This paper describes some foundation work carried out during the past twelve months by the Construction Department of the Metropolitan Gas Company, and this lecture is, it is hoped, the first of several lectures dealing with the construction of the Carburetted Water Gas Plant now nearly completed at the West Melbourne Works of the Gas Company.

The foundations to be described are but a part of the Carburetted Water Gas Plant, but they contain 900 tons of cement and 4000 cubic yards of gravel, mixed and laid in the concrete foundations.

The condition of the subsoil at West Melbourne, in common with that obtaining along the reach of the old river delta, constitutes a nightmare to the engineer charged with the design and construction of heavy structures in that area.

At the north-east corner of the West Melbourne Works, the firm ground of Batman's Hill is met with at about 25 ft. to 30 ft. below ground level; but it rapidly slopes downwards, until at a few hundred yards away no trace of anything more stable than river silt has been discovered down to 150 ft. below the surface. Indeed, close by the area on which the work to be described is built, test borings made about 20 years or so ago penetrated a red gum log at 110 ft. below the surface. During excavations, carried out this year, for a new purifier house, the sheet piling, walings and stringers of the original river wharf, apparently put down in the 1850's, was discovered eleven feet below ground level; it must have originally been three or four feet above the river level, so in that comparatively short space of time the original surface of the ground has subsided eleven feet. This is confirmed by the fact that the ash pans used in the first retort house on that site, and which were always either on or just above ground level, were also found about ten feet below ground. The present river wharf is 164 feet south of our south boundary wall, but the old wharf was found 116 feet north of our boundary wall.

Foundation work is a very difficult problem at these works, and experience has shown that concrete rafts are not to be relied on, as the maximum permissible loading on the soil is not more than 600 lbs. per square foot; even this
is too much, for the fluid nature of the subsoil causes a spewing out into the river on the south and Victoria Dock on the north, the ground gradually subsiding. This accounts probably for the depths at which these old works have been found in our excavations.

This spewing out has been responsible for some very curious happenings to those rafts that have been constructed, and it is within the author's experience that a gradual subsidence of 3 ft. 6 in. occurred over a period of twelve years; it then only ceased because the plant was taken down. The worst case was during the excavations of the crusher pit for the Vertical Retort Houses at West Melbourne, which was 56 ft. long by 37 ft. wide by 17 ft. deep. Here the sheet piling had to be withdrawn and re-driven during the excavation, and hundreds of wire ropes and chains were used to anchor the sheet piling back, yet the night saw a spewing in of the silt from the bottom equal to or sometimes more than the amount taken out during the day. It will therefore be realised that this ground presents difficulties not usually met with.

Concrete rafts are therefore not suitable for foundations here, and are only used for minor plant; they are laid directly on the surface of the ground so that some advantage is gained from the compacted surface. For heavy work, and where excavations are necessary, timber piles are used, and these are always messmate or stringy bark of fifteen inches toe, natural growth. When the length of pile required exceeds 40 to 45 ft., the piles are formed of two lengths, being spliced by bringing the large ends fair and square together, and using four 8 in. x 6 in. x 12 ft. hardwood splice covers secured to the piles by one inch diameter bolts. The driving test is four blows by a two-ton monkey dropping eight feet, when the pile shall not move more than half an inch. This is rather difficult to obtain in practice, as the skin resistance of the silt on the piles is a determining factor. It was found that it was impossible to drive farther than 80 ft. owing to skin friction, as at this depth the elastic nature of the subsoil causes the pile, in many cases, to "rebound." It may be of interest to mention at this point that we always arrange with the Forestry Department to undertake the inspection of our piles in the forest before all the bark and leaves have been stripped off. Timber piles must be protected from the air with at least twelve inches of concrete carried down to a foot below the permanent water, the level of which varies over the site, in places being only three feet below the ground, and in others nine to ten feet below.
The concrete protection becomes expensive when the piles are closely spaced. We allow 20 tons per pile, and this necessitates in many cases piles being driven at 3 ft. 6 in. centres. This requires the whole area to be excavated, after the piles have been driven, to 12 inches below permanent water level. As an example of the magnitude of this class of work, under the vertical retort installation and the attendant coke storage bunkers in the centre of the works, 20 miles of timber piles have been driven.

When we began the preliminary discussions on the layout of the Carburetted Water Gas Plant, with the test borings before us, we discovered that permanent water lay about 9 ft. to 10 ft. below the surface. We anticipated close spacing of piles, especially under the gasholder where the load was 1450 lbs. per square foot. We approached the problem in a rather dubious mood, because immediately adjacent on the south are two gasholders; and, with the behaviour of the large crusher pit in our minds, we very naturally hesitated to do anything that might endanger the gasholders. It can readily be imagined what havoc would follow by the sudden liberation of 24 million gallons of water and the sudden liberation, and perhaps ignition, of two million cubic feet of gas. This led us to consider completely enclosing the piled area with a curtain wall extending to 12 in. below the permanent water, and bonding the top of this wall into the slab supported by the piles. We argued that this curtain wall would be, in effect, a water seal, preventing air reaching the piles, and also that the atmosphere within the seals would rapidly become de-oxygenated by the soil bacteria, and then all further life of decay organisms would cease. This proposal was placed before the company's consulting chemists, who endorsed our views, and further recommended that the upper portions of the piles be treated by brushing with creosote. But on closer examination it was shown that this scheme would be too costly. The excavation of long, deep, narrow trenches would be very difficult. They would require to be timbered, and the question of inserting the reinforcement properly was a puzzle in itself. We therefore turned our attention to concrete piles; but here we were faced by the urgency of the job. At last we resorted to a concrete pile moulded in place, the chief advantages of which were that no time would be lost in curing, and that we would be spared the deep excavations to provide for the concrete protection required for wooden piles. As our investigations proceeded, we found that we would be quite safe in allowing 30 tons load per pile instead of the 20 tons on the wooden piles, thus saving one third of the number required, with consequent wider spacing. Again, the pile moulded in
place had not to be handled, so that expensive reinforcement was not required; and further it was not subjected to the heavy shocks of driving which fall to the lot of the pre-cast pile. Soil irregularities necessitate pre-cast piles being made to maximum lengths with consequent waste of material, and this added cost applies also to timber piles.

Just when we were searching for expedients “Engineering” published (19/8/1927) an article entitled “Macarthur Compressed Concrete Pile,” which seemed specially printed for our benefit.

To make a “Macarthur” compressed concrete pile two steel tubes are required; one, the outer, is called the “casing,” and the inner tube the “core.” The hollow core is filled with concrete for weight, and is provided with a driving point and a driving head. The core and casing are driven together until the desired depth is reached, when the core is removed and the casing raised about 3 ft., and then a charge of concrete is deposited in the bottom of the casing. The core minus the driving point is then inserted into the casing, and dropped on to the concrete until it is rammed out into the ground in the form of a bulb. The core is again removed and another charge of concrete placed in, which is compressed and compacted by the core; charge succeeds charge until the pile is completed and then, with the core resting on the concrete, the casing is drawn up out of the ground and around the core. The result is a densely compact pile with a large bulbous foot. A study of the effect of the spread of the loading at the bottom of the pile due to this bulbous foot caused us to revise some of our ideas as the depths to which we should drive our piles. The test borings disclosed a bed of very stiff clay about three feet thick at about 24 ft. below the surface. Below this was a soft sandy clay which rested on very stiff clay at about 35 ft. from ground level. With timber piles it would have been necessary to drive to this lower clay bed and to penetrate it for a couple of feet, and if timber piles had been used they would have been specified 40 ft. long. With the large bulbous foot of the “Macarthur” pile we decided that we need not go farther down than the first clay bed, as the bulbous foot would, in effect, have such a spread as to form a raft on the clay. That we were right in this assumption was shown later, when piling was in full swing, as, at times, when driving to 3 to 4 feet centres, we found that sinking of the core and casing was stopped by the bulbous feet of the preceding piles.

Our first step was to design and make the “core” and “casing” out of \( \frac{1}{2} \) in. thick steel plate, the casing being \( 15\frac{3}{4} \) in. outside diameter. The core was filled with concrete,
and provided with a mild cast steel driving point and a mild cast steel head. The driving head was recessed and provided with a red gum bolster. The top of the casing was reinforced with a heavy band, and provided with lifting lugs, and the bottom was bevelled to form a cutting edge. All joints in core and casing were butt-welded with the electric arc, and all excess weld metal ground off to a fair surface.

The core and casing as first made were forty feet long, and were not machined. It can be imagined that the fitting of two such long tubes as these with only \( \frac{1}{4} \) in. clearance of their diameters called for extreme skill by our boilermakers. The tubes were brought to exact shape and alignment solely by the use of brains and the oxy-acetylene flame, and the final result was a credit to the boilermakers.

The arrival of the core and casing at the site was the signal for a period of tribulation and vexation. As we had no piling rig of our own, we engaged our usual contractor and his piling rig to drive the core and casing and to place the concrete. For some unexplainable reason the foreman drove the core and casing down the full 40 ft., and into 16 ft. of some of the stiffest clay that can be imagined. It took us a fortnight to draw it out again, and only succeeded by the use of two 100-ton hydraulic jacks and all the power of the steam winch, with a multiplication of wire rope tackles, giving an estimated pull of 150 tons; the piling rig had to be immensely stiffened up to get this. After completing the first pile, we drove two or three very slowly, having to learn the technique. The two tubes were each slightly elliptical, and when their axes became opposed the core and casing jammed together. There was no method of finding out the correct way of entering the core except by trial and error, and we had to continue driving and jamming the tubes until we found the correct position, which was finally carefully marked. Once we had got over these difficulties, we progressed much better, though the piling rig was not suitable for this class of work. The single winch meant too many changes of rope for the handling of the core and casing, and the monkey.

During the first eleven days of driving we drove thirteen piles; or to put it another way, we drove thirteen piles in 25 days from the first drive of the core and casing. We soon began to improve, however, and we later on made some good showing, putting in nine and ten piles a day.

In the generator-house foundations we placed 162 piles, and in the gasholder foundations 261 piles, of lengths varying from 21 to 24 feet overall, a total of 423, with an approximate total length of 1 1/2 miles. Each pile contained
with its bulb—about two cubic yards, the bulb containing about $$\frac{3}{4}$$ cubic yards of concrete.

After the first few piles had been driven, we realised that the core and casing were too long, and the core was therefore shortened to 31 ft. long over all, and the casing to 27 ft. The shorter length of the casing obviated lifting it up after driving so as to form the bulb. The total weight of the shortened core was 4 tons 12$$\frac{1}{4}$$ cwt., and this gives an excellent compression on the concrete when it is remembered that this weight is allowed to fall about 20 feet on to the concrete in the bulb, and of course at decreasing distances as the charges of concrete are placed.

The remarkable strength due to this compression, and of course of the mixture, to which I shall refer later on, is instanced by the following: The weight of the core rests on the green concrete while the casing is being pulled out of the ground and up and around the core. On one of our piles a mistake was made, and the pile formed three feet higher than the ground level. This three feet shaft of green concrete carried the weight of the core without the slightest sign of injury, cracking or subsidence, until the core and casing were entirely removed.

We had never driven any of this type of pile before, and had never seen the operation done, so we were very anxious to try out some tests. As we started by using ordinary cement, we had to wait about three weeks before any test load could be applied. The eighth and ninth piles driven were selected, as the piling machine movements restricted us to that position, and across their heads was built a concrete and R. S. J. table, on which was loaded 60 tons pig iron, the weight of the table accounting for a further two tons, making 62 tons in all. On this table we commenced loading the pig iron on 15th May, 1928, and placed 30 tons that day. Several readings were taken at the north, south, east and west ends of the two axes of the base plate before loading was commenced and at the end of the day, with no observable difference. Notwithstanding shocks received through the ground while the adjacent piles were being driven, the ultimate settlement was only 1$$\frac{1}{2}$$ inches average, and the piles were carrying at the same time considerable flexural stresses.

This deflection was measured the day after the loading. No further difference was subsequently observed, though piling was proceeding nearly all the while, and, as the test load was becoming an obstruction, it was decided to remove
it after a week. The test period may, in actual point of
time, appear to have been short, but we were forced to ac-
cept conditions of such abnormal severity that it might well
be considered as an acceleration test.

The generator-house foundations were the first to be con-
structed, and the over all dimensions of the excavations
were:—96 ft. 2 in. long by 58 ft. 6 in. wide by 8 ft. deep
for the generator house, and 37 ft. 9 in. long by 34 ft. 7½ in.
wide by 10 ft. deep for the machinery room which imme-
diately adjoined the generator house. The excavations
proved extremely tedious and difficult, as they covered the
site of some of the plant erected earlier in the company's
history, and the old foundations were weird and wonderful.
Portion of the area had been piled, and we withdrew one
pile for examination. It proved to be messmate 33 ft. long
by 15 in. diameter with a pointed toe, and was in wonderful
condition. These piles proved an embarrassment, as it was
very hard to know what loading they should be given so as
to act in unison with the concrete piles. The driving of the
piles over the site raised our excavated level eighteen inches,
which had to be removed. To get some sort of surface to
work on, after everything was ready for concreting, we laid
down a six-inch bed of sand. The reinforcements were then
placed and securely welded together. To assist in holding
the slab bars, we laid level lines of old light rails, support-
ing them on little brick piers; and on these were laid one row
of slab bars, across which the other row was laid, and all
were tack-welded together. This made so rigid a reinforce-
ment that we were able to run our wheelbarrows, on planks,
across it without bending or displacement. Concrete walls
were carried up to 12 inches above the ground level, and in-
corporated in these were the piers for carrying the steel work
of the building.

The foundations were designed so that the plant was car-
rried independently of the building. Four units of the Car-
buretted Water Gas Plant are proposed, and three have been
erected. Each unit consists of generator, carburettor, su-
perheaters, waste heat boiler, wash pot and stack—six bases
in all. Of these the generator base, containing about 45
cubic yards, was the most intricate and most important.
The supplier of the plant demanded the utmost accuracy in
the setting out of the 83 holding-down bolts in his base; and
as there were three bases to make we constructed a very
accurate steel form with all holes drilled and the bolts
skimmed up. All holding-down bolts were suspended from
special cross pieces, so that there was but little chance of
any play. So much care was taken that we were, if any-
thing, more accurate than the maker's plant.
The next foundation, taken in order, was the slab and compound wall for the oil tank. This tank is 70 ft. diameter by 20 ft. deep, and contains when full 2000 tons of fuel oil. The foundation disc is 92 ft. 6 in. diameter, and the compound wall round its perimeter is 14 ft. 3 in. high. No piling was placed here, as the loading is about 700 lbs. per square foot, and placing the raft on the ground level, without excavating, it was considered that the compacted surface would carry this load without undue anxiety on our part. The slab is 12 in. thick, on the central 47 ft. diameter of the disc, and is reinforced with ½ in. bars spaced 9 in. each way. On the outer section of the disc the rods are spaced radially, and bent to conform to the cantilever action. The wall is 9 in. thick at bottom, and tapers to 6 in. thick at the top. It is completely reinforced.

The next step was the gasholder slab; this was 123 ft. 2 in. diameter by 15 ft. thick, not including the longitudinal beams. The details of the reinforcement and its treatment are distinctly novel, and will later be described to you by your President. The Macarthur piles went in very sweetly and easily—we got really into our stride on this foundation. We were doing up to ten piles a day, and estimated that with a piling rig properly designed for the purpose we could place 16 easily in a day of eight hours. The number driven is dictated by the movements of the piling rig and the time of mixing of concrete.

The slab and beams contained 660 yards of concrete, which was placed in six days, using two small mixers, one each side of the slab. The concrete was conveyed in side-tipping tubs running on two-foot gauge light rails. Two men only did the wheeling, and each moved 24 tons per hour. On this foundation we took an opportunity to inspect a pile by sinking a close-timbered shaft about 20 ft. down around one pile. The result was extremely gratifying, and probing down with a bar at the bottom we got a good indication of the bulb.

The next major foundation was the piling and concrete slab for the purifiers. The slab was 170 ft. 10 in. long by 52 ft. 9 in. wide by 8 in. thick, and carried on 146 piles. The piling was in four lines, coinciding with the supporting columns above. We had to return to our standard messmate pile for this house, owing to the depth up to 60 feet.

Before concluding, some mention must be made of the concrete used, its composition and its strength. The author entirely disapproves of feeding concrete down chutes. In the specification issued by my own company, when calling
for tenders for concrete work, is included a clause prohibiting the use of gravity chutes. The specification requires the use of watertight receptacles for conveying the concrete from the mixer to the form work, and also requires, if the engineer sees fit, that it be first deposited on steel plates and turned over by hand before going into the forms. Concrete requires, like other things, careful design and honest study not only in the office, but also at the work. It naturally falls under the headings of Cement, Aggregate, Proportions, Volume of water, Length of time in mixer. These must be studied, and the best conditions observed before any materials leaving the mixer can be honestly called concrete.

The Australian cement, made under standard specifications, is a material that the engineer can accept with confidence, and will give him good service as long as he does not abuse it by exposing it to the weather before he uses it.

Turning to the aggregate, it seems to me that the familiar 1—2—4 mix requires to be studied anew with special regard to its fineness modulus, because I am not at present certain that this mix is the best or the most economical. I cannot say more at this moment, as very little Bluestone screenings or of sand has been used in our work during the past twelve months. We have been using instead “Gher-ng” gravel from large deposits about 20 miles the other side of Geelong. This possessed a fineness modulus almost ideal for concrete. The deposits are of large extent and of very uniform character, and after washing there remains a beautiful gravel, ranging from perfect grains of microscopic size up to 1½ in. pebbles. Unfortunately these pits are now closed down, but we were able to get our 4,000 cubic yards for our requirements.

The aggregate, being so well graded, results in a very dense mass. We first found this out when testing it for voids, which was carried out as follows:—A steel box 2 ft. square by 2 ft. 6 in. deep was accurately made, and screening bars were fitted at 6 in. down, thus giving us a 2 ft. cube. In this was placed carefully dried gravel, and then water was accurately measured in until it appeared at the surface. Though not very scientific it was close enough for our purpose, and we ascertained that the dry gravel contained 22 per cent. of voids, indicating a one to five mixture. When it was necessary to empty out each batch, it was found that it had to be nicked out—it would not leave the box in any other way. This advantage somewhat nullified our efforts to reduce the water ratio, as with the volume prescribed we found that the aggregate and cement packed so tightly that no mixing occurred until a further amount of water was placed in the mixer.
The proportions that we decided upon after tests were—
Piles : 1 : 4½, walls 1 : 5, slabs 1 : 6, corresponding to the following mixes with sand and screenings—Piles 1 : 2½ : 4½, walls 1 : 2½ : 5, slabs 1 : 3 : 6.

It will be readily observed that here were all the elements required for legitimate savings, as not so much cement was required to give us a concrete of high quality, and we had only two-thirds the volume of materials to store and handle. This was reflected later in our costs.

The next very important item is the limitation of the water content to its lowest limits. As long ago as August, 1918, my records showed the completion of a series of tests to determine the strength of concrete with varying water:cement ratios. These indicated that concrete cylinders of 1—2—4 mix, with one part of water added, crushed at close to 2000 lbs. per square inch in 28 days, and that reducing the water to five-eights of one part nearly doubled the strength. This is only a very brief summary of the results. We had to increase the quantity of water to a standard volume of water; cement equal to 3: 4 when using gravel in order to turn it over in the mixer.

The time of mixing has also an important bearing on the strength of concrete, and it has been found that three minutes gives the best result, and we endeavoured to maintain that figure, but did not go below two minutes. When using ordinary cement with four parts of gravel and half part water, hand mixing, we averaged 2376 lbs. per square inch in 14 days, and with six parts gravel 2208 lbs. in the same period. There was not much difference in three months when the figure was about 3000 lbs. Very early we changed from the ordinary Australian portland cement to an Australian quick-hardening cement. This proved exceptionally good, and though it is slightly higher in price it well repaid its use. With this we were able to get 2000 lbs. in three days, using 1 : 4½ and 1 : 5 mixes, with three-quarters of one part of water. At 28 days we got well over 4000 lbs. Using a 1 to 8 mix, with 1½ parts of water, we got 1420 lbs. in seven days, and with a 1 : 7 mix, with a little less water, we got 1700 lbs. per square inch breaking in the same time. These results are perhaps better than they sound, for the materials were taken direct from the mixer, and the test cylinders were filled by a labourer using only the same care as he would on the job. Thus the results would approximate more to the actual conditions had the test cylinders been prepared in the laboratory. The sizes of the test pieces were 6 in. diameter by 9 in. deep, and six were the minimum prepared for every test; thus twenty-four were prepared of a mix to be tested at 2, 7, 14 and 28 days.
In view of these results one feels somewhat surprised at the statements made by a deputation to the Minister for Public Works, as reported in the daily press, to the effect that the specification of the Railways Construction Branch, calling for 3000 lbs. concrete, was an impossible condition, and that no builder could supply concrete of that strength. In our work this condition was met easily without doing anything more than using good materials honestly and intelligently.

The strength of the concrete in our piles was impossible to judge, but owing to the great compression it had to withstand in forming it, it would certainly be very much higher. Its character as regards wetness can be imagined when it had to be assisted down a 60 degrees slope.

The PRESIDENT, in moving a vote of thanks to Mr. Grove for his lecture, said that Mr. Grove's papers always contained information of great value to the profession. He had always something new to put before them.

Mr. J. N. Reeson, in seconding the vote of thanks, said he had had experience in foundation work during the greater part of his professional career; but the type of foundation with which he was faced at West Melbourne, on his arrival here in 1914, was quite a revelation to him. The subsoil was found to be so soft that a raft they put down, instead of lying flat, was some three or four feet out of level, and disappearing below the surface of the ground.

In this country, where timber was available, it seemed strange to depart from the use of that material and employ concrete. It would be impossible to employ concrete piles where they had to be driven to a depth of about 70 feet if it was necessary to depend upon skin friction. But clay at a reasonable depth had been discovered, and concrete piles were used with good effect.

Mention had been made of the excellent condition of wooden piles which had been underground for 70 years or more. Wooden piles, as long as they were kept immersed in water, would last almost indefinitely. The difficulty was to be sure that they were continually immersed. During his professional life he had removed scores of timbers that had been partially immersed and partially in contact with air, and they had all rotted away. Whatever might be the advantage of wooden piles, concrete was better. It would last indefinitely in any position if it were made strong enough, and Mr. Grove had shown very effectively how to make it sufficiently strong. He had used most of the pre-cast piles, and the cast in situ piles, but the particular pile mentioned by
Mr. Grove had the advantage of being built to produce a bulb at its toe, and when it was possible to compress the concrete very considerably it was an advantage that was not always realised.

Mr. H. HUGHES, expressing his appreciation of the lecture, said he was particularly interested in foundation work, because of his association with the Spencer Street bridge, where they had found an interesting example of the longevity of red gum; one of their cylinders met an obstruction at a depth of 63 feet, which proved to be a red gum stump. The roots were traced for more than 12 feet, and its position suggested that the surface had sunk about 70 feet. Geologists were of opinion that the tree had belonged to the Pleistocene period, and was probably about 200,000 years old. The wood was quite sound. As to the grading of the aggregate, they had specified that there should not be more than six parts of aggregate to one part of cement. 1/4 sand, 1 1/2 of 1/4 in. screenings and 2 1/2 of 2 in. metal made up the six parts of their mixture to one of cement. They took slump tests. With that mixture they obtained 2600 lb. to the square inch at seven days, and 3700 lb. at 28 days. The cement used was Geelong Portland cement. In some of the mass work in the foundations they used 1—8 mix, and obtained 2000 lbs. to the square inch at seven days and 3000 lbs. at 28 days. They made their tests with great care, and specified that test blocks should be made, so that the test result of 3800 lbs. showed that the structure would be able to stand at least 3000 lbs.
the curves of the bars were circles or catenaries, and what was the bearing pressure of the bars on the concrete.

The President said the bars were curved actually to arcs of circles, the form being sufficiently close to the catenary for practical purposes. The bearing pressure was about 550 lbs. per square inch. That was after three months' maturing.

Mr. J. N. Reeson said members appreciated the exceedingly valuable work the President always gave in connection with stresses, and the enthusiasm with which Mr. Grove attacked the problems of welding. A surprising thing was that even now welding was not so generally adopted as might be expected. He believed he was correct in saying that, with the exception of a few tanks of the kind Mr. Grove had mentioned, riveting was still the practice. Mr. Grove had said it was difficult, if not impossible, to fabricate a rivetted tank so that it would contain oil without leaking. He believed that to be absolutely correct. It was surprising that the oil companies still continued to build rivetted oil tanks, although their petrol containers were welded. He considered that in a few years rivetting as a means of joining material would be out of date.

DISCUSSION ON FOUNDATIONS IN SILT.
(Paper by H. E. Grove).

The President said the paper delivered by Mr. Grove at the previous meeting, and the two papers delivered that evening, would be discussed conjointly, as they were dealing with cognate subjects. At the previous meeting Mr. Grove had dealt with the problems of piling and foundations in silt, together with the strength of the concrete used, and a description of the MacArthur pile. That evening he had briefly described further foundation work, and Mr. Grove had dealt with construction on those foundations.

Mr. J. N. Reeson said that in the case of each of the timber-pile foundations at West Melbourne, there was no substratum; so a sufficient number of piles had to be put down to give the necessary skin friction to support the structure. Where there was a substratum, however, the method of piling so lucidly described by Mr. Grove formed a distinct advance in knowledge of foundation work. Perhaps the disadvantage in that class of piling was that in the nature of things it was impossible to reinforce it. In foundation work such as was experienced at West Melbourne, where lateral
Mr. A. E. Battle said he was particularly interested in tank structures, because to a great extent they showed similarity to ship construction. While certain vessels had been practically welded throughout, it was not generally considered advisable to extend the practice at present. But he looked forward to the time when that system of construction would become general. He also believed that concrete would supersede steel for the building of ships. The information referring to oil tanks was particularly interesting, because it was sometimes necessary to carry certain oils in tank structures built into the ship, and it had practically been decided that those tanks should be welded. But that was a different proposition from welding the ship itself, because the tanks were not subjected to the abnormal stresses and strains that the vessel had to contend with. They did not look unfavourably at the application of welding to tank construction if the tank did not form part of the ship's structure. He considered that the greatest difficulty would be to make sure that the workmen were reliable, and that their welds were reliable. It might be difficult to obtain men who could be absolutely relied upon. With regard to corrosion in contact with sea water, electrolytic corrosion due to the weld had been found.

Mr. H. E. Grove said when they started welding there were no welders available; but the training of welders was relatively quick and simple. They now stipulated that the men to be trained must be first-class boiler makers. The foreman welder was directly responsible to the shop foreman, and the latter knew that if any inferior work was put through he would be the first to go. The result was that there was never any question in their minds as to the quality of the welders. In a welded joint it was their aim to make a wide lap. Regarding corrosion, they found that when it occurred in a welded structure it was away from the welded joint, which showed that the welding had no effect upon it.

The President said that a ductility of 20 to 25 per cent. had been obtained in the metal deposited from certain electrodes. He had made an examination of a welded gas holder built some years previously, and discovered no relation of corrosion to weld. He had also examined the cover of a gas purifier box, which had been immersed in a seal for about four years. The cover was pitted all over, but not more so near the weld than remote from it, and not more on the weld than on the sheeting itself. There was no indication that the weld was in any way detrimental to the life of the sheeting in the cases he had examined.
Mr. A. E. Battle said it seemed to him that an organisation such as the President and Mr. Grove were associated with was somewhat different from a ship building or repairing yard. A gas holder was composed of lighter material than that entering into ship construction. They accepted the fact that the welding of light materials had proved a success, and were pleased to hear that excellent research work was being carried out on it, but up to date it was hardly sufficient to justify the acceptance of electric welding of ships. He did not think the necessary safeguards could be obtained in the ship-building yard. The usually accepted principle in ship work was that welding could be done on certain parts of the ship fore and aft, but not amidships.

Mr. J. N. Reeson thought it fallacious to suggest that welding small materials was easier than welding materials of large area. From the fact that much of the material used in the examples referred to in the lectures had come within the category of $\frac{3}{4}$ inch, it did not follow that materials of larger size could not have been more easily handled. He had noticed in the press reports that the Germans were incorporating welding in their ship building to a much greater extent than was the case in Great Britain. If that were so we might find that the Germans had stolen a march on us, largely due to the conservatism with which we were universally credited.

The President said the policy of caution was sound up to a given point. But the man who waited for others to do a new thing, and to use their results after they had been successful, would still be at a disadvantage. In the case of welding it was necessary to "think" welding before it could be used most economically. To be acquainted with the methods used by others was only part of the story; the rest was obtained only by thinking welding, and that involved years of experience.

At 10.35 p.m. the meeting closed.
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