# PRACTICAL TRAINING OF NUCLEAR SUBMARINE POWER PLANT OPERATORS

BY

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## Introduction

This article is about the further training of officers from those courses at R.N.C. Greenwich (described in the preceding article by Professor Edwards) designed for operators, namely the Nuclear Advanced Course and Nuclear Reactor Course. The practical training of these operators is carried out in two stages: first, they undergo about three months of formal operator training at H.M.S. *Vulcan* at Dounreay, on the north coast of Scotland, followed by

*H.M.S. *Vulcan*, was formerly known as the Admiralty Reactor Test Establisment, Dounreay.

just over three months' training 'on the job' in their first nuclear submarine, before sitting the final examination for a watchkeeping certificate as a Nuclear Engineer Officer of the Watch. At H.M.S. *Vulcan* officers and ratings combine for the first time for nuclear training. Between 30 and 40 officers and about 150 ratings attend the practical courses each year. Of these, 20 to 30 officers and 100 ratings become fully trained nuclear power plant operators; the remainder are doctors, medical technicians, or semi-skilled ratings who are destined for specialist work elsewhere in their submarine.

The aim of naval nuclear operator training, as distinct from the other requirements described by Professor Edwards, is to produce in the shortest possible time an officer who can be relied upon to control the operation of the plant safely and intelligently under the most exacting circumstances in peace or war, and it is the 'most exacting circumstances' that matter and which give naval nuclear operator training its own piquancy and peculiar problems. One can learn to operate the plant safely through ability to absorb drill, and intelligently through ability to apply an understanding of it, but these alone do not enable the Engineer Officer of the Watch to appreciate the needs and orders of the Command and hence permit the submarine to develop its maximum effectiveness as a fighting unit. It is the ability of the operator to do all these things when he is physically exhausted and mentally tired, and when submarine safety as well as nuclear safety is at stake, which calls for the superior qualities that those in charge of trainee naval officers must be confident of proving in every trainee.

The trainee operator may have been qualified for many years as a mechanical or electrical engineer; he may have been trained by the Navy, industry, and/or university. He may be an honours graduate or ex-rating, an experienced submariner or from general service—in fact, if he is a qualified naval engineer his probability of being fed into the 'operator' series of courses is high and the very small failure rate shows that his probability of qualifying is almost as high. If such an officer is inexperienced, the training staff's confidence in his future ability to operate safely (from both submarine and nuclear points of view) is derived from his background, from judgement of his natural ability as an 'operator' (rather than as a project leader, engineer, or administrator) and from assessing his innate sense of the balance between the needs of the Command and his own as controller of the propulsion plant. Confidence that electrical engineers will operate mechanical plant intelligently (as well as safely) and vice versa results from the knowledge that at H.M.S. *Vulcan* the trainees are given ideal conditions in which to learn to harness their natural academic prowess to the approved drills and procedures in the several disciplines involved.

It is necessary also to give practical instruction in subjects which officers have not normally encountered in their previous engineering experience. e.g., water chemistry, atmosphere control, and health physics. During basic training priority is given to chemistry though a good working knowledge of the other two is expected. Full competence in these fields is not expected from engineers until practical experience in the submarine has had time to assert itself. Doctors, however, must be competent in these aspects on arrival in their submarines.

Professor Edwards has already indicated the rapid expansion in the submarine service which took place to meet the nuclear programme. Practical training is therefore devised to train all experienced submariners, not only the ablest ones, for nuclear seagoing duties. This has proved to be a practicable policy capable of modification for the less experienced officers now coming into nuclear submarines direct from basic training. All leave Greenwich with their minds attuned to the degree of understanding and effort needed to achieve the informed and instinctive reactions which are the hallmark of a good operator of sophisticated plant. At H.M.S. *Vulcan*, using ratings as instructors, the sound theoretical basis imparted at Greenwich is exploited to drive home the practical means of propelling the nuclear submarine and the techniques necessary to operate the power plant.

## H.M.S VULCAN

### General

The establishment has three main tasks:—

(*i*) To operate and test submarine prototype machinery as required by the Ministry of Defence and to advise on methods of improving the power plant.

(*ii*) To advise the Ministry of Defence on component design and maintenance procedures for submarine power plants.

(*iii*) To train officers and ratings in their duties as operators of nuclear submarine power plants.

The first two tasks are performed by civilian contractor's personnel and four naval officers (three engineers and a doctor). The naval officers provide liaison with the Ministry of Defence and approve all procedures and trials schedules. The training task is carried out by the Navy assisted in the prototype itself by the contractor's operating staff. The R. and D. requirement tends to fluctuate more than the training requirement, but both aspects are given approximately equal emphasis in terms of allocation of time and resources.

During the early part of practical training it is useful to get the relative importance of systems in perspective. This requirement is met ideally by the Navy's facilities at H.M.S. *Vulcan* where trainees and instructors are free from the day-to-day distraction of administration, maintenance, etc., encountered in an operational submarine and from the restrictions imposed by a warship's operational programme. About 10 weeks of training time are saved in this way. (Later the inexperienced submariners must also master the many other non-propulsion plant operating requirements which are peculiar to submarines, but any attempt to teach these at Dounreay would only be confusing and time wasting.) Another advantage of practical training in a prototype is the opportunity it offers to overcome one of the problems mentioned by Professor Edwards, namely the relatively short shelf life of theoretical instruction in this field. Officers who have joined submarines that are still at the builder's yard have faced this severe problem and return, whenever possible, to practise at H.M.S. *Vulcan*. The trainee receives ordered and concentrated instruction in the classroom, on a simulator which resembles very closely the manoeuvring room of a submarine, and in a prototype submarine nuclear propulsion plant; he should leave with a clear idea of how to concentrate his energies on arrival at his submarine for his final phase of training.

### Instruction at H.M.S. 'Vulcan'

Classroom training is conducted as normal daywork, but practical training is carried out in a three-shift system.

The trainee spends his first two weeks in the classroom learning component detail and systems. This period is interspersed with frequent demonstrations on models, on the simulator, and visits to the prototype. He then spends a week in the simulator becoming familiar with the operating panels. This is followed by two more weeks in the classroom which includes a progress examination. This examination is used to determine whether a trainee may sit usefully, yet safely, alongside a panel operator, as understudy, in the prototype. Further confirmation of this is obtained on the simulator during the next week. Should he fail he is given extra private tuition in the evenings and is scrutinized closely to determine whether his shortcomings are due to his background or inherent lack of ability. At this stage there follows a course of three days in health physics, atmosphere control, and water chemistry, followed by a combined examination. These three subjects are taught by a naval doctor and a chief medical technician (both qualified submariners) using the facilities of the prototype and a training laboratory.

The classroom phase is conducted with the aid of the most modern appropriate techniques, account being taken of instructor/class contact hours, optimum length of lectures, and so forth. Detailed lesson plans are kept available to maintain flexibility; if any instructor is indisposed his lectures can be delivered by another with minimum disadvantage to the classes; typical headings for sections of these plans are: 'Object of lecture', 'Reference books', 'Training aids', 'Order of presentation', 'Depth of treatment required', etc.

The second half of the course is all spent on practical application. The trainees spend about 1½ weeks on the training simulator learning normal operating procedures, then 1½ weeks in the prototype practising these on the real thing, supervised by the Navy's operating contractors at H.M.S. *Vulcan* Rolls-Royce and Associates Ltd. The trainees spend most of the shift in the prototype performing training operations for their own sake and the remainder observing, and perhaps taking part in, research and development; this maintains attention, stimulates interest, and increases depth of understanding. After a written examination they return to the simulator for a week of demonstration of, and practice in, emergency operation. It is now that the simulator really comes into its own: great care and attention was given to the equations governing the simulator and its interface equipment; the maximum credible accident may be exercised with impunity! Classes can thus be given very full training in nuclear emergency drills which could not otherwise be practised. There is evidence to show that this is of paramount importance. At the end of this they take the final examination in the form of an oral Board chaired by an officer with seagoing nuclear operator's experience. Trainees are then given a final oral board.

## Instructors

The instructional staff consists of three officers and 17 senior chief petty officers. They have to spend some months at H.M.S. *Vulcan* learning their subject before they can be considered competent to teach it. One-third of the instructors teach in the classrooms, one-third supervise training in the prototype, and one-third supervise training on the simulator. Senior ratings give 95 per cent of all instruction. The officers on the training staff are responsible for policy, for the broad lines that lectures and examinations should follow, and for explaining the more recondite aspects of the syllabus; and if, owing to intense practical application training, some of the depth of understanding acquired at the R.N.C. Greenwich recedes in the minds of the trainees, the officers are there to indicate how this extra depth will be needed and applied in the future.

## Examinations

Separate examinations are held in mechanical and electrical aspects of operation to monitor progress during the classroom phase, but the examinations in health physics, water chemistry and atmosphere control are combined.

A system of marking the practical ability of the students has been devised and the marks so gained are over 40 per cent of the total gained on course.

The final oral board takes about 50 minutes per candidate, and is designed to probe his weaknesses and allow the examiners to judge whether he will make a safe operator. In making this assessment, the reports of the several instructors from the practical phases of the training are also considered.

**Failures**

The pass mark for all examinations is set at 65 per cent. This is considered to represent the lower limit of knowledge which will ensure that a candidate will be likely to absorb satisfactorily the further training in his first nuclear submarine.

Those who achieve below 65 per cent in any given examination are given additional instruction and subsequently re-examined. If then successful, they are awarded a nominal 65 per cent mark and allowed to continue the course. If unsuccessful on re-examination, they are carefully considered for removal from nuclear training or for employment elsewhere in the nuclear programme where aptitude as an operator is not necessary.

With the lack of outside distractions in the far north of Scotland and the intensive personal coaching and evening instruction available to trainees at H.M.S. *Vulcan*, the trainee who fails on re-examination is unlikely to become a successful nuclear plant operator within a reasonable time in his submarine.

The examinations and board provide a most useful measure of the effectiveness of the teaching given by the instructors, as well as a yardstick of individual achievement on the part of the trainees. The simulator offers a possible alternative post for the type of instructor who proves unsatisfactory in the classroom but who has the technical ability to operate the plant.

## THE SIMULATOR

The simulator resembles closely the manoeuvring room of a nuclear submarine; it is governed by a high-speed digital computer containing 24K of store. Digital signals from the computer are converted to analogue form for display in the manoeuvring room (and vice versa) by a specially designed interface cabinet. The complete time cycle is 400 ms interrupted every 12·5 ms to allow the computer to up-date the displays in the manoeuvring room.

Apart from the obvious advantage of ability to simulate accidents and other incidents which would be unacceptable or dangerous on the prototype reactor plant itself, simulation may be 'frozen' at any time and recorded on a paper tape. Later, this tape may be fed in again and the class may start instruction with reactor and plant in this condition or any other desired by the instructor. Again, if, on the real plant, the operators make a mistake and shut down the reactor, it may take an hour to restart and get back to power; if a similar mistake occurs on the simulator it is only a matter of a minute to feed in the tape again and continue as if nothing had happened. Similarly, if the instructor injects a fault and the class fails to deal with it correctly, the instructor can return to the *status quo*, explain where the mistakes occurred, and start again.

## THE SUBMARINE

After 2½ months at H.M.S. *Vulcan* it is time for the officer to apply his knowledge in the sea-going environment and work up to concert pitch for his final Fleet Board examination for a watchkeeping certificate as Nuclear Engineer Officer of the Watch with the hardware he will actually be operating in his first nuclear appointment.

For 3½ months in his submarine he serves as a watchkeeper in every position, whether it be pumping reserve feed water and bilges, or manning the most sophisticated control panel; thus he becomes fully conversant with the operation and implication of every valve, trap, cock, switch, and knob, and learns every system, equipment, and procedure. He will take oral and written examinations once or twice each week, qualifying first in each system, then each group of systems, finally undergoing a three-hour oral and practical formal examination conducted by a commander from the Ministry of Defence, with recent operating experience himself, and two experienced operators from the submarine.

This formidable looking programme is not as daunting as it might appear once the general technological and operating concept has been thoroughly grasped at H.M.S. *Vulcan*. In an operational submarine an officer lives with the equipment 24 hours a day and can discuss it at any time. He should therefore absorb the detail very rapidly indeed.

The achievement of the Fleet Board qualification is much more difficult for officers appointed to submarines still in the early stages of construction at the builder's yard or in refit. Here, shipboard operational qualification is a protracted process and such officers must be seconded to operational submarines for practical experience whenever possible. Nevertheless, the final test comes when an officer commissions his own submarine. This calls for immense concentration and stamina.

In the early days of the nuclear programme the Navy was training officers who were already experienced as practical seagoing engineers and submariners. However, nearly all the present generation of trainees come straight from graduation and must be taught to become submariners and practical engineers as well as nuclear propulsion specialists. Every attempt is made to give young engineer officers seagoing experience in either the surface fleet or a conventional submarine, but this is not always possible. In the future, with the disappearance of the very large sea training facility provided by the aircraft carriers, and the progressive reduction in the number of smaller surface ships driven by steam, officers may have received little or no steam experience before they start their nuclear training.

The balance between reactor safety and submarine safety is one which every operator must fully understand and is simply illustrated by imagining a relatively minor leak, say, of a gland in a sea water system when deep. This might cause no embarrassment in a conventional submarine, but because such a leak squirts with very great force over an element of reactor protection, the reactor may scram. Imagine now that the submarine has been travelling fast for some time and has become out of trim. If it is heavy, it is being supported by its speed and hydroplane lift and if now there is insufficient steam left for the submarine to drive itself up to the surface, and if it has a downward attitude at the time, main ballast air may also be insufficient to lift it to the surface. Designers must, of course, take this possibility into account but operators must instinctively know when such limits are reached and the Command must appreciate this too. Similarly the Nuclear Engineer Officer of the Watch must understand what is necessary when a manoeuvre by the Command requires full power in spite of potential compromise of reactor safety. In the past one of the necessary and strongest traditions of the submarine service was the need for every officer (engineer or seaman) to have a full understanding and experience of the other's responsibility. The technique of handling the submarine physically and tactically demanded this. The sheer size of the present task makes it unlikely that this versatility will continue quite to the same degree, but the need for appreciation of each other's task is stronger than ever. Achievement of this appreciation forms a very important part of the final stage of a naval engineer officer's training. More than ever there is the need for absolute professionalism.

## Conclusion

This article has perhaps given some idea of the challenge and satisfaction which a naval engineer officer can expect from his nuclear training. The naval nuclear programme brings every officer into close contact with the highly developed application of numerous basic engineering disciplines; it gives many officers the opportunity, early in their careers, to work closely with industry in vigorous research and development. The nature of the work at H.M.S. *Vulcan* provides a useful opportunity for industry and the Navy to compare methods, exchange information and, one hopes, learn from each other.

Finally, while it has been necessary in this article to conform with the requirements of defence security and to avoid politics, it may be said that the naval nuclear prorgamme has much in prospect and there is no doubt that it offers the young naval engineer officer an intensely interesting, vigorous, and broadly based technical training and a rewarding career.