MODELS AND MOCK-UPS

BY

LIEUTENANT-COMMANDER C. M. ROBINSON, R.N., A.M.I.MECH.E.

' It is essential—to carry detailed design into every part of the installation—for the designer to see that the final result is as tidy and accessible as he thought of it in his most ambitious moments.

' I feel that installation, which is possibly the most difficult stage of all, has not perhaps received the attention it deserves '. (Vice-Admiral Sir Frank Mason, K.C.B., 21st Parsons Memorial Lecture, North East Coast Institution of Engineers and Shipbuilders).

The post-war evolution of the warship, and in particular the small ship, has more than ever been towards improving the ship as a fighting unit by reducing the weight and space occupied by its machinery and fuel. A large amount of technical progress has been made towards smaller individual items of machinery with improved performance, but until recently there had been virtually no parallel advance in the field of installation. The installation problem has itself altered from pre-war, when large boilers, engines and gearcases determined the sizes of machinery spaces, leaving a generous remainder in which to site a few comparatively small auxiliaries, to the present day when auxiliaries are, by comparison, larger and more numerous and the major items of machinery may not even decide leading machinery space dimensions.

These facts were forcibly driven home in the cases of the *Daring* Class and Type 12 and Type 14 frigates where it began to be apparent that ' shoehorning ' machinery into the comparatively smaller spaces available in a modern warship by means of conventional layout draughtsmanship could only result in compressing the installation, and, since individual items of machinery are incompressible, this meant that these became closer together, so that the intervening or interconnecting systems were where the compression had to be effected.

It was clear, then, that some new approach to the installation problem was required, and the use of mock-ups, which have been employed for some time in the U.S.A. for surface ships and in this country for submarines, was the logical step forward. A completely new machinery layout procedure was, therefore, devised and has now been used for the first time in developing a new installation.

HOW A MACHINERY INSTALLATION DEVELOPS

Before going into the mock-up method in detail it may be helpful to outline briefly the way in which a new warship installation is developed in this country.

The earliest stage of all, usually known as the ' project stage ', is when the broad features of the design are decided—number of shafts, type of machinery (steam, Diesel, combined plant, nuclear, etc.)—and when the early space allocations are settled, so that the project stage determines, but does not develop, the installation.

The work of developing the installation now begins, and the first objects to be aimed at are the production of a ' Machinery Specification ' and set of ' Guidance Drawings '. These must go forward hand in hand, for the Specification lists every item of machinery and its duties, and the Guidance Drawings, as they develop, find a home for each item and aim to leave space enough for the systems to be fitted. In working out the details of components as the Specification is written, it often transpires that they need to be much larger than was origin-

ally envisaged, or sometimes two or more are needed where it was thought that one would suffice (things do occasionally get smaller or fewer, but much less often) and the Guidance Drawings, as finally produced, must be very close to the final installation in the size and position of every piece of machinery.

When this stage is reached (and it would be useless to try to do it before) the work of producing drawings of systems may be started, although one or two systems which affect the positioning of machinery, such as extraction pump pipes, lubrication oil drains, main steam, etc., may already have been briefly considered.

From now on the design progresses system by system, until ultimately drawings must be available of every machine, every pipe, every valve, every seating or bearer, and every piece of electrical equipment necessary to putting the machinery into the ship.

So it can be seen that the whole process of developing the design from the installation aspect resolves into the problem of the preparation of the drawings necessary to fit a given type of machinery into a given ship.

THE MOCK-UP METHOD

The basic principle of the mock-up method is to produce ship installation drawings from a mock-up, and the object is to build better ships.

In the past, the whole task of developing from the project stage to the ship installation drawings has been straightforward drawing-board work, and it will be seen that this is no mean undertaking even for an expert team of draughtsmen whose job it is. Fitting machinery into a ship is analagous to a three dimensional jig-saw puzzle, with rules to fix the positions of some of the pieces, and a large number of solutions of varying merit. Unfortunately, and despite all ordinary training and care, three dimensional jig-saw puzzles done by drawing are difficult, the rules are not clearly defined, the number of pieces to be included is enormous, and the number of people capable of interpreting the resulting drawing is very few.

The new procedure which was devised, and which has now been used for the first time, was a two-stage process. In the first stage, preliminary project drawing work was first carried out, and a $1\frac{1}{2}$ in. to 1 ft scale model was then completed, officially inspected, modified as necessary, and approved. Only then were the Guidance Drawings prepared, and it was stipulated that the broad principles of the machinery layout should then be frozen unless a major alteration was unavoidable, but that detail alterations were still permissible. The second stage consists of obtaining accurate details of all items of machinery, establishing by drawing their optimum position, preparing preliminary installation drawings of all systems, and building a full scale mock-up incorporating these. A similar process of inspecting, modifying, and approving the mock-up must then be carried out, and the design then frozen and installation drawings prepared. It will be seen that, in effect, the Guidance Drawings are 'as fitted' mock-up drawings. Were no alterations necessary the guidance drawings could be traced straight off the model drawings and the ship installation drawings straight off the mock-up drawings, but experience shows that this is not the case.

The procedure as outlined above was applied to a completely new Class of ship of frigate size, where it was known that more than one ship of the class would be built. Depending, of course, on the size of ship, number off, and other considerations it might not in all cases be necessary to go through the full procedure, and in such cases a modified form could be employed. The merits and demerits of this will be discussed more fully later, but in whatever

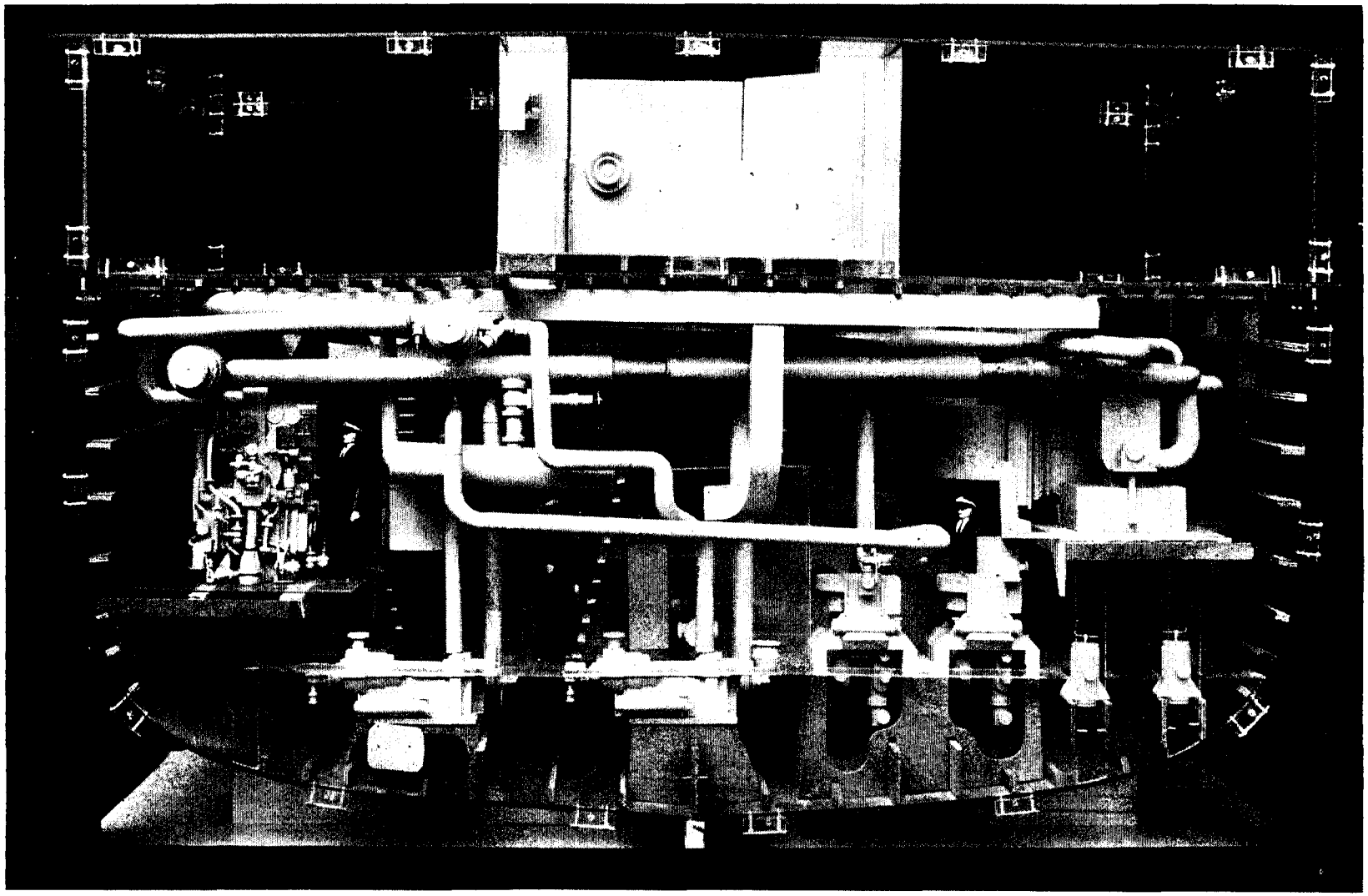

FIG. 1—THE $\frac{1}{8}$TH SCALE MODEL—A VIEW OF THE BOILER FIRING PLATFORM
The hull of the model is constructed of perspex, the machinery and pipes of wood. Note the detached view obtained by the observer which is ideal for deciding the positioning of the machinery in the ship during early design stages (*Model by Yarrow and Co.*)

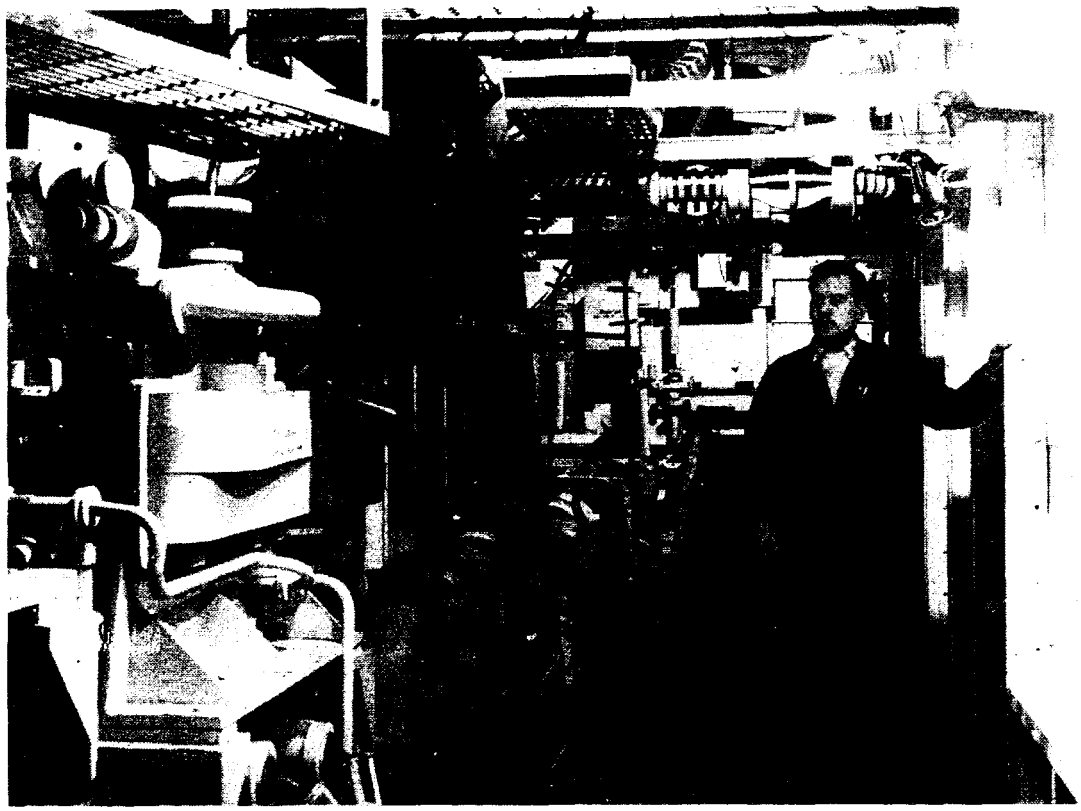

FIG. 2—THE FULL-SCALE MOCK-UP SHOWING THE SAME AREA AS SHOWN IN THE SCALE MODEL

The hull, floorplates, ladders and gratings are of metal, temporarily assembled. All machinery, electrical equipment, etc., are of wood and pipes have a metal core with spaced wooden discs. In this case the viewpoint is internal, for detailed assessment of maintenance and operation (*Built by Yarrow and Co.*)

form it is adopted the principle still remains of building a mock-up which is cheap, easily altered, and easily inspected, and producing the ship installation drawings from it rather than building in faults to the actual ship.

RESULTS OBTAINED FROM THE MOCK-UP METHOD

Obtaining the Optimum Machinery Arrangement

The small scale model and the full scale mock-up represent two powerful additional new tools for the ship installation draughtsman, and it is a fair guess to say that once their use is generally accepted, as with so many new tools, we shall wonder how we ever got on without them. Under this heading, however, it is important to note that if the mock-up method is really to be of use in producing the *optimum* arrangement, it implies that the final arrangement must be better than could be obtained by drawing work alone. This, in turn, means that the drawing-board work leading up to the mock-up must be as conscientiously done as if no mock-up were going to be used, although the drawings obviously need not be progressed to the same degree of detail in pipe and fitting lists, etc.

Experience has now shown that models and mock-ups start to play their part in obtaining the best machinery arrangement from the moment they begin to be built. They may be used, as they develop, to site pipe runs in preparing systems, to adjust the positions of items of machinery for any number of different reasons, to adjust the positions and levels of ladders and gratings, and in many other ways, all more quickly, more easily, and more accurately, than on the drawing-board.

Once completed, and despite all ordinary care in layout draughtsmanship, there were over sixty alterations as a result of inspecting the scale model recently employed, although, except for major steam pipes, no systems were included and the units were in most cases modelled on very sketchy information. In the case of the full-scale mock-up the number of alterations ran into hundreds, varying from major redesigns of complete systems to minor adjustments of detail. But all the alterations had one thing in common—they were obvious on the model or mock-up, but not so on the drawings.

The one feature of the utmost importance is that having once obtained a mock-up the fullest possible use must be made of it.

Ensuring Standardization between Ships of the Class

Many of the shortcomings which, in the past, have shown up in the First of Class and been put right in subsequent ships (but not necessarily all in the same way) should be brought to light by the mock-up provided it is properly evaluated. In addition, since D.M.E. is currently devoting considerable effort towards the standardization of valves and fittings, and the machinery spaces of all ships of a Class will be built to drawings prepared by the leading Main Machinery Contractor from a mock-up, individual ship differences in the machinery spaces should be avoided, thereby simplifying ship knowledge training, maintenance evaluation and planning, as well as the more obvious advantages in the way of minimizing duplication of effort on the part of the shipbuilders and rationalizing the spares situation. The planning and carrying out of refits is also simplified where ships of a Class are known to be identical.

Early Progress and Co-ordination of Drawing Work

Since no approval for manufacture can be given until after the mock-up is complete, and since all systems, etc., must be drawn out before installing in the mock-up, all the systems are progressed to the same stage simultaneously. Thus all the system drawings are produced in very good time for the ordering of materials and thorough co-ordination, and the inter-system tangles, such as can and do occur if one system is progressed and approved before another is started, can be avoided.

Opportunity to Take Stock of the Installation

The completion and evaluation of the scale model and the full scale mock-up both represent definite stages in the development of the design and therefore form an ideal opportunity to take stock of the way in which it is turning out. At the pauses which the model and mock-up introduce, then the whole installation can be evaluated in its entirtty. Hitherto, there have not been these natural pauses, and even had it been decided to take stock there has never been any point when the design *as a whole* had reached some definite stage suitable for evaluation.

Opportunity to Obtain Many Points of View

In the past the study of all the relevant drawings necessary to a useful appreciation of a new installation would have been an enormous task, and one which was in fact impracticable for all except those most intimately connected with it—probably a dozen people at the most.

Use of a model and/or mock-up, however, means that as many people as are concerned or who can usefully contribute can have the opportunity to comment.

This applies to the customer as represented in this case by the Admiralty, to his technical advisers as represented by the Specialist Sections of the various

Admiralty departments, to the user and maintainer as represented by the Class Authority and the Dockyards, the machinery designers and builders, and the Shipbuilding Industry as represented by the builders of follow-on ships of the Class.

It can be seen that the potentialities for constructive criticism before it is too late are enormous.

Fostering Early Effort by Machinery Manufacturers

As already pointed out, completion of the mock-up represents a definite date which must be maintained if ship dates are not to suffer, and if the mock-up is to be of any value the individual units must be true in size and shape. Since in these days of balanced installations virtually every auxiliary is a special design for the Class, obtaining such information from sub-contractors is often extremely difficult, as from their point of view it often means that the design must be progressed in detail much earlier than would otherwise be the case. None the less, this is very desirable, since the shocks come in time to affect the mock-up rather than the ship, and the likelihood of delivery dates being met should be increased by this early effort, since providing the information required for mock-up purposes often represents a large proportion of the total design task.

Improving the Installation of Electrical Equipment

In the past, the positioning of electrical equipment has normally been done as something of an afterthought, frequently on site in the ship when the machinery arrangement had long since been finalized, and adjustment of positions of machinery was no longer possible. It is small wonder then that the electrical boxes and fittings have not always been sited to their best advantage from either the engineer's or the electrician's point of view. Using the mock-up method, however, all the arguments already enumerated about obtaining an inter-related arrangement, early supply of information, etc., apply. In the recent case previously referred to, re-arrangements in the machinery spaces were, in fact, made, giving improved siting of electrical equipment. Once again, these improvements were obvious on the mock-up, but would undoubtedly never have been done had there not been one.

Preventing the First Ship of the Class from Acting as a Mock-up

With past practice it has been a normal occurrence for, say, a pipe to be made, taken to the ship, offered up, and then have to be scrapped or re-made because an electrical box has been installed after the plumber bent his wire. This sort of thing, which is bound to happen more in the First of Class than later ships, amounts exactly to using the First of Class as a mock-up. But it is, of course, a very expensive, time consuming, and unsatisfactory way of doing the job. How much better to use a real mock-up !

EVALUATING THE MOCK-UP

It was mentioned earlier that, having once got a mock-up, it is essential to use it. There is nothing difficult about this, since everyone who has ever had anything to do with ships must at one time or another have fervently wished that he could move such-and-such or so-and-so.

What must be accepted is, first, that the mock-up must be used, and used in this sense means altered until it cannot possibly be further improved upon and, second, that this use is a time-consuming business likely to run into weeks

of living with the mock-up. It is also hard work, for while the first flush of enthusiasm over altering all the more obvious mistakes is the seagoing engineer's dream come true, there follows a series of patient exercises to get right all such details as slinging arrangements, floorplate supports, emergency lighting, and a mental exercise on dismantling, removing, or servicing in place every piece of machinery from the main engines down to drainage of oil from auxiliaries.

Whatever else we may say about a mock-up, whether it be full size or a small scale model, it is upon the evaluation of it that the whole success of the installation rests, and this part must not be skimped.

AN EXAMPLE OF THE RESULTS

It has already been mentioned that in the recently used mock-up it was possible to improve the positioning of some electrical equipment by making adjustments to the positions of machinery, and one other typical example is given here in detail to show the sort of thing that can be achieved.

As first installed in the mock-up the grating at the boiler room mid-level giving access to the feed regulator, gauge glasses, etc., was in a congested area. The grating had had to be cranked in plan and have a step put into it to avoid obstructions, and passage or access to the boiler front was only possible bent double or an all fours. After sorting out on the mock-up, a straight unstepped grating was obtained, giving a clear walkway for a man of average height, and good working space.

This one alteration was achieved in several steps, as follows :—

(*a*) The feed discharge pipe was lowered four inches

(*b*) The grating was lowered six inches to eliminate the step

(*c*) The feed regulator was moved two feet forward and used to the opposite hand, to allow a straight grating

(*d*) The superheated steam pipe to the blowers was re-run to eliminate overhead obstruction

(*e*) The exhaust steam pipes from the feed and fuel pumps were re-run to eliminate obstruction overhead and aft

(*f*) The position of the vent trunks was adjusted.

In order to achieve this by drawing, it would have been necessary to employ the following separate drawings :—

(i) Floorplates, ladders and gratings

(ii) Boiler mountings

(iii) Feed system

(iv) Superheated steam system

(v) Exhaust system

(vi) Ventilation

(vii) Details and handing of feed regulator.

It is the firm belief of all those who saw this both before and after the modification that without a mock-up the same result could not have been achieved.

Much the same sort of major improvement was obtained in other areas, notably below the floorplates in the engine room and gear room, where fuel transfer pipes, lubricating oil supply and drain pipes, sea water systems, etc., had knitted together to produce an impenetrable jungle of pipework. After sorting out on the mock-up a clear walkway with good access to all machinery was obtained in every case.

Hundreds of detail improvements were made, such as altering the run of steam and exhaust pipes to permit easier maintenance of auxiliaries, minor alterations to the positions of pumps to improve access to flanges, etc. Space alone prevents listing more than a few of the alterations resulting from the full scale mock-up—by themselves they would fill more than one issue of the *Journal.*

HOW BIG AND HOW MUCH

It is sometimes argued that good draughtsmanship alone should produce a satisfactory installation, but the arguments already set out and, above all, the experience which has now been obtained, give the lie to this. An obvious difficulty with a full-scale mock-up is its size and the space required, and it is argued that if full use is made of the scale model a full-scale mock-up is unnecessary, and this argument is less easy to dispose of except, again, by experience. After spending some days on the full-scale mock-up, which gave a startling impression of realism, and with just this point in mind, the Author took another look at the scale model for the first time for over a year, and despite the fact that virtually the same things were shown and scale model E.R.A.s paced the floorplates, the model simply did not show up in the same way as the mock-up, although it still fulfilled admirably its original purpose as an aid to the fitting of machinery-shaped blocks into a ship-shaped volume. The relative positions of machinery were still obviously right, but for the purposes for which the full-scale mock-up was being used it appeared that the mind cannot scale its functioning down by the necessary one-eighth. So that until we can do an ' Alice in Wonderland ' act, the Author's opinion, backed by that of other people who have carried out the same test, is that the scale model and the full-scale mock-up are both necessary and neither can fulfil the task of the other. One comes in at a time when the overall view is required and the other when the local view is essential, and, by their very nature, one must be looked at from outside and the other from inside.

A further argument sometimes heard is that only known tight spots should be mocked-up in full. This again is disposed of by the experience to date which shows that the points picked up have as often been in the relatively spacious areas as in the suspected tight spots.

The cost of a full-scale mock-up is, of course, high—something of the order of £75,000 is an indication—but it is necessary to put this into its right perspective. If we consider that to build a frigate today costs about £3m. we begin to approach that perspective, and if we then apply the cost of the mock-up to a Class of, say, ten ships, we get closer still. If we now realize that each of these ships may have a life of approaching fifteen years we can see that, spread over the life of the ships of the Class, the mock-up will have cost some £500 per ship per year, so that if this much can be saved during building, or on easier maintenance or improved availability, the mock-up has paid for itself. It is also worth bearing in mind that the annual wages bill, alone, for a frigate is of the order of £125,000, and that the required saving of £500 per annum represents, almost exactly, a reduction in complement of one Junior Rate. With the greatly improved ease of maintenance and cleaning of a mocked-up installation this should readily be achieved. It is naturally impossible to say just how much improved a mocked-up installation is over what it would otherwise have been, but there is no doubt at all in the minds of those concerned with the recent case that the mock-up will have paid for itself many times over.

CONCLUSION

The above seeks to highlight and advertise some of the many advantages which may be obtained from the mock-up method, but it is only fair to draw

attention to its limitations.

The mock-up method can and, properly employed, will ensure that the very best possible use is made of the space available, but it cannot make space where insufficient exists, nor, if an installation is inherently spacious, should it be given credit for all of the room that results. However, it is to be expected that, when more experience has been obtained with mocked-up installations, the proportion of machinery space volume to machinery volume may be reduced as a direct result of improved installation technique, thereby permitting a reduction in the amount of the ship given over to machinery and fuel and a corresponding gain in fighting potential.

It is now D.M.E.'s departmental policy that models and mock-ups shall be used as necessary in developing future machinery installations, and the Author is firmly convinced of their enormous value towards building better ships and so directly improving the Royal Navy.