cast iron railings round St. Martin's-in-the-Fields, London.

(Reproduced by courtesy of the National Buildings Record.)

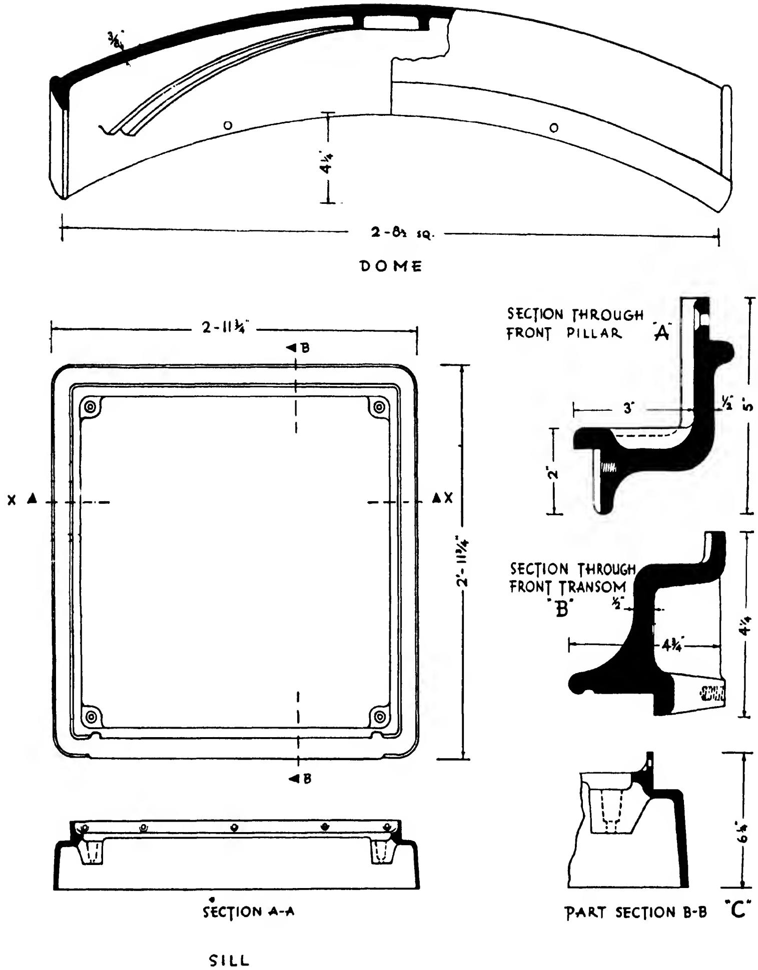


PLATE 32.—Working drawings, above and opposite, showing the construction of the G.P.O. cast iron telephone kiosk. (These drawings are reproduced by courtesy of the Postmaster-General.)

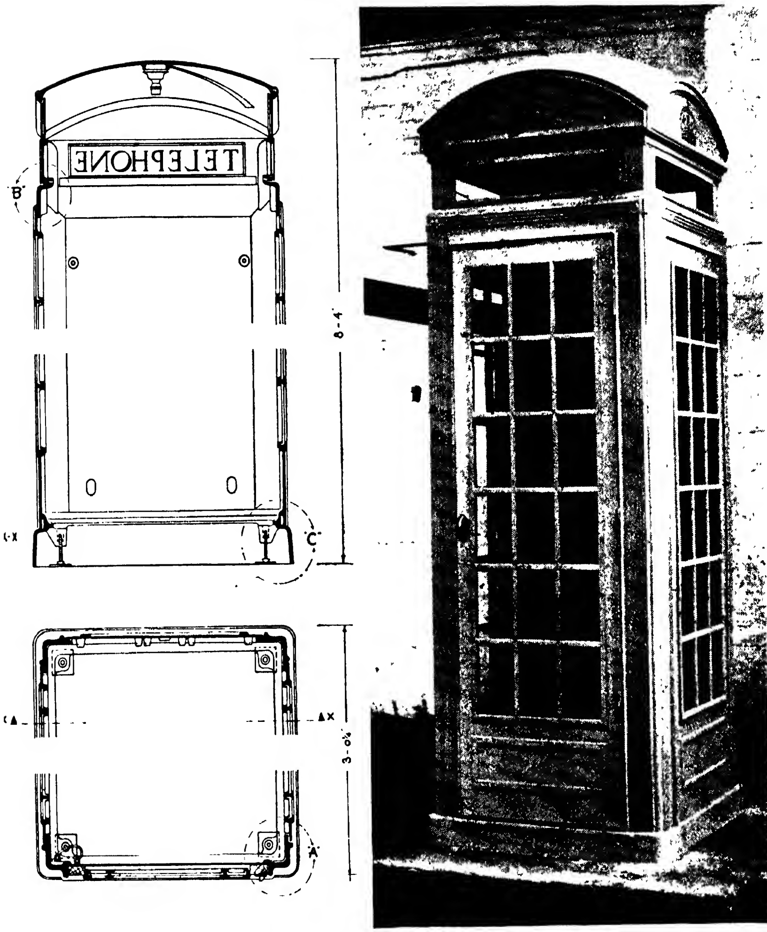
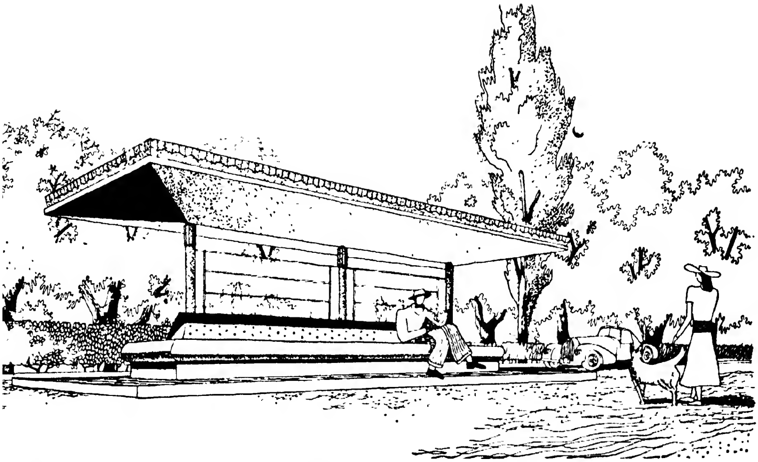


PLATE 33.—The most familiar independent structure made in cast iron is the telephone kiosk, designed for the G.P.O. by Sir Giles Gilbert Scott, PP.R.I.B.A. It represents a most appropriate use of the material, and is an excellent example of pre-fabricated building.



ATE 34.—*Above:* A suggested contemporary use of cast iron for a sea-front shelter. (This drawing is made from a sketch by Thomas Tait, F.R.I.B.A.)
Below: A cast-iron shelter on the sea front at Blackpool.

PLATE 35.—A typical example of the highly ornamental use of cast iron in the late nineteenth century. A bandstand at Southend-on-Sea.

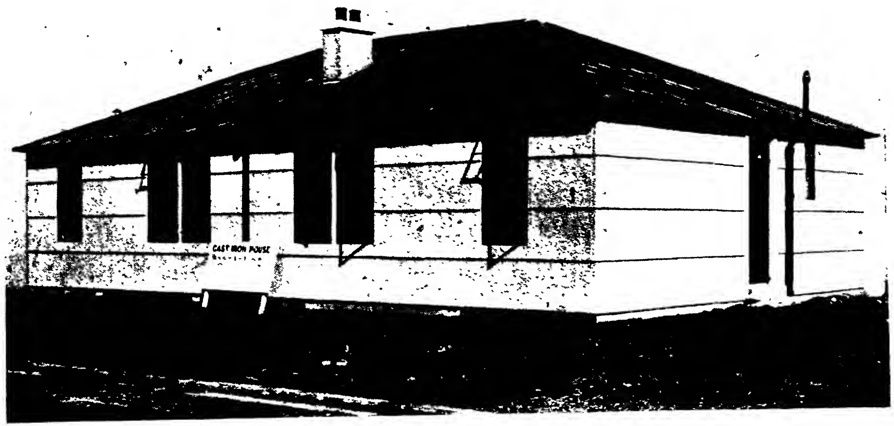


PLATE 36.—A cast iron bungalow erected at Glasgow. Externally there is little to distinguish this building from those constructed in more familiar materials. The use of cast iron has not suggested any special form; a normal prototype has been followed, as with the much earlier example, the Lock house at Tipton Green, Staffordshire, which is shown on page 71.

PLATE 37.—Here cast iron has been used for the principal bones of an independent structure: the vertical columns, the treads and risers of the stairs—indeed, the whole conception of this footbridge has been made possible by the properties of the material. The seat in the foreground has an elaborate cast-iron frame.

Plate 38.—Cast iron as a material took the impress of architectural taste in the late eighteenth century. Architects like Robert Adam designed decorative railings, plaques and medallions, which could be translated admirably in terms of this new and permanent material. Some balcony railings are shown on Plate 28, in the prevailing classical mode of the seventeen 'eighties and 'nineties. On this plate, and opposite (39) are two examples of such designs. Here is a fire grate panel by Henry and William Haworth. The special properties of the material did not greatly influence these designs: they might have been intended for execution in plaster: the fact that they were cast in iron endowed them with permanence and a darkly burnished, rich metallic finish.

PLATE 39.—Venus and Adonis: an oval plaque designed for execution in cast iron by Henry and William Haworth.

PLATE 40.—A late eighteenth-century cast iron fire grate at Charter House Hall. (Reproduced by courtesy of the National Buildings Record.)

PLATE 41.—The discipline of Georgian design has been abandoned. In this mid-nineteenth-century garden seat an orderly outline persists; but the immensely decorative possibilities of cast iron have been discovered and are beginning to get out of hand. (Reproduced by courtesy of the British Cast Iron Research Association.)

PLATE 42.—The gates at Kensington Gardens, made in 1851. These gates have historic significance in the record of nineteenth-century design. They indicate the growing delight in exuberant complexity that inspired manufacturers and designers. They represent immense technical skill in casting; they retain, as the garden chair on Plate 41 retains, an orderly outline: the main bones of the design still indicate a traditional respect for proportion, but the decorator—the man who likes ornament for its own sake, never mind about its relevance—is in charge of the situation. The results of this shifting of control from the trained designer to the inventive draughtsman who knew what a vast number of highly decorative things could be done in a foundry, is shown in greater detail in the Plate opposite.

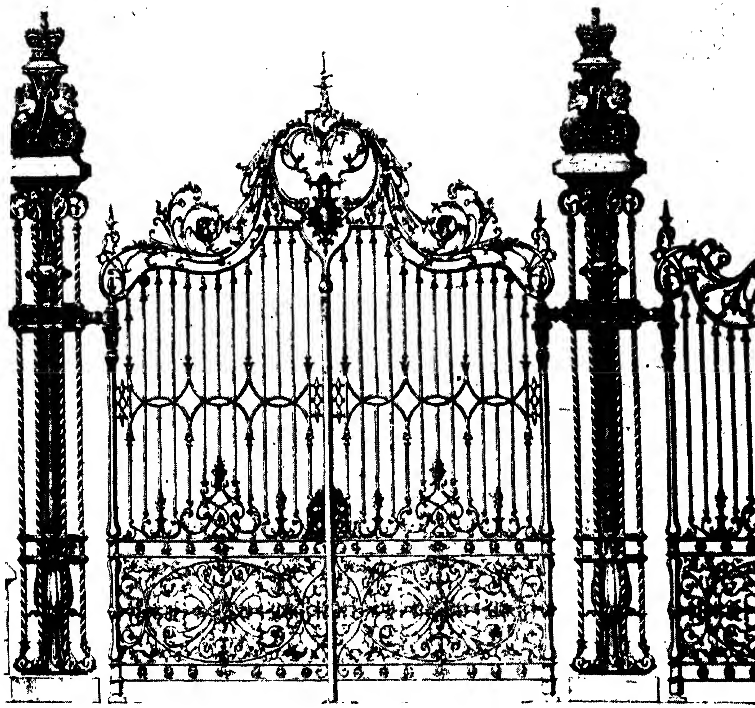


PLATE 43.—Intricacy of ornament within a firm and well proportioned framework has characterised many of the great periods of architectural design; but here the designer's desire for bigger and better intricacy is fighting against the discipline of outline imposed by the framework. The makers described this work as "cast iron entrance gates of Italian design." Anything particularly ornate was likely to be described as "Italian" in this period; but whatever view may be taken about the merits of the design, there is no question that these gates show in excessive and complicated detail the high standard of technical ability British ironfounders had attained.

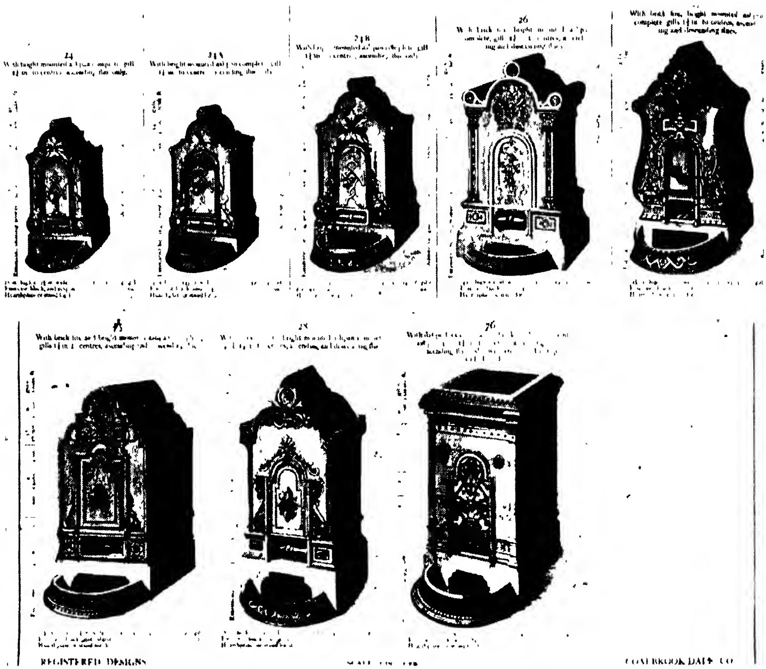
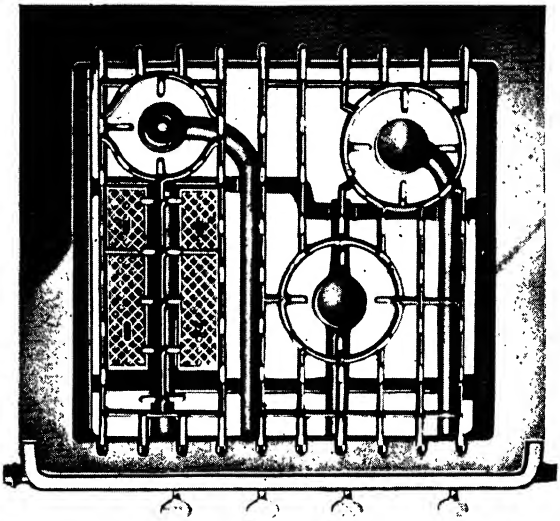


PLATE 44.—With domestic appliances, kitchen ranges, fireplaces and stoves, cast iron unfortunately became associated with a work-making external finish, and the very name of the material became in the minds of housewives synonymous with "black-leading." But sometimes a little brass or bright steel enlivened the blacklead finish and slightly increased the amount of housework. Here are some hot-air stoves, which show the persistence of pseudo-classic forms even as late as 1875. The Georgian tradition was a long time dying; but in these designs the ornament, though debased in detail, is at least under control, and is related to the outline and proportions of each stove.

PLATE 45.—Another nineteenth century design, for an independent stove, enriched with unrelated ornamental *motifs*, and supported on front legs that suggest an early eighteenth century ancestry. An efficient stove for solid fuel; but its form is a tribute to the technical skill of the ironfounder rather than to the judgment of the designer.



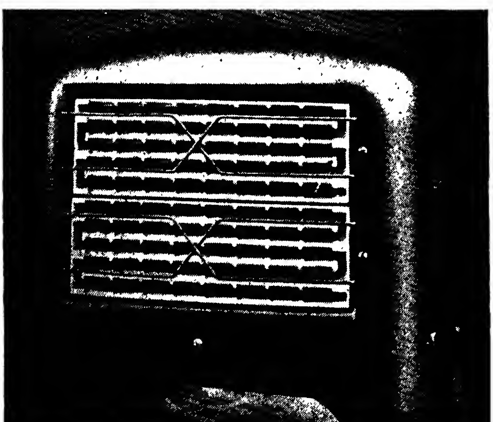


PLATE 46.—*Above:* The intricate castings needed for gas cookers, the burners and grills, are perfect examples of a most practical and appropriate use of cast iron. *Below:* Again, the ability to create a simple and comprehensive enclosing shape for an appliance is conferred by cast iron. Compare this untroubled surface with some of the earlier examples shown on previous Plates.

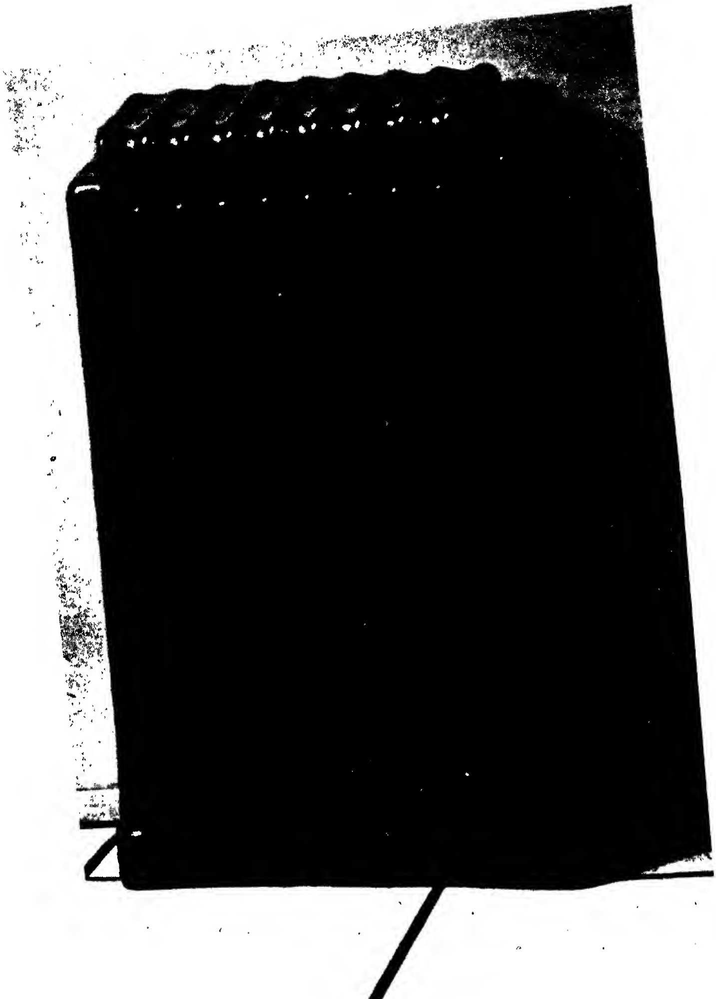


PLATE 47.—Another example of the smooth surface that may be used in cast iron appliances. This electric heater has a simplicity of form that is partly dictated by functional needs, but also because the designer has been wisely content to add nothing unnecessary. With the finishes that are now available for cast iron, appliances can depend for their decorative quality on the colour and surface treatment that serve best to enhance their form. (See Plates 6 and 7.)

PLATE 48.—A kitchen installation, with a sink, draining-board and splash-back tiles of cast iron.