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EVALUATION OF THE GRAESBY OTTO FUEL MONITOR **OFM 2**

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Defence Research Establishment Atlantic

Centre de Recherches pour la Défense Atlantique

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Approved by: R.M. Morchat
Head / Dockyard Laboratory (Atlantic)

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Abstract

This report describes an evaluation of the Graesby Otto fuel monitor OFM 2. This Otto fuel monitor was procured to replace the aging MK 15 Mod 0 Otto fuel vapour detectors used on ships and submarines. Shortly after introduction of the Graesby OFM 2 to the fleet inexplicably high levels of atmospheric Otto fuel contamination were reported on several instances. These high positive indications of atmospheric contamination caused considerable concern regarding either potentially hazardous conditions to human health or the reliability of the new unit. Therefore DREA Dockyard Laboratory was requested to conduct a laboratory evaluation of the new monitors and this report describes the preparation and calibration of gas phase standards that were used to evaluate the Graesby OFM 2 response to atmospheric propylene glycol dinitrate (PGDN) concentrations from Otto fuel. The unit was found capable of detecting PGDN atmospheric levels of 0.018 parts per million (v/v) and the response of the unit increased with increasing concentration up to 0.049 parts per million (v/v).

Résumé

Ce rapport décrit une évaluation du contrôleur de carburant Otto OFM 2 de Graesby. On a fait l'acquisition de ce contrôleur pour remplacer les anciens détecteurs de vapeur de carburant Otto MK 15 Mod 0, utilisés sur les navires et les sous-marins. Peu de temps après l'installation du contrôleur OFM 2 de Graesby dans les bâtiments de la flotte, on a inexplicablement signalé à plusieurs reprises des niveaux élevés de contamination atmosphérique par le carburant Otto. Ces niveaux élevés de contamination atmosphérique ont suscité beaucoup d'inquiétude en ce qui concerne les risques possibles pour la santé humaine ou la fiabilité de ces nouveaux appareils. On a donc demandé au laboratoire du chantier naval du CRDA de procéder à une évaluation en laboratoire de ces nouveaux contrôleurs. Ce rapport décrit la préparation et l'étalonnage des étalons gazeux utilisés pour évaluer la réponse du contrôleur OFM 2 de Graesby aux concentrations atmosphériques de dinitrate de propylèneglycol (PGDN) provenant du carburant Otto. Le contrôleur pouvait détecter des concentrations atmosphériques de PGDN de 0,018 partie par million (vol./vol.); la réponse du contrôleur augmentait avec la concentration, jusqu'à une concentration de 0,049 partie par million (vol./vol.).

DREA TM/98/204

Evaluation of the Graesby Otto Fuel Monitor OFM 2

D. E. Veinot, R. D. Haggett and J. J. Power

EXECUTIVE SUMMARY

Introduction

This work was done at the request of NDHQ, DSSPM 3/HAZMAT, following the purchase of new Otto fuel monitors for the CF. CF personnel became concerned about the reliability of these new monitors after some unexpected high levels of Otto fuel were indicated in areas previously thought to be uncontaminated.

Principal Results

This report describes the evaluation of the Graesby Otto fuel monitor, OFM 2, which is a handheld portable unit used to measure atmospheric Otto fuel concentrations in submarines and torpedo overhaul facilities. The unit was evaluated using atmospheric propylene glycol dinitrate (PGDN) standards and a laboratory gas chromatographic analytical procedure. The portable Graesby OFM 2 was easily able to detect concentrations of PGDN below the required level of 0.02 parts per million (v/v) and response varied linearly with increasing concentration up to 0.05 parts per million. Further, users in the overhaul facility at CFAD Bedford found the unit user friendly and easy to operate and consequently were inclined to conduct more atmospheric analyses than when using the previously recommended gas chromatographic procedure.

Significance of the Results

The results indicated that the new Otto fuel monitors were suitable for use.

Future Plans

This project is complete.

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1.0 Introduction

Otto fuel II is the liquid monopropellant used to power Canadian Forces torpedoes. Liquid Otto fuel II is composed of three components; namely, 1,2 propylene glycol dinitrate (PGDN), di-n-butyl sebecate and 2-nitro diphenyl amine. PGDN is the propellant and comprises approximately 76 percent of Otto fuel II while di-n-butyl sebecate and 2-nitrodiphenyl amine act as desensitizing agent and stabilizer, respectively.

PGDN is a recognized health hazard in either the liquid or gaseous state. The time weighted average threshold limit value for exposure to PGDN in air is 0.05 parts per million (ppm) but the Canadian Forces currently recognize 0.02 ppm as the upper allowable limit for atmospheric contamination in shops, ships and submarine workplace environments. To ensure that this upper limit is not exceeded through inadvertent leaks and spills of Otto fuel II, atmospheric monitoring is periodically conducted using the MK 15 MOD 0 Otto Fuel II Vapour Detector on ships and submarines and the Scintex TVD-1 Model 300 Otto fuel vapour Detector at CFAD Bedford. The units used on the submarines, the MK 15 MOD 0 Otto Fuel Vapour Detectors, operate on the basis of causing a colour change on a chemically coated absorbent contained in a cylindrical glass tube when a sample of air contaminated with Otto fuel is drawn through the unit, pyrolyzed and passed through the absorbent. The length of the colour change in the tube is indicative of the quantity of Otto fuel contamination in the air. The MK 15 MOD 0 Otto Fuel vapour detector was developed before the presently acceptable level of atmospheric contamination was established and when the acceptable level was higher than at present. Consequently this monitor has difficulty determining contamination levels near the new lower limit (1). Additionally, it was reported that the supply of absorbent tubes for the units was almost depleted and no replacements were available (2). Therefore a new unit, the Graesby Otto Fuel Monitor OFM 2, (NSN 6665-21-257-2526) shown in Figure 1 has been brought into service.

Before being brought into service the new unit was evaluated at Naval Engineering Test Establishment (NETE) [3] and was found to have the required sensitivity for Otto Fuel monitoring by the Canadian Forces. In addition NETE also tested the unit's response to several common atmospheric contaminants found on submarines, including diesel fuel, lubricating oil and exhaust gases and concluded that these contaminants would cause no interference. However, it was reported that upon introduction to the fleet several unexpectedly high levels of atmospheric Otto fuel contamination were indicated thus causing some alarm and lack of confidence in the unit's capability to provide accurate and specific measurements [4].

DREA Dockyard Laboratory was therefore tasked to evaluate these new units for their accuracy and specificity for Otto fuel analysis [2]. It was also requested that this study compare the performance of the Graesby OFM 2 with that of the Scintex TVD-1 (NSN 6665-21-904-3113) used at CFAD Bedford. Additionally it was suspected that residue from the smoke simulants used during training operations onboard the submarines may interfere with measurements obtained with the Graesby OFM 2 so a trial to assess this was conducted onboard the training submarine Olympus.

2.0 Procedure

2.1 Instrumentation

Four Graesby OFM 2 Otto fuel monitors were obtained for this study so that variations in readings amongst units could be evaluated. One of the units had been used previously by the submarine squadron while the other three were unused units obtained directly from stores.

The Scintrex TVD-1 Otto fuel vapour detector used at CFAD Bedford was used for this work and samples of PGDN standards produced at DREA Dockyard Laboratory were collected in evacuated 250 milliliter gas sampling tubes and taken to CFAD Bedford for analysis.

2.2 Preparation of Gas Phase PGDN Standards

Pure propylene glycol dinitrate was obtained by vacuum distillation of Otto Fuel II. Gas phase standards containing known quantities of PGDN in air were prepared in the laboratory using a dynamic gas phase sample generator (CAE Instruments, Inc. SC-100 Calibrator). A weighed quantity of pure PGDN was placed in the permeation tube of the dynamic gas phase sample generator and clean air at a constant and measured flow rate was passed over the permeation tube for a measured time. After a predetermined period of time (approximately 24 hours) the permeation tube was removed from the unit and weighed. The average concentration of PGDN in the air was calculated by dividing the weight loss of PGDN from the permeation tube by the total volume of air that passed over the permeation tube during the measured time. This procedure was repeated several times until it was determined that the average concentration of PGDN in the air was constant for a given set of gas phase sample generator conditions. To obtain gas phase PGDN standards of different concentrations, adjustments were made to the size of the permeation tube used in the dynamic gas phase sample generator, the temperature at which the permeation tube was operated and to the flow rate of clean air over the tube or to a combination of these three variables. Gas phase standards containing 0.025 ppm(v/v), 0.039 ppm(v/v) and 0.05 ppm(v/v) were made using this procedure.

2.3 Analysis of PGDN Gas Phase Standards

In order to verify the concentration of these gas phase standards they were collected and analyzed as unknowns using the following procedure. Individual samples of fifteen liters of each of the gas phase standards were drawn through respective Tenax tubes (Supelco ORBO 402 Tenax Tubes 100/50 mg) at a flow rate of 1.0 liter per minute for 15 minutes using a calibrated personal monitor pump. Each tube contained two sections of packing in series and separated by glass wool; the first section encountered by the air sample weighed 100 mg and the second section weighed 50 mg. After sampling, the tubes were opened and each of the sections was washed separately in a vial with reagent grade methanol. The intent of having the two separated sections of packing in series is to provide a means of determining the appropriate sampling volume and flow rate so that the majority of any contaminant was caught on the first 100 mg section of packing. It is desirable that the second section of packing trap less than 20 percent of the amount of contaminant trapped on the first 100 mg section. The amount of PGDN in each of these individual washings was determined using capillary gas chromatography with electron capture detector and on column injection using PGDN analytical standards prepared in reagent grade methanol. The details of the analytical method are given in Table 1 and the resulting calibration curve is shown in Figure 2.

Injector	on column
Column	Restek RET-5 30 m
Detector	ECD @200°C
Oven	70°C for 3 min then increase @10°C min^{-1} to 100°C and hold for 6 min

Table 1: Capillary Gas Chromatographic Method for the Analysis of PGDN

The efficiency of removal of PGDN from the Tenax packing with methanol washing was determined by deliberately contaminating unused Tenax packing with known quantities of PGDN and conducting the washing experiment and subsequent analysis by capillary gas chromatography as described above. Measured quantities of pure PGDN were injected directly onto the Tenax tubes which were then resealed and left at room temperature overnight to allow the PGDN to disburse evenly throughout the Tenax packing. The absorbents were then removed from the glass tubes and washed with methanol as described above. The quantity of PGDN in the methanol washings was then determined using the capillary column gas chromatography method, also described above, and from this an average washing efficiency was obtained. The average efficiency for PGDN removal from the Tenax packing was found to be 75 percent over the concentration range studied.

2.4 Response of Graesby OFM 2 to Gas Phase PGDN Standards

The Graesby Otto fuel monitor OFM 2 is a hand held instrument designed to measure PGDN vapour in the atmosphere as may be caused by fuel leaks from torpedoes, for example. The unit is a single mode detector using a single cell, (a drift tube type cell), for separation of PGDN contamination in the air. Separation of components in the air sample is based on time of flight of the contaminants across the detector cell to the nickel^{63} based detector. The unit displays concentration of PGDN in bars on the digital readout and these bar readings have been calibrated by the manufacturer so that an indication of 3 bars represents 0.02 ppm and an indication of 6 bars represents 0.2 ppm.

3.0 Results and Discussion

The concentration of the gas phase PGDN standards that were prepared using the dynamic standards generator was calculated using the measured weight loss of PGDN from the permeation tube and the total volume of air that passed over the tube during the measured time interval as follows:

conc. PGDN (ppm wt/v) = wt PGDN (mg)/vol air (L)

This calculated concentration in parts per million (wt/v) was converted to concentration in parts per million (v/v) as follows:

conc. PGDN (ppm v/v) = (wt PGDN(g) x 22.4L mole^{-1}/166grams mole^{-1})/vol air(L)

Atmospheric PGDN standards containing 0.025 ppm(v/v) ,0.039 ppm(v/v) and 0.051 ppm(v/v) were made using this procedure. Analysis of these standards following the gas chromatographic procedure described earlier indicated actual concentrations of 0.018, 0.034, and 0.049 ppm (v/v) respectively.

The response of each of the four Graesby OFM 2 Otto fuel detectors and the Scintrex TVD-1 to each of these gas phase PGDN standards made in the laboratory using the dynamic standards generator is shown in Table 2.

Prepared Conc. ppm (v/v)	Measured Conc. ppm (v/v)	OFM 2 #1005 bars	OFM 2 #1006 bars	OFM 2 #1009 bars	OFM 2 #1023 bars	Scintrex TVD-1 ppm (v/v)
0.025	0.018	3	3	3	3	0.022
0.039	0.034	4	4	4	4	0.022
0.051	0.049	6	5	5	6	0.022

Table 2: Response of the Graesby OFM 2 Otto Fuel Monitor and the Scintrex TVD-1 Otto Fuel Vapour Detector to Laboratory Prepared Standards

The four Graesby OFM 2 Otto Fuel Monitors all gave very similar responses to the laboratory standards and the responses varied with the concentrations of the standards. From the results shown in Table 2 it can be seen that all four Graesby units gave a response of 3 bars for a standard which contained 0.018 ppm (v/v) PGDN which is in agreement with the the markings on the unit. Similarly all units gave a response of 4 bars for a standard containing 0.039 ppm (v/v) PGDN. For the standard which contained 0.051 ppm (v/v) PGDN two of the units gave readings of 5 bars and two gave readings of 6 bars. Thus the response of these units did vary with concentration but a reading of 6 bars was obtained for a standard which contained 0.051 ppm (v/v) PGDN while markings on the unit indicate that a reading above 6 bars would correspond to 0.2 ppm (v/v).

The Scintrex TVD-1 Model 300 Otto Fuel Vapour Detector used at CFAD Bedford gave an average response of 0.022 ppm(v/v) for all 3 of the standards and thus it appears that this unit is unable to determine PGDN concentration differences in the range

0.018 to 0.051 ppm (v/v) but does give a detection indication in the vicinity of 0.02 ppm (v/v) for all standards.

3.1 Smoke Simulation Trial Onboard HMCS OLYMPUS

During smoke simulation trials onboard submarines one of two possible smoke simulants is used, namely, "Mini Mist" and "Roscoe". Samples of each simulant was submitted to DREA-DL for investigation and it was determined that only the simulant labelled "Mini Mist" was found to give a positive, concentration dependent response on the Graesby OFM 2. This simulant may have been responsible for some of the positive Otto fuel II indications reported immediately after introduction of the unit to the fleet. Therefore the smoke trial onboard HMCS OLYMPUS was conducted using the "Roscoe" simulant. All four Graesby OFM 2 monitors were used to monitor the environment throughout the submarine prior to the trial and then immediately after the trial. No positive indications were recorded on any of the monitors and this situation was monitored daily for four successive days at approximately with similar nil responses.

4.0 Conclusions

The Graesby OFM 2 Otto fuel monitors were able to monitor atmospheric PGDN concentrations in a range which is useful to the Canadian Forces for monitoring potential atmospheric Otto fuel contamination. The units were able to easily detect atmospheric PGDN concentration at the required level of 0.02 ppm (v/v) typically giving a response of 3 bars which is in agreement with the manufacturer's markings on the units. Further, the response of the units varied consistently with increasing PGDN concentrations up to 0.05 ppm (v/v) where the response was typically 6 bars. No positive indications for Otto fuel II were obtained in any submarine compartments after a smoke trial conducted using the Roscoe smoke simulant.

5.0 References

1. Morchat, R. M. and Shaw, C.A., Gas Chromatographic Analysis of Otto Fuel II in Air, DREA Technical Memorandum 84/E, April 1984.

2. NETE Report IT 1098 22/93. "Evaluation of Portable Otto Fuel II Vapour Detectors, 1993.

3. Telecon, R. Thompson, DSSPM 3/HazMatDet / D. E. Veinot, DREA-DL(A), 23 Aug 1996.

4. 16665-173 (DSSPM 3/HazMatDet), "Evaluation of OFM 2 Detection Accuracy and Persistence of Smoke Simulant", 18 Sept 1996.

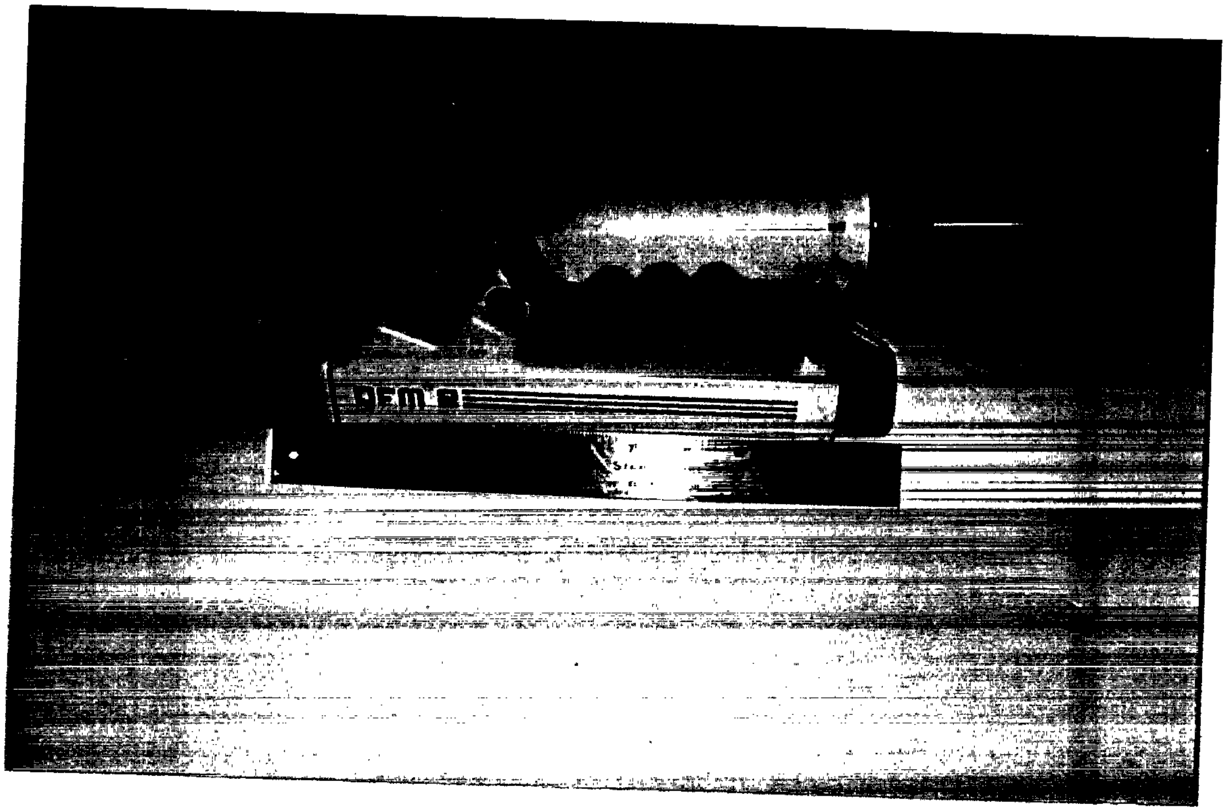

Figure 1: Graesby OFM 2 Otto Fuel Monitor

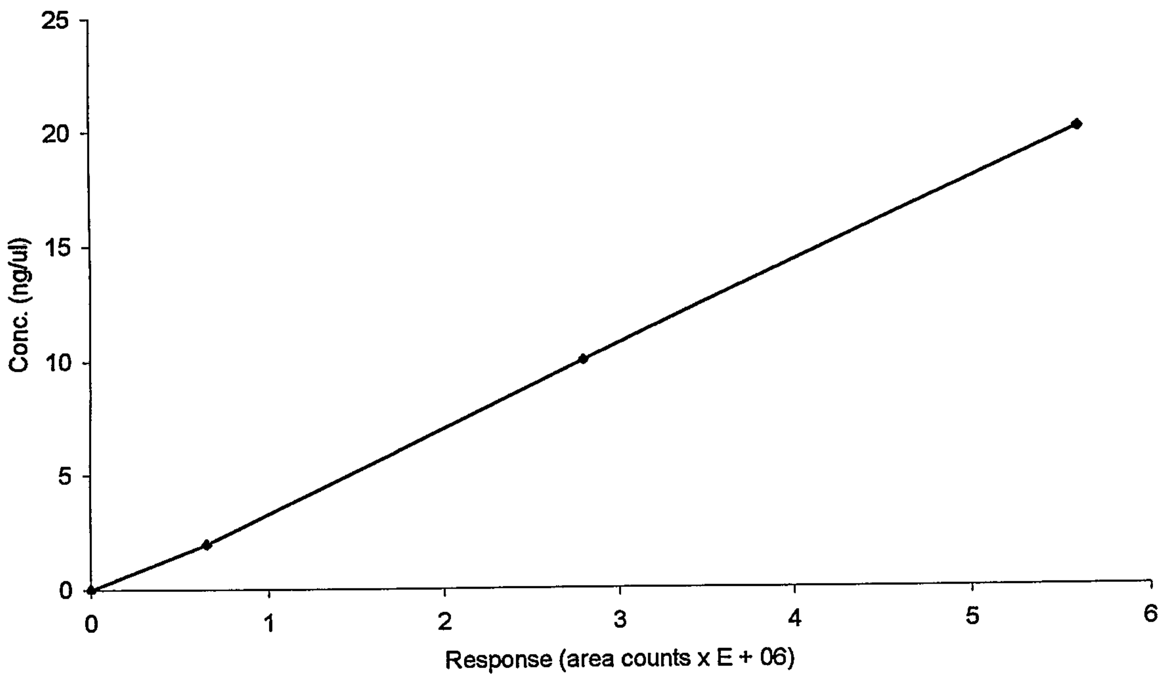

Figure 2: Calibration Curve for PGDN in Methanol

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