

WHY BOTHER WITH SIGNATURE REDUCTION?

S.J.Davidson and G.J.Webb

Ultra Electronics PMES, Armitage Road, Rugeley, Staffs, WS15 1DR, United Kingdom

Tel: +44 (0)1889 503300, Fax: +44 (0)1889 572917

Email: sdavidson@ultra-pmes.com, Web site: www.ultra-pmes.com

ABSTRACT

Most warships have a signature requirement in various influences but, apart from mine countermeasure vessels (MCMV), the signature cannot be reduced to near invisibility. In particular, the magnetic signature of the most thoroughly degaussed steel ship is easily detectable. Is it worthwhile going to the expense and trouble of building in on-board countermeasures? Is it worthwhile taking up valuable ship time on the degaussing range? This paper compares achievable signatures with hypothesised threats and, using a statistical analysis, provides answers to the above questions.

INTRODUCTION

The most simple magnetic mines are triggered when the measured magnetic field due to a vessel signature exceeds a certain value. The magnitude of magnetic signatures from steel vessels can be reduced using on-board degaussing systems, which will in turn significantly reduce in the likelihood that the mine will fire and the vessel be damaged. Typically vessel signatures are reduced by a factor of between 4 to 10. It is generally impractical to reduce steel vessel signatures further. In this paper we will discuss the mine threat to steel vessels and the degree of protection supplied to steel vessels by the use of degaussing.

The mine threat is provided by arrays of sensors distributed primarily over priority routes. The density of mine distribution within a minefield clearly governs the likelihood of mine detonation and consequent vessel damage. MCMVs, that are used to clear the route prior to the arrival of the steel vessel fleet, have significantly lower signatures than even the degaussed steel vessels and consequently are invisible to mines with trigger values set to damage steel vessels. Efficient mine sweeping or hunting will reduce the number of operational mines present and hence reduce the effective density of the remaining mines. The probability of a vessel remaining undamaged as it traverses a minefield in littoral waters has been determined as a function of mine separation. The results and conclusions will be discussed.

WHY DEGAUSSING?

The steel that is used in the construction of many vessels produces a magnetic field which can trigger magnetic mines present in the vicinity of the vessel. In order to reduce the magnetic field or, in other words degauss the vessel, there are two methods of degaussing available: firstly magnetic treatment which semi-permanently alters the magnetic state of the steel comprising the vessel and secondly the use of on-board degaussing coils which create a magnetic field which counteracts that of the vessel hull. The most widely used methods are the utilisation of on-board degaussing coils or a combination of an initial magnetic treatment followed by utilisation of on-board degaussing coils. Use of degaussing coils is advantageous as it gives a greater control in determining the final vessel signature. We assume in this study that on-board degaussing coils are fitted to an untreated vessel and will refer to the vessel states with and without the coils in operation as DG-on and DG-off. A ship in the DG-off state is clearly in the same state as when no degaussing coils have been fitted.

Figures 1 and 2 show an elementary demonstration of the principles of a degaussing system and represent the DG-off and DG-on magnetic signatures of a steel hulled vessel respectively. In Figure 1 the DG-off signature maximum of the vessel is greater than the trigger level of the mine (indicated by the horizontal dotted line). The mine explodes beneath the vessel as it approaches. In Figure 2 the vessel is in its DG-on state which reduces the vessel's signature to a value below the mine's threshold level and as a consequence the mine is not detonated.

A more detailed study into the mine threat reveals a more complicated group of ideas. We consider first the sensitivity of the mine itself. It may appear at first that by increasing the mine sensitivity we can immediately trigger the mine for vessel in its DG-on state. However it is not merely necessary to trigger a mine: its main purpose is to cause sufficient damage for the mission to be aborted. Detonation must therefore occur close enough to the vessel to cause the required level of damage. Applying the inverse of this case to mine clearance, one possible method of clearing mines is to fit an additional large coil to the front of a vessel such that any mines would explode at a sufficiently large distance that no damage was caused. This method was trialed in the Second World War, but is obviously a relatively dangerous method of mine clearance. Recent developments of this idea involve using unmanned drones.

We can conclude from the above examples that mine sensitivity is not the sole factor that determines the effectiveness of a mine or minefield. Although the presence of a minefield will provide a deterrent, for true effectiveness a mine's performance should be tailored to the vessel type being targeted. The identification of this requirement lead to the development of smart mine's which can be programmed to recognise particular vessel types. Mines of this type cannot be cleared by the method discussed above. In this case sweeps are designed to produce representations of vessel-like signatures (Karis et al (3), Bracke and Goussaert (4), Donohue(5)).

Clearly detonation without damage to a vessel is a waste of the mine: the ideal performance for a mine is one in which the mine fires *and* causes damage when a vessel is detected. Table 1 indicates the four possible outcomes of a vessel crossing a minefield. For a mine of given sensitivity, the detection of a vessel depends on the vessel being sufficiently close to the mine: we will refer to this distance as the detection distance. Another parameter that must also be taken into account, when determining whether or not a mine should detonate, is the distance at which damage can be caused. This is known as commonly known as the damage radius. However the name incorrectly implies that about the vessel there is a hemi-spherical volume in which damage will be caused if a mine is present. In fact the volume around the vessel is much more complicated and depends on many factors in addition such as the strength of the hull at all points and the capability of onboard equipment to withstand shock (Maier (1)).

Figure 3 illustrates the ideal situation from a mine's point of view for a simplified damage surface; the damage distance and detection distance have closely similar values i.e. if a vessel is detected then sufficient damage will be caused to abort the mission. In designing a degaussing system the ideal method to overcome a minefield is for the vessel not to be detected at all. Figure 4 illustrates the ideal situation for a vessel in which the detection radius is insufficiently large for a seabed mine to detect the vessel. The mine is therefore in a state of identified in table 1 as 'incorrect no fire' because at this distance damage could have been caused by the mine, but was not. As indicated above, the damage radius and detection radius can in practice have more complex interactions. As illustrated in Figure 5, a combination of the possible mine states detailed in Table 1 can occur depending on the relative sizes of the damage and detection distances at a given point.

MINE FIELD SIMULATION

In order to determine the relationship between vessel protection and minefield density we have determined the likelihood of a vessel on a straight track surviving a crossing of a regular array of mines. Note that in a real mine field, mines will be randomly spaced due to unreliable navigation or positioning when mines are deployed. We have simulated a vessel travelling at distances of between 0.5 and 100m from a mine. For a regularly spaced minefield this corresponds to a mine spacing of between 2 and 200m. The vessel magnetisation is assumed to be a simple box shape. The detection distance occurs when the total field exceeds a given field level. We have assumed simple mines such that the mines always fire when the first vessel is detected and that there is no delay in firing. No moored or moving mines or mine like objects are assumed to be laid (Andersson (2)). Depending on vessel class and type, damage distances can vary between 40 and 200m (Maier (1)); we have chosen a value of 50m.

In order to determine the probability of survival we have calculated the percentage of possible mine to vessel separations for a given mine separation for which the vessel will not be damaged. This provides an indication of the level of protection supplied to the vessel. The DG-on state was assumed to have signature 10 times smaller than the DG-off state. The results for a DG-off and DG-on vessel in 30m of water are shown in Figures 6 and 7. The shaded area in each figure represents the proportion of vessels that would remain undamaged. The ideal result for a vessel would be 100% protection for all mine separations; this would indeed be true for a minesweeping vessel. The DG-off vessel has no protection at all when mines are more densely spaced than 160m. So what improvement in protection does the vessel's DG-on state provide? The shaded area in Figure 7 is significantly larger than in Figure 6 and a degree of protection is provided down to a mine separation of 48m, a marked improvement. Vessel degaussing has been shown to be clearly beneficial, and a practical and cost-effective method of reducing vessel loss.

In general of course a channel suspected of containing a minefield will be cleared using minehunters and /or minesweepers. We can use a graph such as Figure 7 to calculate the benefits of mine sweeping. Consider a minefield comprising mines separated by a 50m

spacing. A 50% efficiency in minesweeping will result an effective mine separation of 100m and an increase in the percentage of DG-on vessels remaining undamaged from 3% to 53%. Obviously further mine clearance will improve this percentage. In contrast the DG-off vessel would still be unable to cross the minefield without loss.

The advantages of degaussing become even more apparent when considering deeper waters. If we increase the water depth in our simulation to 60m, the DG-on vessel becomes 100% protected and is able to cross the minefield freely, whilst the DG-off vessel still facing to a high degree of risk. In a minefield containing mines spaced at 200m only 33% of vessels crossing the area will remain undamaged.

CONCLUSIONS

Although much effort can be expended in calculating the precise mine threat to particular vessel classes, it has been straightforward to show that DG is highly beneficial in many scenarios. Benefits are especially clear in modern mine fields which are increasingly difficult to clear. We therefore conclude that signature management programmes using on-board degaussing systems in conjunction with fixed magnetic ranges at home and transportable ranges and check ranges in field of operation are an essential feature of any mine threat reduction plan (Webb et al (6), Davidson et al (7)). As expected the use of a degaussing system decreases likelihood of damage and in addition allows operations to be undertaken in shallower coastal waters. This factor is of particular relevance to Navies operating in predominantly littoral waters.

REFERENCES

- (1) Wolfgang Maier and Jurgen Runge, 'Evaluation of Improved Damage Contours for Minefield Planning', 1997, UDT Conference Proceedings, pg 125-127
- (2) Olov Andersson, 'New Approaches to Mine Warfare - Homing Mines Combined with Stationary Mines ...', 1994, Warship '94, International Conference on Mine Warfare, Vessels and Systems - 3, Paper No.2
- (3) H.P.M.Karis et al, 'The Replacement Programme of the Minesweeping Capabilities for the Year 2000 of the Royal Netherlands Navy', Warship '94, International Conference on Mine Warfare, Vessels and Systems - 3, Paper No.10
- (4) A.Bracke and F. Goussaert, 'A New Minesweeper : the KMV', 1994, Warship '94, International Conference on Mine Warfare, Vessels and Systems - 3, Paper No.9
- (5) H.J.Donohue, 'Australian Emulation Influence Minesweep - a New Approach to Influence Minesweeping', Warship '94, International Conference on Mine Warfare, Vessels and Systems - 3, Paper No.11
- (6) G.J.Webb et al, 'Multi-Influence Electromagnetic and Acoustic Ranging', 1998, UDT Pacific Conference Proceedings
- (7) S.J.Davidson, 'Applications of a Novel Magnetic Tracking Method to Multi-Influence Ranges and Security Monitoring Systems', 1998, UDT Pacific Conference Proceedings

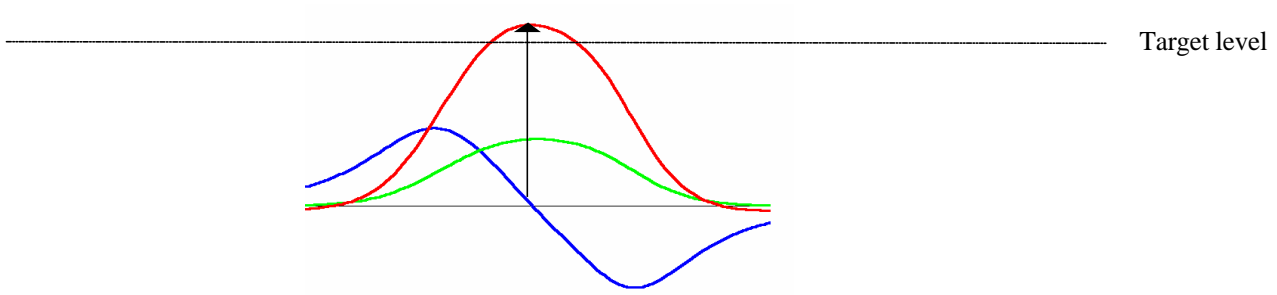
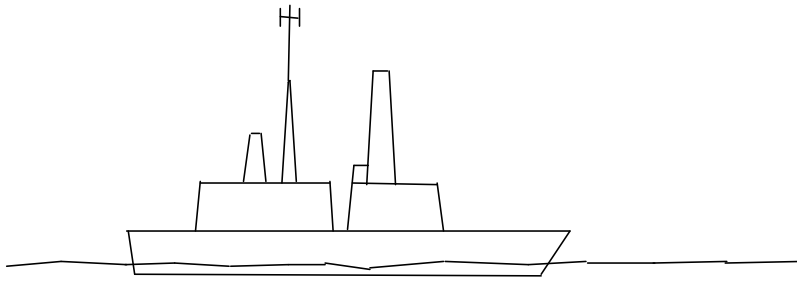


Figure 1

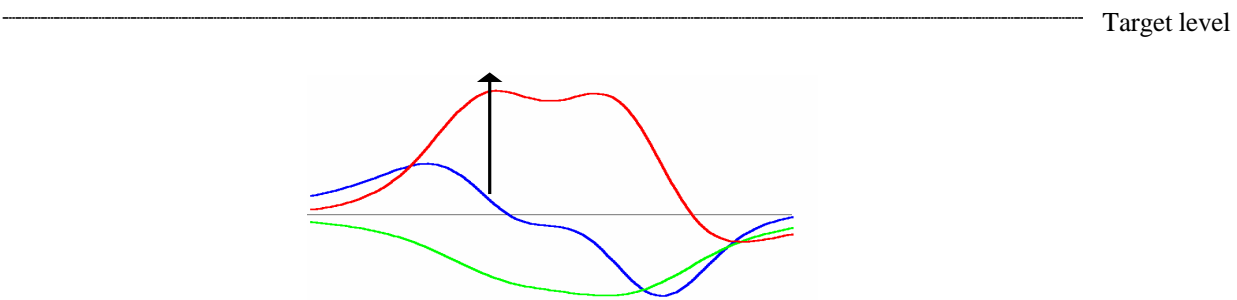
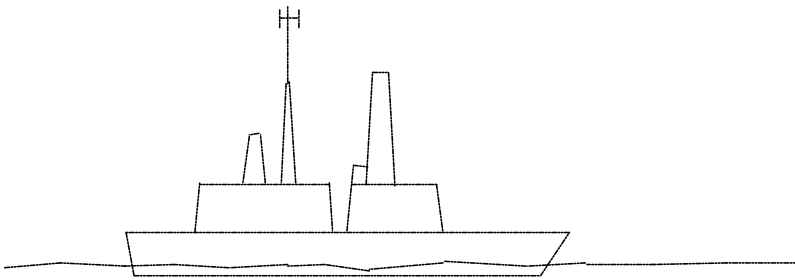


Figure 2

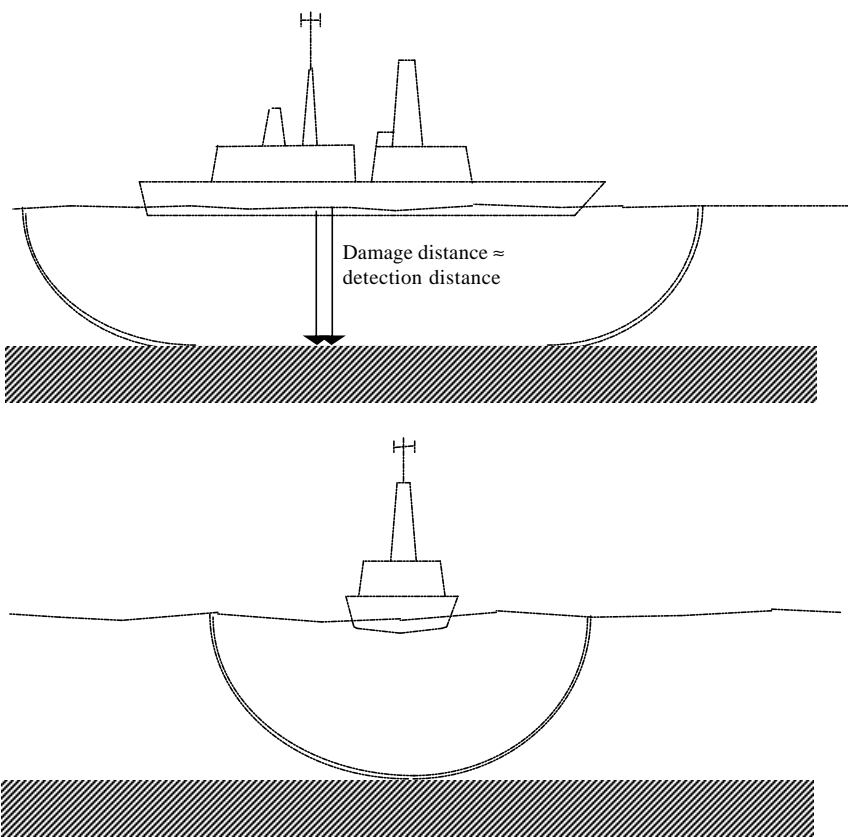


Figure 3

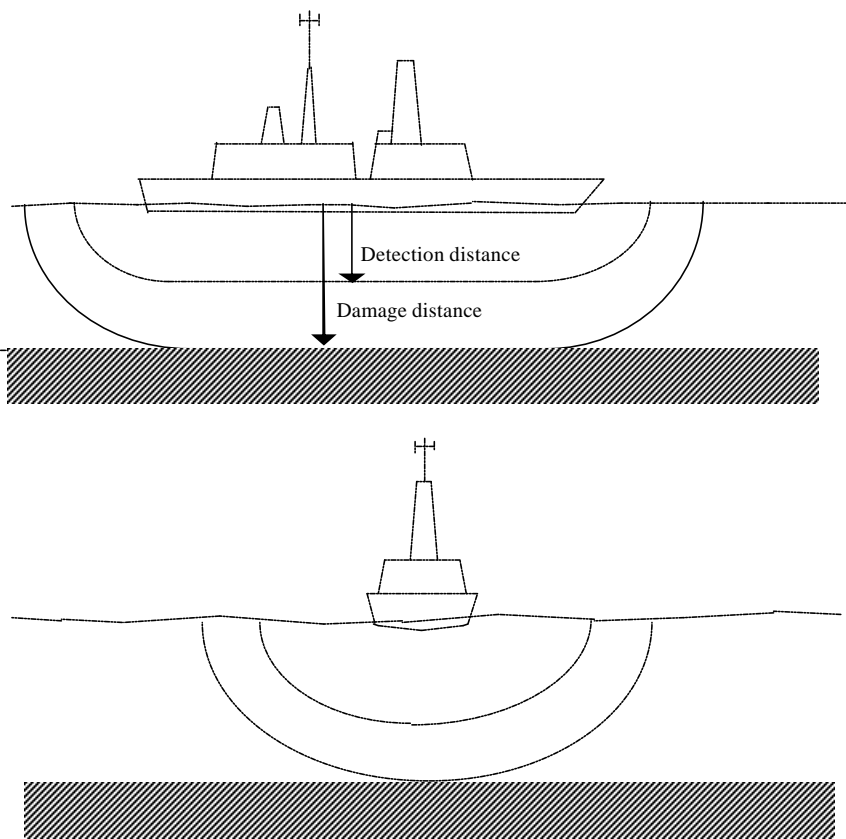


Figure 4

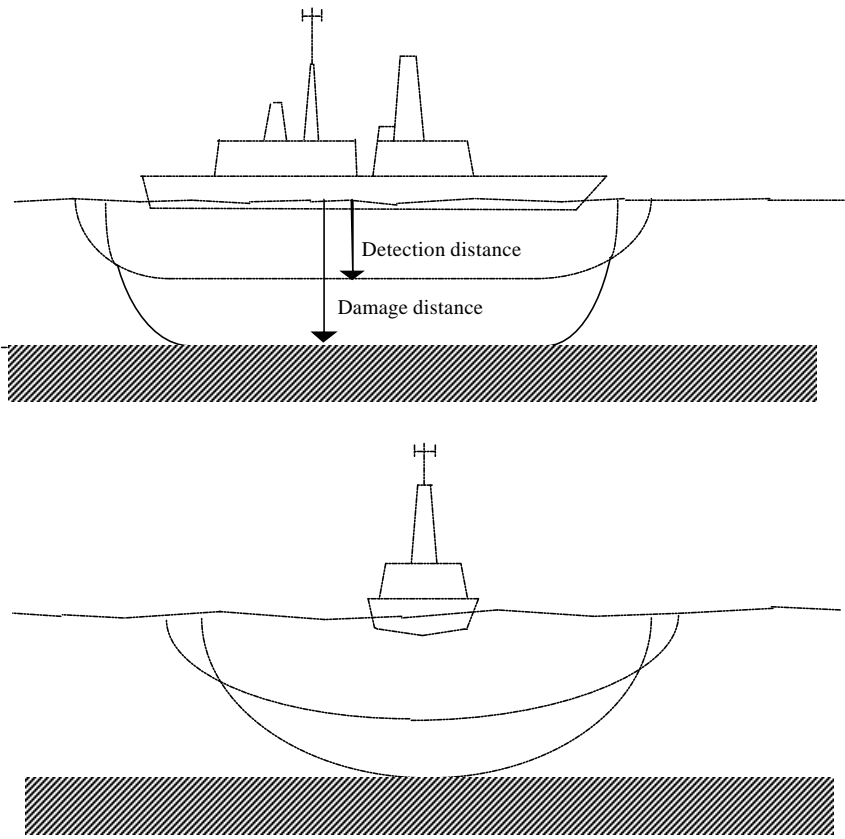


Figure 5

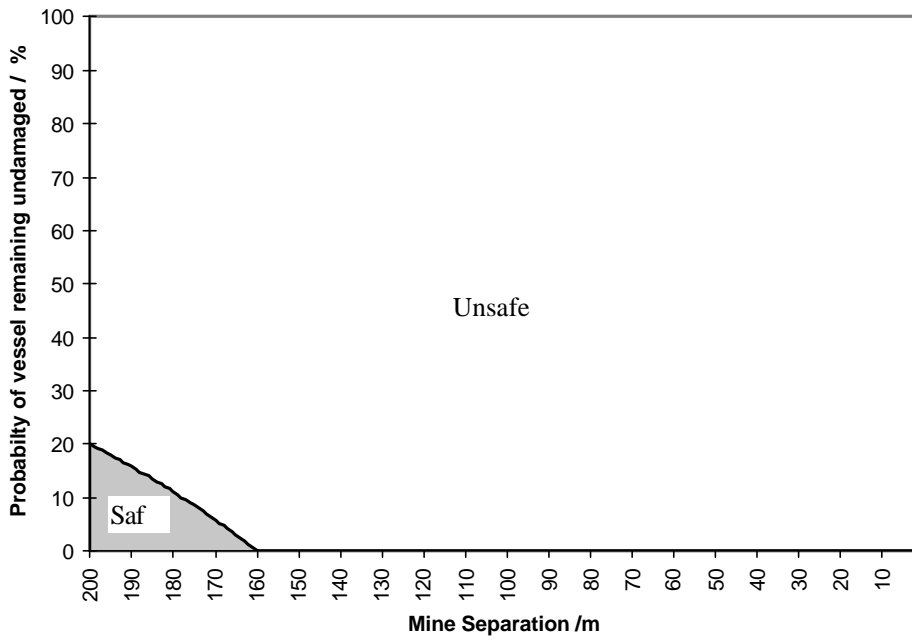


Figure 6

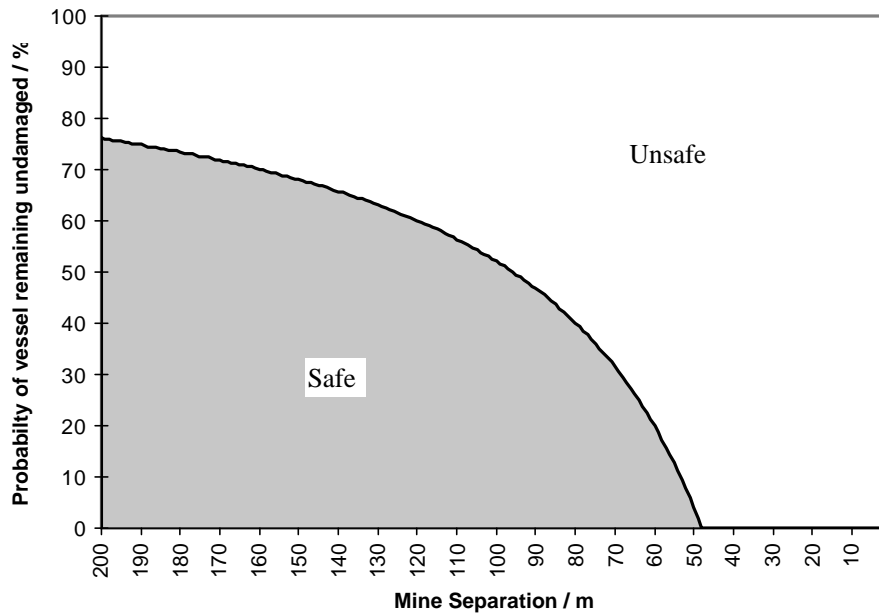


Figure 7

	Vessel detected	Vessel not detected
Damage possible	Correct fire	Incorrect no fire
No damage possible	Incorrect fire	Correct no fire

Table 1

© Copyright 1998 Ultra Electronics Limited

This document is the property of ULTRA ELECTRONICS LIMITED and may not wholly or partially be copied, stored in a data retrieval system, disclosed to third parties or used for any other purpose than that for which it is supplied without the written authority of ULTRA ELECTRONICS LIMITED.