REFITTING POLARIS SUBMARINES

BY

LIEUTENANT-COMMANDER C. W. SMITH R.N., M.SC.

Introduction

Rosyth Dockyard, with the experience of work on H.M.S. *Dreadnought* behind them and with the refuelling complex already built and operating, were instructed to undertake the refit of H.M.S. *Resolution* commencing in June 1970. It is now past history that the refit was completed in time, to a very satisfactory standard and within its financial estimate. The second SSBN under refit, H.M.S. *Repulse*, has also completed to time and to an even better standard.

The purpose of this article is to describe some of the procedures and methods of working which were developed and instituted in Rosyth in order to achieve the desired results. To avoid too lengthy an article, some over-simplifications have been made.

Refit Philosophy

The Polaris submarines are twice the size of the *Dreadnought* yet, although they have a very sophisticated weapon system, considerably more complex machinery and more of it, they have to be refitted in a short fixed period. This required a number of changes in philosophy, organization, procedures, and support to the work force, particularly in respect of more detailed planning, scheduling, and better spares support, together with full co-operation between DPT(S/M) (the SSBN design sections), CED, FOSM, ship's staff and the dockyard.

The major changes in philosophy can be listed as follows:

(*i*) That the work content of the refit should be limited to essential defects, planned maintenance items, and a limited number of equipment modifications and As and As to enable the submarine to operate to the required level of reliability until the next refit. Submarine refits had tended to become a 'strip out–refit–replace–test' sequence of events, and all equipments and systems were treated in the same way, i.e. 'refit by survey'.

It was inconceivable that an SSBN could be refitted in the same manner in the time available, so it was necessary to restrict the work to that which was considered to be essential. Thus a large number of equipments, systems, and parts of systems would not be disturbed. This concept produced its own problems, as now the production centres had to be told in detail what they should or should not refit. The work to be carried out was defined by DPT (S/M) in a Work Package document supplied to the dockyard twelve to eighteen months before the refit start date.

(*ii*) That there should be stringent control over changes to the Refit Work Package. These can occur in the most insidious way, as good arguments cannot generally be produced to reject a proposed change where the work content is fairly trivial. It is, of course, the aggregation of a large number of small changes that can lead to significant increase in work load and possible extension of the time in hand. Each proposed change, therefore, was subjected to careful consideration in accordance with a defined procedure to assess its effect on the refit.

(*iii*) That there should be a guarantee of high spares availability, that the spares required for the refitting submarine should be given the same

priority as those required for the running submarine and that there should be a large stock of SSBN spares held at Rosyth. (In fact, about forty thousand line items are held at Rosyth on SSBN account).

(*iv*) That there should be a high element of repair by replacement, not only for major equipments such as pumps, fans, heat exchangers, etc., but also for valves, cocks, fittings, etc. Naturally, this would speed up the refit phase but would require early planning and procurement by DPT S/M), would throw a considerable load on the stores organizations, and would necessitate increased stocks of the more expensive permanent items. Repair cycles for the replaced equipments had to be organized with nominated repair points. In addition, the turn round times for these equipments would have to be fairly short in order to meet the requirements of the running boats and subsequently for the next boat into refit.

(*v*) That there should be a facility to work the labour force in shifts as required and that the Dockyard Incentive Bonus Scheme (DIBS) should be abolished for work on SSBNs. The DIBS scheme was too cumbersome, too slow to negotiate, and not sufficiently flexible for the increased tempo of work which would be required.

(*vi*) That 'Quality Assurance' should be applied to all work on nuclear and first level systems and equipments. (A first level system can be loosely defined as one affecting submarine safety). This meant that not only should there be quality control of the standards of workmanship on these systems but that there should be documentary evidence of this by means of quality record cards, test record cards, dimensional inspection charts, etc. Moreover, the dockyard had to be satisfied that the quality certification of the raw materials and spares supplied was adequate. If not, then either local certification by means of NDT and chemical tests was necessary or, where this was not possible, a new, fully-certified spare had to be obtained.

A price would have to be paid for these changes to the dockyard's traditional practices. The more detailed planning and control of work acceptance required large increases in non-industrial staff, particularly at PTO III (Inspector) level. The provision for shift working was negotiated with the unions and a shift agreement established which also required additional non-industrial staff to provide supervision on a three shift basis. Offices, stores, transit areas, lay-apart stores, refuelling facilities, dockside services, workshops, cranes, computer buildings, canteens, amenity centres, car-parking, housing, barrack accommodation in H.M.S. *Cochrane*, married-quarters, and numerous other items all had to be designed and built, or extended and improved.

SSBN Refit Organization

The refit cycle can be divided into three main sections, namely:

(*i*) Pre-refit phase —when all planning activities are carried out and some manufacturing work done.

(*ii*) Refit phase —the period from take-in-hand to sailing for sea trials.

(*iii*) Post-refit phase —this period comprises sea trials, defect rectification period, work up, DASO (Demonstration and Shake-out) and post-DASO defects period until the time the vessel is fully operational and ready to sail on patrol.

To each SSBN is appointed a Project Manager whose function is to link

PROJECT MANAGER'S CONTROL ORGANISATION

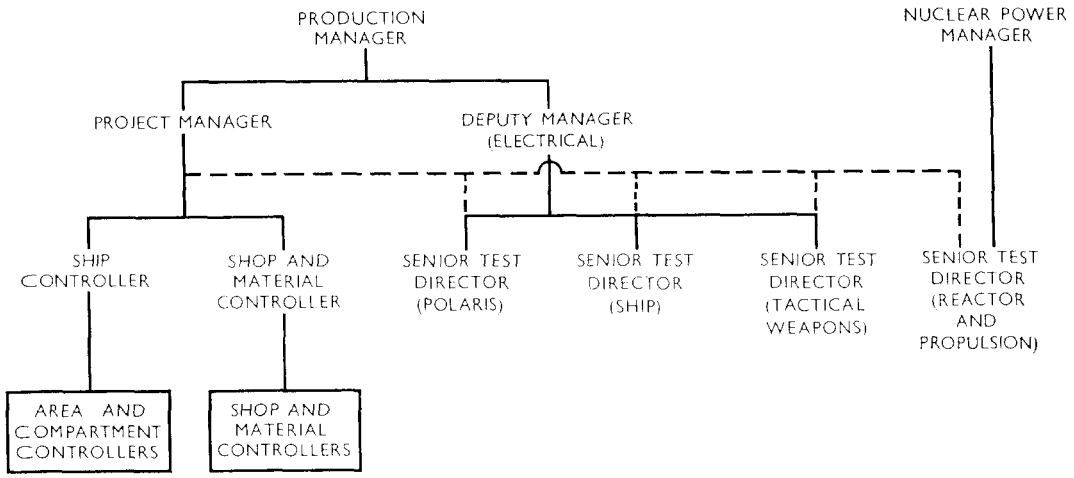

FIG. 1

together all facets of pre-refit, refit, and post-refit activities contributing to satisfactory and timely completion of the whole process. Towards this end, he is the focal point of contact for ship's staff, headquarters, and external authorities generally. The Project Manager is administratively responsible to the Planning Manager during the pre-refit phase, and to the Production Manager during the refit phase.

During the pre-refit phase, he will have five professional Main Grade Officers under him, namely constructive, mechanical and tactical weapons, electrical, polaris weapons, and nuclear (see FIG. 1), who, with their respective planning staff, will deal with all the planning, stores ordering, and scheduling activities associated with this period.

Near the start date of the refit, the Project Manager will be transferred administratively to the Production Manager. He will take over the SSBN control organization and will move to the SSBN refit building, situated between the two nuclear refitting docks. During the refit phase, he will manage the dockyard's adherence to the plan which he and his staff have prepared. His authority stems from the schedule itself, inasmuch as he is responsible to the Production Manager that the work is carried out in accordance with that schedule and for the capacity assessments that have been made. He has the Production Manager's authority to direct the non-industrial staff of the Production Department as necessary to achieve adherence to the schedule and to administer situations involving the preparation of recovery schedules. He plays no part, however, in the direct administration of industrial labour.

To enable the Project Manager to discharge his function, all officers in charge of production centres or test groups having day-to-day responsibility for some facet of the refit task are required to report to the Project Manager's organization regularly and particularly if the timely completion of their task is threatened. The Project Manager is authorized to resolve interface problems directly with the main grade officers in all departments, although those officers remain responsible to and are administered by their departmental deputy managers.

During the refit phase, the Project Manager has a staff of two main grade officers, the Ship Controller and the Shop and Material Controller, working as a team and each capable of deputizing for the other. The duties of these officers are as follows:

(*i*) The Ship Controller co-ordinates all refitting activities at the ship and between production centres, convening such meetings as are necessary to resolve problems as they arise. He is responsible for the preparation of recovery schedules where scheduled dates cannot be held, and for monitoring the progress of the refit by means of the computer-based monitoring system (PROMMIS—Progress Monitoring and Management Information System) supplemented by the reports of his staff and by personal observation. He is responsible for the acceptance or rejection of additional work at the ship.

To assist him he has a staff of three Area Controllers one for each of the three major divisions of the ship, i.e. forward end, reactor compartment, and after end, who themselves each have a number of Compartment Controllers. These officers deal with the everyday problems at the ship, indicating priorities of work in their own compartments, resolving congestion problems, monitoring and reporting progress, etc.

(*ii*) The Shop and Material Controller has precisely the same responsibilities as the Ship Controller, except that he deals with the progress of work through all the shop centres in the yard. He is responsible for producing detailed schedules for all shop work and ensuring that they are related to the removal and replacement of equipment from the ship. He is also required to give assistance to the production centres in the procurement of stores and spares, if all normal channels of stores procurement have been explored without success.

The Project Manager for a nominated SSBN will be appointed to his post about fifteen months before take-in-hand date. At this time, the preceeding Project Manager will be transferring to the Production Department to carry out the refit phase of the SSBN about to come in hand. The new Project Manager will take over the SSBN Planning Teams, finish off any outstanding planning activities on the refit of the current boat, and start the planning of the refit of the next one at least twelve months before it is taken in hand.

In addition to the Project Manager's organization, a Dockside Test Organization was instituted. The tests and trials of a nuclear submarine call for a more rigorous standard of organization and control than has ever previously been attempted. The potential hazards of a reactor accident coupled with the complexity of the equipment and systems being tested, and the possible interrelation between tests and trials which might, at first sight, be considered entirely independent, make it necessary to form a properly constituted test organization to ensure the safe, efficient and timely completion of the refit. The Dockside Test Organization comprises four separate but linked organizations to deal with the following:

(*i*) Reactor and Propulsion Systems
(*ii*) Polaris Weapon Systems
(*iii*) Tactical Weapon Systems
(*iv*) Ship Systems, which cover everything not included in (*i*) to (*iii*) above.

Each Test Organization is administered by a Senior Test Director (Commander R.N.) who is responsible to his Deputy Manager for the organization and conduct of the appropriate tests and trials, and to the Project Manager for the execution of these in accordance with the schedule (See FIG. 1). Each test team is staffed with the necessary basic, technical and drawing office grades and also has industrial labour attached to it for assistance in carrying out tests and rectifying defects on the spot.

The refit phase itself can be split into two main sections, namely production and testing. Some tests and trials start within four weeks of the ship being taken in hand but the bulk of the testing really gets under way after about six months.

Thus, over half of the refit phase is devoted to tests, trials, setting to work, and rectification of the defects found on test. Only half of the time in hand is given to actual refitting work, and this is where the need for refit by replacement becomes evident.

The Pre-refit Phase (Planning and Scheduling)

The Alterations and Additions Working Party holds a number of meetings, the final one of which is the SCRUTIT meeting at which the As and As are categorized and selected for the refit. Guidance information is forwarded to the dockyard and work in the drawing office is started on the production of A and A drawings and material lists. The SCRUTIT meeting is held about fifteen to eighteen months before take-in-hand date and a moratorium is applied from the date of the SCRUTIT. Any additional alterations and additions which the dockyard may be asked to undertake in accordance with the change control procedure must be of mandatory status and be submitted to the Board for approval to break the moratorium.

Some twelve to eighteen months before take-in-hand, the 'Work Package' is received from DPT (S/M). This is a datum document and all changes, either additions or deletions, to it are subject to a change control procedure from this time onwards. The Work Package will comprise:

(*i*) All planned maintenance items of refit periodicity plus all four-annual, two-annual and docking items which would fall due during the ship's time in refit (Items of less than two-annual periodicity are generally undertaken by the ship's staff, where applicable). These maintenance schedule items form the bulk of the Work Package and include such work as a hull survey and extensive preservation painting, a refuel, opening up of one main engine and one turbo generator, inspection of gearing and clutch, repair by replacement of some 300 major equipments and about 600 valves and cocks, NDT inspection, cleaning and repair/renewal of about 3000 pipes large and small.

(*ii*) As and As on the following basis:

(*a*) All mandatory As and As are to be undertaken.

(*b*) Priority I(a) As and As are also to be undertaken unless the dockyard feel that they are an unacceptable load for the timescale involved, in which case they are negotiable.

(*c*) Priority I(b) As and As are only undertaken if there is an advantage to the conduct of the refit. In some cases it is easier to do the A and A than to carry out a maintenance routine on a certain item. In other cases, the work could be used to even out the peaks and troughs in the work load of any one trade. A new procedure, using a system of Military and Essentiality Codings, which provide a numerical marking for the importance (priority) of an A and A, has recently been introduced. However, this does not alter the above principle for including As and As in the Refit Work Package.

(*iii*) Those outstanding equipment modifications considered by the A and A Working Party to be equivalent to Priority I(a) As and As and for which kits and information were forecast to be available by the start of the refit.

(*iv*) Defects raised by ship's staff or DPT (S/M) on Forms S2018 both before and during the refit, this being the major source of additional work. Such items raised before the refit are categorized by FOSM and DPT (S/M) and forwarded progressively to the dockyard for inclusion in

the Work Package. A series of pre-refit tests, aimed at revealing defects which would not normally become evident during normal use, are carried out on systems and equipments some six months before the refit start date. A pre-refit hull survey is also carried out. Defect items raised on Forms S2018 after the start date are negotiated directly between the ship's staff, the local DPT (S/M) office, and the dockyard so that they can be processed quickly.

From the time of its receipt, the Datum Refit Work Package is subject to the formalized change procedure. Changes in specification, design, configuration, arrival of equipment behind schedule, modifications, A's and A's, maintenance schedule amendments, PIL amendments, etc.—all have their downstream effects which invariably result in extra work at the 'coalface'. Thus, any changes to the Work Package, whoever has proposed them, are channelled through DPT (S/M) and CED before being forwarded to Rosyth.

The Project Manager's organization is the sole authority for the acceptance of work on SSBNs during the pre-refit and the refit phases, and all change proposals and S2018s are passed to his staff in the first instance. The changes are scrutinized by the Project Manager's staff who, in consultation with line production officers and, if applicable, the Nuclear Power Department, assess the work content and investigate any interference factors. The change is then either accepted or rejected with an explanation of the reasons for doing so. If rejected by the dockyard, DPT (S/M) still have the option of insisting that the change should be accepted, and the dockyard are obliged to state what penalties (in terms of money, time, interference, contract assistance, etc.) would result.

The only other way in which work can be taken on is by the S2018 procedure. Again each S2018 is passed through the Project Manager's organization who assess the implications to the schedule. (For H.M.S. *Resolution*, about 1600 S2018s were raised throughout the entire refit). In the case of a rejection by the dockyard when the ship particularly want the job done, DPT (S/M) arbitrates and the procedure thereafter is the same as that for a rejected change proposal.

Any work which involves changes to configuration, rectification of build defects (so called 'original sin' defects), or departure from drawings, is referred, together with an indication of the dockyard's preparedness to undertake the work, to DPT (S/M) for decision. In fact the number of change proposals or S2018s rejected was very small; this was largely due to the excellent relations which existed between all interested parties, who met regularly and understood each others problems. In a refit of this type there can never be too much communication between the authorities involved and this philosophy was fostered throughout.

The Project Manager's planning staff now examine the Work Package in detail and, after consulting handbooks and drawings and making numerous visits to the ship, dissect and transform it into a form suitable for use by the production centres. This involves the creation of about 4500 job orders, each one being an instruction and authority for the work detailed on it to be carried out by the production department. Each job order covers separately the various aspects of a job, such as: remove, repair, replace, test, manufacture of items, etc. Each job order has a unique number which is related to the system or equipment in the ship and to an area of the ship, which is sub-divided into a number of compartments. Each job order should be a logical refitting activity and should include work which will:

(*i*) form a continuous sequence
(*ii*) be co-ordinated by one lead centre
(*iii*) have a definite beginning and end.

The job order defines explicitly the task to be undertaken and provides, either by

inclusion of or by reference to other documents, the information necessary to carry out the task. Associated documents may include drawings, handbooks, procedures (for nuclear work and work on the Polaris systems), specifications, quality assurance documents, PILs, some or all of which may be required for the job.

The text of the job orders contains instructions on what to do, but not how to do it. For nuclear and Polaris work, the procedures provide detailed step by step instructions for each job. These procedures are mandatory and no job on the primary systems is allowed unless an authorized procedure is being used. The job order defines the boundaries of each job (e.g. where to disconnect cables and pipes), states what is to be done to the equipment or system components, indicates what associated work is necessary, points out any prerequisites which must be fulfilled, etc. It will also include other useful information, such as the weight and dimensions of the equipments, test pressures for system components, etc.

Concurrent with each job order, a list of material requirements (MATREQ) is prepared. This is a list by stock number of the stores and spares which may be required to do the job. This list is passed to the material co-ordinating group (MATCOG) who take the necessary demanding action on the appropriate depot. The MATREQ is also used by the production centres as a document which they can present at the main store for requisitioning spares.

The MATREQ, the job order, and any other references considered necessary to do the job are issued to the appropriate centres about three months before the ship arrives. Each production centre's trade office then extracts these job orders in accordance with the schedule promulgated to them by means of the computer print out, and raises the necessary work instructions for issue to the technical supervisors on a weekly basis. The trade planning office also establishes the availability of material, physically earmarks that which is available, and takes the necessary hastening action for all vital 'not availables'.

As the operational control of all systems and the responsibility for ship safety remains with the commanding officer throughout the refit, strict control over the state of systems must be maintained by the ship's staff. All work instructions are therefore passed through the ship's control office so that a check can be kept on work and impending work on valves, pipes, and equipments to enable the system state boards to be kept up to date. The commanding officer has the power to block any work instruction which is considered likely to lead to a dangerous situation. This is a full time commitment for the ship's staff who have to work in shifts in order to suit the dockyard's routine.

Scheduling

Probably the most important task in the entire pre-refit phase is to produce a workable and credible plan, which is agreed by production centres and is thereafter updated continuously as the situation changes. So often in past refits, slippages from the schedule occurred which caused the plan rapidly to become so out of date that eventually it became discredited and each centre forged on as best it could, probably at the expense of the other centres. It is of vital importance to convince everyone that the schedule is a good one, that it will be kept up to date, and that it must be maintained. All scheduling and updating activities are carried out by the Project Manager's staff and agreed with the production departments.

For H.M.S. *Resolution*, a network analysis was done and a PERT programme run through the computer using about 6,000 activities. From this a critical path, together with the earliest and latest acceptable start dates for each job order, was obtained. Bar-charts were then prepared for each compartment and each job order was spread within its allowed float in order to achieve a balanced

labour loading for the production centres over the production phase.

For subsequent SSBNs, the Work Package was so similar to *Resolution's* that it was not considered necessary to do a network analysis for each one. For these boats, therefore, the first step is to prepare a 'key-event' schedule taking into account the many lessons learned during *Resolution's* refit. This schedule contains about 250 major events occurring during the production and testing phases whose achievement will ensure a smooth passage to completion date.

The 'key-event' schedule is produced as a simple time-based bar-chart, although it also shows the dependencies of one event on another. Using this as a basis, each job order is individually scheduled on its own compartment bar-chart so that all the pre-requisites for each key-event are fulfilled. It is worth noting that these compartment bar-charts are not 'hard left' schedules, but that the jobs are spread in order to take account of a logical sequence of refitting as equipments became accessible and, as in *Resolution*, to achieve a balanced labour loading. The compartment bar-charts cover all work at the ship and are prepared by the Compartment Controllers. In conjunction with these, separate schedules are prepared by the Shop Controllers for all shop work, e.g. factory, pipe shop, shipwrights shop, boilermakers, etc. These schedules naturally have to be tied to the removal and reinstallation dates given by the compartment schedules. The Test Organisations produce their own schedules, also based on the key-event schedule. These cover the ship system-wise, so the completion of systems by compartment have to be tied in with the test schedules.

On a finer scale, a refit start schedule covering the first few weeks of the refit is produced. It was found from experience in *Resolution*, that one of the keys to a successful programme was to get the holes in the pressure hull cut as soon as possible. Five major holes have to be cut in order to get the removal routes working and a rapid flow of equipments from the ship to the shops; days saved during this period can mean weeks saved later on. The holes can not be cut until all the fittings in way of the holes have been removed; as this is mostly pipework and cabling, the ship has to be in a safe condition before these systems can be individually released.

A large number of interdependent activities, such as reactor cool-down, connection of a multitude of shore services, ship de-storing, resin discharge, dock down, pre-refit testing of some Polaris weapon systems, and release of ship systems (air, hydraulics, sea-water services, etc.) has, therefore, to be accomplished in a very short time. The refit start schedule covers this period in great detail and involves some rather complex network logic. The ship's staff play a major part in the production of this schedule and it is largely due to the close pre-refit liaison between the ship's staff and the dockyard that this period went so successfully in *Repulse's* refit.

Other 'mini-schedules', usually of about three weeks duration, may need to be produced from time to time during the refit when troubles occur in a particular area or system and recovery action is necessary to meet a particular key date.

Materials

Any successful industrial project hinges largely on the way in which material is handled. This covers every aspect of the process, i.e. removal of equipment, transportation, adequate identification, correct routeing, repair, cranage, spares identification and ordering, hastening, receipt and despatch, etc. The subject is too vast to do any more than give a superficial description of the procedures used at Rosyth which, although by no means perfect, are improving all the time.

Very few items were lost or mislaid during the refits of *Resolution* and *Repulse* due to the strict enforcement of identification and routeing disciplines.

The stores and spare gear system used is fairly simple; its main problems are caused by the large number of items with which it deals (about forty thousand line items). All SSBN stores and spare gear are held on an SSBN suspense account in one main store situated at the end of the dock. The only exception to this are the primary system spares which are held in the nuclear store and are subject to special controls.

The MATREQs are the source documents and being raised job by job the total material requirement is not known until all the MATREQs have been compiled; as this takes nearly a year, it is unacceptable to wait until their completion before taking ordering action. Each MATREQ is, therefore, compared to the stockholding in the store, and only additional quantities of any item or new patterns to the range are ordered during the planning stage. Admiralty supply items for A's and A's are provided by Headquarters and are not included in this system.

As production centres draw material from the store, an automatic 'top-up' action is initiated and that item is re-demanded for the next SSBN. Re-provisioning action well in advance of the requirement is, therefore, being taken all the time, thereby giving the supply depots plenty of notice to satisfy the demands.

A well-defined hastening procedure for 'non-availables', understood and operated by all authorities, has been instituted; it is designed to ensure that the requirement is a real one and that all reasonable alternatives have been investigated. It is at this point that the Project Manager's Shop and Material Controller becomes involved. In any given situation involving the non-availability of spares, the options open are usually fairly numerous and the requirement is to investigate and decide on the quickest and most effective solution. The number of occasions on which the supply of a spare is the only solution is in fact remarkably small.

Control and Execution of the Refit Phase

The Project Manager takes over the SSBN control organization about three months before the ship's arrival. During this time, the job orders and MATREQs are being issued to production centres, the controllers are finalizing the schedules and agreeing them with production, scheduling information is fed into the computer, the material supply situation is monitored and problem areas highlighted, dockside services are checked available, regular meetings are held with the off-crew ship's staff, and already a considerable amount of production work is being progressed through the shops.

On the arrival of the ship, the main function of the Compartment Controllers is to ensure that the schedule is followed at the ship by monitoring the progress of work in their own compartments, by resolving priorities of work and access to machines and equipments, and also by means of the computer-based progress information system (PROMISS).

PROMISS

This has three main functions:

(*i*) It is the means by which changes to the schedule are communicated to production centres.

(*ii*) It provides a job by job statement of progress by monitoring the number of hours to be worked and highlighting any job which has overrun its scheduled dates.

(*iii*) It provides statistical data which can be used as an appreciation of the progress of the refit.

The computer is loaded with the following information:

(*i*) Job order number and title.
(*ii*) Compartments in which the job takes place.
(*iii*) The production centres involved.
(*iv*) The schedule start and completion date of each job.

A variety of print-outs can then be obtained whose value is different to each user, for example:

(*i*) It provides a complete list, in job order sequence, of all the job orders which have been raised showing the scheduled start and completion dates and highlighting by means of a 'D' (delinquent) any jobs which have overrun either of these scheduled dates.
(*ii*) For each individual centre, it provides a list of the jobs for which they have an input; this is in both job order sequence and scheduled start date sequence and also gives the same information as at (*i*) above.
(*iii*) It provides a list for each compartment in the ship of all the jobs in that compartment in the same form as at (*i*) and (*ii*) above.

It can provide information on the progress of any job by means of a 'Kimball Tag' feedback system. As hours are worked on any job, they are fed into the computer by means of these tags, and the machine then prints out the total man-hours by all centres on that job. This, when compared to an estimated figure, gives an indication of the progress of any job. Any jobs appearing on the 'delinquent' list can be investigated and the problem remedied or the job re-scheduled if necessary. Re-scheduled jobs are also highlighted by means of an indicator so that they can be picked up quite simply and the necessary action taken.

Statistics of job order starts and completions, by centre and by compartment, are also provided. Statistics of this nature are a useful indicator of the progress of the refit and provide data for monthly progress presentations given by the Project Manager to the Port Admiral and the General Manager of the dockyard. The Deputy Controller Polaris, DPT (S/M), CED, FOSM, and the Captain SM10 also attend or are represented.

The refit itself hinges round several major milestones and all effort is directed towards meeting these dates. The first, already mentioned, is the completion of the cutting of the holes in the pressure hull allowing the major equipment exchanges to take place and the removal of valves, fittings, pipes, etc. to the shops for refit. This strip-out period lasts only a few weeks during which time items are removed from the ship at a remarkable rate, hence the need for a strict discipline in the identification of all items.

The following period, although quieter in the ship, sees intense activity in the shops. The nuclear refuellers are, however, working in three shifts to finish the refuelling which is the next milestone due to complete. Apart from this, the major activities at the ship are the implementation of A's and A's, the painting of bilges and bedplates of machinery while they are accessible, and the refit of some items *in situ* which are better treated in this manner. This period lasts for roughly eight weeks and then activity gradually builds up as equipments are replaced, pipes are returned, valves, cocks, and fittings are reconnected and system testing begins to gather momentum, although in some areas, particularly Polaris, testing has been going on since the middle of the first period.

The next major milestone occurs when the dock is partially flooded, although not sufficiently to lift the boat off the cradle. This flooding, although it is principally to progress tactical weapon testing, really signifies the end of the production phase as all the holes in the pressure hull must have been replaced and radiographed, and hence all the equipment must have been completed and the major systems pressure tested. There follows concentration on the reactor and

propulsion systems because the next milestone is the start of Cold and Hot Ops; these are a series of tests and trials of all the reactor systems followed by the steam, feed and lub-oil systems culminating in taking the reactor critical for the first time and then working it up to full power.

Each system will normally be subjected to a series of tests starting with an installation inspection, followed by a pressure and endurance test, and then flushing and setting to work. Deficiencies have to be rectified after each trial, bearing in mind that in order to take the reactor up to full power the majority of the systems in the ship have to be fully operational.

After completion of power range testing, the refit enters its final period during which defects are rectified, the finishing trades, i.e. joiners, sailmakers, painters, etc., are allowed in to complete the ship. This is not, however, the end of the dockyard's commitment as the Test Organizations still have an input during the sea trials period and during the subsequent defect rectification period which is carried out at the Clyde Submarine Base using dockyard labour.

Role of the Ship's Staff

The role of the ship's staff is a vital one. Both SSBN crews are appointed to the ship for the refit and they are fully employed all the time. Their duties and responsibilities are the traditional ones of a ship in refit, namely: welding sentries, reviewing spare gear, witnessing opening up and closing of machinery and all tests in the shops, security, etc.

In addition, however, operation of all systems throws a considerable load on them as they have to vet all work instructions and be represented at the preparation and authorization of all test procedures. They also have a considerable work package of their own in carrying out the maintenance of annual periodicity and less. Furthermore, they have to continue the operation and maintenance of all completed and signed off systems.

Finally they have a large training commitment not only to maintain qualified operators at a high state of competance but also to bring the state of competance of trainees to as high a level as possible.

The life of an SSBN ship's company in refit is not an easy one.

Conclusion

The procedures described have been proved during two refits and, with minor modifications, have survived. Doubtless they will evolve and improve from refit to refit as experience is gained and the learning curve ascended. There are still a large number of problems which remain to be solved, and no procedures devised by man will run 100 per cent correctly. They are, probably, in the majority of cases procedures which would only work at Rosyth and they are undoubtedly expensive to operate. The expense can in part be measured by the need to employ non-industrials and industrials in equal number at Rosyth for each SSBN refit. On the other hand, how much is it worth to keep the nuclear deterrent at sea?