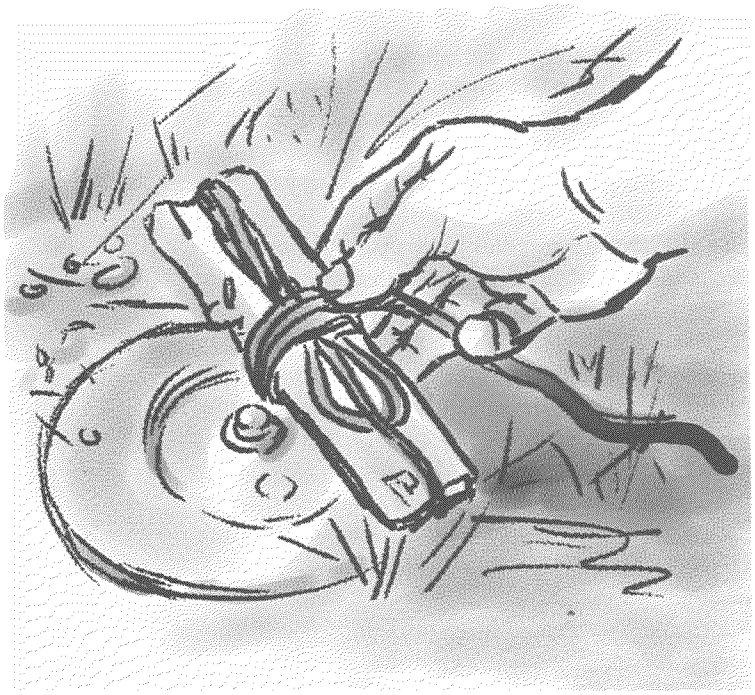
others. That would leave the mines next to the last of the chain in an indefinite state of reactivity.

- In all cases, on-site destruction should be accompanied by measures of **restoration of the area** where it was performed, especially when it comprises roads or paths (filling-in craters). Besides, on-site destruction should not be performed in cases where environmental degradation is intolerable (archaeological sites or costly installations).



On site destruction

- Finally, a **pollution by projection of metal fragments** can be caused by the destruction of mines with a high metal content (fragmentation mines for instance). This is likely to generate a high rate of false alarms, detrimental to both the safety of the personnel and to further controls. The protection of the environment can be guaranteed to some extent by a series of preliminary measures using sandbags or shields can reduce or eliminate some difficulties. Occasionnally, some earthworks may be resorted to:
- embankments against fragments
- trenches agaisnt shock waves.

- **Neutralization of the mines and off-site destruction**
Under certain circumstances, it may be necessary to take the mines out of the mined zone to destroy them in specifically prepared sites. Prior to transportation of the device, the latter will obviously need to be neutralized. Neutralization is not to be mixed up with destruction. Neutralizing a mine consists in making it inert, usually by following a process provided by the manufacturer to allow for its reuse. It is therefore critical that the mine-clearing operator be able to identify the device and be aware of its specific neutralization process.
Neutralization of a mine is a delicate process that requires the presence, or even the intervention of an expert. Howevern not all mines can be neutralized:

- some mines were specifically designed so as not to be neutralized. They will have to be transported with particular care to avoid triggering their ignition mechanism,
- beyond a certain degradation state, no mine can be neutralized (frequent for wooden mines),
- no mine should be neutralized if it is unknown to the mine-clearing operator,
- as any mine may be booby-trapped, any suspicion will lead to the use of a specific grapnel for the extraction, so as to enable the operator to stand at a safe distance.

The neutralized mines are usually taken out of sensitive zones, then grouped together, stored and destroyed by the same methods as on-site, usually by using explosives. Such destructions are completed on a daily basis so as to avoid having to guard the stores and limit risks of robbery. In the case of massive destruction of mines, the consumption of explosives is, of course, greatly reduced.
From a doctrinal point of view, on-site destruction is frequently opposed to neutralization; this argument, often nourished by personal rivalry or competition, is pointless: both methods have positive and negative aspects. The choice must be made by the chief technician present, who is the only one qualified to evaluate the situation and risks.

OTHER MEANS FOR THE TREATMENT OF MINES

DESTRUCTION OF THE DEVICE

- **Deflagration of the charge:**
«Primary» (particularly reactive detonators) or «secondary» (relatively stable main charge) explosives are designed to detonate, which means they are supposed to generate a «brisance» effect, accompanied by a violent thrust. Between the combustion phase, a reaction propagated by thermal conductivity, and actual detonation, there exists an intermediate phase called deflagration.

Deflagration causes a progressive thrust with no brisance effect. While the detonation speed counts in km/sec., the deflagration speed counts in hm/sec. The combustion speed counts in cm/sec.

The methods used to achieve the deflagration of a charge are usually based on direct shots with a rifle (up to 12.7 mm) onto a sufficiently accessible mine, or with a gun (approx. 20 mm) onto a bigger unexploded ammunition. It will open a breach in the casing and trigger the deflagration. The opening of the casing can be achieved with a specific hollow charge controlled remotely.
Due to the small amounts of projection caused by deflagration, this process does not pose any great hazard. This kind of reaction will be particularly useful in the case of large munitions for which neutralization is more complicated (unexploded bombs). However, this job requires some technical expertise, as the slightest mishandling might increase the reaction rate sufficiently to cause a detonation, as long as the temperature given off reaches a critical threshold

• **Pyrotechnic means for mine-clearance:**
Pyrotechnic systems have been adapted to mine action. Two principles have been used:
• **Gaseous explosive** FAE (Fuel Air Explosive) has been used by US Forces in Vietnam to neutralize their own sub-munitions. As they hit the ground, the 3 containers within each bomb break open and release a gas made of ethylene oxide, generating a cloud 15 m in diameter and 2.5 m in height. A delayed-action igniter causes the gas to detonate, thus generating a 22 kg/m3 over pressure spread over 182 m2. A variant using salvo-fired rockets has been developed as well.
• **Long explosive cordons**, designed to induce the sympathetic explosion of mines can be sent forward by rockets (or in some cases moved forward by a tank) throughout the field to be cleared of mines. The best known of these devices, the Giant Viper, was used in the fight by the British army. During the «Desert Storm» operation, every one of those devices opened a 187 m long and 7 m wide breach in Iraqi minefields within a few minutes.
Pyrotechnic systems are not well adapted to civil use (loudness, blast, fire etc...) or even to military use excluding imminent assault. Furthermore, they offer limited possibilities for controls, and of course they tend to disrupt the setting of the minefield. However their military efficiency is worth mentioning: it underlines the ineffectiveness of mines against well-organized forces.

• **Destruction of the devices with neither detonation nor deflagration:**
Destruction operations can still be conducted with more sophisticated means that do not involve any explosion
• **Laser (1 to 2 kW)** can burn both the casing and the explosive by means of a mere combustion, or even a slow deflagration **without detonation.**
• **Corrosive foams** (not to be mixed up with explosive foams) alter the chemical structure of the explosive which in the process loses its reactivity.
• **Other methods** (pressurised water, electric arc, heat...) are being investigated but their application appears as particularly complex.

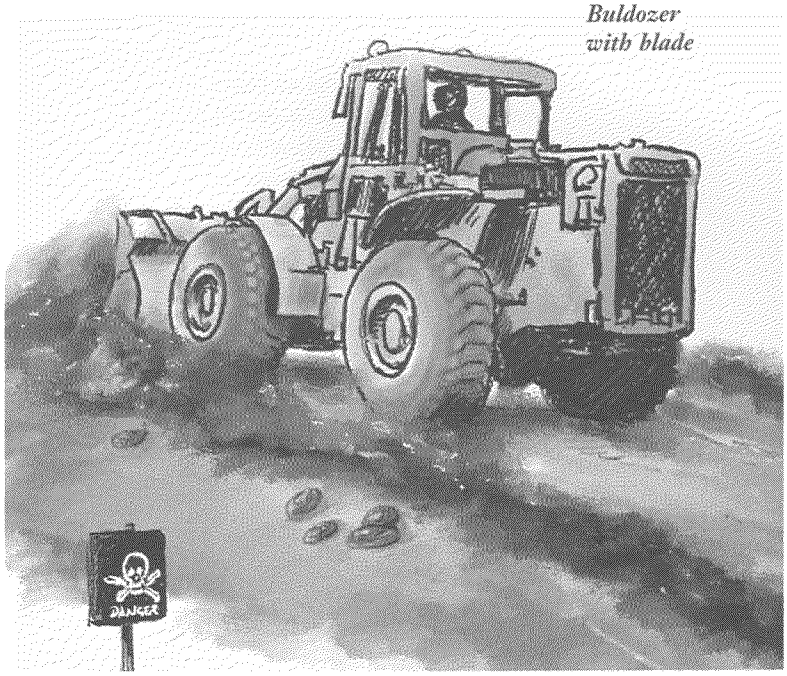
Fragmentation of the explosive into pieces smaller than the critical weight (which is the minimum weight at which explosion is possible) is also being studied.

• **Mechanical means**

Mechanical means used to treat the ground:
A polluted field can be treated mechanically without the loss of time caused by the treatment of mines themselves. The operation consists in merely removing a layer (approx 10 cm thick) of mine-loaded soil. This operation can be conducted by using a simple bulldozer blade.

Treating the field only fulfils the speed requirements necessary in assault mine-clearance but can not yield the minute precision required in zone or itinerary mine-clearance; mine clearance is completed in part by only pushing the still active and greatly degraded mines to the side, a solution which is not acceptable for peace-time mine-clearance. This type of mine-clearance generates undesirable side-effects on the environment: for instance they may lead to the destruction of roads or paths expected to be reopened to traffic.

Mechanical means used to treat the mines:
Classic means:
Because of the high cost of manual mine-clearance, and of the dangers posed, automated mine-clearance



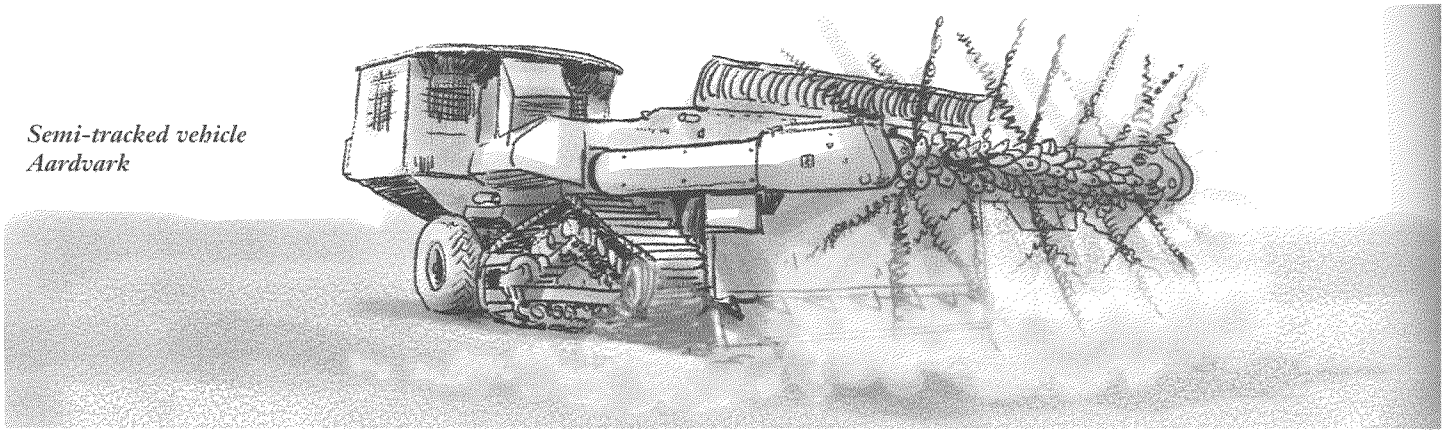
Buldozer with blade

appears as a better solution. Although expensive, machines could in fact reduce the amount of risks facing the operators. Mechanical equipment should be adapted to all varieties of soils, resist the effects of anti-personnel mines and also shield the operator inside from the effects of antitank mines (up to 12 kg of explosives).
No manual mine-clearance is necessary with these systems, and the whole area treated is handled in the same way, whether mines are actually present or not.
The military experience acquired within this area is not currently transferrable to peace-time mine-clearance, but further development of these methods does present interesting possibilities.

Modern means:
The systems designed to handle mines directly are aimed to set them off by using flails or rollers attached to the front of an armoured vehicle. Because they handle the mines, these systems may be used by civilians in certain conditions (for instance in uninhabited areas). The characteristics of the engines enable them to clear flat-surfaced (difficulty to reach curved areas), straight fields (large turning circle); they are well adapted to mine-clearance of roads, **tracks and electrical lines.**

The efficiency of flail- or roller-equipped devices was chiefly shown in demonstration fields: in other conditions, their efficiency is impaired by the relief as well as by flooding (rice fields). Although these devices do resist explosions, they usually show signs of degradation in the long run (violent impacts, strong vibrations).
The (semi-tracked) anti-mine vehicle «**Aardvark**» (GB) for instance is under study for the treatment of mines by rotation of a flail. However, the smallest mines («butterfly mines» scattered by aircraft) could theoretically slip through the 3.5 cm open space left between the flails.

The use of a mine-clearing device like the Aardvark requires a series of structures on the side (workshop-vehicle, transporting vehicle, parts in mobile stores); it would therefore be more profitable to create units of two or more devices so as to decrease the costs related to maintenance and logistics
Furthermore, due to exceptional constraints, the weekly planning should allow 2 days for maintenance or repairs for 5 days of mine-clearing operations. However, it is the best-suited device for mechanical mine-clearance, whether in association with manual mine-clearance or not.



Semi-tracked vehicle Aardvark