can tell, be as copious as those of Sirius or Vega. But they are intercepted in a deeply-laden atmosphere, which can indeed be escaped by only a small per-centage of their entire radiations. This explains at once the uniform inconspicuousness of such objects. A star of this class should possess, say, a hundred times the radiating surface of Vega, to send us, from an equal distance, the same quantity of light.

No star of those yet known to show banded spectra of either kind has an ascertained parallax. This is not wonderful, since the stars at measured, or perhaps measurable, distances from the earth, constitute a scarcely perceptible fraction of the whole. Still, the fact remains that all members of the two classes under consideration are indefinitely remote. We are accordingly without the means of estimating, even in the most general way, the real quantities of matter contained in, or of light emitted by, them. We can only say that their dimensions must be very great in proportion to their apparent magnitudes.

The question of their distribution is of much interest, as involving their relations to the vast ground-plan of the sidereal system. And one circumstance connected with it becomes immediately evident. This is, their largely predominant occurrence in and near the plane of the Milky Way. M. Dunér, it is true, considers that they merely obey the general law of stellar condensation. But this law applies more and more closely to the lessening orders of stars; and we have just seen that, physically, stars characterised by strong absorption should rank with stars optically by many degrees their superiors. The hypothesis, then, of some special connexion with the galactic streams and rugosities is by no means excluded; and it is countenanced by statistics as to the distribution of red stars in the southern hemisphere, recently afforded by M. Pechüle ("Expédition danoise pour l'Observation du Passage de Vénus," 1882, p. 38).

One of the most assured peculiarities of stars with banded spectra is their marked tendency to fluctuations of light. Amongst innumerable examples of this connexion may be cited "Mira" Ceti, and Gore's "new star" in Orion, both of which display brilliant prismatic flutings. Nearly all variables, in fact, save the few which complete their cycle of change in a few days, belong to one or other of the subdivisions of Class III. Whatever may be the secret of their constitution, it is indissolubly bound up with the still mysterious cause of stellar variability. We can scarcely penetrate the one without divining the other. Already something is gained by the mere fact of the connexion being established. We learn from it that the steadfast shining of a sun or star is conditioned by the quality of its surrounding gaseous envelope. Continuous study, then, of the spectra of variables affords probably the best chance of progress in knowledge of their nature. M. Dunér's incidental observations show that the reinforcement and extension of banded absorption apparent at minima, do not sufficiently explain the diminution of light, which must accordingly be in part due, either to a real failure of emissive power, or to an increase of general absorption. The analogy of sun-spots favours the latter alternative.

M. Dunér concludes his valuable memoir with the admission that the order of stellar development postulated by Vogel, and advocated by himself, may, after all, be the inverse of that pursued in nature,—a possibility surely worth thinking about.

The heavens are no longer in our eyes "incorruptible." Reason and revelation alike lead us to seek for symptoms of growth and decrepitude in their bright inmates. Not in human affairs alone "the old order changeth, yielding place to new." But the subject is one on which we are without the guidance of experience, and can scarcely hope to acquire any, regard being had to the almost infinite disproportion between our hurried notions of time, and the unimaginable leisureliness of cosmical progression. Caution is then all the more needful, if we would avoid wide wandering from the truth.

Now it has to be objected to Vogel's scheme, that it gives no account whatever of suns in process of becoming. Yet they must be as numerous, one would think, as suns in process of decay. From the summit of brilliancy and vigour, the course of decline is traced downward towards the final quenching. But what of the other branch of the curve? Stars now at their acme of splendour must have passed through long periods of preparation. Sirius and Canopus, we are fully assured, did not all at once blaze out in their present radiance. What, then, we cannot abstain from asking, was their anterior condition? What quality of light did they emit? How were their atmospheres constituted? What kind of spectra, in short, would they then have afforded? A system of classification, based on the supposed order of stellar development, in which no account is taken of this wide branch of the inquiry, must be regarded as essentially incomplete.

A. M. CLERKE

THE INSTITUTION OF NAVAL ARCHITECTS

THE twenty-seventh annual session of the Institution of Naval Architects, held at the rooms of the Society of Arts, was one of the most successful of the series. The meetings began on the 14th inst. and concluded on the 17th. There were seven sittings, averaging from three to four hours each, and no less than eighteen papers were read and discussed. As on previous occasions, too much was attempted to be done in the time available, with the result that some important matters received scant notice. This may be to some extent inevitable in a Society embracing such wide and varied interests, yet meeting but once a year. But it may be anticipated that the autumn meetings in the outports which are now contemplated may somewhat relieve the congestion in future.

Lord Ravensworth presided as usual, and delivered a Presidential Address, in which various matters of interest were touched upon, *inter alia* the use of liquid fuel instead of coal in steamships, the development of triple-expansion engines, the prospects of shipping and the statistics of shipbuilding, including the extended use of steel. It may be hoped, although the immediate future scarcely justifies the expectation, that before the next meetings a change in circumstances may enable the President to speak more cheeringly. On the other hand, it is an undoubted fact that the period of depression through which the country is now passing is forcing into prominence inquiries into possible economies in the construction and propulsion of ships which might otherwise have been neglected.

No less than seven of the papers read had relation to the propulsion of steamships. The first on the list—"On the Speed Trials of Recent War-Ships"—was read by Mr. W. H. White, Director of Naval Construction. It contained a succinct account of the remarkable advances made during the last quarter of a century in the speeds and propelling machinery of war-ships. The fact that huge battle-ships carrying enormous weights of armour and guns are now driven at speeds of 17 to 18 knots—20 to 21 miles per hour—is sufficiently remarkable. Yet the fact that such a ship, weighing 10,000 tons, can be driven 9 knots in an hour with an expenditure of only 1 ton of coal is no less striking. Much has been learnt, too, of late years as regards the influence of *form* upon the resistances of ships; thanks, in great measure, to the researches of the late Mr. Froude, whose work received the substantial support of the Admiralty. In the paper above mentioned it was shown that by suitable selection of form, the *Howe*, a vessel of 9600 tons, 325 feet long and 68 feet broad, was driven as easily as the *Warrior* up to the highest speed reached by the latter, although she was 380 feet long, 58 feet broad, and of 8850 tons only. The *Warrior* reached 14⅛ knots only; the *Howe* attained 17 knots. Improvements in marine engineering made this tremendous speed possible in the *Howe*. In her each ton weight of propelling apparatus corresponded to 10 indicated horse-power; in the *Warrior* 6 indicated horse-power required 1 ton. This economy of weight in the propelling apparatus was shown to be due to several causes, including a higher steam-pressure, quicker-running engines, the use of forced draught in the stoke-holds, and the introduction of wrought iron, steel, and gun-metal instead of cast iron.

Two papers dealt with the interesting subject of "forced draught" from different points of view. Mr. Sennett described at some length the Admiralty system of "closed stoke-holds," by means of which air is delivered into the boiler-rooms by powerful fans, and at a sensible pressure. The stoke-holds being thus *in plenum*, the air can escape only through the furnaces, and combustion is quickened greatly. With the best *natural* draught, about 10 indicated horse-power per square foot of furnace (or grate area) is considered a good performance: with forced draught and closed stoke-holds, this may be increased from 60 to 80 per cent. It will be seen therefore that for war-ships, which only require to steam occasionally and for comparatively short periods at full speed, the system is admirably well adapted. And it has been proved to be not nearly as wasteful of fuel as might have been supposed; while it certainly makes the stoke-holds cooler and more comfortable to work in. For the mercantile marine the conditions are different: ships have to steam ordinarily at practically their full speed; the restrictions of weight and space are not so great as in war-ships; and economy in coal consumption is of primary importance. Still even here forced draught promises to supplant natural draught, and to enable large economies to be made in weight and size of boilers concurrently with savings in coal. Mr. Howden described his system of forced combustion, which has been tried at sea over a long period, and promises to be successful. He does not close in the stoke-holds, but delivers air under pressure from fans direct into the furnaces and ash-pits, this air having been heated by passing through a special apparatus placed in the up-takes. Great economy is claimed for this system, and it was well spoken of by competent authorities in the discussion which followed. Competing plans are also being tried, so that more will certainly be heard of forced draught in the mercantile marine. Hitherto economy has been sought in higher pressures and in the *use* of steam in the engines: now engineers are turning attention to the boiler, and the means of generating steam with a minimum expense.

Hard times in the mercantile marine have led to a wholesale conversion of compound engines into engines of the triple or quadruple expansion type. Mr. Cole read a thoughtful and well-considered paper on this subject, which is of general interest to shipowners just now. It may prove a very desirable thing to reduce the coal-bill by 20 per cent., even at the cost of converting the machinery to the more highly expansive type.

It is a natural transition from the propelling machinery to the propellers of steamships. Mr. R. E. Froude, who has succeeded his father in the superintendence of the Admiralty model-experimental works, contributed one of the most valuable and scientific papers read at the meetings, on "The Determination of the most Suitable Dimensions for Screw Propellers." He attempts from experiments with models of ships and screws to ascertain the resistance experienced by a ship moving at a given speed, and the "augment" of that resistance produced by the action of the propeller behind her. By means of a lengthy series of experiments with model screws he further attempts to fix the best diameter and pitch for a given number of revolutions of the engines. And finally, the results are thrown into a form adapted for practical use. The paper is in all respects admirable, but we are bound to say that it can be regarded only as another step forward on a very difficult road, and may be treated as provisional rather than conclusive. Some of the inferences do not accord, either, with the results of general experience. It is to be welcomed, however, for as yet the theory of the screw propeller is not in a satisfactory condition; and it is well known that very remarkable economies are frequently realised by changes in propellers. In the course of the discussion Mr. White mentioned a case of recent occurrence, where, by a change of screw only, the speed of a ship was raised from 12 to 13¼ knots per hour.

M. Marchal, of the French Génie Maritime, contributed an interesting paper, in which the results of a number of experiments, made by order of the Government, were described. It was desired to obtain data for guidance in deciding on the relative advantages of two or three screws as applied to an ironclad of 10,000 tons. A model steamer of 10 tons was built, and tried at "corresponding speeds," with two screws and with three. The publication of this paper marks a distinct change of policy in France, and it places before English designers a mass of valuable facts, which may prove very useful hereafter as the speeds of ships are increased.

Mr. Hall read a paper on "Flexible Shafting for Screw Steamers," describing a plan by which he hopes to reduce the number of breakages or serious accidents to the screw shafts of ocean-going steamers. His contention was that in not a few cases there is a want either of accuracy in the line of shafting and shaft-bearings, or of rigidity in the hulls of steamships; so that, by special joints between the various lengths of shafting, a certain amount of flexibility might advantageously be secured. Experience will prove whether he is correct or not in the anticipation that his plan will reduce accidents or breakages—serious matters in single-screw ships carrying large numbers of passengers and having very small sail-power.

Another important group of papers are those dealing with the use of rolled and cast steel for shipbuilding. It is well known that steel is rapidly gaining upon iron, and Mr. Martell (of Lloyd's) stated some very interesting facts as to the extension of its employment in the mercantile marine. War-ships are now all steel-built. Seven years ago only 4470 tons of steel ships were built as against 518,000 tons of iron ships. In 1885 over 165,000 tons of steel ships were built as against 290,000 tons of iron. Confidence in steel was expressed by Mr. Martell in his paper, echoed by Mr. Ward in another excellent paper recording eight years' experience in building steel ships, and indorsed by all who took part in the discussion. Incidentally the question arose of the introduction of steel made by the "basic" process for shipbuilding purposes; as yet this "make" of steel has not found much favour, but the Admiralty authorities are now about to undertake a series of experiments from which much may be learnt. Every one agrees that thorough and systematic testing has done much to secure the excellent qualities of steel now made by both the Bessemer and the Siemens processes; and even the manufacturers are in favour of maintaining the full severity of the tests in order to prevent any deterioration in quality. Of more recent date than the use of "mild-steel" plates and bars is the introduction of mild-steel castings in lieu of iron forgings. Mr. Warren, who had been chairman of a Committee appointed by the Admiralty to look into this question, gave to the meeting an excellent summary of the results of their inquiries. There can be no question but that heavy iron forgings are doomed to give place to steel castings, which can be produced rapidly and cheaply, of sound and ductile quality, and in finished forms, avoiding costly machine-work. As a record of experience up to date, Mr. Warren's paper will have a permanent value.

The remaining papers on the list are of a miscellaneous character, but all of considerable interest. Mr. Heck described a "Mechanical Method of Finding the Stability of a Vessel," by means of a simple model. This is a very ingenious and labour-saving device, likely to prove of great assistance in ordinary ship-yards, where a staff of trained calculators may be wanting. Mr. Stromeyer described a "Strain Indicator" which he has invented. This instrument is extremely simple in its construction: the essential parts consisting of two flat plates between which is inserted a "rolling-pin" of fine steel wire. Relative motion of the two plates causes the rolling-pin to rotate, and its rotation is the means of measuring the strain to which the material is subjected in any portion of a sample or a structure to which the indicator may be attached. If this instrument answers as well as it promises to do, much will be learnt from its indications as to the strains brought upon ships under various conditions and more especially at sea. Such information carefully compiled and collated ought to prove of value in determining the structural arrangements of ships.

Admiral Paris, the venerable Curator of the Naval Museum at the Louvre, long known for his eminence as a scientific naval officer and as an archæologist in shipbuilding, attended the meetings, and contributed an interesting paper on the "Rolling of Ships," exhibiting an instrument designed to represent the relative movements of ships and waves. His reception was deservedly cordial.

Capt. Colomb described, in a well-written paper, some of the more important results of recent measurements of turning powers of ships in the Royal Navy. These trials are now systematised, and much has been learnt from them which will be of value to future naval tactics, as well as useful to shipbuilders in designing rudders and steering-appliances. A novel steering-gear was described by Mr. Maginnis, who also laid before the Institution some valuable autographic information on the obscure subject of the strains brought upon a rudder when it is "put over" to various angles in a ship moving at speed.

Mr. Read's contribution, "On the Strength of Bulkheads" in ships, was seasonable, the recent loss of the *Oregon* having again drawn public attention to the necessity for water-tight subdivisions as a means of safety from foundering. Mr. Read put into a mathematical form the principles which should regulate the construction of bulkheads if they are to successfully withstand the water-pressure which must come upon them when the compartments are "bilged" and sea-water enters. He did not deal with the principles which should govern the disposition of bulkheads; but these principles are well understood, and more generally acted upon now than formerly.

Another paper by Mr. Benjamin described a "Proposed Steam Lifeboat" which had been designed to be practically uncapsizable; and for that purpose, among others, made of a very peculiar form. The only other paper on the list described the improved methods of working anchors and cables devised by the author, Mr. Baxter. This was a paper of a practical and historical character, on a subject of undoubted importance.

From this hasty summary it will be seen that the Institution of Naval Architects maintained at its recent gatherings its old reputation for widely diversified topics of discussion. And it is to be added that the papers as a whole, numerous as they were, were also of more than average merit.

ON THE USE OF MODELS FOR INSTRUCTION IN THE MAGNETISM OF IRON SHIPS

THE deviations of the compass produced by the iron used in the construction of wooden ships was a source of considerable perplexity to the navigators of the last and early part of the present centuries; and no sooner were these difficulties fairly overcome than the building of ships entirely of iron commenced.

With the introduction of iron ships, prolonged investigations into their magnetism and the resulting deviations of the compass on board were undertaken by some of the most eminent philosophers and mathematicians of the day, the subject being still one which occupies the attention of many observers, from the increased use of iron in the equipment, as well as construction, of the hulls and decks. These investigations were much facilitated by the increased knowledge of the earth's magnetism, which received such notable additions from magnetic surveys made by travellers on land and navigators at sea during the years 1819–45.

Moreover, as time rolled on, these observations were embodied in trustworthy graphic representations of the declination or variation, the dip or inclination, and the horizontal force, which have done such good service in the work of obtaining a clear understanding of the cause of the magnetism of iron ships, and the changes to which such magnetism is liable when the vessel's position is altered either geographically or in respect to the magnetic meridian.

It is not here intended to enter into any historical *résumé* of the names of the several investigators in this branch of science, nor of the results which each obtained, but to indicate at once where the physicist and mathematician may find the theory and examples of its application; also, how the practical results of this elegant theory may, by the use of models, be made intelligible and available to the seaman and other inquirers who have neither the time nor the opportunity for abstruse studies requiring considerable mathematical knowledge.

The text-book which is now generally accepted in all countries is the "Admiralty Manual for the Deviations of the Compass," in Appendix No. 1 of which will be found the three fundamental equations of Poisson, which form the whole theory of the deviations of the compass, and the expressions of these equations "in terms of the quantities which are usually given and required," written by the late Archibald Smith, M.A., F.R.S.

The whole of the action of the soft iron of a ship is represented in these equations by the parameters a, b, c, d, e, f, g, h, k, and in a model by nine soft iron rods fixed in definite positions, distinguished by the same letters.

The effects of the magnetism of the hard iron of the ship are represented in these equations by the parameters P, Q, R, and in the model by two permanent magnets held horizontally in definite positions, and a third permanent magnet held vertically under the compass.

One of the most important contributions to magnetical science as regards iron ships was made by Sir George Airy (late Astronomer-Royal) in a paper published in the *Phil. Trans.* Royal Society for 1839. After making a series of experiments in certain iron-built ships, he discussed the results mathematically with the purpose of discovering a correction for the deviation of the compass. He concluded his paper with the announcement of his invention of the system of correction by magnets and soft iron, which is universally practised in the present day, always with advantage, and often as a matter of necessity in ships of certain types, where to find a suitable place even for the standard compass is a matter of no small difficulty. This system of correction, coupled with the analysis described in the "Admiralty Compass Manual," provides the means of correcting a compass even in position on the 'tween decks of our armour-plated ships of war.

With these preliminary remarks, the description of some different forms of models will be given, and their uses for instruction in the magnetism of iron ships considered.