ATMOSPHERE MONITORING DURING TRIAL OF CLEANING FLUIDS FOR SUBMARINE MAIN GENERATORS

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Introduction

The method of *in situ* cleaning of submarine main generators described in the previous article in this Journal inevitably presented a potential toxic hazard in confined spaces as most electrical cleaning agents are based on volatile organic solvents.

The Institute of Naval Medicine was approached in 1976 to ascertain whether the use of the Ayrodev generator cleaning process using Meggawash and Meggaboost cleaning fluids and Devolac and Salvameg varnishes was feasible on toxicity grounds.

The manufacturers were contacted and details of the constituents of the products were supplied under a 'Commercial-in-Confidence' cover. The volatile component of both Meggawash and Meggaboost was white spirit. This has a threshold limit value (TLV) of 100 ppm (Reference 1). The solvent in the varnishes is a mixed petroleum hydrocarbon (called SBP6) with a boiling range of 144–172°C and an aromatic content of 18·6 per cent. This has a TLV of 130 ppm (from the formula given in Appendix B3 of Reference 1) for calculating TLVs of petroleum distillates. A small amount of xylene (TLV = 100 ppm) was used to thin the varnish before spraying. In addition to the airborne contamination hazards associated with the use of solvents, care in handling is necessary to prevent skin contamination.

A meeting was arranged between the manufacturers, DPT14, FOSM, SM1 and INM on 15 February 1977 at which it was agreed that a trial would be carried out to enable FOSM and INM to assess the technical and health aspects of the process (Reference 2). INM would also assess in what areas of the engine/motor room and under what ventilation conditions other work could safely be undertaken during the cleaning process.

Ayrodev Process

Meggawash and Meggaboost are alternately sprayed into the windings and coils of a generator at 60–80 psi until the required level of insulation is achieved. At the pre-trial meeting it was estimated that about 15 gallons of Meggawash and 20 gallons of Meggaboost would be used. Ayrodev Ltd. stressed that the cleaning fluids were sprayed and not atomized implying that vapour droplets would be of sufficient size not to spread rapidly through the compartment atmosphere.

The volume of the submarine engine and motor rooms between 77 and 103 bulkheads was established at 11 500 ft^3. It seemed probable that the normal ventilation of the compartment would be inadequate to prevent considerable spread of solvent vapour away from the generator and the TLV being exceeded in areas of the engine or motor rooms where staff may be required to work. As the main generators are under the engine room hatch, FIG. 1, it was felt that the vapours could be prevented from spreading by creating a flow of air from the engine and motor rooms out of this hatch. This would be achieved by having:

(*a*) engine-room hatch open;

(*b*) 77 and 103 bulkheads shut;

(*c*) battery ventilation exhausting into motor room;

(*d*) ship's ventilation into engine and motor rooms;

(*e*) three DB fans on the casing with trunking through the engine room hatch, the best mode of operation (i.e. exhaust from close to the spray or supply to augment general ventilation) to be determined.

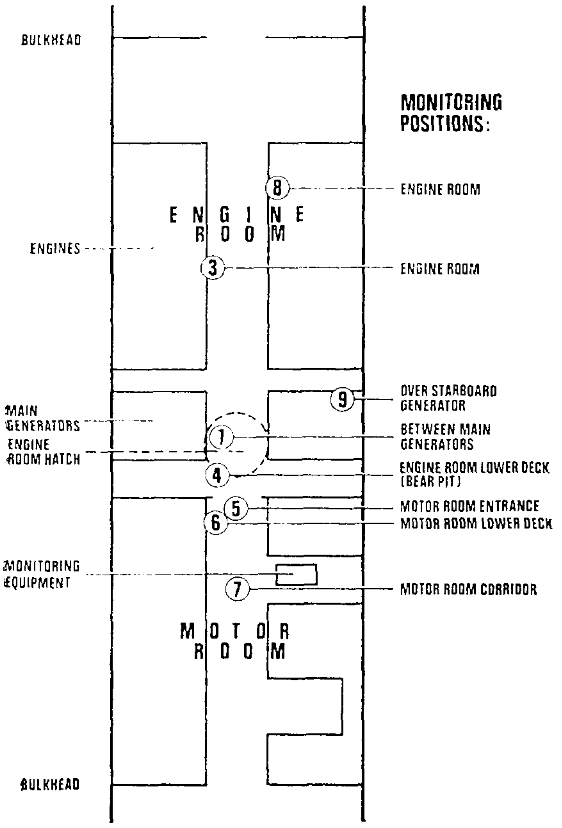

FIG. 1—DIAGRAM OF ENGINE/MOTOR ROOM

Analytical Method

Equipment

The concentration of white spirit vapour from Meggawash and Meggaboost, and SBP6 and Xylene vapour from the varnishes, was monitored during the trial using a pre-calibrated Miran 1A long-path infra-red analyser. Since white spirit is a petroleum fraction distilling between approximately 150°C and 200°C and normally containing a mixture of aromatic (about 15 per cent.) and aliphatic hydrocarbons, the only infra-red absorption band which can be used to monitor these mixtures is that due to saturated carbon-hydrogen bond stretching mode at 3·4 μm.

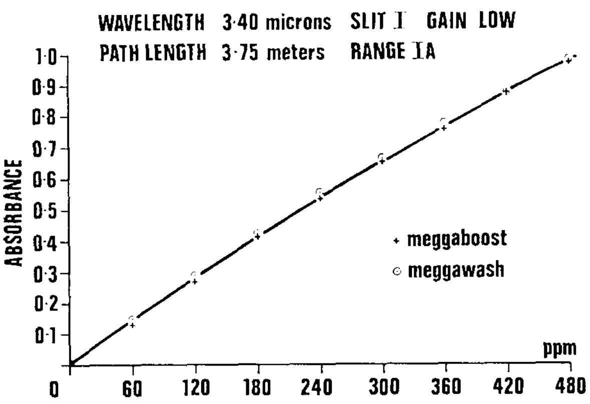

FIG. 2—CALIBRATION GRAPH FOR MEGGABOOST AND MEGGAWASH

Calibration

The Miran analyser was calibrated using solvents actually distilled from samples of Meggawash, Meggaboost and the varnishes. Successive 2 μl samples were injected into the Miran closed-loop calibration system to obtain the graphs shown in FIGS. 2 and 3. The solvents from Meggawash and Meggaboost gave almost identical near linear calibration lines. By assuming that the varnish solvent contained 25 per cent.

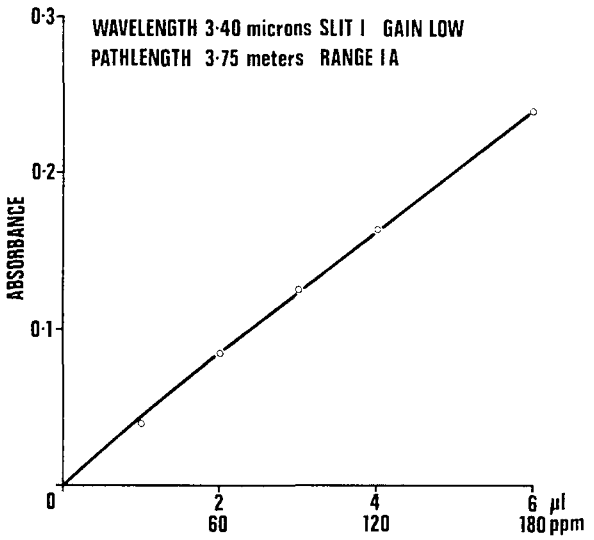

FIG. 3—CALIBRATION GRAPH FOR VARNISH SOLVENT

xylene (the xylene was added by hand just before spraying to obtain the correct varnish consistency), even though the true amount was probably less, the analytical error is on the side of safety due to the low sensitivity of xylene at the wavelength used.

Operation

An electric pump attached to the Miran sucked air through a movable probe line (30 ft long) into the instrument. A continuous record of absorbance (which can be converted to concentration in parts per million (ppm) from the calibration graphs, FIGS. 2 and 3) was obtained by linking the Miran output to a Phillips chart recorder which also acted as a time marker and log.

Trial Procedure

The trial started on the morning of Sunday 6 March and continued day and night until the afternoon of Tuesday 8 March when the varnishing was completed. The vapour levels were monitored in various positions in the engine and motor rooms the whole time during spraying operations except during the third and final coat of varnish. Any changes in the ventilation arrangements were noted.

As any hydrocarbon vapour will absorb at 3·4 μm it was necessary to ascertain if any background level existed in the engine/motor room of the submarine, caused for example by diesel fuel fumes, before the cleaning process began. This was carried out on Friday 4 March after the compartment ventilation had been arranged as described above. With the area venting in this way a considerable flow of air was achieved out of the engine room hatch, the average velocity being 1500 ft/min (measured using an ETA 3000 anemometer). This corresponds to a flow of approximately 4500 ft^3/min, i.e. an air change rate of about 25 per

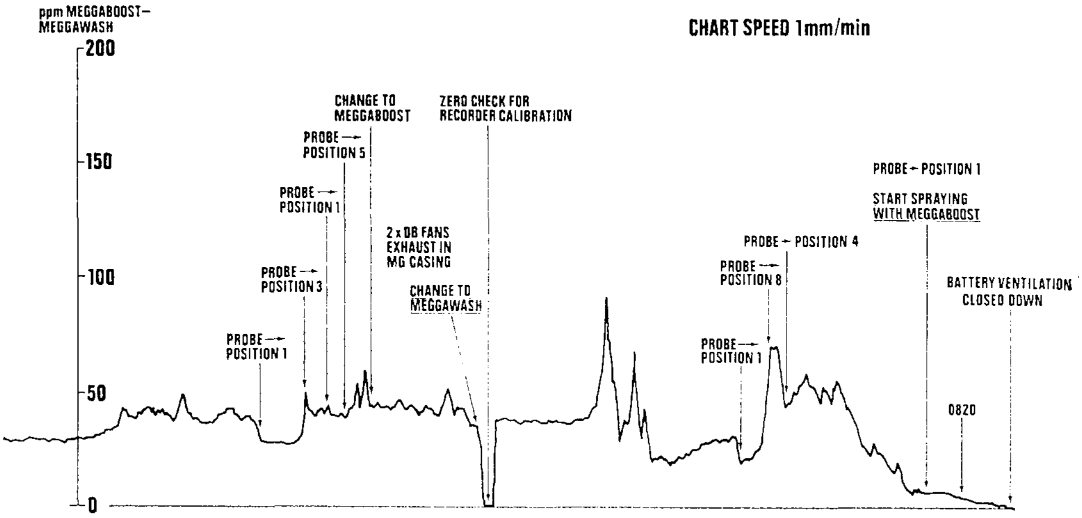

FIG. 4—REPRESENTATIVE SECTION OF TRACE OBTAINED WHILST SPRAYING WITH MEGGABOOST AND MEGGAWASH

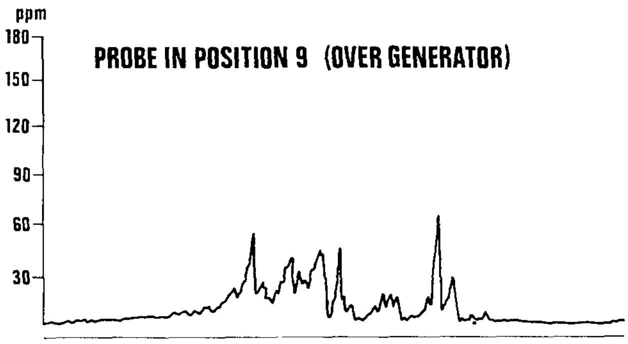

FIG. 5—EXAMPLE OF TRACE OBTAINED WHILST SPRAYING WITH VARNISH

hour for the whole engine/motor room area. As a result of this high rate of general ventilation, the background level of hydrocarbons as measured by the Miran was zero.

Results

FIG. 1 shows the basic layout of the engine and motor rooms and the various sampling positions to which the Miran probe was moved during the trial. Examples of the trace/log are shown in FIGS. 4 and 5 and a numerical digest of the data from the trace during spraying periods is given in TABLE I.

TABLE I—*Results of levels of white spirit during the Ayrodev cleaning process*

Day	*Process*	*Ventilation*	*Probe*		*Maximum Level (ppm)*	*Average Level (approx.) ppm*	*Minutes Level Exceeds 100 ppm*
			Position	*Duration (min.)*			
Sunday	Alternate Meggawash and Meggaboost Spraying	Battery and ship's ventilation on and 3 × DB fans blowing into compartment	1	27	105	60	1
			3	19	40	40	—
			4	28	275	180	24
			5	18	30	30	—
			1	11	55	25	—
			4	6	155	100	3·5
			6	5	40	40	—
			7	2	65	60	—
		One DB fan switched to exhaust	1	12	30	10	—
			3	15	< 10	< 10	—
			4	90	50	25	—
Monday		Battery ventilation shut down	1	35	70	40	—
			4	5	75	75	—
			8	80	20	20	—
			1	60	95	45	—
		All 3 DB fans exhausting	1	40	60	50	—
			3	10	35	35	—
			5	5	40	40	—
			1	180	95	30	—
Tuesday	Spraying varnish	Battery ventilation on again. Plastic 'tent' around work area	1	50	90	50	—
			3	5	0	0	—
			5	5	0	0	—
			9	240	85	30	—
	No spraying	All DB fans blowing to dry varnish	1	17	110	70	1

Conclusions

During the initial spraying of Meggawash and Meggaboost with the ventilation in the first configuration (see TABLE I), the concentration of white spirit vapour in position 4 (the lower region of the engine room known as the 'bear pit') exceeded the TLV of 100 ppm for 27·5 minutes of the 34 minutes for which the probe was in this position.

The general ventilation in the compartment, i.e. continually forcing air from the engine and motor rooms out of the engine room hatch, restricted the spread of vapour effectively as the levels measured in positions 3 (Engine Room), 5 (Motor Room Entrance), 6 (Motor Room Lower Deck), 7 (Motor Room Corridor) and 8 (Engine Room) were always below the threshold limits.

TLVs were not exceeded at any measuring positions when the DB fans were exhausting vapour from close to the point of generation. Vapour levels in the 'bear pit' tended to be higher than elsewhere.

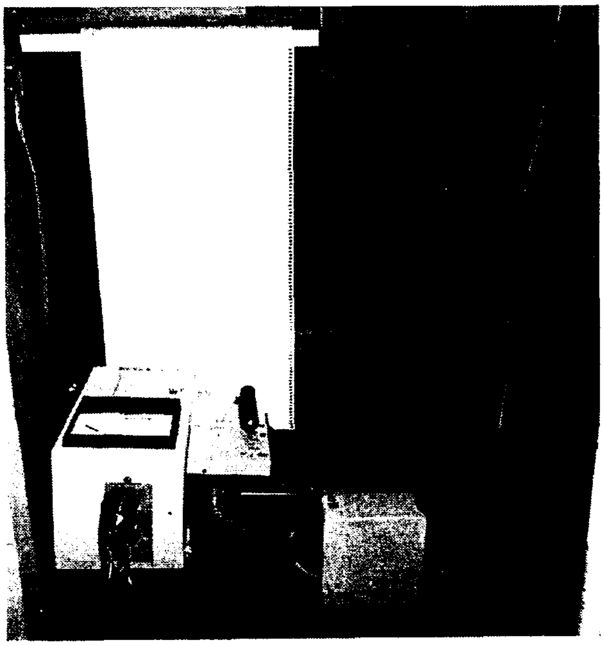

FIG. 6—INM MONITORING EQUIPMENT

Although measurements were not taken in the operators' breathing zones, the TLVs were probably exceeded regularly during spraying of Meggawash, Meggaboost and the varnishes.

Discussion

During the initial spraying sequence when the TLV for white spirit was exceeded in the 'bear pit', all three DB fans were blowing air into the compartment. Clouds of vapour could be seen emanating from the casing of the motor generator. When a DB fan was switched to exhaust, these clouds were visibly removed. When the DB fans were again altered to blow air into the generators (to aid the drying of the varnish) the concentration in the area of the generators increased rapidly. It was, therefore, decided that exhaust should be used only during the spraying and blowing only during drying.

It is understood that in future the main solvent for Meggawash and Meggaboost will be Clairsol 315, a refined (low aromatic content) petroleum distillate with a higher TLV, and the thinners used for the varnish will in future be Meggawash. These two changes will reduce the toxic hazard.

Recommendations

1. The Ayrodev process should be used under the following conditions of ventilation:
   (*a*) 77 and 103 bulkheads shut during the spraying process.
   (*b*) Ship's ventilation and battery ventilation exhausting into engine room.
   (*c*) Three DB fans must be used to exhaust air from the generator casing except when used to aid solvent or varnish evaporation as noted above.
   (*d*) The positioning of the DB fan trunking must be altered and supervised by a responsible person so that the maximum exhaust takes place during the spraying operation.
2. Appropriate fire precautions should be taken.
3. Except for the 'bear pit' and the immediate vicinity of the motor generators, which should not be entered during spraying, restricted access should be allowed for maintenance work in the engine and motor rooms as long as the above precautions are taken.
4. The operating personnel should wear both respirators and gloves during spraying of Meggawash, Meggaboost and the varnishes.

The recommendations apply to the process as described and the ventilation system as in H.M.S. *Ocelot*.

Acknowledgements

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1. 'Threshold Limit Values 1976'. American Conference of Governmental Industrial Hygenists.
2. Captain SM1 Report on '*In Situ* Generator Clean Using the Ayrodev Process in H.M.S. *Ocelot*' dated 15 March 1977 (Annex A to letter No. 4130/1/13).