DISCUSSION.

MR. F. C. MARSHALL thought the Members of the Institution were to be congratulated on having met with a gentleman of Mr. Blechynden's experience and position to give them the result of the progress during the last ten years in the development of the marine engine. The whole question seemed in the present paper to have been treated from beginning to end in a most masterly manner.

With regard to the omission (page 40) to say anything about the triple-expansion engine in his own paper in 1881, there were at that time only two instances of triple-expansion engines; and he might be pardoned if, in the midst of so many other engineering matters, those two were not then mentioned. They had indeed lain dormant from about 1874 to 1881, and up to 1881 nothing further had been done by the mechanical world in that direction. There was now, however, a record of enormous progress since 1881, which might be said to be unprecedented. How it had been brought about had been shown in the present paper; and the paper had begun, as it ought to do, with the boiler furnace, with regard to which it was stated (page 41) that during the last ten years the principle known as forced draught had been introduced into the larger class of vessels, having been previously known and used chiefly in torpedo vessels. On previous occasions he had mentioned a fact that seemed to be generally lost sight of, especially in the design of marine boilers, namely that forced draught was the secret of the success of the locomotive, and had been introduced by George Stephenson. But for their forced draught produced by the blast-pipe, locomotive engines would now probably be a long way behind their present development. On the occasion of his own paper in 1881, three vessels had just been completed at Newcastle with forced draught, and some of the members had then accompanied Lord Armstrong and Sir Frederick Bramwell, at the invitation of the Chinese Admiral, to witness the working of one of the vessels on the Tyne. Since that time, forced draught had become almost a universal feature in the development of marine engines. He was pleased to find that the adoption of forced draught was regarded by the author (page 42) as reducing the coal consumption of 1·573 lbs. per I.H.P. per hour with natural draught to 1·336 lbs. with forced draught, or a saving of 15 per cent. A further effect of the introduction of forced draught had been an increase of power in each boiler of from 30 to 50 per cent, ; while a still further advantage had been that the most inferior coal could be used with perfect safety. There were steamships which had been using, almost from that time to the present, nothing but slack, costing now about 5s. 6d. per ton. instead of lump coal at 12s. 6d. The arrangement of forced draught adopted had remained almost the same; there had been but little change. The inconveniences alluded to in the paper (page 41) had gradually tended to produce a dislike to the closed stoke-hold, and the substitution of the closed ashpit. There had been a good deal of discussion in scientific and professional circles regarding the evils of forced draught in connection with the boilers of the navy. But he believed Mr. White would confirm the opinion that forced draught had really nothing to do with any of the mishaps which had occurred with boilers in the navy. In this question he himself felt a kind of paternal interest, having been the first to apply forced draught in large vessels.

With regard to boilers, it had been pointed out (page 44) that there had not been much change in respect of form and design; but in another respect he thought all would agree with the author that there had been a great change. For it was impossible to go into any modern boiler shop which had kept pace with the advance of improvements without realising that a great change had come over the manufacture of boilers. The application of machinery to boiler-making, the better design of the boilers, the more careful manipulation of the material, and the introduction of the surveyor into the boiler shop in the same way that he had previously been introduced into the shipyard—having in both cases been greatly objected to in the first instance—had all together produced a much better class of work throughout. The material now employed was altogether of a highly superior character to anything used twelve or fifteen years ago. Reference had been made (page 46) to the subject introduced by Mr. Sennett of reduction in the thickness of shell plates: a principle which he thought might be wisely adopted by Lloyd's Committee and the Board of Trade. There was a general consensus of opinion, he believed, that a change was necessary in this respect, and that the recent great modifications in the material employed should be recognised in the existing rules, which now dated twelve or fifteen years back. The mild steel now used could be perfectly relied upon; or if it was defective in any way it was so through the fault of the surveyors. The workmanship also was as perfect as could be, every rivet-hole being drilled, every piece fitted as carefully as possible, and all the work done under the oversight of the surveyor. He could therefore confirm the author's opinion that there was no reason why it should still be compulsory to recognise large factors of safety, in order to allow for deficiencies in workmanship and for decrease in strength of material from corrosion. It was now no longer necessary to take these drawbacks into consideration. He wished it to be recognised that the excessive precaution and waste attending high factors of safety in boilers were altogether unnecessary, seeing that both the material and the workmanship could now be so fully relied upon. What ought to be done was to fix the standard for the material and the manner in which it was to be used, and then to make the rules correspond with these conditions. In the case of the Admiralty, the effect of such a course had been to reduce the thickness of boiler shells 18 per cent.; and there was no reason why the same should not be done by the Board of Trade and Lloyd's. The remark made in page 310 in relation to boilers he thought was of great importance, namely that, so long as they had been properly designed, no serious trouble had ensued. In one respect he thought the present practice in marine boilers was defective. In locomotive engines for many years past the fire-box had been made as large as it was possible to make it; whereas the attention of marine engineers, he thought, had been far too much directed to the extent of tube surface. If, however, the idea were rejected that tube surface was highly important, it would probably be much better for the boilers. It was considered by George Stephenson, and was a standing maxim with locomotive engineers, that the fire-box did three-quarters of the work, and that the first foot of length of the tubes did as much as all the rest. A large proportion of the tube surface might therefore easily be cut off, and the boiler still prove equally efficient.

The Hackworth valve-gear referred to in page 52 had been used by the Admiralty for the last ten or twelve years, and they had had no reason to regret it. He was surprised that it had not been more used elsewhere also, because the whole gear was so much more simple than others, as it had fewer working parts. With regard to the author's objections to radial valve-gear for high-speed engines (page 52), he had the pleasure of knowing that many high-speed torpedo-cruiser engines had been fitted by Mr. Cramp of Philadelphia with radial gear of the kind constantly used in this country, and were now working most satisfactorily.

The subject of copper steam-pipes he was glad had been included in the paper (page 53), because there had been a feeling that copper pipes were essential to marine engines. Although they were seen nowhere else, they were always seen in marine engines; and it was difficult to account for the difference. There were only two reasons that had led to their universal adoption in marine engines: one was the use of salt water, with the consequent risk of corrosion in iron or steel pipes; and the other was that copper pipes were supposed to give greater elasticity in the working of what was regarded as an elastic structure, namely a ship. It had been pointed out that the copper pipes which had been used had a tendency to become injured under certain conditions: that in brazing generally—and in his own experience in the brazing particularly of the flanges, though this had not been specially mentioned in the paper—there was a serious difficulty in connection with copper pipes. The many explosions that had taken place had occurred mostly near the brazing of the flange, showing that the brazing of the flange had something to do with the weakening of the copper at that place. It had also been shown experimentally that copper was seriously injured by being slightly overheated in the neighbourhood of the flange, where the flange had to be brazed on; and the introduction of solid-drawn copper pipes he was sorry to say did not improve the matter; for unfortunately it was found that, as in steel ingots, so in copper ingots there were small blow-holes, which in the drawn pipe drew themselves out, not into slight injuries, but into serious injuries in the shape of slits, the pipe being slit where the blow-holes occurred. Many cases of that kind had been met with; and, therefore, even the introduction of solid-drawn copper did not remove the evil, which had to be remedied in the patchy way mentioned in the paper, namely, by wrapping or strapping the pipes with copper or steel wire. Something better, he thought, might be hoped for, and that in a little time Lloyd's and the Board of Trade would issue regulations allowing the use of cast-iron, wrought-iron, or steel pipes, fitted, of course, under their own supervision with a sufficient number of expansion joints. For bends in particular, cast-iron or cast-steel might be used. Cast-iron pipes had been employed for many years by Mr. Douglas Hebson, in Liverpool; and he knew of several vessels in which they were now being used.

In the author's proposal (page 65) to take the coal burnt as the measure of the power expended in propulsion, he entirely concurred. He also wished to say in the presence of Mr. Macfarlane Gray that for further progress in marine engineering there was a necessity for engines which would work economically at low powers (page 50). The expenditure of fuel, when large engines were working as frequently required in war vessels while cruising, was so great that there was wanted some ready means of throwing one cylinder out of action, or disconnecting the connecting-rod, or something of that kind, which would give the opportunity of using the machinery at a low power.

The screw experiments made under the author's direction (page 59)—with which he had himself had something to do—were highly interesting; but even the description now given of these experiments and of the conclusions deduced from them he thought had not advanced the question much beyond what he had himself ventured to say on the subject in 1881, namely, that the screw propeller was still to a great extent an unsolved problem. The data given by the author needed confirmation before a propeller could be designed absolutely to suit any particular ship. It was largely an empirical question that had to be dealt with. In regard also to the weights of marine engines as compared with their power (page 63), this question seemed to stand pretty much where it did in the statement furnished in his own paper in 1881.

Mr. William Laird, Member of Council, concurred in congratulating the members on the paper which had now been placed before them. An application which he should like to mention of modern forced draught, successful in a commercial sense, had been made to the vessels belonging to the City of Dublin Steam Packet Company, running between Holyhead and Kingstown. This was in consequence of the circumstance that, when tenders were invited for a fresh contract for the mail service, the conditions imposed had been somewhat more exacting than those under which these boats had been working for over twenty years. There were four vessels, which were known to be in perfectly good condition, as were their engines also; and the difficulty was to make perfectly sure of their maintaining with the necessary regularity the increased speed required under the new contract. After consultation with his firm it had been decided to apply forced draught with a closed stoke-hold, and to reduce slightly the dip of the paddle wheels. The result had been that for several years past these vessels had been doing their work most satisfactorily, with the same consumption of fuel for the higher speed, and without any trouble at all in regard to the endurance of the boilers. This was no doubt due to the cause alluded to in the paper (page 43), namely, ample heating surface in the furnace and in the combustion chamber, and plenty of room for the circulation of the water. The adoption of that course had practically enabled those four valuable vessels, with a slight overhauling, to do the required work, instead of its being necessary to build new vessels and put in new machinery. It was true that one new vessel, called the "Ireland," had been built as a stand-by, which had a greater speed than the other four vessels; but these—the "Ulster," "Munster," "Leinster," and "Connaught"—had worked perfectly satisfactorily at the increased speed obtained with forced draught. For other reasons the London and North-Western Railway Company, desiring to carry their passengers at a greater speed, had also placed in the hands of his firm the re-arrangement of two other vessels, the "Lily" and the "Violet"; and, in order to obtain as great an economy of fuel as possible, it had been decided to make the engines on the triple-expansion principle. The three cylinders were vertical, and arranged more or less like the old steeple engines. In order to economise space and diminish the width of the engines across the ship, they were fitted with Joy's valve-gear. The members visiting his works in Birkenhead the day after to-morrow would have the opportunity of seeing these engines in one of the vessels. The boilers were somewaht novel, being on the locomotive plan; and the stoke-holds were closed, the air being supplied by fans, on the principle of employing a moderate draught. One vessel which had now been at work for some months on this plan was doing exceedingly well; it had given no trouble either in the boilers or in the engines, and was burning less than half the coal that had previously been used with the old-fashioned simple condensing engines which had been taken out. Another set of three vessels working with forced draught in the stoke-holds was employed by the Great Western Railway in the service between Weymouth and the Channel Islands; and the results they were giving were so satisfactory, both for speed and economy of coal, that a fourth vessel of larger size was now being built and was nearly completed. These facts rather confirmed the author's views, and were proofs that the exigencies of modern marine service called for the application of all the improvements which from time to time were introduced. The various progressive steps that had been made during the last ten years were described in the paper in a most interesting way; and he only hoped that after the next ten years the author might be able to show still further advances, although perhaps they might not be so rapid as during the ten or twelve years just past.

Mr. William H. White, Member of Council, said it should not be forgotten that in the history of forced draught there was a chapter preceding that included in the present paper. It was indeed quite true, as he believed, that in this country the use of forced draught in any vessels larger than torpedo boats had first been carried out by Mr. F. C. Marshall in designing the machinery for the Chinese cruisers of which mention had been made (page 75); but it would be within the memory of many of the Members who had visited the Paris Exhibition in 1878 that in the marine collection there shown the results had been given of extensive experiments made on a large scale in connection with the French navy, with various forms of what was termed *tirage forcé*. These experiments were largely the work of M. Bertin, and they comprised not only closed stoke-holds and under-grate draught, but also induced draught in various forms, including the use of compressed air in the form of jets introduced at the base of the funnel, so as to avoid any closing of the stoke-hold or any interference with the firing. The French were at that time already employing the plan of closed stoke-holds, which they had taken up by preference after trying those various plans in large ships; and it was the action of the French which had led the English Admiralty to go further into the matter at that time. The French had gone in at once for the closed stoke-holds. The first application of assisted draught in the English navy had been made in vessels where from the arrangement of the armament there was a great difficulty in getting a sufficient air-supply in the stoke-holds. The stoke-holds were open, but with great fan power for supplying air; and in some trials that had been made in other ships with practically the same boilers 25 per cent. more power had been obtained without any closing of the stoke-holds at all, simply by the improved supply of air due to the assisted draught. Experiments had then been made with closed stoke-holds, beginning with a ship of moderate size, and gradually working up to one in which the horse-power developed exceeded 6,000; and so gradually all the ships in the navy had come to be fitted with appliances for forced draught and with closed stoke-holds. In this way it had become practicable to get the results described in the paper (page 43) in the way of a possible increase in speed under circumstances of emergency. But it had never been intended that the ships furnished with forced-draught appliances should be worked continuously at the higher air-pressures. At an early period it had been laid down that under the ordinary conditions of service the air-pressures in the stoke-holds when closed should not exceed half an inch of water, which he thought was not excessive as an upper limit. Going over a considerable period of years, and within this limit of pressure under ordinary working conditions —excluding boilers of the locomotive kind, in which the corresponding limit was about one inch—the experience in the navy was that, with all except a special type of double-ended boilers, there had been no difficulty whatever; and the author had exactly expressed the fact when he said (page 43) that the discredit which had fallen upon forced draught in consequence of difficulties experienced with boilers should really be borne not by the forced draught, but by the particular design of boiler used. In a limited number of ships there were double-ended boilers, in which all the furnaces at both ends of the boiler delivered into a common combustion chamber. This was the kind of boiler in which, not under circumstances of extravagant air-pressure, difficulties had arisen; and these difficulties had since to a great extent been overcome by reducing the tube surface, by improving the circulation, and by protecting the tube plates in the way to which the author had properly referred (page 44). But in these boilers it was not considered advisable to apply the higher or "emergency" air-pressure, which with the ordinary marine boilers in the Admiralty service had formerly been two inches of water as a maximum. In the later designs of the ships of the navy the limit of air-pressure for circumstances of emergency had been fixed at one inch, which he believed did not exceed the pressure that had been used continuously on Atlantic voyages in some of the finest passenger steamers running between Liverpool and the United States. In confirmation of the opinion that the trouble experienced with certain boilers was a question of boiler design and not of forced draught, the further important fact might be mentioned, that in one class of ships where every condition was identical—except that in the earlier vessels a combustion chamber common to all the furnaces was adopted, while in the later each furnace had its own separate combustion chamber—whereas difficulties had arisen in the earlier vessels with the common combustion chamber, no difficulty whatever had arisen in the later vessels with the separate combustion chamber. This difference occurred in boilers of identical dimensions working at the same steam-pressure, even when the air-pressure in the stoke-holds of the later vessels had been fully two inches. It was only right in the interests of progress that these facts should be recognised, because forced draught had in many minds been charged with troubles which were only indirectly associated with it. The question of how best to apply assisted draught, as he should prefer to call it rather than forced draught, was of course one largely for experience to answer. In the navy closed stoke-holds had hitherto been used; and from his own personal observation when he had been afloat on various ships of the navy he had found that it was an arrangement which the stokers liked. He had repeatedly known the stokers close themselves down for the sake of comfort; and he had himself gone from the engine-room into the stoke-hold to be more comfortable. Of course there were objections to the several plans. If the stoke-hold were closed and the air delivered under pressure, air-locks were rendered necessary, with less easy entrance and exit; but then there was no trouble whatever in the stoking. If the under-grate draught were used, the blast must be shut off when firing. If the induced draught were employed, it had to be obtained by jets of compressed air or steam discharged into the base of the funnel, or by an exhausting fan producing suction at the same place. The latter plan had been worked out with great success by Mr. W. A. Martin, of London, and had been experimented upon in the navy, and it was proposed to experiment upon it still further. With either of these plans difficulties must of course be expected in maintaining the appliance in full working order. In the Admiralty there was no other desire whatever than to get the best thing that could be obtained at any time, and to give the machinery of the navy the greatest possible efficiency. The authorities, he hoped, had no prejudices in the