THE STRATEGIC PLANNING PROCESS IN THE REMOVAL OF REFRIGERANT R22 FROM COOLING AND REFRIGERATION PLANTS IN ROYAL NAVY WARSHIPS

BY

COMMANDER B.N. DARCH, BSC, MDA, CENG, MIMECHE RN
(Ships Support Agency—ME235)

This is a slightly edited version of the paper presented at the Seventh Annual Conference of the Institute of Refrigeration 'R22 Phase Out—Impact on End Users Today', *held 17 November 1998.*

ABSTRACT

Faced with the requirement to comply with the EC Legislation resulting from the Montreal Protocol, the Royal Navy has produced a complete inventory of refrigerants and refrigeration plants, conducted design reviews, and formulated a strategy for the conversion or replacement of non compliant plant. From the agreed strategy, a plan has been prepared that dovetails with the operational programme and the expected maintenance cycle of the Fleet. Based on this plan, a taut and realistic bid for finance has been made to achieve the agreed target dates.

Refrigeration Plants in the Royal Navy

There are three main uses for refrigerants in warships:

(*a*) Refrigeration plant is used to cool a number of provision rooms (usually three in a ship of frigate size). The temperature of the rooms varies from $-20°C$ to $+45°C$.

(*b*) Chilled water plants cool a ringmain around the ship. This ringmain provides cooling to electronic equipment and air conditioning heat exchangers. Plants are normally in excess of 300 kW and numbers vary from around 4 for a frigate to 8 for an aircraft carrier.

(*c*) Self contained refrigerators, water coolers and icemakers (white goods) are numerous and are maintained by an 'upkeep by exchange' policy. Thus the change to compliant refrigerants is achieved by the normal turnover of machines.

Government directive

As a signatory to the Montreal Protocol, and as a member of the EC, the United Kingdom is committed to a reduction in the production and consumption and eventual use of CFCs, HCFCs and Halons. In 199O the MoD agreed the following approach (as applied to cooling plants) to ensure that it played its part in meeting the National targets:

(*a*) The cessation of the deliberate venting to atmosphere of Protocol controlled substances.

(*b*) The modification of existing plant so as to permit the earliest possible introduction of acceptable alternative substances as they became available.

(*c*) The elimination of the need to use Protocol controlled substances in all future designs.

(*d*) The modification of all MoD standards and specifications which provide for the use of the Protocol controlled substances, to eliminate the requirement to use them.

The Directorate of Marine Engineering, as the Design Authority and Equipment Project Manager, has taken the lead in formulating a Strategy Paper and preparing plans for compliance with the Montreal Protocol and EC legislation.

Gathering data

As a first step it was necessary to complete an inventory of refrigeration plants, and for each plant the capacity, and the type and size of refrigerant charge. This provided the starting point and the baseline for any future assessment of achievement. For the major warships this was not difficult but the RN operates a large number of smaller craft and these had to be included. The result of the survey is shown in Table 1.

TABLE 1—*Survey of chilled water and refrigeration plants (excluding minor vessels)*

CHILLED WATER PLANTS				
Vessel	**Total Number**	**Number of platforms**	**Type of Plant**	**Refrigerant**
T42 Destroyer/T22 Frigate	98	22	APV Baker 300kW	R12
Aircraft Carrier	24	3	APV Baker 540kW	R22
T23 Frigate	24	8	APV Baker 370kW	R22
T23 Frigate	24	8	York International 370kW	R22
Mine Countermeasures	50	25	Lightfoot Ref. 53kW/96kW	R22
Submarines	20	4	York International 400kW	R114
Submarines	48	12	York Int. 210kW/238kW	R12
REFRIGERATION PLANTS				
Destroyer/Frigate	22	22	Lightfoot Refrigeration	R12/R502
Aircraft Carrier	3	3	Lightfoot Refrigeration	R22
T23 Frigate	16	16	West Beynon	R12
Mine Countermeasures	13	13	Lightfoot Refrigeration	R22
Submarines	8	4	York International	R12
Submarines	12	12	Lightfoot Refrigeration	R12

Outline strategy

From the start it was decided to address the problem in three ways, namely:

a. Plant husbandry
b. Compliance on all new build/new design plants
c. Conversion or replacement of existing plant.

To reach agreement with all interested parties it was essential to 'spread the message' on the Montreal Protocol and this was achieved by a series of presentations, the 'Roadshow' as it became known. This provided the catalyst for detailed discussions with:

- The 'customers' (the operational Fleet)
- Original equipment manufacturers
- Lubricant manufacturers
- The Defence and Experimental Research Agency (DERA).

Within our own organization it was essential to work closely with the WPMs, the Ship Support Agency being a matrix organization, as shown in (FIG.1).

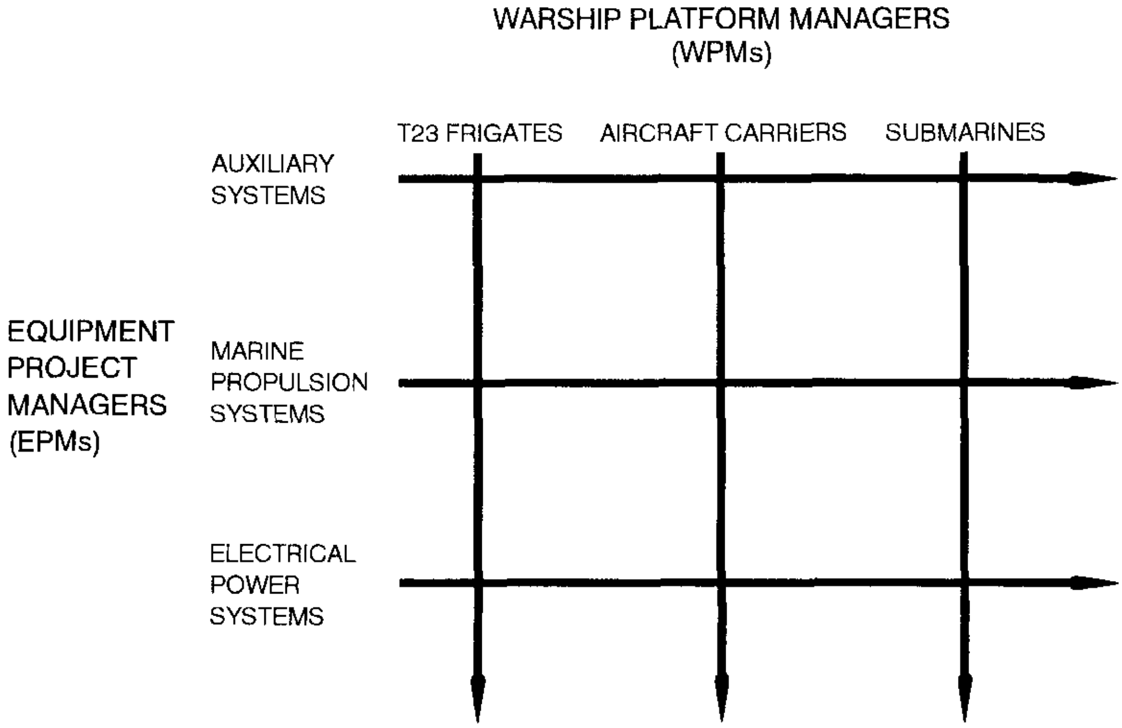

FIG.1 - SHIPS SUPPORT AGENCY MATRIX MANAGEMENT

The result of this was the production of a Strategy Paper to which all interested parties have agreed (FIG.2). This has remained a live document and has been updated as the strategy has evolved following trials and conversions. Every six months a meeting with all the interested parties has discussed progress, changes in plans and the future programme. This has ensured that there is complete agreement and that both operator and maintainer are working towards the same goal.

Plant husbandry

Emissions

The aim here is to reduce all refrigerant emissions to the atmosphere. This has been addressed by improving plant husbandry, primarily reducing refrigerant leakage and by completing a programme of modifications that enable the refrigerant charge to be isolated within the plant during maintenance.

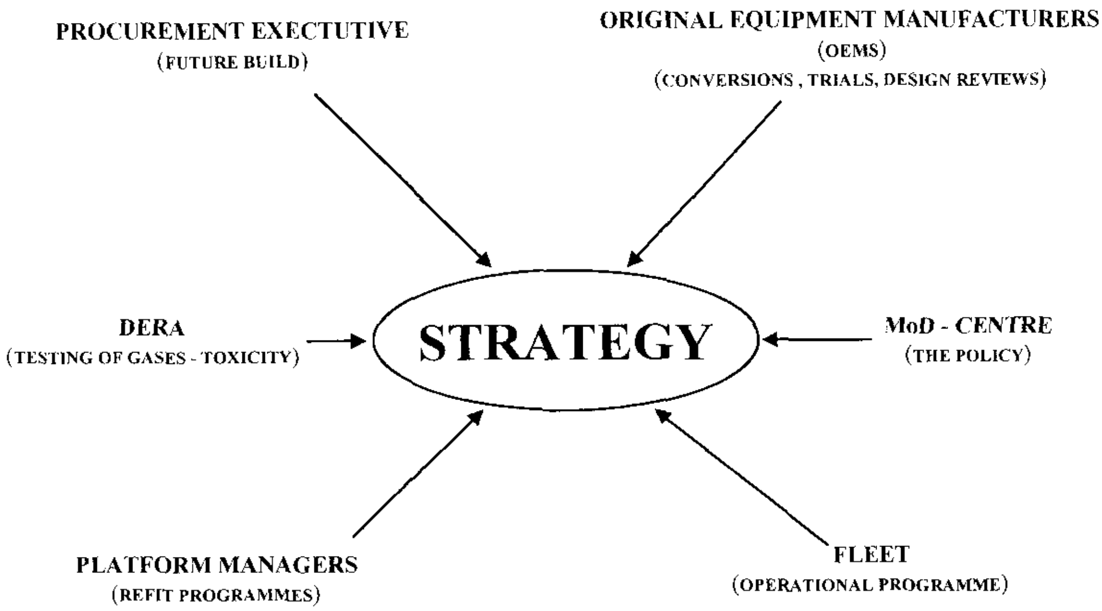

FIG.2 - AGREEMENT OF THE STRATEGY

Refrigerant Usage Monitoring

All ships and submarines are required to produce a monthly report of refrigerant used and refrigerant recovered and this is cross-checked with the issues from Naval Stores. The emphasis is on usage monitoring which readily identifies plant problems and hence leakage is minimized.

Leak detection

Long established methods using soapy water and/or hand-held lamps have always required a high degree of skill and knowledge of the plant to work effectively. To encourage good leak detection practice it was essential to find new leak detection methods that were effective, quick and easy to use. The strategy evolved two methods:

Firstly

Following a successful sea trial, a proprietary dye has been progressively introduced into the Fleet. This UV dye has shown that leaks previously not easily detectable with conventional methods can be found.

Secondly

It was decided that a fixed leak detection system would be necessary both for husbandry and as a Health and Safety measure. Such a system will be fitted to all new equipment and back-fitted where thought necessary and economical.

Refrigerant Recovery

Refrigerant recovery pumps and dedicated recovery cylinders have been provided to each ship and submarine to enable the refrigerant charge to be removed for disposal or recycling.

Compliance on all new build and new design plants

It was decided that all new design chilled water plants and refrigeration plants would specify the HFC R134a as the refrigerating medium. This was chosen because:

- It was the only single phase zero ODP refrigerant currently marketed.
- It was seen to have a secure supply.
- On many ships it eliminated the requirement to carry more than one refrigerant.

Conversion strategy

Policy

From the start it was decided to employ the Original Equipment Manufacturers (OEMs) in the conversion of their own equipment. Only complete replacement, if found necessary, would go out to competitive tender. Replacement of refrigerants in nuclear submarines comes with a host of problems concerning the submarine atmosphere. The major problem is the breakdown of refrigerants into carbon dioxide, hydrochloric acid and hydrogen fluoride when subjected to high temperatures. On inert surfaces the breakdown will not occur until about 600°C, but on an oxidising catalyst, as used in the equipment to remove carbon monoxide and hydrogen, breakdown will begin at about 250°C. Breakdown is accelerated by the introduction of R134a, and even more so by a mixture of refrigerants. Luckily these problems do not exist in the removal of R22 for surface ships.

Experience from the CFC conversion programme

The early work in the removal of R12 from the Type 42 and Type 22 chilled water plants provided invaluable experience. It was found that the greatest risk to the programme was the unforeseen, albeit necessary rectification work on the plants presented for conversion. To reduce this risk the OEM inspected the plants 4 weeks prior to the conversion and advised of potential problems. The decision was then made as to whether the rectification work would be carried out by ships staff, base services or by the OEM under the authority of a separate running contract. This system proved very effective, problems were identified early and rectified without delay to the programme. There is, of course, an additional small cost but this proved to be a wise investment.

Safety

The Ship Safety Management System requires either a Safety Case or Safety Assessment to be carried out on all new equipment prior to ship or submarine installation. This requirement has been included in the contract for conversion or replacement.

Appraisal of R22 replacement in surface ships

Background

The early design studies showed that the conversion of R22 plants to use R134a would result in a drop-off in performance of 35%-50% in the chilled water plants and a significantly greater amount in refrigeration plants.

Options

There are three options:

(*a*) Modify plants to use an HFC blended refrigerant. Blended refrigerants are becoming well established and early reservations concerning differential leakage and flammability have been largely resolved. Drop-in solutions are now available, making this a relatively inexpensive way ahead but the long-term commercial availability could still pose a problem. Warships operate worldwide and universal availability is a logistic bonus.

(*b*) Replace all HCFC R22 plant with a new plant designed to use HFC R134a.

(*c*) Bank HCFC R22 in support of existing plants and reject conversion. This would appear to be the most inexpensive and easiest option to implement however, the cost of banking and the requirement for bank facilities could make this an expensive option. There is also the risk that legislation will be tightened, such that banking will only be allowed for the support of equipment's for the period necessary to facilitate conversion/replacement. Indeed banking may not be allowed at all.

Blend Trials

Blend trials placed on the OEMs identified a number of 'drop-in' blend alternatives to R22. Evaluation continues but as yet there is no preferred alternative.

Chilled Water Plants

To establish a baseline, a redundant chilled water plant has been placed with the OEM where a series of trials will establish the performance of alternative blends against R22. At the same time design reviews for each class of ship have been placed on the OEMs to indicate whether it will be possible to convert to a blend without any reduction in plant performance. During some of the early design reviews concerns were raised about the effect of blend/ polyolester lubricant on the oil return system within some chilled water plants. This will be investigated during the trial.

Refrigeration Plants

With the exception of one vessel, where warships use R22 in the refrigeration plants, they fail to meet the temperature requirements of the Food Safety Act 1990. The Act stated that all quick frozen foods should be stored at a minimum temperature of −18°C; the majority of RN cold rooms were designed to operate at −10°C. A recent change to longer deployments has necessitated larger cold room capacity, achieved by conversion of one of the cool rooms. Taken together, these two factors will increase the projected load on existing plants. Using R134a results in a drop-off in performance at cold room temperatures and it soon became apparent that the present plants were incapable of accepting the extra duty on conversion to R134a. Therefore, it was decided to procure new plants using R134a.

Conversion specification

With the privatisation of the Royal Dockyards came a new way of conducting business. The ability to make up any shortfalls in the specification or bring in ancillary trades at short notice disappeared; we no longer worked for the same 'company'. The conversion work to be placed on the OEM or the fitting of the replacement plant by the winning tenderer had to be all embracing—a 'turnkey operation'. With the Invitation to Tender the manufacturers are given the opportunity to inspect the compartment within the warship and ask questions. The specification or 'statement of requirement', as it is known, is all embracing and includes removal of the old plant, where necessary, slinging, welding and setting-to-work. One important aspect is the power requirement. Running new lengths of cable in a warship is a nightmare. It is essential that the manufacturer either remains within the original capacity of the fitted cable and fuse panel, or specifies and costs a new fit. The contract will also include a Safety Case or Safety Assessment, amendments to handbooks, parts catalogues and drawings. In other words, the MoD does not wish to be caught with an 'extras bill'.

Conversion work

As stated earlier it was decided to employ OEMs on the conversion of their own plants. Only complete replacement would go out to tender. The OEM will be contracted to produce a modification kit and, following a pre-conversion inspection to unearth any hidden defects, install the modification during an appropriate window in the warship operating cycle. During a refit the ship is de-stored and access to the plant compartments is straightforward, but during a maintenance period the ship will invariably have to de-store to large portable units. Careful planning with the Fleet is therefore essential.

Timetable of work

Having selected a modification package and knowing from the OEM or winning tenderer the required fitting time, the real problem is identifying a window of opportunity. Warships, on average, undergo a refit every 7 years with an intervening docking period for underwater work and the repair of major defects. Maintenance periods of about 4 weeks duration occur about twice a year but these tend to be very hectic and invariably cover a leave period. Unlike a supermarket or brewery a warship moves about, spending over 60% of the time away from its UK base port. Conversion at sea is impossible as the plants are always in use or at immediate readiness. With these constraints in mind, negotiation with the WPMs will identify fitting opportunities. Other constraints are the ability of the manufacturer to undertake a number of conversions or replacements at the same time and, the ability of the MoD to monitor and accept the completed work.

Finance

Bidding for money within the Ministry of Defence is by a process known as the Long Term Costing (LTC). This spans a period of 10 years but only the first 4 are covered in any detail. Money is bid for, and allocated, based on agreed programmes; in this case the programme is in the Strategy Paper. The bid is based on budget prices from the manufacturers and experience. Plans are adjusted to match the allocated funds; the priority of Montreal Protocol conversion work being assessed against other Safety and Environmental programmes. The driver, of course, is the phase-out date in the legislation. Another factor, which has over shadowed our work in the last year, has been the Strategic Defence Review. This delayed some decisions until warship platform numbers had been finalized.

Follow-up work

Areas of follow-up work include:

(*a*) Feedback to ships in the form of graphs of the amount of refrigerant used (FIG.3). This encourages good husbandry and identifies problem plants.

(*b*) Taking account of the lessons learned from the CFC conversions and subsequent HCFC work.

(*c*) Ensuring that where more than one type of refrigerant is used aboard, accounting, maintenance and recovery procedures are correct.

(*d*) Monitoring plant performance and verifying output.

(*e*) Monitoring the long-term effect on lubricants and seals.

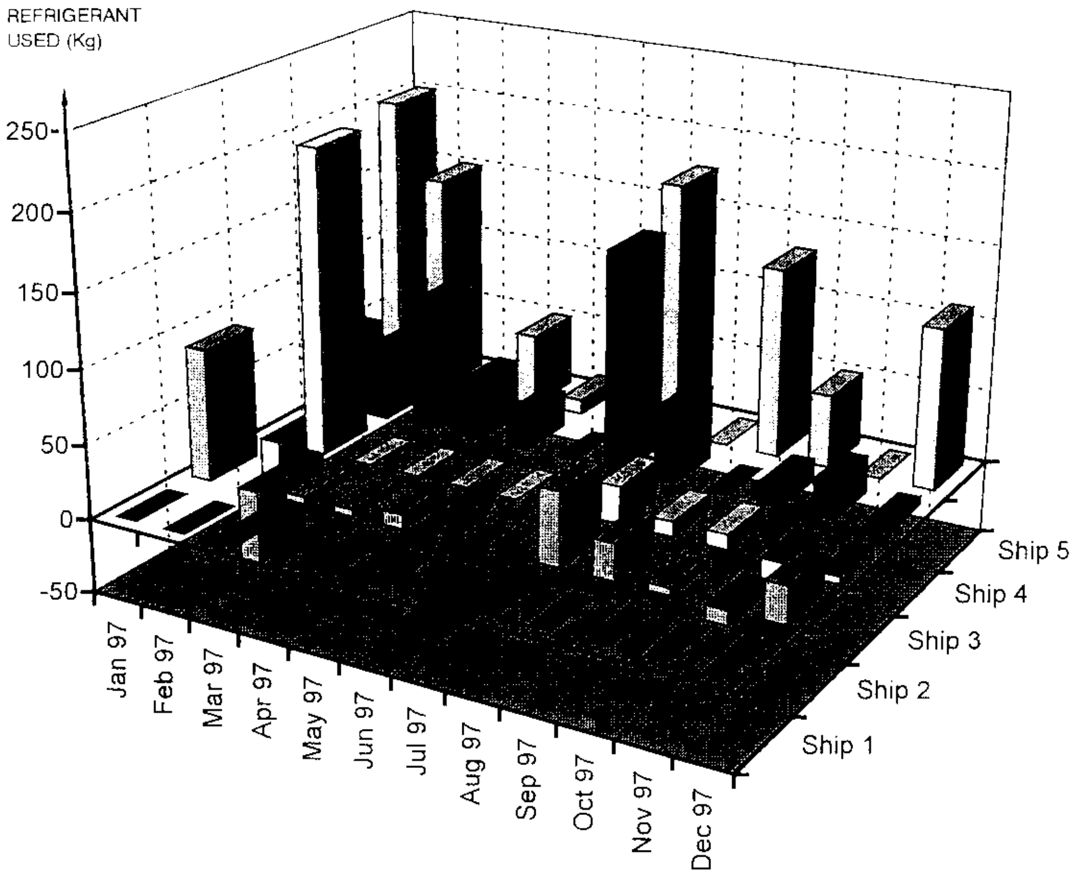

FIG.3 - TYPICAL GRAPH OF REFRIGERANT USAGE FOR A CLASS OF SHIP