



**TECHNICAL REPORT  
NATICK/TR-00/017**

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**DISPOSAL METHODS FOR FLAMELESS RATION  
HEATERS AND MEALS, READY-TO-EAT  
FOR THE FOOD SERVICE PROGRAM**

by  
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## **PREFACE**

This document was prepared for the U.S. Army Natick Research, Development, and Engineering Center under Contract No. DAAN02-98-P-8808. Mr. Peter Lavigne, chemical engineer for the Equipment and Energy Technology Team, Combat Feeding Program, Soldier Systems Center served as the technical point of contact. The objective of this project was to investigate effective handling and disposal procedures for Flameless Ration Heaters. This work included evaluating product characteristics and disposal methods. The work also included an investigation into how waste material is handled in Germany. The results of this work provided the necessary information to prepare a document on the proper handling, storage, and disposal of FRHs which is presented in Appendix A. This project is a follow-up effort for Contract No. DAAK60-97-P5135.

Timothy R. Hilgeman and Julia A. Fields of Environmental Quality (EQ) Management, Inc. were the principal authors. Robert S. Amick, P.E. of EQ served as senior reviewer. Technical assistance in the leadership of landfill investigative studies was provided by Gene Jergens of EQ. Tom Robertson of EQ provided the technical assistance in the study of incinerators. Fred Hall of EQ also provided assistance in the area of product reaction and characteristics. We would also like to thank Mr. Tom Kyzar, Environmental Engineer HQ USAREUR/7A, for his effort and support. Finally, we would like to express our gratitude to Ms. Monika Deegen for the numerous translations.

# **DISPOSAL METHODS FOR FLAMELESS RATION HEATERS AND MEALS, READY-TO-EAT FOR THE FOOD SERVICE PROGRAM**

## **EXECUTIVE SUMMARY**

The flameless ration heater (FRH) is a chemical pad which produces an oxidation-reduction reaction of magnesium and water that generates heat as a by-product. This heat of reaction is utilized to warm soldier meal rations, Meal Ready-to-Eat (MRE), in the field. The heater consists of magnesium, iron, polyethylene powder, salt, surfactants and buffering agents blended together and sintered into a 3.5" by 4.5" by 0.125" flexible pad.

Misunderstandings regarding the reactive nature of the FRH have resulted in costly, and often unnecessary disposal actions. The focus of this study is to provide information to eliminate misunderstandings through a straightforward presentation of information for determining proper procedures for disposing the FRH and MRE. This report presents the results of a product evaluation. The evaluation was used to characterize the MRE/FRH waste in order to determine appropriate disposal methods. MRE/FRH characteristics were compared to the characteristics of other waste materials, both hazardous and non-hazardous. This evaluation demonstrated that the MRE/FRH material appears to be non-hazardous in nature. Although the FRH pad does react with water, it is a controlled, low energy reaction.

Next, a detailed analysis was performed on the storage of MRE/FRH waste. The MRE/FRH material was subjected to numerous conditions that are typically found in a dumpster. The reacted FRH pad is harmless and can be disposed of as normal refuse.

Unopened MREs and FRHs are protected against water and are not likely to aid in the ignition or continuation of a fire in a dumpster. Although the unreacted FRHs are difficult to ignite they are capable of producing large flames in the presence of both water and fire, simultaneously. Therefore, it is beneficial for any unreacted FRH material, whether packaged with the MRE or alone, to be segregated from normal refuse and disposed of separately. This practice can prevent the FRH pad from simultaneously reacting with both water and fire.

Disposal conditions for the MRE/FRH material were also evaluated, specifically, the reaction of the MRE/FRH when placed in a landfill and an incinerator. Incineration and landfill are both viable options for the disposal of MREs and FRHs. Unreacted FRH material should be placed in a separate landfill cell that is capped prior to compaction, thereby assuring the FRH pads will not rupture and react. Incineration of the MRE/FRH does not pose any problem unless an entire truckload of unreacted FRHs are incinerated at one time.

Finally, the report which researched the refuse at Grafenwohr and Hohenfels Germany was translated and evaluated. The report was conducted for the Incineration Cooperative in order to determine the best method for disposal and treatment of refuse at these U.S. Army training areas.



## **1.0 INTRODUCTION**

### **1.1 Product History**

The need for hot meal rations for military personnel resulted in an investigation into the design of a flameless heating device. Initial studies of heating systems showed that an optimal device would be lightweight, safe and convenient to use, inexpensive, require little or no set up, heat food rapidly, allow heat-on-the-move capability and not produce a flame. In 1973, the U.S. Army Natick Research, Development and Engineering Center (Natick) contracted Power Applications Inc., to determine the feasibility of using their patented heat pad as a means of heating the Meal Ready-to-Eat entree. Studies concluded that the pad would require certain modifications in order to be utilized.

In 1980 the Navy conducted research on electrochemical reactions, based on powder metallurgy, for use in certain devices. Natick provided additional funds for the ongoing research since the products would be more cost-effective. The research resulted in the development of a portable electrochemical heater, referred to as the Dismounted Ration Heating Device (DRHD). The DRHD consisted of chemical heating pads composed of magnesium-iron alloy attached to the inside surfaces of the insulated pouch, and a separate pouch containing saline solution. The DRHD was considered too bulky and fragile to use in an operational environment.

The principal inventor of the chemical heating pad used in the DRHD formed a corporation called ZestoTherm Inc., soon after filing a patent for the device. ZestoTherm modified the heating pad and developed the flameless Combat Ration Heater (CRH) by 1986. In 1989, the Food Engineering Directorate (FED) initiated a program to provide a more convenient and effective method of heating the MRE entree. The result of the program was the development of the Flameless Ration Heater (FRH) which is now used to heat MRE entrees. The FRH is covered by U.S. Patent Number 4,522,190.

The U.S. Army Natick Research, Development, and Engineering Center is evaluating the handling and disposal of the FRH, individually and when packaged with soldier Meal Ready-to-Eat (MRE) portions. Disposal concerns within the European Union and the United States prompted the need for investigative studies.

### **1.2 Project Objective**

The objective of this project was to investigate effective handling and disposal procedures for Flameless Ration Heaters. This work included evaluating product characteristics and disposal methods. The work also included an investigation into how waste material is handled in Germany. The results of this work provided the necessary information to prepare a document on the proper handling, storage, and disposal of FRHs which is presented in Appendix A. This project is a follow-up effort for Contract No. DAAK60-97-P5135.

### 1.3 Approach

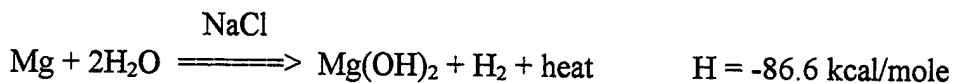
The scope of this project included evaluating disposal options for the MRE and FRH. The work did not include a regulatory review specific to one country. The scope of the work was broad enough as to be beneficial throughout the world. The range of activities to evaluate disposal options for the MRE and FRH were as follows:

- Evaluate the MRE and FRH in relation to hazardous and non-hazardous waste.
- Identify potential adverse impacts of the FRH when placed in a dumpster.
- Identify reactions of the MRE and FRH when disposed of in a landfill and an incinerator.
- Recommend proper handling, storage, and disposal of the MRE and FRH.
- Investigate disposal methods in Germany.
- Translate and evaluate findings of the German Incineration Cooperative Report.

## 2.0 PRODUCT DESCRIPTION

### 2.1 Flameless Ration Heater (FRH) Product Description

The flameless ration heater (FRH) is a chemical pad which produces an oxidation-reduction reaction of magnesium and water that generates heat as a by-product. This heat of reaction is utilized to warm soldier meal rations in the field. This heater consists of magnesium, iron, polyethylene powder, salt, surfactants and buffering agents blended together and sintered into a 3.5" by 4.5" by 0.125" flexible pad. Magnesium was chosen as the anodic material because of its relatively high energy density, cost and availability. In the presence of salt water, magnesium oxidizes slowly and energy is not produced at a usable rate. However, when anodic magnesium and cathodic iron materials are electrically connected, forming an electrochemical cell, the system sufficiently liberates energy (heat) for use as shown in the following equation:



One by-product of the magnesium to magnesium hydroxide conversion is the production of hydrogen gas. Hydrogen is a small molecule and the lightest of all gases. It is considered flammable in air within the concentration range of 4.0 to 74.2 volume percent and detonable within 18.3 to 59.0 volume percent. The auto-ignition temperature for hydrogen is 550° C, thus making hydrogen very difficult to ignite under ordinary circumstances. Hydrogen burns cleanly producing water as the by-product with very little radiation.

The FRH product weighs about 36 grams. It consists of a heater pad weighing approximately 20 grams, a heater cover weighing 8.8 grams and a high-density polyethylene outer bag weighing about 7 grams. The heater requires approximately 2 ounces of activating water for the reaction to go to completion. The amount of hydrogen produced during the reaction is approximately 0.7 grams. This information is based on the reaction above which states for every gram mole of magnesium reacted one gram mole of hydrogen is produced. Therefore, 8 grams of magnesium (0.33 gram moles) will react with water to form 0.33 gram moles of hydrogen or 0.66 grams.

Operating the heater is rather straightforward. The soldier tears the hermetically sealed, high-density polyethylene bag open, inserts a food pouch and adds approximately 2 ounces of water. He/she then folds the bag, and places it back in the food pouch's fiberboard box. The box is laid flat for 1 minute and then placed at a slight (15-degree) angle for an additional 11 minutes. During the reaction, steam evolves and water may boil in the bag. At 12 minutes, the soldier removes the bag from the box, tears open the bag near the food pouch, and removes the hot food pouch. The hot bag and heater are then discarded. The FRH is presented in Figure 1.

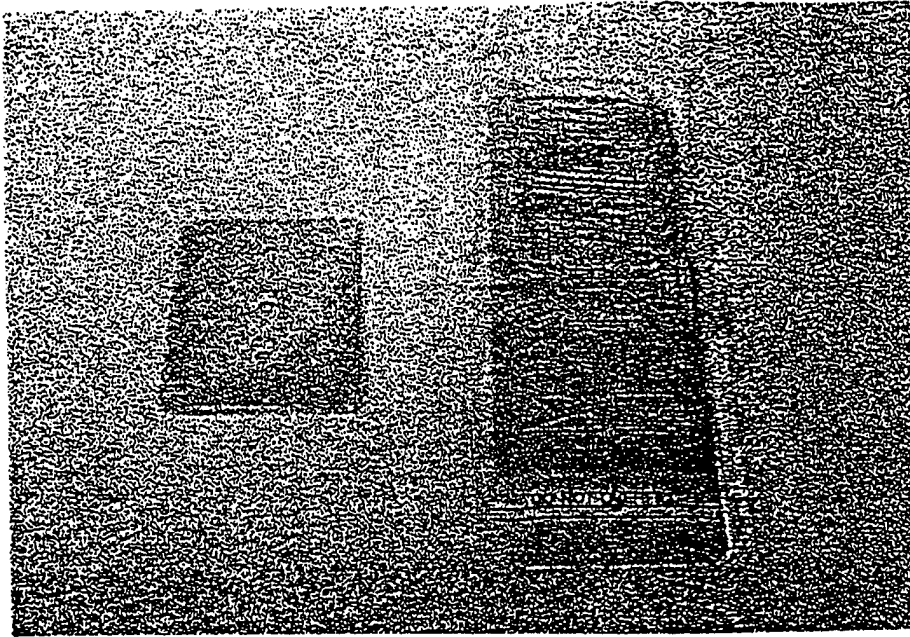


Figure 1. Flameless Ration Heater (FRH)

## 2.2 Meal Ready-To-Eat (MRE) Product Description

The Meal Ready-To-Eat is a complete operational ration packaged for one complete meal for an individual soldier. The MRE units weigh between 615 grams (1.35 lbs) and 866 grams (1.91 lbs). The ration is packaged in a sealed, flexible bag containing toiletries and an assortment of food items: entree, fruits, bakery items, crackers, spreads, sauces, dehydrated beverages, snacks, and candy. The MRE is presented in Figure 2. The meals are ready to eat and have a shelf life of 3 years. In 1992, the military started including a flameless ration heater in every MRE meal bag for heating the entree. These FRHs added between 4% to 6% to the total MRE weight.

Army Veterinary Service and the USDA inspect food for the Department of Defense. Expiration dates can be extended by having the food sampled and reinspected by the Veterinary Service. MREs are routinely re-inspected and shelf lives extended each year. When a military base has MREs reaching their expiration date they contact Veterinary Services and request an inspection. A representative sample of the product is statistically sampled, based on the particular parcel's storage history and lot size. The samples are inspected and labeled as edible or expired.

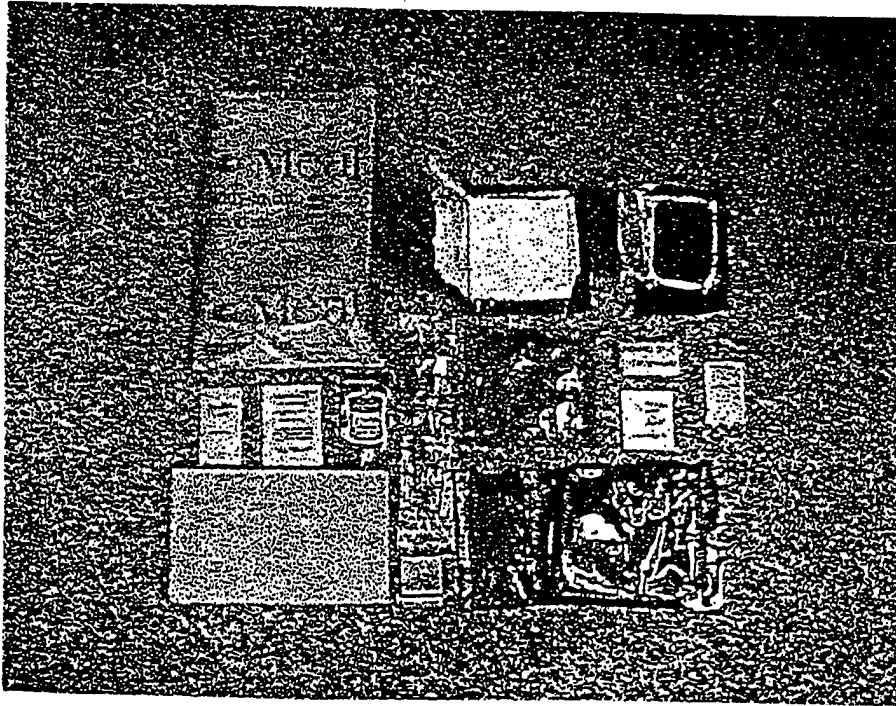


Figure 2. Meal Ready-to-Eat (MRE) w/out FRH

### 2.3 MRE/FRH Product Characterization

The regulatory classification of the MRE/FRH material is an important first step in the determination of disposal requirements and procedures. In order to characterize the MRE/FRH product, one must first define hazardous and non-hazardous waste. In December 1985, the United Nations Environment Programme published a qualitative definition of hazardous waste:

*wastes (solids, sludges, liquids, and containerized gases) other than radioactive wastes which, by reason of their chemical activity or toxic, explosive, corrosive, or other characteristics, cause danger or likely will cause danger to health or the environment, whether alone or when coming into contact with other waste...*

Although this definition is vague, it lays a framework whereby one can distinguish between hazardous and non-hazardous waste. The European Union (EU), an institution created to unite the nations of Europe, has a similar procedure for identifying hazardous waste. The EU specifically lists wastes which are hazardous. The MRE/FRH are not listed as hazardous according to the EU.

The United States regulates waste under the Resource Conservation and Recovery Act (RCRA) which is governed by the Environmental Protection Agency (EPA). RCRA was enacted in October 1976 to promote the protection and health of the environment and to conserve valuable material and energy resources. This is achieved by tracking hazardous wastes from generation to disposal or "cradle to grave." These regulations establish a set of requirements for

the generation, transportation, treatment, storage, and disposal of hazardous waste. Those who generate hazardous waste are required to analyze the material, maintain records, record volumes, and report any off-site disposal.

The regulations within RCRA are the framework for determining whether a waste is hazardous. In order to classify a waste as hazardous, it must meet two criteria:

- It must be determined if the material is a solid waste.
- It must be determined if the solid waste is hazardous.

According to the regulations, all materials are categorized as 1) garbage, refuse, or sludge; 2) solid, liquid, semi-solid, or contained gaseous material; or 3) something else. Materials in the first category are considered solid waste. Materials in the second category are also considered solid waste unless they have been given a special exclusion identified in RCRA. Materials in the third category are not considered solid waste.

For solid waste to be considered hazardous waste, it must meet one of the conditions outlined in RCRA. These conditions are summarized below.

1. The waste exhibits any of the following characteristics of a hazardous waste as defined in RCRA.
  - Ignitability
  - Corrosivity
  - Reactivity
  - Toxicity
2. The waste is specifically listed as being hazardous in RCRA. The hazardous constituents are outlined in the Code of Federal Regulations Part 261 Appendix VII, and are categorized as hazardous wastes from nonspecific sources, hazardous wastes from specific sources, acute hazardous wastes, or toxic wastes.
3. The waste is a mixture of a listed hazardous waste and a nonhazardous waste.
4. The waste has been declared hazardous by the generator, regardless of whether the waste meets the regulatory criteria for this classification.

According to RCRA, the only applicable condition by which expired MRE/FRH material could be classified as hazardous waste is in the characteristic of reactivity. Reactivity as defined in RCRA is:

A solid waste exhibits the characteristics of reactivity if it, is normally unstable and readily undergoes violent change without detonating, reacts violently with water, forms potentially explosive mixtures with water, or when mixed with water it generates toxic

gases, vapors or fumes in a quantity sufficient to present a danger to human health or the environment. There are other criteria that are not relevant to the study of MRE or FRH waste material classification.

As stated in the Federal Register, Vol. 45, No. 98, May 19, 1980, pgs. 33109, 33110, and 33122, the definition of reactivity was intended to identify wastes which because of their extreme instability and tendency to react violently or explode, pose a problem at all stages of the waste management process. The definition to a large extent paraphrased the narrative definition employed by the National Fire Protection Association, although test protocols for measuring thermal and shock instability were prescribed as a partial aid in assessing reactivity.

As stated in the Federal Register, Vol. 45, No. 98 (May 19, 1980):

"EPA received a large number of comments which argued that the prose definition of reactivity employed by EPA is too indefinite and vague and gives generators inadequate guidance in assessing the reactivity of their waste."

"EPA has attempted where possible to define hazardous waste characteristics in terms of specific, numerically quantified properties measurable by standardized testing protocols. The available test methods for reactivity, however, suffer from a number of generic and individual shortcomings which make a numerically quantified definition with accompanying test protocols inappropriate. First, these tests are too restrictive in scope and confine themselves to measuring how one specific aspect of reactivity correlates with a specific initiating condition or stress. No test is sufficiently general to even begin to measure the variety of different stresses and reactions found within the reactive classification. Second, because the reactivity of a waste sample is a function not just of its intensive properties such as mass and surface areas, the reactivity of the sample as measured by the tests will not necessarily reflect the reactivity of the whole waste. Third, most of the available tests are not of the "pass-fail" type and require subjective interpretation of the results."

"The unavailability of suitable test methods for measuring reactivity should not cause problems. Most generators of reactive wastes are aware that their wastes possess this property and require special handling. This is because such wastes are dangerous to the generators' own operations and are rarely generated from reactive feed stocks. Consequently, the prose definition should provide generators with sufficient guidance to enable them to determine whether their wastes are reactive."

Therefore, according to RCRA requirements, FRH and MRE materials are not regulated. It is important to note that hydrogen, formed during the reaction of the chemical heater with water, is also not regulated under RCRA.

The EU, United Nations and the U.S. EPA all describe hazardous wastes as exhibiting specific characteristics including corrosivity, flammability, reactivity, oxidizing potential, explosivity or toxicity. A hazardous waste may exhibit at least one of these characteristics in a manner that presents danger to human health or the environment.

## CORROSIVITY

A waste is corrosive if it is a liquid with a pH less than or equal to 2 or greater than or equal to 12.5 or if it is a non-liquid waste and when mixed with an equivalent weight of water produces a liquid that corrodes steel. Examples of corrosive materials are acids and bases that have the ability to cause destruction to living tissue or steel surfaces. Battery acid is a good example of such a material.

The MRE/FRH is not considered corrosive. The MRE/FRH will not corrode steel when mixed with water. In fact, when the FRH is mixed with water to utilize heat the resulting water mixture is harmless. The mixture is merely comprised of magnesium hydroxide, a substance commonly found in antacids.

## FLAMMABILITY

A flammable material is any material that will ignite easily and burn rapidly. A waste that is solid is considered flammable if it is capable of causing fire through friction, moisture absorption, or spontaneous chemical change. A waste that is liquid is considered flammable if it has a flash point less than or equal to 140°F or if it contains greater than or equal to 24% alcohol. Examples of flammable materials are solvents such as benzene and ethanol and gases such as methane.

The MRE/FRH is not considered flammable. The MRE is comprised of plastic and food materials that do not easily ignite. The FRH is also difficult to ignite and will not cause fire through moisture absorption or friction. Studies concluded that the FRH pad can only be ignited by large intense flames and not under ordinary circumstances. The hydrogen gas produced from the reaction of water and magnesium is minimal and would be extremely difficult to ignite. The auto-ignition temperature for hydrogen is 550°C which is far hotter than the conditions of a dumpster or container. Hydrogen, the lightest of all substances, is extremely buoyant and thereby diffuses in the atmosphere rapidly. Therefore, the evolution of hydrogen gas from the FRH would not likely start a fire due to its rapid diffusion into the ambient air.

## REACTIVITY

A reactive material is any material that reacts violently with or forms potentially explosive mixtures with water or air. A material is also reactive if it forms toxic gases when exposed to water or air or if the material is unstable. A material is reactive only if it displays these characteristics in a manner that presents danger to human health or the environment. Examples of reactive materials are strong acids and sulfides.

This definition of reactive is vague and subjective. The MRE/FRH does react with water but not in a way that presents danger to human health or the environment. The reaction of the FRH and water is specifically designed as a controlled, predictable and low energy reaction. The reaction produces an average temperature of only 60°C which is not sufficient to cause violent or explosive reactions. The MRE/FRH is specifically manufactured to remain a stable product



during storage and reaction whereby it does not readily undergo violent change. Therefore, the MRE/FRH is not considered a reactive material.

## OXIDIZING POTENTIAL

An oxidizing material is any compound that evolves oxygen, either at ambient conditions or when exposed to heat. Oxidizing materials release oxygen when reacting with other chemicals, specifically reducing materials. Oxidizers also react with organic materials in such a manner as to start fires. Examples of oxidizing materials are nitrates, peroxides, and chlorates.

The MRE/FRH is not an oxidizing material as it does not evolve oxygen or react with organic materials in the manner described. The only by-products of the water/magnesium reaction are magnesium hydroxide, hydrogen gas, and heat.

## EXPLOSIVITY

Explosive materials detonate as the result of shock, heat, or other initiating mechanism. Examples of explosive materials are dynamite and TNT. The MRE/FRH is not explosive as it will not detonate under normal circumstances.

## TOXICITY

Toxic materials can be classified as poisons that in small doses either kill or cause adverse health effects. Examples of toxic materials include chlorine, hydrogen cyanide, and PCBs. Exposure to these materials will result in serious health problems or death.

The MRE/FRH is not considered a toxic material as its products and by-products will not impair one's health. Toxic materials are generally materials that can be inhaled or absorbed through the skin and cause immediate and damaging effects. The MRE/FRH does not cause damaging effects to human health or the environment as magnesium and hydrogen gas are abundant, not-toxic compounds found throughout the world.

## 2.4 Regulatory Summary

As stated previously, the MRE/FRH is not considered as hazardous according to the definitions established by the United States, the United Nations and the European Union. Although it is recommended that the product be maintained under controlled storage and disposal procedures, treating the MRE/FRH as hazardous is unnecessary. The MRE and FRH are specifically designed and manufactured to support soldiers in the field. The FRH is manufactured to heat MREs through a controlled, non-violent reaction that is harmless to soldiers and the environment. The water and magnesium reaction is a stable reaction that produces harmless by-products. The amount of hydrogen and heat produced from the reaction is minimal and the magnesium hydroxide is harmless. Therefore, the MRE/FRH is not considered as hazardous as they pose no threat to humans or the environment.

### 3.0 WASTE HANDLING IN GERMANY

An investigation into the handling of waste material at U.S. Army Bases in Germany was performed. In particular, the disposal practices at Grafenwoehr and Hohenfels were evaluated. These U.S. Army Bases currently report no problems with the disposal of MREs and FRHs.

### 4.0 STORAGE AND HANDLING OF MRE/FRH WASTE

#### 4.1 Potential Disposal Problems

Whether the MRE/FRH has lost its shelf life, been damaged, or been utilized it is typically disposed of in a dumpster or similar waste container. Whether reacted or unreacted, the product does not have the ability to start a fire when placed in such an environment. FRHs that have been reacted do not produce hydrogen or heat when in contact with additional water. These reacted products are stable and will not aid in the ignition or continuation of a fire in a dumpster.

The possibility of an unreacted FRH causing a fire in a dumpster is also unlikely. Unreacted FRH pads are not considered a source of ignition. When in contact with an ignition source they do not sustain a flame. The pad can, under certain conditions, produce a small flame but it will immediately self extinguish. When an FRH fully reacts with two ounces of water the temperature of the product rises to approximately 60° C. This temperature is far too low to ignite any substance in the dumpster. Oily rags would not ignite as the autoignition temperature for petroleum products is greater than 225° C. The hydrogen gas that forms from the reaction would not ignite as its autoignition temperature is 550° C. Therefore, without the presence of an ignition source FRHs reacting in a dumpster will not initiate a fire.

Although the FRH/water reaction cannot initiate a fire, it could, under certain conditions, prolong a fire. Thus, it is necessary to discuss each of the possible scenarios that an FRH could react with water when placed into a dumpster. One scenario involves soldiers throwing complete undamaged MREs into a dumpster. The MREs are packaged in a flexible sealed plastic cover which is impermeable to water. These MREs contain a single hermetically sealed FRH. Therefore, any amount of rain or liquid coming into contact with the MRE will not cause a reaction. The only possibility for a reaction to occur is if the MRE is damaged in the dumpster to a point that the FRH is exposed. This scenario is also unlikely as something would have to puncture the outer MRE package and then tear open the inner FRH package. Furthermore, water would then have to enter both packages in sufficient quantities as to start a reaction.

Soldiers also discard opened MREs that have either been damaged or partially utilized. Soldiers may occasionally open the MRE and discard the unreacted FRH. The unreacted FRH packages are still hermetically sealed and would need to be punctured in order to react with water. Therefore, opened MREs with unreacted FRHs are also not likely to react during storage in a dumpster.

The scenario that best offers a chance for an FRH/water reaction is when opened and unreacted FRHs are disposed of. It is possible that during transportation or field training MREs

The scenario that best offers a chance for an FRH/water reaction is when opened and unreacted FRHs are disposed of. It is possible that during transportation or field training MREs and FRHs could become damaged to a point where the pad is exposed. This would allow water to come into contact with the pad and initiate a reaction. As previously mentioned, the FRH/water reaction produces a temperature that is incapable of igniting a fire in a dumpster. In the presence of an ignition source, an FRH/water reaction is also unlikely to start a fire. For instance, a lit cigarette placed on top of the FRH pad during reaction causes a small flame that immediately extinguishes. The same pattern holds true when a direct flame from a lighter is placed on the pad during reaction. A direct flame from a torch is the only method by which a reacting FRH pad can ignite and sustain a flame. When the FRH pad is ignited, it resembles the burning of ordinary paper but with the presence of occasional sparks. The fire is not large, energetic, or long lasting. A problem with a burning FRH pad arises when additional water comes into contact with the pad. Whether the FRH pad is burning or recently been extinguished, water can cause the magnesium to react and produce moderately large flames. Therefore, water only causes a significant reaction when the FRH pad is burning. These reactions are summarized in Figure 3 and displayed in Figures 4 through 7. Under certain conditions additional water may produce large flames.

Ignition Source	Unreacted FRH	Reacting FRH
Cigarette	No Fire	Small Flame, Self Extinguish
Lighter	No Fire	Small Flame, Self Extinguish
Torch	Small Flame, Self Extinguish	Flames

Figure 3. Reaction of FRH Pad in Contact with Certain Ignition Sources.

## 4.2 Fire Fighting Methods

In the unlikely event that the MRE/FRH does catch fire, special procedures are necessary in order to avoid potential problems. Under certain conditions water applied to extinguish magnesium fires may decompose into oxygen and hydrogen. The oxygen combines with the magnesium and the hydrogen released adds to the intensity of the fire. Water is only an effective extinguishing agent when supplied in large quantities. Therefore, extinguishing agents made up of water are not suitable for extinguishing magnesium fires. Halogen gases are also ineffective on magnesium fires. The burning of magnesium constitutes a Class D fire. Class D fires result from the combustion of certain metals, such as magnesium, that possess unique characteristics. Special fire extinguishers are required to extinguish a Class D fire. For instance, graphite and sodium chloride can be used as well as smothering the fire with sand or other dry agents. Carbon dioxide and noble gases have also been used to extinguish fires involving magnesium.

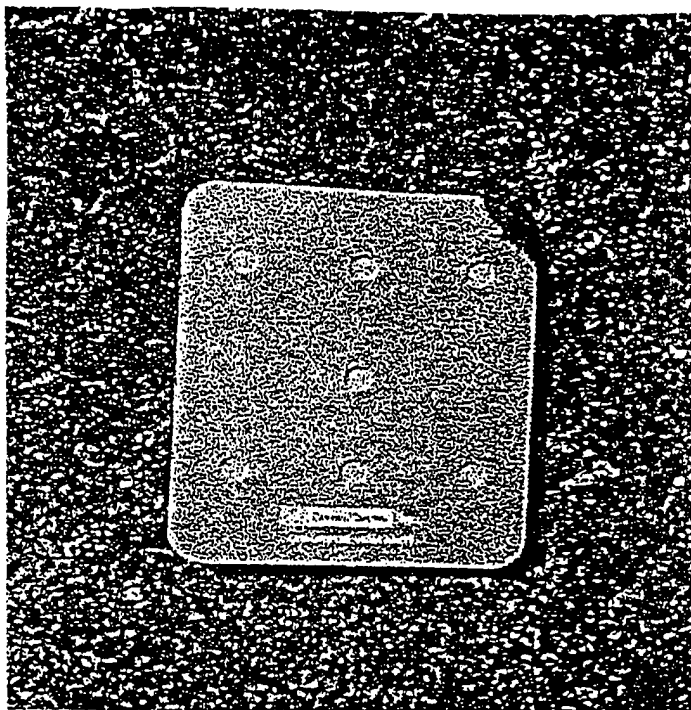


Figure 4. Unreacted FRH in Contact with Butane Lighter.

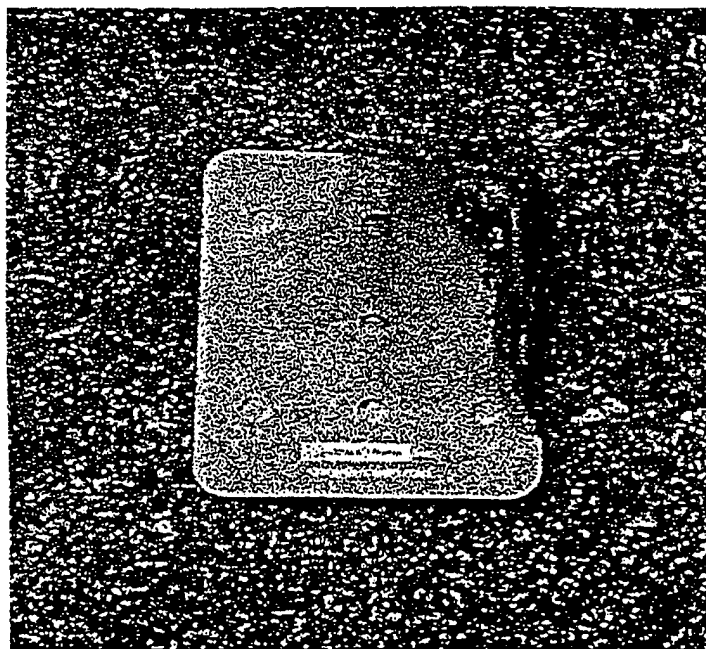


Figure 5. Unreacted FRH in Contact with Propane Torch

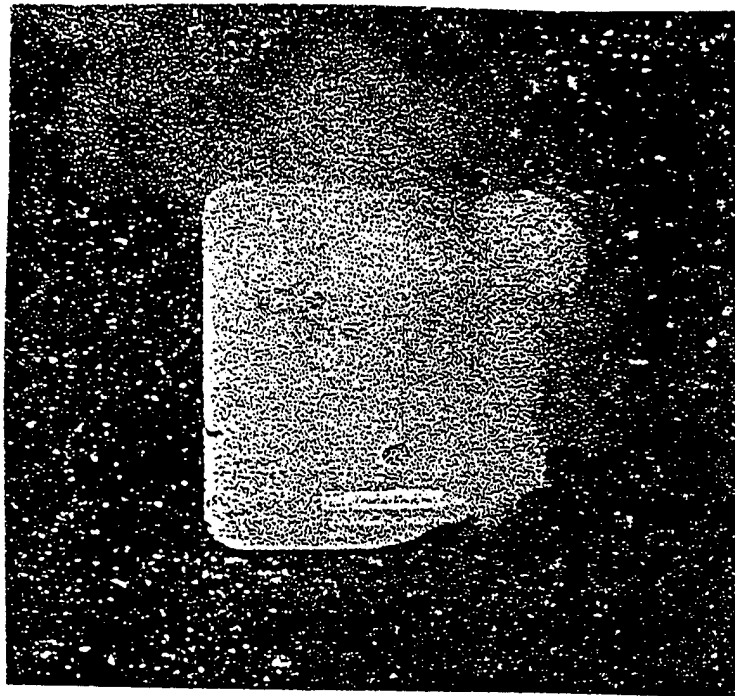


Figure 6. FRH Reacting with Water and Ignited by Propane Torch.

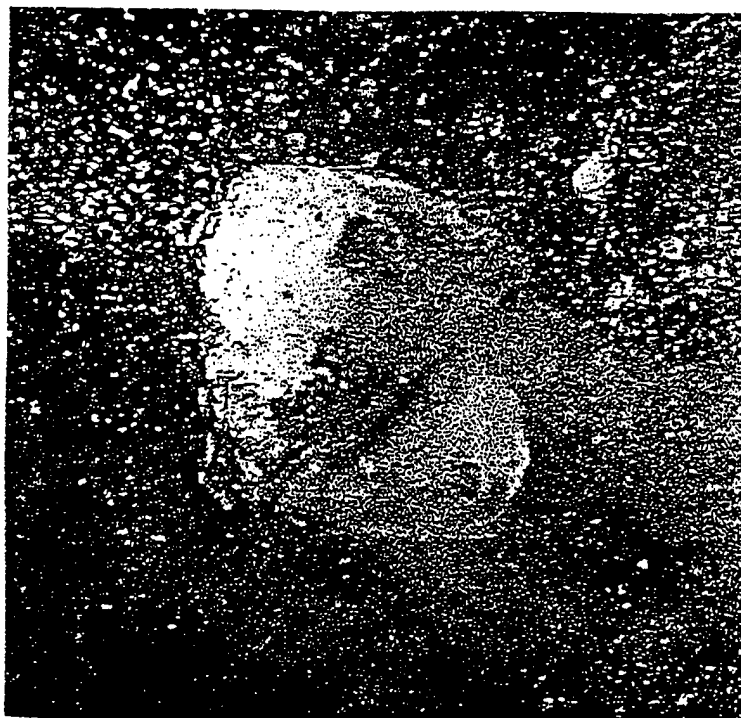


Figure 7. FRH Reacting with Water and Ignited by Torch,  
Additional Water Provided.

### **4.3 Storage and Handling Summary**

In conclusion, reacted FRHs are not a concern and should be disposed of as normal refuse. The unopened MRE is unlikely to open and react with water when stored in dumpsters. The same holds true for unopened and unreacted FRHs. FRH pads with exposed unreacted magnesium are capable of reacting with water. This reaction is not violent or dangerous as the

hydrogen gas diffuses away and the generated heat is not significant. Therefore, the MRE and FRH should not aid in the ignition of a fire in a dumpster. A problem does arise when the FRH is exposed to fire and water simultaneously. The FRH pad does not light easily and when lit will not significantly aid in the continuation of the fire, but the addition of water to the burning FRH can, under certain conditions, produce large flames. Due to this potential hazard, it is recommended that all unreacted MREs and FRHs be segregated from other waste and stored in separate containers. Although the potential of igniting a FRH is low, it can be avoided. This can be accomplished by storing MREs and FRHs destined for disposal in a cool dry place until a significant quantity is collected. Special collection bins can be strategically placed around each U.S. Army Base. These collection bins would be used solely for the storage of MRE/FRH waste.

Soldiers would place their MRE/FRH waste in these bins, thereby eliminating disposal of the waste in dumpsters. This procedure ensures that MRE/FRH waste remains segregated from other waste. The products can then be loaded into a container or onto a truck and shipped to the disposal facility. Unreacted FRHs with exposed magnesium should be reacted before disposing. This is accomplished by submerging the pad in water until reaction is complete. Reacted FRH pads do not react with water again and can therefore be disposed in a dumpster with ordinary waste. These procedures eliminate any potential for problems during the disposal process.

## **5.0 DISPOSAL OF WASTE MATERIALS**

### **5.1 Landfill Disposal Methods**

The purpose of this section is to describe the impact of disposing FRHs in a landfill. This section also provides an overview of landfill inspection and operation, as well as typical monitoring practices.

#### **5.1.1 Landfill Operations**

A municipal, solid waste landfill (RCRA Subtitle D) is typically a discrete area of land or an excavation that receives household waste, and that is not a land application unit, surface impoundment, injection well, or waste pile. This type of landfill may also receive other types wastes, such as commercial solid waste, nonhazardous sludge, small quantity generator waste and industrial solid wastes. Industrial Solid Waste is waste generated by manufacturing or industrial processes that is not a hazardous as defined by RCRA. Such waste may include, but is not limited to, waste resulting from the following manufacturing processes: Electrical power generation; fertilizer/agricultural chemicals; food and related products/by-products; inorganic chemicals; iron and steel manufacturing; leather and leather products; nonferrous metals manufacturing/foundries; organic chemicals; plastics and resins manufacturing; pulp and paper industry; rubber and miscellaneous plastic products; stone, glass, clay, and concrete products; textile manufacturing; transportation equipment; and water treatment.

When solid waste is sent to a landfill it is handled using one of several methods. The method depends on information about the waste, provided by the waste generator. The most common method for waste handling at a landfill is the open dump method in which a truck hauling residential or industrial waste backs into the open face area of the landfill being worked that day

and dumps the load. The landfill equipment operator, using a bladed dozer spreads the waste out in 12 to 18 inch layers to be compacted and covered before additional waste is dumped. The waste is then compacted using a sheep's-foot compactor. These steps are sometimes combined, using a sheep's-foot compactor with a dozer blade. Figure 8 presents a sheep's-foot compactor performing mechanical compaction at a landfill. The sheep's foot compactor is a specialized piece of heavy equipment which is designed with two rollers with numerous offset teeth which provide compaction of 1,000 to 2,000lb/yd<sup>3</sup>. A minimum of 3 to 5 passes should be made for proper compaction. At the end of each day the waste is covered with 6 to 12 inches of compacted soil or other suitable cover.

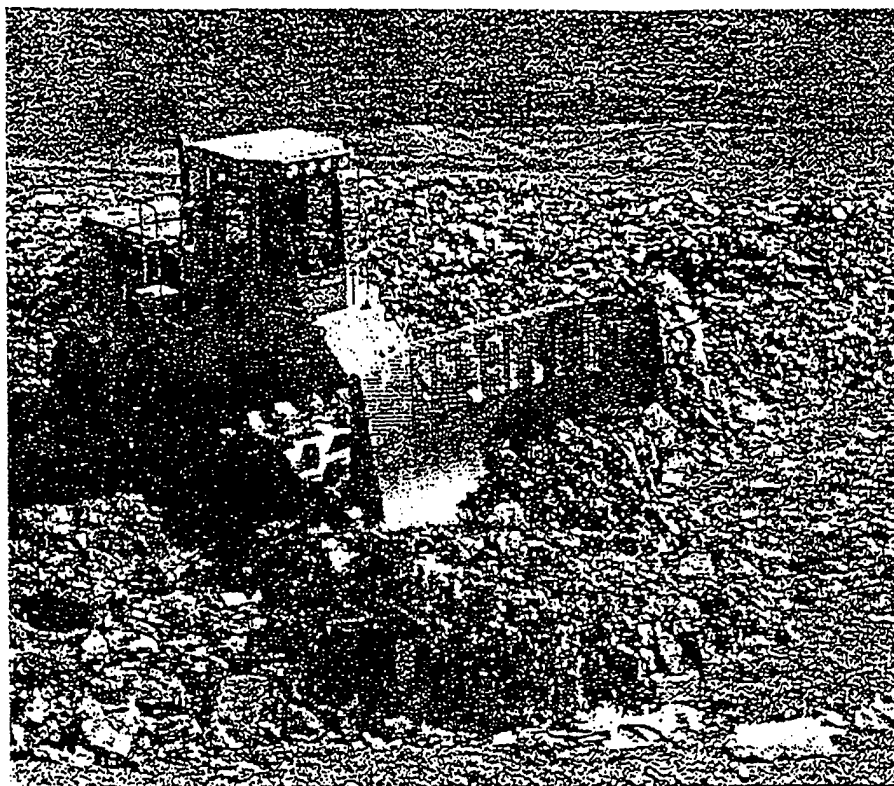


Figure 8. Sheep's Foot Compactor.

### 5.1.2 Landfill Inspection

Proper full-time supervision is necessary to control dumping, compaction, and covering. Landfill personnel typically erect signs for direction of traffic to the proper area for disposal. A supervisor is present at all hours of operation to ensure that the fill is progressing in accordance with all requirements.

In supervising an operation, the owner and operator of a landfill implement a program for detecting and preventing the disposal of wastes that are prohibited. This program includes



random inspection of incoming loads; inspections of suspicious loads; records of all inspections; training of facility personnel to recognize prohibited waste; procedures for notifying the generator and transporter if regulated hazardous waste or PCB waste is discovered at the landfill.

### 5.1.3 Leachate Collection

Leachate is defined as a liquid that has passed through or emerged from solid waste and contains soluble, suspended, or miscible materials removed from such waste. Leachate from existing community sanitary landfills and from industrial waste storage and disposal sites can be expected to contain organic and inorganic chemicals characteristic of the contributing community and industrial wastes. Although no significant leachate originates from the MRE or FRH, landfills are designed to prevent any potential contamination.

In order to prevent landfill leachate from contaminating the groundwater in the areas surrounding the landfill, construction is designed to ensure that the concentration values for volatile organic compounds and metals will not be exceeded in the uppermost aquifer. In the event that, if prevention of groundwater pollution cannot be ensured, a composite liner and a leachate collection system is designed and constructed to maintain less than 30 cm depth of leachate over the liner (see Figure 9).

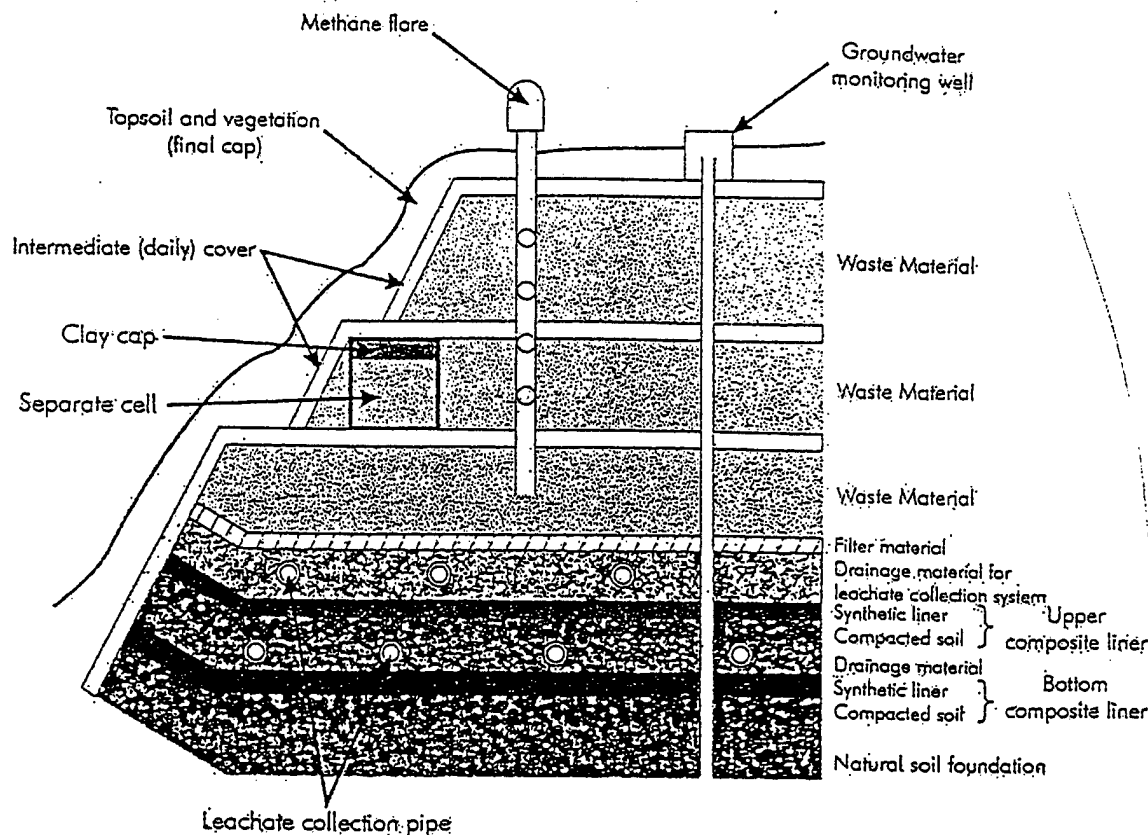


Figure 9. Landfill Containment System with Separate Cell.

A composite liner is a system consisting of two components; the uppermost consists of a minimum 30-mil flexible membrane liner (FML), and the lower component consists of at least a two-foot layer of compacted soil. FML components consisting of High-Density Polyethylene (HDPE) be at least 60-mil thick.

The leachate collection system, which lies just above the flexible membrane liner and under a geomembrane liner typically consists of 1 to 2 feet of sand, which may or may not contain pipes. The landfill cell and therefore the collection system will generally be designed with a slope intended to collect the leachate in one or more central locations from which it can be pumped into storage containers for treatment. Treatment of leachate can be accomplished through onsite chemical treatment and discharge to a treatment plant, by shipment to a licensed, permitted treatment, storage, or disposal facility, or by recirculation through the landfill. Leachate can be minimized through optimizing the slope of the landfill, appropriate daily cover and final capping practices, and the use of a liner to prevent groundwater infiltration.

#### 5.1.4 Gas Monitoring and Venting

Landfill gas is produced as a by-product of anaerobic decomposition of organic material, and consists primarily of methane and carbon monoxide. The control of methane, or other combustible gas, is a concern at all landfills. Landfill gas is typically vented to the atmosphere or collected and flared or incinerated. Atmospheric vent systems generally consist of a series of horizontal, perforated collection pipes located atop the landfilled material and under the final cap and vented to the atmosphere via vertical riser pipes. Landfills also use control measures such as impermeable cut-off walls or barriers, or by the provision of a ventilation system such as gravel-filled trenches around the perimeter of the landfill (see Figure 9).

The exposure of the magnesium contained in FRHs or MREs with water will generate hydrogen gas in the landfill. Any hydrogen generated in the landfill setting would be handled by the same ventilation system, however, the quantity of FRHs or MREs generating hydrogen gas is insignificant compared to the quantity of methane generated at a landfill. This hydrogen will not add any significant load to the landfill gas handling system present at most landfill sites.

Figure 10. presents a comparison between methane and hydrogen gas. The major differences of these gases are: the heat of combustion (hydrogen has more than twice the heat content per pound than methane but less than one-half the heat content per cubic foot); the maximum flame speed or burning velocity (hydrogen is eight times that of methane); and the upper explosive limit (75 percent for hydrogen and 15 percent for methane). The ignition temperatures of the two gases are similar as well as the lower explosive limit (4 percent for hydrogen and 5 percent for methane). These differences, however, will not impact the existing landfill gas handling system because the hydrogen generated from the reaction of water and magnesium is negligible compared to the methane generated at landfills.

Property	Hydrogen	Methane
Formula	H <sub>2</sub>	CH <sub>4</sub>
CAS Number	1333-74-0	74-82-8
Molecular Weight	2.016	16.041
Density, lb/cu.ft. @ 60° F & 1 atm.	0.0053	0.0424
Specific Volume, cu.ft./lb @ 60° F & 1 atm.	187.723	23.565
Sp. Gr (Air = 1.000)	0.0696	0.5543
Heat of Combustion, Btu/cu.ft.		
Gross (High) @ 60° F & 1 atm.	325	1013
Net (Low) @ 60° F & 1 atm.	275	913
Max. Flame Speed, ft/second	8.7	1.1
Lower Explosive Limit (LEL), %	4	5
Upper Explosive Limit (UEL), %	75	15
Spontaneous Ignition Temperature, ° F	1060	1170

Figure 10. Comparison between Hydrogen and Methane.

#### 5.1.5 MRE/FRH Landfill Disposal

The FRHs disposed in a landfill may consist of individual, unreacted FRHs, unreacted FRHs packed in the MRE, and/or reacted FRHs, either with or without MRE waste. These three categories can be disposed of in quantities ranging from single units to multiple boxes and/or skids. The final variable involved in disposal of the FRHs is condition of the packaging containing the FRH. This may be whole, intact packaging or damaged/opened packaging.

As stated previously, the typical method of landfill disposal includes compaction of the waste. This method may cause sealed FRH packages to rupture thereby increasing the possibility of exposure to water (due to rainfall and/or groundwater seepage) and potential reaction. Although this reaction is of no harm to the landfill or its personnel, it could cause concern. This concern could lead to misinformation of the FRH and its reaction with water. If landfill personnel are not informed of the nature of FRH waste being received, they will be unaware of the special handling procedures necessary to accommodate the material's unusual properties.

The preferred method for landfilling of FRH waste is to excavate a separate cell designated specifically for the FRHs (see Figure 9). This procedure is commonly used at many sanitary landfills for asbestos wastes. This method requires that the generator inform the landfill that they have a "special non-hazardous" waste and provide them with data about the FRH. The landfill, armed with sufficient knowledge of the waste and its hazards will then excavate a separate cell in which the FRH waste will be placed. Once the waste is placed in this excavation, soil or other cover will be placed over top. No direct compaction takes place on the FRH thereby drastically reducing the potential for rupture of the packaging. Groundwater, leachate, and/or rainfall infiltration is still likely but since the packaging is intact no reaction can occur.

MREs and FRHs placed in a landfill will decompose at an extremely slow rate. Biodegradation of the plastic packaging may take centuries. Over the years water will slowly seep into the FRH package and react with the magnesium. As previously stated, the amount of hydrogen gas produced is absolutely insignificant compared to the amount of methane gas at a landfill. The magnesium hydroxide produced through the reaction is also harmless. Magnesium hydroxide is a common substance found in antacids and poses no danger to the surrounding environment. Furthermore, the heat produced is incapable of igniting any material present in a landfill. Therefore, buried MREs and FRHs pose no danger to landfill personnel or the environment.

In the case of FRH waste with either opened or damaged packaging which is to be shipped to a landfill it should first be fully reacted with water. This precaution is to avoid any accidental contact with water either in the transport vehicle (i.e., dumpster, truck, or garbage bag) or at the landfill. FRHs in whole, intact packaging may be disposed of without any pretreatment.

## **5.2 Incineration**

### **5.2.1 Incineration Methods**

Incineration systems are an effective means of reducing large volumes of waste. These systems burn a wide variety of wastes including municipal and institutional, hazardous, toxic, and mixed (containing both hazardous and radioactive materials) waste. These systems are designed to process large quantities of waste while meeting air quality standards. The design of these facilities includes a waste treatment and feed system, a primary combustion chamber, an ash collection system, a secondary combustion chamber, and an off-gas treatment process (see Figure 5.4).

In general, there are three types of incineration systems: hazardous, toxic, and mixed waste facilities. These facilities dispose of 5 to 750 tons of waste per day, operate the combustion chambers between 1,200° F and 2,300° F, provide solids residence times (time from when the waste material enters the combustion chamber until the ash exits) ranging between 30 and 90 minutes.

A waste feed system transfers material to the primary combustion chamber. Here, solid waste material can be either fed into a shredder to reduce the size of the waste for easier handling and to expose greater surface area of the materials, or it can be directly dumped (placed) onto a tipping floor or pit where it will be transferred to the primary combustion chamber.

There are two methods for feeding the primary combustion chamber: direct (gravity, ram) feed and conveyor systems. In the direct feed system, a front-end loader takes the solid waste dumped on the tipping floor and loads a ram feeder (hopper). A hydraulically operated ram pushes the waste out of the hopper directly into the primary combustion chamber for incineration. The hopper then gets reloaded and this cycle continues. A conveyor system utilizes a chute which feeds the waste material down to a moving grate. In a tumbling action, the continuously loaded grate moves the waste throughout the primary combustion chamber.

Mass burn incinerators can be stationary (modular or traveling grate) or rotary combustion chambers. The waste feed system is often characteristic of the incinerator type. Both modular and rotary incinerators use the direct feed loading system. The modular incinerator is typically a smaller, two-chamber starved-air system with capacities between about 5 and 100 tons/day, whereas the rotary incinerator has a rotating combustion chamber mounted at a slight angle revolving at a rate of 10 to 20 revolutions per hour and processing between 200 and 450 tons of waste per day. The traveling grate incinerator processes between 150 and 750 tons per day. A mass burn incinerator is demonstrated in Figure 11.

Ash is the solid residue left when combustible material is thoroughly burned. Some ash remains airborne and is captured in the off-gas treatment process. Ash handling systems are positioned downstream of the primary combustion chamber and can be either wet or dry systems. A wet ash system uses water to quench the hot residue as it exits the primary combustion chamber. The ash is sampled and tested to determine if it is hazardous or non-hazardous.

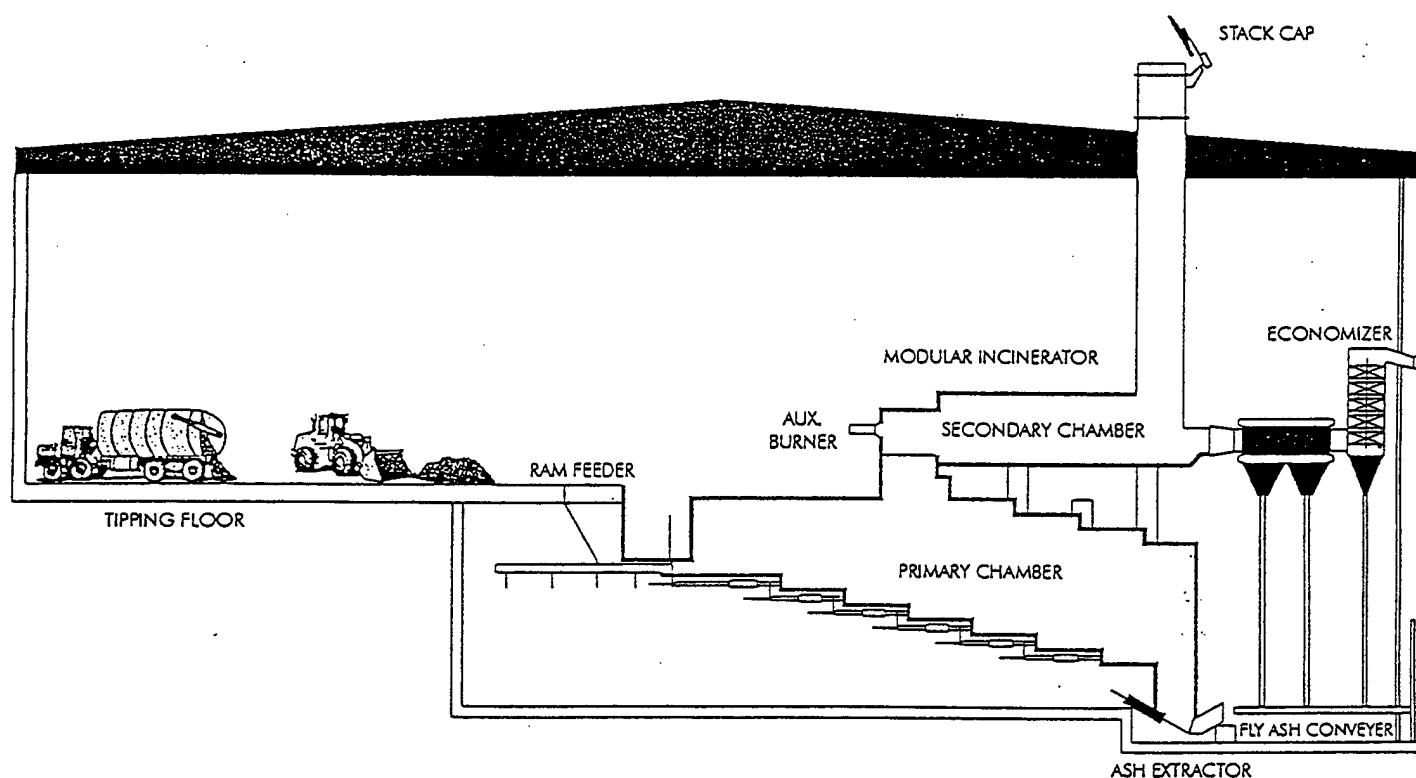


Figure 11. Modular Mass Burn Incinerator

### 5.2.2 MRE and FRH Incineration Assessment

Incineration facilities evaluate incoming waste by heat content, in Btu/lb. The process of waste MRE and FRH skid incineration was previously evaluated on a theoretical basis to determine suitability for the disposal method. The evaluation results are presented in Appendix B. FRH skids were theoretically determined to contain 12,080 Btu/lb. Skids of reacted FRH waste were theoretically determined to contain 7,980 Btu/lb. MRE skids were determined to contain 4,890 Btu/lb. FRH and MRE waste Btu values are well within the normal range of materials that are typically incinerated. The heat content of some common materials is presented in Figure 13.

Material	As-Received Heat Content, Btu/lb
Polyethylene	19,885
Fuel Oil	17,500
Fried Fats	16,466
Mixed Plastics	14,100
Coal (Bituminous, Eastern KY)	13,750
Oils and Paints	13,400
Unreacted FRH (Skid)	12,080
Rubber	11,200
Magnesium	10,624
Household Waste	8,820
Ripe Leaves	7,984
Reacted FRH (Skid)	7,980
Corrugated Boxes	7,043
MRE (Skid)	4,890
Street Sweepings	4,800
Mixed Food Waste	2,370

Figure 13. Heat Content of Materials Commonly Incinerated.

A potential problem could arise in the event an entire truck load of unreacted FRHs is incinerated. It is quite common for incinerator operators to drop an entire truck load of solid waste into a mixing bin. A truckload of FRHs contains approximately 3200 pounds of magnesium. The burning of magnesium as contained in the FRH can accumulate into puddles of molten burning metal. The adiabatic flame temperature of these puddles can reach 4000° F. Depending on the heat transfer properties of the incinerator and the materials of construction, the temperatures reached by these burning puddles can cause cracking and spalling of the refractory and warping of the drying and burning grates. This amount of magnesium would also produce a considerable amount of hydrogen if fully reacted with water. Therefore, truckload quantities of unreacted FRHs are problematic and operational restrictions are appropriate. These hazards can be all but eliminated by assuring the FRH processing rate is less than 10 to 20 percent of the total amount of material being incinerated at a time. This entails burning waste that includes 10 to 20

percent FRHs and 80 to 90 percent other solid waste. The probability of incinerating truckload quantities of FRHs is unlikely as the FRH has a long shelf life and can be stored for use at a later time. Compared to FRHs, the magnesium content of the MRE is considerably less. The weight percent of magnesium per MRE skid is approximately 0.9 percent. This allows for 100 percent of the incinerator feed to be MREs.

There are no special personal protective equipment required by the workers at an incineration facility during the combustion of FRHs or MREs. Standard equipment such as safety glasses, steel-toed shoes, and hard hats will protect the workers from injury. Special gear, such as fire retardant clothing or respirators may be required for some maintenance or monitoring activities at an incineration facility, but these requirements are not dependent on the combustion or handling of FRHs or MREs.

## 6.0 INCINERATION COOPERATIVE REPORT EVALUATION

The U.S. Army currently maintains several bases in Germany. Two of these bases are training areas located in Grafenwohr and Hohenfels. The refuse from these training areas is disposed at an Incineration Cooperative, MKW-Schwandorf, that serves three counties in Germany. This incineration facility hired a contractor, Industriebanlagen-Betriebsgesellschaft mbH, to investigate the refuse originating from Grafenwohr and Hohenfels. The investigation included inspecting all waste streams from the training areas in an effort to ensure the refuse would not danger the incinerator and its personnel. The findings of this investigation along with recommendations were compiled into a report. A draft translated version of this report is presented in Appendix C.

The report indicated that a majority of the waste streams contain MREs and FRHs. The FRHs were found alone and packaged in the MRE, and of those found 50% were unreacted. The inspectors also recovered a small amount of ammunition and pyrotechnical simulants but concluded that these were not expected to cause any problem during disposal. The inspectors reported that the FRHs heat up to 95° C when reacted with water. They stated that if the FRH reacts with water in a dumpster or during storage the surrounding waste could ignite. The report also stated that the incinerator grates would become damaged while burning the FRH because magnesium burns at 3000° C. Due to these potential problems the inspectors recommended a shredder system be installed at the U.S. Army training area. The system shreds all the waste from Grafenwohr and Hohenfels thereby exposing the FRH magnesium. The shredded waste is then sprayed with water in an effort to react the magnesium. This waste is then transported to the incineration facility and burned.

Several errors were found in the report. The inspectors reported a temperature of 95° C when the FRH is reacted with water. The reaction has been shown through numerous tests to produce a temperature of approximately 60° C. A 60° C temperature is unable to ignite other wastes products. The autoignition temperature of hydrogen gas and petroleum is 550° C and 225° C respectively. Other products typically found in the waste stream have much higher autoignition temperatures. Therefore, the FRH/water reaction is not capable of igniting other wastes.

The report also states that magnesium burns at the temperature of 3000° C. This temperature is also not correct as the adiabatic flame temperature of magnesium is 2190° C. The inspectors report that the burning magnesium can cause cracking or spalling of the incinerator grates. Although there is the possibility of causing damage to the grates, it is highly unlikely. The magnesium would cause a problem if "puddles" accumulated on the grates and burned. This would only happen if numerous skids, (i.e., an entire truckload), of unreacted FRHs were incinerated at one time. Burning literally thousands of FRHs without the MREs at one time will most likely never occur at these bases. The FRHs are normally packaged with the MRE. Incinerating MREs does not pose any problem as magnesium accounts for less than one percent by weight of a skid of MREs. Therefore, unreacted FRHs do not pose a significant problem to the incinerator as the magnesium content of the dumpster waste stream is extremely low.



The shredder system currently being utilized at Grafenwoehr effectively shreds the waste and reacts the magnesium. The cost of purchasing and installing such a system was in excess of one million U.S. dollars. Shredding the FRHs is extremely costly considering the non-hazardous nature of the material. As previously stated, it is unlikely for the FRH to ignite or prolong a fire. In order to eliminate any potential concern, the FRH product should be segregated from all other waste. Soldiers should be educated on the proper handling and disposal of the FRH to ensure the product is disposed properly. This method is much more cost effective than shredders and can be quickly implemented.

## 7.0 CONCLUSIONS

The FRH was developed as a compact module to heat MREs in the field without the use of fire or bulky equipment. The reacted FRHs are easily disposed of since the activated ingredient, magnesium, is deactivated during use. MREs that do not include the FRH can also be easily disposed of as normal refuse. The unactivated FRH, either alone or packaged with the MRE, has led to uncertainties regarding proper disposal methods. Misunderstandings over the reactive nature of the FRH have resulted in costly, often unnecessary, disposal actions. The focus of this study is the removal of these misunderstandings through a straightforward presentation of the product properties and proper procedures for disposing the FRH and MRE.

The MRE and FRH are not considered hazardous materials. The products are specifically designed and manufactured to remain stable during storage and use. Thus, the MRE and FRH are not harmful to humans or the environment. FRHs are unlikely to ignite a fire in a dumpster. The pads are hermetically sealed and packaged within the MRE. This ensures the FRH pad is not exposed to water or fire under ordinary conditions. Dumpster fires occur when flammable materials, such as oily rags or paper, come into contact with an ignition source. For instance, a lit cigarette landing on dry paper can potentially start a fire. The FRH is not considered an ignition source nor is it capable of contributing to a fire under ordinary circumstances. A problem only arises when the FRH is exposed to fire and water simultaneously. This scenario enables the FRH, under certain conditions, to produce large flames that may ignite the surrounding material. The potential for this is low but can be avoided by segregating the unreacted MRE/FRH material from other waste.

Landfill and incineration are both practical solutions for the disposal of MRE/FRH waste. Although it is highly unlikely for problems to occur during disposal, certain procedures should be implemented to prevent incidents from occurring. Excavating a separate cell at a landfill will ensure that no direct compaction of the product takes place. This prevents the FRH from rupturing and thereby eliminating the risk of reaction with water. This reaction, although not harmful or deleterious, may become the source of concern or misinformation. Once the MRE/FRH waste is buried in the landfill it will slowly biodegrade producing no harmful by-products. Incineration of the waste is also an effective means of disposal. The MRE/FRH waste is typical of other waste normally disposed of at an incinerator. A potential problem would arise if an entire truckload of unreacted FRHs was incinerated. Burning this amount of magnesium at one time could damage the incinerator grates. The problem can be alleviated by processing 10-20% FRH waste with 80-90% other waste.

The Incineration Cooperative Report incorrectly evaluated the characteristics of the MRE/FRH. A shredder system was installed at a U.S. Army Base in Germany in order to eliminate problems with the FRH. A more cost effective solution may have been achievable. For example, an education program for the soldiers, identifying the proper handling and disposal of FRH material, would enable segregation of the FRH from ordinary waste.

This document reports research undertaken at the U.S. Army Soldier and Biological Chemical Command, Soldier Systems Center, and has been assigned No. NATICK/TR-~~66~~017 in a series of reports approved for publication.

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**APPENDIX A**

**TECHNICAL GUIDANCE DOCUMENT**

The flameless ration heater (FRH) is a chemical pad which generates heat from reaction with water to warm soldier meal rations, Meal Ready-to-Eat (MRE), in the field. The FRH is bulk packaged or packaged inside the MRE. The MRE also contains an assortment of food items and accessories. The heater consists of magnesium, iron, polyethylene powder, salt, surfactants and buffering agents blended together and sintered into a 3.5" by 4.5" by 0.125" flexible pad. The heater is activated by tearing open the sealed bag and adding approximately 2 ounces of water.

The reaction of the FRH and water is a controlled, stable reaction in which magnesium reacts to form magnesium hydroxide and heat. Hydrogen gas is also generated as a by-product. The hydrogen gas is minimal and extremely difficult to ignite under ordinary ventilated conditions. The autoignition temperature for hydrogen is 550° C which of course is much hotter than the conditions FRHs are stored. Hydrogen is also extremely buoyant thereby diffusing in the atmosphere more rapidly than any other substance. Therefore, the evolution of hydrogen gas from a reacting FRH would not likely start or aid in the continuation of a fire. The FRH pad itself is also extremely difficult to ignite. Lit cigarettes and other small flames will not ignite the FRH. Fires in which the FRH is involved would have to be initiated by other sources such as dry paper or oily rags in contact with an ignition source.

The MRE and FRH are not considered as hazardous materials. The MRE/FRH was specifically designed to remain a stable product during storage and use. The FRH is sealed in a polyethylene bag and packaged in the sealed flexible plastic MRE bag. This provides a multi-layer barrier that is impermeable to water. The risk of a reaction occurring during storage or disposal is minimal. Under certain conditions the FRH can produce undesirable reactions, such as large flames in the presence of water and fire. Although the unreacted FRH is not considered as hazardous, care should be taken in its handling, storage, and disposal.

A fire cannot be initiated by a FRH, however the fire's intensity may be prolonged by it. Large, intense flames have the ability of igniting the FRH. The FRH pad, when burning, produces small flames. A problem arises when water comes into contact with the burning FRH as large shooting flames can be produced. This scenario offers the only method by which an FRH could be considered dangerous. Although the chances of this situation occurring are extremely low, care should be taken to eliminate any possibility.

The following procedures can be established for MRE/FRH material destined for disposal to ensure the safety of all personnel. FRHs that have been activated with water are easily disposed of, since the active component, magnesium, is reacted during use. MREs that do not include the FRH can easily be disposed of as normal refuse. All opened and unreacted FRHs should be reacted with water in order to render the magnesium inactive. This can be accomplished by placing a small amount of the opened FRHs in a bucket of water. Reacted FRHs should then be disposed of with normal refuse and without special handling requirements. MREs without the FRH included should also be discarded with other ordinary waste. An unactivated FRH, whether alone or packaged with the MRE, requires special attention. To avoid any potential problem, the FRHs should be stored in a cool dry place and not disposed of in a dumpster. Segregating the unreacted FRHs from other waste ensures that in the event of a

dumpster fire the FRH will not prolong the fire. Thus, problems only arise when the FRH is exposed to fire and water simultaneously. FRHs destined for disposal should be stored in a cool dry place until a significant quantity is collected. At this time the FRHs can be shipped to an appropriate disposal facility. Once again, FRHs disposed of in dumpsters will most likely not cause problems. These precautions are not required but merely presented as a way to eliminate any possible incident.

FRH pads that have not been reacted or damaged can be stored for an indefinite amount of time and utilized when needed. Therefore, it is not necessary to dispose of unreacted FRHs as they can be used at a later time. The MREs have a shelf life of 3 years and the expiration dates can be extended as necessary. Supplies of MREs can be inspected by Veterinary Services and reissued if the contents are acceptable. Disposal of the MRE and FRH should be a last option unless the product is used, opened or otherwise damaged.

FRHs destined for disposal at landfills should be given special attention. The typical method of landfill disposal involves compaction of the waste which may rupture the sealed FRH thereby increasing the possibility of reaction. Although a FRH/water reaction at a landfill is not particularly important, it may cause unneeded concern. Therefore, special precautions should be administered when landfilling the FRH. Landfill personnel should be informed of the material being disposed of. This allows personnel to treat the FRH with caution and prevent any unnecessary reaction. The preferred method for landfilling the FRH is to excavate a separate cell designed specifically for the product. The FRH is placed in this cell and soil or other cover is placed over top. No direct compaction occurs thereby reducing the potential for rupture of the FRH package. This method ensures the FRH avoids any ignition or water source which prevents any reaction from taking place.

Incineration is a common disposal procedure practiced throughout the world as it is an effective means of reducing large volumes of waste. The magnesium content of the FRH is the only component that makes the product unique for incineration. The other components of the MRE are materials commonly incinerated. Incineration facilities are capable of burning the MRE with the FRH as the temperatures and gas produced are well within its operating range. A potential problem arises when an entire truckload of unreacted FRHs are incinerated. This scenario is unlikely as FRHs, unless damaged, can be stored for a period of time and utilized later. Furthermore, FRHs are typically packaged with the MRE which poses no incineration problem. The magnesium present in entire skids of FRHs may accumulate into puddles of molten burning metal. Depending on the heat transfer properties of the incinerator and the materials of construction, the puddles of burning magnesium may cause cracking and spalling of the refractory and warping of the drying and burning grates. This potential problem can be alleviated by processing 10 to 20 percent FRHs with other waste thereby reducing the percent of magnesium in the incinerator.

Pretreatment of all refuse is another option that will alleviate concerns over disposal. Shredders can be installed at the facility that act to open the FRHs and react the magnesium.

These shredders would accept all the waste produced at a facility and process it thereby eliminating any possibility of reaction. This option is extremely costly and time consuming.

In conclusion, the FRH is not considered a hazardous material. It is specifically designed and manufactured to be a stable, safe product in which to heat meals in the field. The magnesium/water reaction is a controlled, low energy reaction that is not capable of igniting a fire. The pads are hermetically sealed and packaged within the MRE. This ensures the FRH pad is not exposed to water or fire under ordinary conditions. Dumpster fires occur when flammable materials, such as oily rags or paper, come into contact with an ignition source. For instance, a lit cigarette landing on dry paper can potentially start a fire. A problem arises when the FRH is exposed to water and fire simultaneously. Although the potential of this occurring is low, it can easily be avoided by segregating MRE/FRH waste from all other refuse. MRE and FRH waste can be landfilled without incident although it is recommended to follow certain procedures. MRE and FRH waste placed in separate cells will ensure that no reaction occurs. Incinerators are also a viable option for the disposal of MREs and FRHs. MREs pose no problems to incinerators as they are equipped to handle such waste. Precautions are only warranted when entire skids of FRHs are incinerated.

## **APPENDIX B**

### **FRH/MRE HEAT CONTENT EVALUATION TABLES**



Table 1. Heat Content Evaluation of FRH Components 100% Oxidation (Before Reaction)

Material	Weight per Pad <sup>a</sup> , gr	Weight per Skid <sup>b</sup> , gr	Weight per Skid <sup>c</sup> , lb	Ignition Temp. °F	Heat of Combustion <sup>d</sup> , Btu/gr	Heat of Combustion <sup>e</sup> , Btu/lb	Heat Content per Skid, Btu	% of Total Heat Content
Magnesium	8.0	69,120	152.2	1153 <sup>a</sup>	23.4	10,624	1,617,408	14.7%
Iron	2.0	17,280	38.1	-	7.0	3,178	120,960	1.1%
NaCl	0.6	5,184	11.4	-	-	-	-	0.0%
Polyethylene in pad	10.0	86,400	190.3	716 <sup>f</sup>	43.8	19,885	3,784,320	34.3%
Polyethylene in bag	5.4	46,656	102.8	716 <sup>f</sup>	43.8	19,885	2,043,533	18.5%
Sleeve	9.2	79,488	175.1	536 - 932 <sup>g</sup>	18.0	8,172	1,430,784	13.0%
Shrink Wrap		1,728	3.8	716 <sup>f</sup>	43.8	19,885	75,686	0.7%
Cases		60,900	134.1	536 - 932 <sup>g</sup>	18.0	8,172	1,096,200	9.9%
Skid & Other		47,292	104.17	536 - 932 <sup>g</sup>	18.0	8,172	851,256	7.7%
Totals		414,048	912.0				11,020,147	100.0%
Hydrogen generated <sup>h</sup>	0.7	5,702	12.6	1065 - 1095 <sup>h</sup>	114.0	51,756	650,028	5.9%
Natural Gas (methane) for comparison				1170 - 1380 <sup>h</sup>	53.3	24,198		

a) Blazetech Corporation. Fire Hazard Testing and Evaluation of the Flameless Ration Heater. Prepared for the Department of the Army Natick Research, Natick, MA. January 1992.

b) Based on 30 boxes of FRHs on a skid with 288 FRHs in each box.

c) Calculated based on 454 gr/lb. Weight of "cases", "skid and other", and total weight based on sample skid of FRHs provided by Natick Research.

d) Based on heat content values in Blazetech Report and Perry's Chemical Engineers Handbook (Fourth Edition, 1969).

e) Calculated by multiplying heat content in Btu/gr by 454 gr/lb.

f) Fire Protection Handbook, Seventeenth Edition. National Fire Protection Association, Quincy, Massachusetts. 1992.

g) Calculated based on the reaction:  $Mg + 2H_2O \rightarrow Mg(OH)_2 + H_2$  or for every gram mole (gmole) of Mg reacted

(24.3 gr/gmole), one gmole (2 gr/gmole) of  $H_2$  is produced. For example, 8 gr of Mg (0.33 gmole) will react with

water to form 0.33 gmole of  $H_2$  (0.66 gr). Natural gas ignition temp. and heat content provided for information only.

h) Steam, Its Generation and Use. The Babcock & Wilcox Company, New York, New York. 1963.

Table 2. Heat Content Evaluation of MRE Components 100% Oxidation (Before Reaction)

Material	Weight per Pad <sup>a</sup> , gr	Weight per Skid <sup>b</sup> , gr	Weight per Skid <sup>c</sup> , lb	Ignition Temp. °F	Heat of Combustion <sup>d</sup> , Btu/gr	Heat of Combustion <sup>e</sup> , Btu/lb	Heat Content per Skid, Btu	% of Total Heat Content
Magnesium	8.0	4,608	10.1	1153 <sup>a</sup>	23.4	10,624	107,827	1.9%
Iron	2.0	1,152	2.5	-	7.0	3,178	8,064	0.1%
NaCl	0.6	346	0.8	-	-	-	-	0.0%
Polyethylene in pad	10.0	5,760	12.7	716 <sup>f</sup>	43.8	19,885	252,288	4.6%
Polyethylene in bag	5.4	3,110	6.9	716 <sup>f</sup>	43.8	19,885	136,236	2.5%
Sleeve	9.2	5,299	11.7	536 - 932 <sup>g</sup>	18.0	8,172	95,386	1.7%
Food and Containers and Cases			1,087.30	536 - 932 <sup>g</sup>	10 estimated	4,540	4,936,342	89.2%
Totals		20,275	1,132.0				5,536,142	100.0%
Hydrogen generated <sup>g</sup>	0.7	379	0.8	1065 - 1095 <sup>h</sup>	114.0	51,756	43,236	0.8%
Natural Gas (methane) for comparison				1170 - 1380 <sup>h</sup>	53.3	24,198		

a) Blazetech Corporation. Fire Hazard Testing and Evaluation of the Flameless Ration Heater. Prepared for the Department of the Army Natick Research, Natick, MA. January 1992.

b) Based on 48 boxes of MREs on a skid with 12 MREs in each box.

c) Calculated based on 454 gr/lb. Weight of "food and containers and cases" and total weight based on sample skid of MREs provided by Natick Research.

d) Based on heat content values in Blazetech Report and Perry's Chemical Engineers Handbook (Fourth Edition, 1969).

e) Calculated by multiplying heat content in Btu/gr by 454 gr/lb.

f) Fire Protection Handbook, Seventeenth Edition. National Fire Protection Association, Quincy, Massachusetts. 1992.

g) Calculated based on the reaction:  $\text{Mg} + 2\text{H}_2\text{O} \rightarrow \text{Mg}(\text{OH})_2 + \text{H}_2$  or for every gram mole (gmole) of Mg reacted (24.3 gr/gmole), one gmole (2 gr/gmole) of  $\text{H}_2$  is produced. For example, 8 gr of Mg (0.33 gmole) will react with water to form 0.33 gmole of  $\text{H}_2$  (0.66 gr). Natural gas ignition temp. and heat content provided for information only.

h) Steam, Its Generation and Use. The Babcock & Wilcox Company, New York, New York. 1963.

Table 3. Heat Content Evaluation of FRH Components (After Reaction)

Material	Weight per Pad <sup>a</sup> , gr	Weight per Skid <sup>b</sup> , gr	Weight per Skid <sup>c</sup> , lb	Ignition Temp. °F	Heat of Combustion <sup>d</sup> , Btu/gr	Heat of Combustion <sup>e</sup> , Btu/lb	Heat Content per Skid, Btu	% of Total Heat Content
Magnesium Hydroxide	19.2	165,888	365.4	-	-	-	-	0.0%
Iron Oxides	4.0	34,560	76.1	-	-	-	-	0.0%
NaCl	0.6	5,184	11.4	-	-	-	-	0.0%
Polyethylene in pad	10.0	86,400	190.3	716 <sup>f</sup>	43.8	19,885	3,784,320	40.8%
Polyethylene in bag	5.4	46,656	102.8	716 <sup>f</sup>	43.8	19,885	2,043,533	22.0%
Sleeve	9.2	79,488	175.1	536 - 932 <sup>f</sup>	18.0	8,172	1,430,784	15.4%
Shrink Wrap		1,728	3.8	716 <sup>f</sup>	43.8	19,885	75,686	0.8%
Cases		60,900	134.1	536 - 932 <sup>f</sup>	18.0	8,172	1,096,200	11.8%
Skid & Other		47,292	104.17	536 - 932 <sup>f</sup>	18.0	8,172	851,256	9.2%
Totals		528,096	1,163.2				9,281,779	100.0%
Hydrogen generated <sup>g</sup>	-	-	-	1065 - 1095 <sup>h</sup>	114.0	51,756	-	0.0%
Natural Gas (methane) for comparison				1170 - 1380 <sup>h</sup>	53.3	24,198		

a) Blazetech Corporation. Fire Hazard Testing and Evaluation of the Flameless Ration Heater. Prepared for the Department of the Army Natick Research, Natick, MA. January 1992. Also assumes 100% reaction of Mg and Fe with water.

b) Based on 30 boxes of FRHs on a skid with 288 FRHs in each box.

c) Calculated based on 454 gr/lb. Weight of "cases", "skid and other", and total weight based on sample skid of FRHs provided by Natick Research. Not including water retained in cases, skid, and other. The retained water would considerably reduce the overall heating value of the skid of reacted FRHs

d) Based on heat content values in Blazetech Report and Perry's Chemical Engineers Handbook (Fourth Edition, 1969).

e) Calculated by multiplying heat content in Btu/gr by 454 gr/lb.

f) Fire Protection Handbook, Seventeenth Edition. National Fire Protection Association, Quincy, Massachusetts. 1992.

g) No hydrogen is potentially generated under this scenario. Natural gas data are provided for information only.

h) Steam, Its Generation and Use. The Babcock & Wilcox Company, New York, New York. 1963.

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## **APPENDIX C**

### **DRAFT INCINERATION COOPERATIVE REPORT TRANSLATION**

**DRAFT**

**Gutachten**  
**über die Möglichkeiten der Entsorgung des**  
**anfallenden Hausmülls für die Truppenübungsplätze**  
**Grafenwöhr (Süd- und Ostlager) und Hohenfels**

**Bericht zur Phase 2**

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# Report Sheet

1. Report Number Ordering Party	2. Type of Report	3. Report Number Contractor B - UM 9169/00
4. Report Title Expert opinion on the possibilities for the disposal of household waste generated at Troop Training Areas Grafenwöhr (South Camp and East Camp) and Hohenfels Report to Phase 2		
5. Author(s) (name, first name)  Oettinger, Karl  Dr. Hollaus, Beate Heuschneider, Peter		11. Date of Completion 22.07.1997  12. Date of Publication
6. Contractor, Department, Address.  Industrieanlagen-Betriebsgesellschaft mbH Abt. UM 11 Postfach 1212 85503 Ottobrunn		13. Number of Pages 100 14. List of References 8
7. Ordering Party, Department, Address  Staatliches Hochbauamt Amberg Kirchensteig 3 92224 Amberg		15. Tables 9 16. Illustrations 7
8. Brief Report  The expert opinion studies and appraises the effects of the planned disposal of residual waste from troop training areas Grafenwöhr and Hohenfels on the facilities of Zweckverband Müllverwertung Schwandorf (ZMS) (special-purpose association for waste management) as well as on the licenses issued for these facilities. To do this, it was necessary to <ul style="list-style-type: none"> <li>• examine residual waste samples in order to determine their composition and hazard potential</li> <li>• ascertain the additional emission loads resulting from potential problem materials contained in the residual waste</li> <li>• review whether these additional burdens will entail interferences in the facility licenses</li> <li>• review how a potential pretreatment of the residual waste should be carried out in an economically and ecologically meaningful manner in order to eliminate the hazard potential for the ZMS facilities</li> </ul>		
9. Key Words  flameless ration heater; waste; waste-incinerating heating plant; waste flow; waste incineration; waste disposal; landfill; residual waste; emission load; facility safety; corrosion; plan determination decision; shredder plant		
10. Remarks		



## Summary

### *Introduction*

It was noted already during phase 1 of the expert opinion that ammunition and pyrotechnical simulants will not constitute the main problem of residual waste management for troop training areas Grafenwöhr and Hohenfels. The reason for this is that it can be taken as a basis that the ammunition which is contained in the residual waste contrary to regulations involves only rifle, pistol and machine-gun ammunition. The pyrotechnical simulants, on the other hand, are some sort of big firework article for the generation of smoke and light flashes, as they are used in a similar type also on the civilian sector. Other ammunition, especially large-caliber ammunition (over 12.7 mm = cal. 50), cannot be in the residual waste due to the strict multiple monitoring system. The same applies to hand grenades, mines, rockets, etc.

The main problem in connection with the disposal of residual waste are the chemical heating elements that are contained in the field rations of the training soldiers for heating up parts of these rations (flameless ration heater - FRH). The heating elements, in the following referred to as FRH, heat up to 93°C when water is added. They hold this heat about ten minutes; after that, their reaction potential is used up and they cool down and become entirely harmless. Heat generation is effected through hydrolysis of magnesium powder mixed with binding agents. The reaction is interrupted as soon as there is no more liquid, yet continues when new liquid is added.

The hazard potential of the FRH, on one hand, is that when they are torn open in the waste bunker of the waste-incinerating heating plant (MKW) Schwandorf or in one of the waste reloading stations they can react in the presence of water and generate heat as a result of which the surrounding residual waste may start to burn. Consequently, they constitute a permanent source of ignition in the reactive state. On the other hand, however, FRH constitute quite some danger for the combustion grate of the particular furnace line of MKW-Schwandorf when several of them (more than around 20) reach the grate at the same time because magnesium burns at a temperature of 3000°C and thereby can cause damage to the combustion grate.

Because these findings were in parts made already during phase 1 of the expert opinion, it was clear that the residual waste of some waste flows cannot be disposed of in the facilities of Zweckverband Schwandorf (ZMS) without pretreatment or without sorting out the FRH.

Based on these findings, a number of follow-up questions had to be studied and clarified in the course of phase 2 in order to take suitable measures allowing the safe disposal of the residual waste.

Altogether, the following four study fields were formed for phase 2 of the expert opinion:

1. Investigation of the hazard potential of the residual waste by means of selective residual waste samples
2. Investigation in regard to the endangerment of the technical facilities of ZMS and the operating staff
3. Investigation of an organizational and administrative solution to the FRH-problem
4. Investigation of a technical solution to the FRH-problem for the event that an organizational/administrative solution is not feasible.

The individual study fields were based on the following detail questions among other things:

- To what extent is the residual waste of the housing areas contaminated with ammunition, simulants and FRH? Can residual waste flows be disposed of without pretreatment in the ZMS facilities?
- To what degree is the residual waste that is scheduled for pretreatment contaminated with ammunition, pyrotechnical simulants and FRH?
- Which impairments will arise from pretreatment and disposal with regard to safety at work, facilities safety and fire prevention?
- How do the pyrotechnical simulants behave when they reach MKW-Schwandorf in an undamaged and functioning state?
- Which additional emission loads will the residual waste from the troop training areas bring for MKW-Schwandorf? (loads on exhaust gases and consequential loads)?
- Under which conditions will black powder and propellant powder ignite?
- Will hydrochloric acid which occurs as a reaction product cause damage to the facilities of MKW-Schwandorf?
- Which legal effects will the disposal of residual waste with FRH have on the plan determination decision [official plan approval] for MKW-Schwandorf, on the DeNOx-decision and on the plan determination decisions for the reloading stations?
- Which organizational and administrative measures will prevent the contamination of the residual waste with FRH?

- With which shredder facilities can ammunition and pyrotechnical simulants be crushed safely so that disposal is possible in the ZMS facilities?
- Which technical solution is economically and ecologically meaningful to resolve the FRH-problem in case organizational administrative measures cannot be carried out?
- Which investment costs must be expected and which consequential expenses will arise?

Assessment regarding the possibilities of the disposal of the accumulating household garbage of the training area Grafenwöhr (Süd- and Ostlager) and Hohenfels Areas.  
Report to phase 2

Version 1.0

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## Results

It had been calculated (due to errors, and accounting deficiencies) in phase 1 of the assessment, that the following maximum munition contamination could exist:

- o one cartridge per 10 Mg (tons) of remaining garbage and
- o one pyrotechnical device (Hoffmann Device) per 20 Mg of remaining garbage.

Phase 2 of the assessment was to inspect and sample and examine the remaining garbage and determine whether this contamination holds true and if deviations can be determined.

Additionally, it was to examine which remaining garbage streams are free of munition, Hoffmann Devices and FRH packets.

Overall one has to proceed with the fact that the contamination with munition is much lower than originally assumed due to the accounting deficiencies. However for safety reasons, in connection with the calculation of the emission, the originally prognosticated contamination with munition and Hoffmann Devices was retained.

Due to the sampling of the remaining garbage one can conclude that the following is the actual contamination:

- o one cartridge per approximately 60 Mg of remaining garbage and
- o one Hoffmann Device per approximately 190 Mg of remaining garbage.

With this, due to sampling established numerics one has to assume the cartridges found were not only disposed of (placed) in the remaining garbage against regulations but that this almost reflects criminal intention. Further more one has to conclude from the fact that the discovered Hoffmann Devices got into the garbage despite of an already established disposal procedure. However the modifications to the "Standard Operating Procedures" (SOP) will exclude further contamination with Hoffmann Devices.

Examinations of the remaining garbage however also show the fact that one cannot conclude that exclusivity in certain garbage streams rule out that munition and Hoffmann Devices can be found, but that in contrary to the prognosis from phase 1 of the assessment all garbage streams

can be tainted. Therefore, for safety reasons, all garbage streams need to undergo a pre-treatment.

Examinations of possible dangers to workers safety, equipment safety and fire regulations during pre-treatment of remaining garbage lead to the conclusion that these aspects are mostly concerned with equipment related aspects. Experiences with respect to legal and official imposts cannot be followed are not known to our knowledge since it could not be found out where a similar equipment in this configuration is in operation. According to the opinion of the experts (evaluators) it can be concluded that the specified imposts can be followed, that one does not have to deal with a new, unproven technology.

Examination in to how far work safety, equipment safety, and fire regulations, the equipment of the ZMS (MKW-Schwandorf and reloading stations) is harmed by the disposal of the remaining garbage of the training areas Grafenwöhr and Hohenfels showed no negative results because the remaining garbage of the training areas consists exclusively of household garbage, household-like garbage and trash and that those, according to the operating plans are allowed to be disposed within the equipment of the ZMS.

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In the opinion of phase 1 it was discussed that an explosion of a functioning, undestroyed Hoffmann Device in a stove furnace- line of the MKW-Schwandorf could lead to an opening of the bypass and therefore to a mandatory reporting incident. Experiences about the burning of Hoffmann Devices were not known, contrast to the experiences that we have in the burning of rifle and MG munition, and because of this reason experiments were necessary. The following reflect the results of these experiments:

- o Hoffmann Devices do not explode when being burned because their plastic cover which could function as a possible confinement first melts so that the gun powder burns off with a flare up.
- o Even if several undestroyed Hoffmann Devices get into a furnace- line no pressure build up develops because the necessary confinement for an explosion is missing.
- o An ignition of Hoffmann Devices in the ZMS is not possible because in order for this to happen much higher temperatures are necessary than exist basically in the equipments.

The thermal disposal of cartridge munition, Hoffmann Devices as well as FRH packets is influenced by the following basic limits:

- o Overall dust
- o Organic substances, indicated as overall carbon
- o Gaslike inorganic chlorine compounds, indicated as hydrochloric acid
- o Sulphurdioxide and sulfurtrioxide, indicated as sulphurdioxide
- o Nitrogenoxide and nitrousoxide, indicated as nitrousoxide
- o Antimony and its compounds, indicated as Sb
- o Lead and its compounds, indicated as Pb
- o Copper and its compounds, indicated as Cu
- o PCDD and PCDF

On basis of the proportion and the stoichiometric reactions the following substances contribute in a higher degree to harmful emission in the process of a thermal disposal of the remaining garbage and were therefore included in the calculation of the emissions:

- o Inorganic chlorine compounds
- o Sulphurdioxide
- o Sulphurtrioxide
- o Nitrogenoxide
- o Nitrousoxide and
- o Lead and its compounds.

On basis of the allowed limits as well as the from the operator of the MKW-Schwandorf measured emission values of the MKW one is to conclude that there is no change in the consistency of the emission during disposal of the remaining garbage of the training areas when considering the amount of the garbage and its consistency.

An endangerment through monobasic and dibasic propellant (powder) "Treibladungspulver" as well as through the black powder "Schwarzpulver" during transport of the garbage and the storage in the dumps can be widely excluded on basis of the substance characteristics and the estimated quantity as mentioned above. Because of the shredding of the garbage an additional destruction of the cartridge munition and the Hoffmann Devices is realized, ...

... so that a detonation danger can be excluded. In addition to that a partly mixing of the garbage occurs in the process of shredding which contributes to a further reduction in local concentrated maximum values of the explosive substances and of the danger potential.

During thermal disposal of chlorine containing waste gaseous reaction products such as hydrochloric acid can be formed in addition to solid chlorine compounds. In the case of the cartridged munitions as well as signal munitions and the Hoffmann devices the following chlorine containing substances can be contained in the following components:

- o phosphors
- o accelerators
- o sulphurs
- o additional additives

On basis of the quantity of the chlorine containing compounds in the cartridged munitions and Hoffmann devices one cannot assume that the hydrochloric acid (HCl) that forms during the thermal disposal of those substances leads to a relative additional corrosive strain. Furthermore one can conclude that not all the chlorine in these substances is changed to hydrochloric acid (HCl) during reaction.

The purpose of the Phase 2 assessment was to examine and check if and to what extent the disposal of the garbage from the training areas Grafenwöhr and Hohenfels had on the issued permits, especially to inspect the effects on the decision of March 27, 1992 and the DeNO<sub>x</sub> ruling from June 7, 1993 as well as the decisions of the planned reloading stations.

Consequently the results of these inspections with regard to the thermal disposal of the garbage from the Training Area Grafenwöhr and Hohenfels neither

- o the limits of the operating limits from 03/27/1992 (MKW-Schwandorf) nor
- o the limits of the permit from 06/09/1994 (MKW-Schwandorf Furnace -line 4) nor
- o the limits of the DeNO<sub>x</sub> Permit from 06/07/1993 nor
- o the limits of the operating limits from 08/09/1984 (Mathiaszeche)

were reached. The results from the testing of emissions noted in the section "Emission in the Off-gasses and Waste Sediments from the Fume Scrubber" produced no legal problems with regard to the permits, without regards to whether and to what extent the waste from the troop

training area Grafenwöhr and Hohenfels was contaminated by munition, munition components, or Hoffmann devices.

Thereby the operating limits from 03/27/1993, the permit from 06/09/1994 (modifications to furnace -line 4), the DeNO<sub>x</sub>-Permit from 03/07/1993, and the operating limits from 08/09/1994 (Mathiazeche) were not negatively influenced by the thermal disposal of the garbage.

Due to extenuating grounds on side of the US-Army's general evasive strategy no distinct regulations regarding the collection of the FRH packets can be realized.

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Henceforth as the Phase 2 assessment continued there would be no solution to the collection system of the field camps, and the garbage there would contain FRH packets and MRE packages. The above mentioned result in an abandonment to an organized and administrative solution to the FRH-Problem.

Because the FRH packets and not the cartridged munitions or the pyrotechnical Hoffmann devices represent the main disposal problems connected with garbage from the troop training area, a separate inspection of the shredded munitions and Hoffmann devices will be abandoned.

The inspection and experiments concerning the safe disposal of the garbage (eliminating the potential danger from FRH packets, munitions, pyrotechnics) of the troop training area have shown that a two stage shredder is necessary. The specifications of this two stage shredder is noted in the section entitled "Technical Specifications" in the following way:

- o Coarse shredding with a low RPM shredder
- o Fine shredding with a high RPM shredder
- o Ferromagnetic separation following coarse shredding
- o Spray system for the fine shredder discharge
- o Loader with a high cabin to simultaneously charge (furnace) and control the entire system
- o Large-Container with a roll-up roof (ex. ? compactor in various configurations ?)



The rough estimated investment for this equipment is as follows:

1. Coarse Shredder	600.000,--DM
2. Ferro-magnetic Separator	60.000,--DM
3. Fine Shredder including Spray System	450.000,--DM
4. Conveyor-belts, Controls, Assembly, Steel Framing, etc.	190.000,--DM
5. Loader	350.000,--DM
6. Containers approximately 40m <sup>3</sup> , total of 10 @ 15.000,--DM each	150.000,--DM
7. Electrical equipment (Transformers, etc.)	200.000,--DM
8. Building investment ( land, foundations, bunkers, drainage, fence etc.)	600.000,-DM
OVERALL:	<u>2.600.000,-DM</u>

Operating costs are exclusively dependent on the configuration of the equipment and can at this time not yet be estimated. However, one can conclude that there will be no increase in costs of personnel. This means that no additional personnel is necessary for the operation of the equipment or the operation of the loader. Only initial instruction and little training (estimated at a couple of days) is necessary.

Because of the fact that the shredding equipment has a low maintenance requirement and repair rate (information supplied by the operators) except for the changing of worn parts, one has to conclude that the current personnel are basically able to change the parts themselves and that they are also able to perform maintenance work if the shredding equipment is electrically operated.

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In the case of an operation with diesel motors the maintenance requirements however will be higher and will most likely require specially trained personnel and will probably no longer be performed by the available personnel .

Within the scope of the "Technical Specification" it must be realized that the necessary construction is limited to site preparation, including drainage, foundations, necessary electrical installations (ECR,etc.), fencing, garbage stockpile enclosure (? L ?-stressed skin construction, or similar) and roadways. Superstructures, for example the construction of a hanger, in our opinion is currently not necessary.

The connection of the drainage system to the present system will probably not cause any problems because this can be added to the current permit.

During the course of the planning stage, the question of approval of the plant must be cleared, and the respective authority must be contacted and informed early enough.

In summary it can be established that,

- o a safe disposal can only be assured through use of the "Technical Specifications"
- o the suggested "Technical Specifications" afford little hidden dangers
- o no additional personnel are required
- o the maintenance can largely be performed by the operators
- o the initial training of the existing personnel will require a couple of days  
(3-5 days for operation, maintenance, loader, and shredder)
- o the operating and maintenance costs will therefore be contained
- o currently, no superstructure is necessitated
- o all other construction is typical and without risk
- o the "Technical Specifications" should be readily attained in order not to cause an emergency disposal situation because of the closure of the disposal facility.

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## List of Abbreviations

### Abbreviations Used

AbfG	Waste Disposal Laws
ASG	Area Support Group
ASP	Ammunition Supply Point
ATC	Army Training Command
B	Width
BayAbfAIG	Bäyer Waste Industry and Recycle(?Law?)
BGS	Borderguards
Bw	German Military
Cal.	Caliber
cbm	cubic meter
DM	German Model
DPW	Director of Public Works
DV	Service Instructions
EOD	Explosive Ordinance Disposal (Fire Department)
FRH	Flameless Ration Heater (chemical heating-element to warm field rations)
GFK	Fiberglass reinforced plastic
ggf.	occasionally
GGVS	Hazardous Waste (roadway) Transportation Law
H	height
i.d.R	as a rule
IA	Impact Area
IABG	Industrial Consortium Management Company Ltd.
Kal.	caliber
Krw-/AbfG	District Trade-/Waste Industry
KVB	District Trade Authority
KWKG	(Military)Weapons Control Law
LAGA	Federal States Waste Team
LKW	Truck
ltr	liter
M	model (Engineering)
MG	machine-gun
Mg	Megagram (1000 kilograms)
MKW	Waste Powered Electric Plant
MRE	meal ready to eat
MVA	waste incineration facility

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#### Abbreviations Used

NATO	North Atlantic Treaty Organization
NC	Nitrocellulose (?TNT?)
NG	Nitroglycerin
o.g.	mentioned above
OFD	chief financial directive
SOP	Standard Operating Procedures
SP	blackpowder
SprengG	Explosives Law
StHBA	State Building Authority
TA	technical instructions
TL	propellant charge (explosive)
to	1000 kilograms
TrÜbPI	troop training area
u.a.	as follows
u.ä.	and similar
US	United States
USAREUR	United States Army; Europe
UTIL	Utilities Division
VS-NfD	CONFIDENTIAL - Only for Official Use
WaffG	Weapons Law
z.Z.	at this time
ZMS	Joint Goal , Waste Disposal, Schwandorf



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## Text Excerpt

### 1 Potential Danger and Garbage Collection

In Phase 1 of the assessment additional samples of the remaining garbage from the Firing Range, the Grafenwöhr and Hohenfels field camps as well as the training area in Hohenfels were inspected.

It has become apparent that this garbage is contaminated with ammunition as well as Hoffmann devices. Further more each incinerator charge contained a relatively large quantity of Flameless Ration Heaters, hereby referred to as FRH packets, and Meal Ready to Eat packages, Hereby referred to as MRE packages. These loose unused and unreacted FRH packets as well as those remaining in the MRE packages are a potential danger in the refuse storage due to the heat generated when reacted with water.

A similar, but much less dangerous potential is caused by the unlawful disposal of ammunitions, ammunition parts, and Hoffmann devices.

Within the scope of the Phase 1 assessment it was assumed that the waste from the living quarters and the office areas would not be contaminated with ammunitions, Hoffmann devices, or FRH packets. Consequently there was no sampling. However, at closer inspection of the garbage from each single Housing Area and the refuse collected from the Main Post it became apparent that contamination of the garbage from these areas could not be excluded with certainty.

Given that the troops on practice from the Field Camps and Training Areas meeting at Mess, to those repairing their vehicles, and the simple fact that they could walk uncontrolled (unsupervised) through the Housing Areas and throughout the Main Post, there is a danger that FRH packets and munitions ex. Hoffmann devices could have been thrown into the Housing-Area garbage containers. Additionally it cannot be ruled out that a partially full truck of garbage from the Housing-Area (due to cost-control practices), was not filled with garbage from one of the other areas.

These considerations led to the conclusion to conduct sampling of both the Housing Areas and the Main post to ensure with certainty that this garbage is not contaminated with munitions and Hoffmann devices.

### 1.1 Sample Quality and Analysis of Garbage from the Housing Areas

During the sampling process the Investigators were assisted by the waste-facility personnel. In Grafenwöhr the inspection/sampling was always located at the Haderbühl waste facility. With help from the facility personnel the incoming garbage was unloaded, and spread out with their equipment so that the un-bagged garbage could also be searched and inspected. Most of the bagged garbage was emptied so that their contents could be thoroughly inspected. Similarly, this procedure would be performed on the loose garbage. In principal the waste was searched for munitions, munition parts, such as fuses, empty casings, etc. Furthermore, the waste was extensively searched for ...

---

...Hoffmann Devices, FRH packets and MRE-packages. The MRE-packages were often emptied to determine if the FRH packets was still present and if still reactive.

In Phase 2 of the assessment the following samples were obtained from the Housing-Areas and the Main Post:

- o Grafenwöhr, Main Post, 05/26/97
- o Grafenwöhr, Main Post, 06/23/97
- o Grafenwöhr, Housing-Area, 06/23/97
- o Vilseck, Main Post (Garbage Truck 1), 06/23/97
- o Vilseck, Main Post (Garbage Truck 2), 06/24/97
- o Vilseck, Housing-Area, 05/27/97
- o Hohenfels, Housing-Area, 05/28/97

#### 1.1.1 Garbage Sample on 05/26/97 - Grafenwöhr, Main Post

Contrary to what was expected, the waste out of East Waste Dump Grafenwöhr (Housing- and Office areas) was contaminated with FRH packets and MRE packages. Of the FRH packets found, approximately 50% of these were still reactive. Additionally, of the MRE packages found, 50% of them contained unused FRH packets. This observation, that approximately 50% of the FRH packets found, irregardless of whether they were still in the MRE packages or lying loose in the garbage, were still reactive and also unused, was made at each sample.

During the inspection of the garbage it was noted that if numerous FRH packets (approximately 10-20 packets) were in close proximity of one another, it would cause a greater potential danger to the garbage bunker and loading station as would single or fewer FRH packets.

Also, contrary to all expectations, was the discovery of three fully functional 50 cal.. (12.7 mm) rounds of ammunition. These were in a crushed tin can along with an empty scatter-gun shell and sand, probably from a pool. Misfire Pit. On the grounds that munitions and munition components were found, it must be concluded that these munitions were illegally thrown in the refuse.

Additionally, a 1.5 meter long belt filled with fully functional blank rounds was found. Moreover, there were (approximately 10 rounds) of blank rounds scattered throughout the garbage.

The separation of the waste, irrespective of the FRH and the munition uncertainty, could be improved at this location.

#### **1.1.2 Garbage Sample on 05/27/97 - Vilseck, Housing Area**

The garbage inspected at this location originated directly from the Housing-Areas and the office areas of the Troops stationed here.

In spite of an extensive search (of the garbage from the Troops stationed here) there were no FRH packets and no MRE packages found.

Additionally no munitions, Hoffmann Devices nor Blank-Cartridges were found.

Also, no munition components such as empty cartridges or fuses were located.

This garbage separation conformed somewhat to German household garbage standards.

---

#### **1.1.3 Garbage Sample on 05/28/97 - Hohenfels, Housing Area**

The garbage at Hohenfels was spread out across the old dump and inspected. Contrary to what was expected this garbage was also contaminated with FRH packets and MRE packages.

Altogether there were fewer FRH packets and MRE packages than at other sampling, however this garbage cannot be classified as FRH-free garbage.

The FRH packets and the MRE packages were similar in composition and concentration to all the other previously sampled areas (50% reactive, 50% reacted). The MRE packages also still contained both reactive and reacted FRH packets.

Despite an extensive search no munition, munition components, fuses, blank-rounds, or Hoffmann devices were found.

The garbage separation was relatively good however contained plastic bags with collected cans.

#### **1.1.4 Garbage Sample on 06/23/97 - Vilseck, Main Post**

To ensure sample quality a second inspection of this garbage was conducted. The same procedures as in the first sample (spreading of the garbage and emptying of the bags) were followed.

The sampling revealed that there was a relatively large amount of FRE packets and MRE packages. The composition - 50% of the FRH packets were still functional, 50% were reacted - was not different in any way from the inspection conducted in May 1997.

Munitions, Hoffmann devices, and munition components such as empty cartridges, fuses etc. were not found.

However, four fully functional 5.56mm blank-rounds and one 12.7mm blank-round were found.

This garbage separation conformed somewhat to German household garbage standards.

#### **1.1.5 Garbage Sample on 06/24/97 - Vilseck, Main Post**

This sampling is related to the second garbage-truck that collected garbage on 06/23/97. Based on the composition of this garbage it can be determined that in addition to garbage collected from the housing-areas that garbage from other areas could also have found itself collected with this "household" garbage. This household garbage contained many empty boxes of blank-rounds as well as garbage from fast-food restaurants (Burger King).

Few FRH packets and MRE packages were found. These originated from the supposedly additional containers (garbage) collected. This is due to the fact that the garbage collection route can be traced and that the containers must have been in the vicinity of munition issuing stations or munitions storeroom.

There were no munitions, munition components, blank-rounds and Hoffmann devices found.

There was a potential for further garbage separation with regards to specifications.

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#### 1.1.6 Garbage Sample on 06/23/97 - Grafenwöhr, Main Post

As the previous sampling determined there were once again a great number of FRH packets and MRE packages found during the 06/23/97 sampling. The garbage bags contained many more FRH packets, for example high concentrations of MRE packages in close proximity, and thus an increased potential danger. This can be explained as the result that either somewhere the garbage is gradually disposed of separately or that the FRH packets and MRE packages are being partially collected then disposed.

An exact inspection of the FRH packets and the MRE packages yielded approximately 50% reactive FRH packets.

There was no munition, munition components such as fuses, empty cartridges etc. and blank-rounds found.

However one Hoffmann device (? rocket ? flare) was found. A closer examination revealed that the object must have been in the garbage or elsewhere for some time and presumably within the scope of the clean-up operation regarding garbage separation, was placed in the garbage illegally.

#### 1.1.7 Garbage Sample on 06/23/97 - Grafenwöhr, Housing Area

As with the two previous sampling, this garbage was purposely inspected for contamination by FRH packets and munitions such as Hoffmann devices.

Due its composition it can be concluded that its origin was both household and office area garbage.

There were no munition, munition components, blank-rounds, Hoffmann devices, FRH packets or MRE packages found.

This garbage separation was consistent with the traditional German standard.

## 1.2 Additional sampling of the pre-treating garbage

In the scope of the Phase 1 assessments there were already several samples inspected, first to establish the garbage composition, and secondly to understand what degree was the possibility of contamination with munition, Hoffmann devices, and similar objects.

The garbage from the field camps, the firing ranges, and the training area Hohenfels was inspected exclusively. Only in Hohenfels a sample of garbage from the Housing Areas was exclusively inspected which later in course of the garbage sampling was mixed with garbage from the field camps.

As demonstrated by the inspections, although contamination with munition and Hoffmann devices is negligible, contamination by FRH packets and MRE packages is extensive. To ensure a greater understanding as to the extent of the possible contamination, the scope of Phase 2 of the assessment includes a greater sampling area than included in Phase 1 of the assessment.

As a consequence of the Phase 1 assessment, the US-Army 7TH ATC/100TH ASG-SAFETY was forced to revise the Safety Manual (SOP for the Garbage) with the goal to change the procedures in handling of the Hoffmann Device contaminated refuse.

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Within the scope of the Phase 2 assessment sampling these changes in SOP could be examined.

The following samplings of pre-treated garbage were examined in Phase 1 as well as Phase 2 assessment

Phase 1:

- o Schießbahnen (Firing Ranges), Grafenwöhr
- o Feldlager (Field Camp), Hohenfels and
- o Training Area, Hohenfels.

Phase 2:

- o Schießbahnen (Firing Ranges), Grafenwöhr, 05/25/97 and 07/15/97
- o Feldlager (Field Camp), Grafenwöhr, 05/26/97
- o Training Area, Hohenfels, 05/27/97, in Grafenwöhr
- o Training Area, Hohenfels, 05/28/97, in Hohenfels
- o Feldlager (Field Camp), Hohenfels, 06/28/97, in Hohenfels

It should be stated early, that an exact sorting of the waste streams will not be possible. The reasons for this are the different techniques used by each of the areas: First the practicing troops dispose of their garbage in the living areas illegally themselves...especially in the outer areas of Grafenwöhr and Hohenfels. Secondly these streams are mixed with, presumably due to economic reasons, containers from the field camps which are disposed of by disposal companies.

Therefore, due to safety reasons concerning the ZMS equipment, it was suggested that the entire garbage from the TrÜbPl Grafenwöhr be pre-treated (sorted) (see also Chapter 4).

By doing this an originally planned sampling of the garbage from the housing areas could be dropped. Instead the garbage from the housing areas can be sampled at an intensified rate at the previously unplanned pre-treatment, and thereby insuring greater security within the system.

### 1.2.1 Garbage Sample on 05/26/97 - Firing Ranges, Grafenwöhr

Examination of this garbage revealed many FRH packets and MRE packages. Approximately 50% of the FRH packets were unused or unreacted. The MRE packages also contained unused FRH packets.

Munitions or Hoffmann Devices were not found.

One 5.56 caliber unfired blank round was found, probably mistakenly thrown away when unpacking (this munition was still in its packing container), as well as one used blank round.

This sampling was somewhat similar to the Phase 1 assessment. This garbage had a very high moisture content. The garbage separation can still be improved.

### 1.2.2 Garbage Sample on 05/26/97 - Field Camp, Grafenwöhr

As previously determined in the sampling conducted during the Phase 1 assessment, this garbage was contaminated by a high concentration of FRE packets and MRE packages. In the examination of this waste, the FRH packets and the MRE packages were always

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disposed of together, basically 10 to 20 FRH packets and MRE packages in close proximity in one garbage sack. As already described in the garbage samples from the Housing areas, this increases the danger potential.

An explanation for this condition could be presumed to be the method of garbage collection in the Training Area. There the garbage is probably collected in groups (8 to 10 soldiers) and disposed of in garbage bags. If the garbage is collected from several groups, 10 to 20 FRH packets and MRE packages can simultaneously get into one garbage bag. A change in this collection procedure can hardly be realized because the training groups are in the training areas for a short time.

As with all examined garbage approximately 50% of the FRH packets are still reactive.

In this examined garbage, no munitions, munition parts, blank rounds, or Hoffmann Devices were found.

### 1.2.3 Garbage Sample on 05/27/97 - Training Area, Hohenfels

This garbage to be examined was transported for disposal to the Grafenwöhr - Haderbühl Garbage Dump.



The contamination of the garbage with FRH packets and MRE packages was consistent with the samples examined of the Phase 1 Assessment and had a similar consistency as the garbage from the field camps TrübPI Grafenwöhr. In this sampling there were also FRH packets and MRE packages found. Therefore the potential danger was consistent with the one from the field camps Grafenwöhr.

Munitions, munition parts, blank rounds, or Hoffmann Devices were not found. The numerous packing of Hoffmann Devices and munitions were each opened and examined in detail.

The fact that numerous Hoffmann Devices were used could be determined by the presence of @@@@ materials used with the Hoffmann Devices, (? trip ?) wire rolls.

#### **1.2.4 Garbage Sample on 05/28/97 - Training Area and Field Camp, Hohenfels**

This garbage was examined in Hohenfels on the old garbage dump. The consistency of both garbages was very similar and no distinction is necessary.

This garbage was examined in detail so as to form a conclusive judgement with regards to the garbage from the training areas and the field camps. The consistency of this garbage corresponded to that from previous field camps. The FRH packets and MRE packages were once again in greater concentrations. 50% of the FRH packets were still reactive.

Despite an extensive search, there were no munitions, munition parts, fuses or Hoffmann Devices found.

However, one functional 5.56mm caliber blank round was found. Also, numerous empty 5.56mm caliber and 12.7mm caliber casings were found. Although these should not be in the garbage, they pose no potential danger.

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One impression is that the empty casings were collected, then disposed with the normal garbage.

### **1.2.5 Garbage Sample on 07/15/97 - Firing Ranges, Grafenwöhr**

After the "burn" trials of the pyrotechnical Hoffmann Devices, an unplanned sampling of a truck-load of garbage from the Grafenwöhr Firing Ranges was conducted.

At the garbage dump Grafenwöhr - Haderbühl the garbage was spread out and thoroughly examined. The bags were opened and emptied. The consistency of this garbage was the same as on the firing ranges. From its consistency, any garbage from other training areas could therefore be excluded.

As usual, numerous FRH packets and MRE packages were found. 50% of the FRH packets were unused. There were also large concentrations of "bundled" FRH packets.

There were no munitions, munition parts, blank rounds, or pyrotechnical Hoffmann Devices found.

### **1.3 Conclusions Regarding the Garbage Samplings**

On the basis of the garbage samplings conducted, it has to be concluded that basically all garbage streams contain FRH packets and MRE packages, except for the very limited "living areas" where no FRH packets or MRE packages were found. In all other areas, especially those with troop access, one must assume contamination with FRH packets and MRE packages, along with the occasional "blank" round.

In the garbage from the field camps, the training area Hohenfels and then firing ranges, as well as the border areas surrounding the living and administrative areas, the contamination with FRH packets and MRE packages is especially high. Additionally there are numerous instances of single "blank" rounds, with these being almost exclusively the 5.56mm caliber round.

There was only one instance of Hoffmann Devices and components found. Noting that this Hoffmann Device found its way into the garbage before the new regulations (SOP) were in effect

The contamination by heavy gun and MG munition was relatively light. Only three (3) functional 12.7mm caliber cartridges were found. These cartridges were obviously placed in the garbage illegally. With all likelihood these originated from a misfire pit from the firing range. They were stolen from there and with high probability, later illegally disposed in the Motorpool garbage. The evidence led to these conclusions. No additional heavy pistol-, gun-, or MG munitions were found (during the Phase 1 and Phase 2 assessments).

No large caliber (>12.7mm caliber) munitions, handgrenades, rockets, mines, or parts thereof were found in any of the samplings (during the Phase 1 and Phase 2 assessments). The strict procedures of distribution and usage prevented any illegal disposal. Only two (2) empty 25mm caliber cartridge casings were found, and judging by their condition, were disposed of some time ago.

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Finally, it can be determined:

- o overall 13 truckloads of garbage were examined and analyzed in detail in Phase 2 of the report. It was found:
  - (3) 12.7mm caliber cartridges and
  - (1) Hoffmann Device
- o heavy munitions and pyrotechnical Hoffmann Devices are not a problem of the garbage from the training areas Grafenwöhr and Hohenfels because they exist in limited quantities.
- o blank rounds, which are present against regulations, are not a disposal problem even if they should be present in greater quantities.
- o FRH packets and MRE packages present the biggest problem. They are found in principally every garbage load. It cannot be excluded that
  - training soldiers dispose of their garbage illegally in the living areas,
  - for economic reasons, a half-full garbage truck is filled by the disposal company with garbage from other areas, and is therefore filled with contaminated garbage.

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## **2 Examination with regard to the Dangers involving the Technical Equipment of the ZMS and the Operating Personnel**

### **2.1 *Examination of Possible Impairment of Worker Security, Equipment Security, and Fire Protection during Pre-Treatment***

#### **2.1.1 Basic Considerations**

From reasons of security to the equipment of the Zweckbandes Müllverwertung Schwandorf (ZMS), the "expert" of this report suggests a two-step shredding of the garbage. By shredding, the danger of fires in the garbage-bunker and in the loading stations, that are indirectly caused by the FRH elements, shall be eliminated. Furthermore, by shredding, an explosion of Hoffmann Devices (similar to large pyrotechnical "fireworks") is eliminated preventing a Bypass-"? fire ?" in MKW-Schwandorf. The most important side effect of shredding is the destruction of illegally disposed of weapon- and MG-munitions.

In scope of the experiments conducted with the shredding equipment, it was determined that only through a two phase shredding could the asserted goals and results be obtained.

The essential goal of the shredding is the definite destruction of the FRH elements present either loose or contained in the MRE packages, packed together in relatively high concentrations, approximately 10 to 20 pieces, within the garbage.

Another essential goal of the shredding has to be the definite destruction of the Hoffmann Devices, independent of the fact of whether they are disposed of as misfire (partially used) or as unused pyrotechnics.

The destruction and "voiding" of the weapon- and MG-munitions must also be accomplished, in addition to the other previous goals.

## **2.1.2 Equipment Security and Garbage Shredding / Garbage Pre-treatment**

### **2.1.2.1 Worker Security and Fire Regulations**

Due to the fact that works security and fire protection are mainly equipment dependent, at this point no conclusions can be made regarding these points, especially given there is no decision over equipment configuration or components. In the scope of a technical solution of the FRH-problem, based on shredding experiments, a suggestion regarding a two-phase shredding of the garbage is done in chapter 4.3 of this report. Any other information regarding the further treatment of this suggestion and its acceptance by the employer, the government of the Oberpfalz including the responsible Offices are not available at this time. Overall in the scope of this report only general security and fire regulation suggestions can be shown.

In accordance with the experiments conducted, and the information obtained from the experiments, as well as the experience of the experts, the following demands concerning worker security and fire protection must be fulfilled for the garbage pre-treatment equipment:

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- (1) equipment basically has to be able to be operated by one person
  - (2) loading of the equipment has to be supervised optically; intervention by operating personnel must be possible at several locations.
  - (3) emergency stops are to be located at several positions on the equipment; the stop button is to be the shape of a mushroom button
  - (4) corners and edges of the equipment must have a radius edge to avoid injuries
  - (5) servicing and repair must be able to be performed in a way as to avoid injuries
  - (6) disassembly of the shredder "inlet-throat", in order to replace the hammers/blades, must have "? mechanical-hydraulic ?" assistance
  - (7) specific access devices (gates, doors, covers, etc.) must have suitable lifting rings in order to utilize suitable lifting devices
  - (8) head-knee bumping hazards must be clearly marked
  - (9) required signs-instructions must be installed in obvious locations
  - (10) pre-treatment equipment must be designed to be easily, safely cleaned without danger
  - (11) devices-equipment parts must be equipped with handles or castings for transport
  - (12) Shredder 1 (coarse shredder) must be equipped with an automatic, oversize particle (part) expeller
  - (13) Shredder 2 (fine shredder) must be equipped with an automatic sprinkler "mister" to ? deactivate ? the FRH and dust abatement
  - (14) transition from Shredder 1 to Shredder 2 must be automatic due to emission reasons
  - (15) the operating personnel must be instructed in the equipment operation
  - (16) the transition device for the Shredding equipment must be enclosed for noise abatement
  - (17) the equipment must be designed in a way as to prevent injury-damages from flying debris in the event of failure
  - (18) safety and protection devices must be checked regularly
  - (19) the operating cabin of the loader must be equipped with an emergency stop
  - (20) necessary operating and functional instructions must be designed within the scope of the equipment
  - (21) proven, established techniques in noise abatement are to be used to keep noise emissions as low as possible

- (22) rules and regulations as listed in ZH 1/493 must be observed
- (23) electrical systems must be protected from the "misting" water
- (24) electrical service wires must be installed in such a way as to avoid damage from the loading equipment
- (25) electrical systems must comply with the regulations of the VDE
- (26) overall construction must be equipped with lightning protection and ground protection
- (27) fire warning systems and licensed fire extinguishers must be installed in sufficient numbers through-out the equipment and coordinated with the county fire commissioner. The fire extinguishers must be inspected every other year.
- (28) a minimum of one (1) fire water hydrant must be located-planned for the waste handling area, the location of which must be coordinated with the county fire commissioner and possibly the Training Area Fire Brigade
- (29) access to the equipment must be available for fire trucks with a weight of 16 Mg; with the corresponding DIN 14090 "Space for Fire-Trucks on Properties" being observed
- (30) fire warning devices and water supply must be coordinated with the Fire Brigade of the Training Area Grafenwöhr and the county fire commissioner in addition to the local authorities
- (31) an individual responsible for fire protection must be named and the county fire commissioner and fire squads must be kept informed about that person
- (32) the pre-treatment area must be secure day or night against unlawful access

The previous information regarding fire protection, worker security, and facility security may be setup as necessary; if not yet completed; prior to operation.

### 2.1.3 Security of the MKW - Schwandorf and the Reloading Stations

According to legal aspects in Chapter 2.6 of this report and in accordance with the "Planfeststellungsbescheid" (overall project specifications - rules - permit) from March 23, 1992 for the MKW - Schwandorf and in accordance with the "Planfeststellungsbeschlüssen" (operating specification - rules - permits) for the planned reloading stations, only household garbage, household-like garbage and trash are to be disposed.

The "Planfeststellungsbeschlüsse"(operating specifications - rules - permits) contain the detail regulations of fire protection, facility security, and work protection to be followed.

Because the fact that the garbage to be disposed of from the training areas Grafenwöhr and Hohenfels is within the limits of the approved specifications, no additional limitations of fire protection, facility security and work security must be developed due to this garbage.

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The "Planfeststellungsbeschlüsse" (operating specifications - rules - permits) are not negatively influenced by the disposal of the garbage from the training areas Grafenwöhr and Hohenfels and will not be revised.

## 2.2 Experiments with Hoffmann Devices in order to Determine Pressure Increases (*? when burned ?*).

### 2.2.1 Background Information Regarding the Experiment with Hoffmann Devices

In Phase 1 of the report it was pointed out, within the scope of description, of the possible danger potential of the Hoffmann Devices and the associated dangers for the garbage "works" in case of explosion. A possible result of this reaction is the danger of bypass-switch and the extinguishing of the reactor (reactor-incident) or other causative, unusual event. The reason for this would be a local pressure increase of several GPa. Due to the fact that 12.7mm caliber cartridge munitions would yield a similar result, they must also be included in further consideration.

After lengthy discussion regarding the potential danger to the garbage "works" through possible explosion of munitions and Hoffmann Devices, the leader of the MISSION-SAFETY suggested and other experts agreed, to drop the examination of the effects of the explosion of weapon-munitions in the incinerator. If there is to be some consequential effect from an explosion, it must have encroachment. This encroachment is provided by the barrel of the weapon- or machine-gun (and is not the case in the furnace). During the burning of the propellant charge of the cartridge with out this encroachment, (provided by the barrel of the weapon) only a little flame develops according to the experts and this is of little consequence for the MKW.

With regards to the Hoffmann Devices, no opinions of experts could be found due to limited experiences with these devices. The well-known expert literature give few clues to the problem. It was only determined that explosions with pressure build-ups can develop. In the meanwhile, experiments conducted with the Hoffmann Devices by the MISSION-SAFETY leader resulted in observances similar to the cartridges weapon and MG-munitions. These opinions are to be examined and possibly confirmed within the scope of Phase 2 of this report.

### 2.2.2 Experiment Set-up and Execution

On the area of the Troop Training Ground-Fire Brigade Grafenwöhr, gasoline soaked rags were ignited in a tin tub (see picture 2-1). Wrapped in the rags were two (2) new Hoffmann Devices.

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An additional experiment of (2) two Hoffmann Devices being thrown in open flames was conducted. The result was similar to the first; a detonation did not occur. During this experiment it was clearly shown that the plastic covering burned through and the exposed powder then burned off.

### 2.2.3 Experiment Results with regard to the MKW - Schwandorf

Overall, two experiments with (2) two Hoffmann Devices were conducted. The results confirmed the experiment with the Hoffmann Devices previously performed by the MISSION-SAFETY leader.

On the basis of the experiments one can conclude there is no direct or indirect danger for the MKW - Schwandorf should Hoffmann Devices, illegally dumped in the garbage undestroyed, get into one of the incinerator lines. There is even no danger to the MKW - Schwandorf should several Hoffmann Devices get into the incinerator lines at one time.

As the experiment showed, a self-ignition of illegally dumped Hoffmann Devices (eg. in the garbage-bunker) is to be excluded due to the relatively high temperatures necessary for self-ignition. Such high temperatures, to promote a self-ignition of the Hoffmann Devices, would first result in a general garbage-bunker fire. The same holds true for the re-loading stations.

This conclusion also holds true for the cartridge weapon- and MG-munitions and there is no danger to MKW - Schwandorf "burning-down". An explosion cannot take place due to the lack of encroachment.

## 2.3 Determination of Additional Emission Burden in MKW - Schwandorf

### 2.3.1 Relevant Reaction Products

According to 17. BImSchV, which regulates emissions of garbage burning facilities, certain limits for burning substances such as Sulphur dioxide, Nitric oxide, heavy metals and similar must be followed. The exact limits are to be found in the "Planfeststellungsbeschluss" (operating specifications - rules - permits) for the MKW - Schwandorf from March 27, 1992 or the DeNO<sub>x</sub> - Permit from June 7, 1993 (see Chapter 2.6).

The gas-like reaction products that can be formed during the thermal disposal of cartridge munitions, Hoffmann Devices, and FRH components are summarized in tables 2-1 and 2-2.

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Table 2-1: Relevant reaction products from munition and Hoffmann Device components

Substance	relative Reaction Product
Akardit I $C_{13}H_{12}N_2O$	CO, CO <sub>2</sub> , NO <sub>x</sub> , (NO, NO <sub>2</sub> , N <sub>2</sub> O <sub>3</sub> ), H <sub>2</sub> O, N <sub>2</sub>
Akardit II $C_{14}H_{14}N_2O$	CO, CO <sub>2</sub> , NO <sub>x</sub> , (NO, NO <sub>2</sub> , N <sub>2</sub> O <sub>3</sub> ), H <sub>2</sub> O, N <sub>2</sub>
Aluminum Al	Al <sub>2</sub> O <sub>3</sub>
Antimony Sb	Sb <sub>2</sub> O <sub>3</sub>
Antimony trisulfide Sb <sub>2</sub> S <sub>3</sub>	Sb <sub>2</sub> O <sub>3</sub> , Sb <sub>2</sub> O <sub>4</sub>
Barium nitrate Ba(NO <sub>3</sub> ) <sub>2</sub>	BaO, BaCO <sub>3</sub> , NO <sub>x</sub> , (NO, NO <sub>2</sub> , N <sub>2</sub> O <sub>3</sub> ), N <sub>2</sub>
Lead nitrate Pb(NO <sub>3</sub> ) <sub>2</sub>	PbO, Pb <sub>3</sub> O <sub>4</sub> , NO <sub>x</sub> , (NO, NO <sub>2</sub> , N <sub>2</sub> O <sub>3</sub> )
Lead oxide PbO <sub>2</sub>	PbO, Pb <sub>3</sub> O <sub>4</sub>
Lead stearate C <sub>36</sub> H <sub>70</sub> O <sub>4</sub> Pb	CO, CO <sub>2</sub> , H <sub>2</sub> O, PbO, Pb <sub>3</sub> O <sub>4</sub> , PbO <sub>2</sub> , Pb <sub>3</sub> O <sub>4</sub>
Lead tri"zinate" C <sub>6</sub> H <sub>9</sub> N <sub>3</sub> O <sub>8</sub> Pb	PbO, Pb <sub>3</sub> O <sub>4</sub> , NO <sub>x</sub> , (NO, NO <sub>2</sub> , N <sub>2</sub> O <sub>3</sub> ), N <sub>2</sub>
Calcium silicate CaSi <sub>2</sub>	CaO, SiO <sub>2</sub>
Camphor C <sub>10</sub> H <sub>16</sub> O	CO, CO <sub>2</sub> , NO <sub>x</sub> , (NO, NO <sub>2</sub> , N <sub>2</sub> O <sub>3</sub> ), H <sub>2</sub> O, N <sub>2</sub>
Chlorine carrier	HCl, CO <sub>2</sub> , CO, H <sub>2</sub> O
Diamino anthraquinone C <sub>14</sub> H <sub>10</sub> N <sub>2</sub> O	CO, CO <sub>2</sub> , NO <sub>x</sub> , (NO, NO <sub>2</sub> , N <sub>2</sub> O <sub>3</sub> ), H <sub>2</sub> O, N <sub>2</sub>
Diamylthiolate ? C <sub>18</sub> H <sub>26</sub> O <sub>4</sub>	CO, CO <sub>2</sub> , H <sub>2</sub> O
Dibutylthiolate ? C <sub>16</sub> H <sub>22</sub> O	CO, CO <sub>2</sub> , H <sub>2</sub> O
Diphenol??? C <sub>12</sub> H <sub>11</sub> N	CO, CO <sub>2</sub> , NO <sub>x</sub> , (NO, NO <sub>2</sub> , N <sub>2</sub> O <sub>3</sub> ), H <sub>2</sub> O, N <sub>2</sub>
Glass Powder	-
Graphite C	CO, CO <sub>2</sub>
n-Hexane C <sub>6</sub> H <sub>14</sub>	HCl, CO <sub>2</sub> , CO, CO <sub>2</sub>
Potassium chlorate KClO <sub>3</sub>	KCl, KClO <sub>4</sub>
Potassium nitrate KNO <sub>3</sub>	KNO <sub>2</sub> , NO <sub>x</sub> , (NO, NO <sub>2</sub> , N <sub>2</sub> O <sub>3</sub> ), K <sub>2</sub> CO <sub>3</sub> , KOH, N <sub>2</sub>
Potassium perchlorate ? KClO <sub>4</sub>	KCl
Potassium sulfate K <sub>2</sub> SO <sub>4</sub>	-
Cuprous (II) oxide CuO	CuO, Cu <sub>2</sub> O
Magnesium Mg	MgO
Sodium nitrate NaNO <sub>3</sub>	NaNO <sub>2</sub> , NO <sub>x</sub> , (NO, NO <sub>2</sub> , N <sub>2</sub> O <sub>3</sub> ), Na <sub>2</sub> CO <sub>3</sub> , NaOH, N <sub>2</sub>
Sodium oxalate C <sub>2</sub> Na <sub>2</sub> O <sub>4</sub>	CO, CO <sub>2</sub> , Na <sub>2</sub> CO <sub>3</sub>
Nitrocellulose (C <sub>6</sub> H <sub>7</sub> N <sub>3</sub> O <sub>11</sub> ) <sub>x</sub> N concentration > 12.6%	CO, CO <sub>2</sub> , NO <sub>x</sub> , (NO, NO <sub>2</sub> , N <sub>2</sub> O <sub>3</sub> ), H <sub>2</sub> O, N <sub>2</sub>
Nitroglycerin C <sub>3</sub> H <sub>5</sub> N <sub>3</sub> O <sub>9</sub>	CO, CO <sub>2</sub> , NO <sub>x</sub> , (NO, NO <sub>2</sub> , N <sub>2</sub> O <sub>3</sub> ), H <sub>2</sub> O, N <sub>2</sub>
PVC (C <sub>2</sub> H <sub>3</sub> Cl) <sub>x</sub>	HCl, CO <sub>2</sub> , CO, CO <sub>2</sub>

Sulphur S <sub>8</sub>	SO <sub>2</sub>
Silicon Si	SiO <sub>2</sub>
Stearic acid C <sub>18</sub> H <sub>36</sub> O <sub>2</sub>	CO <sub>2</sub> , CO, H <sub>2</sub> O
Strontium peroxide SrO <sub>2</sub>	SrO
Strontium nitrate Sr(NO <sub>3</sub> ) <sub>2</sub>	SrO, SrCO <sub>3</sub> , NO <sub>x</sub> (NO, NO <sub>2</sub> , N <sub>2</sub> O <sub>3</sub> ), N <sub>2</sub>
Tetrazine C <sub>2</sub> H <sub>6</sub> N <sub>10</sub>	CO, CO <sub>2</sub> , NO <sub>x</sub> (NO, NO <sub>2</sub> , N <sub>2</sub> O <sub>3</sub> ), H <sub>2</sub> O, N <sub>2</sub>
Paraffins	CO, CO <sub>2</sub> , H <sub>2</sub> O
Zinc stearate C <sub>36</sub> H <sub>70</sub> O <sub>4</sub> Zn	CO, CO <sub>2</sub> , H <sub>2</sub> O, ZnO

Table 2-2: Relevant Reaction Products from FRH Components

Substance	Relative Reaction Products
Magnesium	MgO
Additives, Fillers- and Binders *	CO <sub>2</sub> , CO, H <sub>2</sub> O, u.U. HCl, PCDD, PCDF

\* the exact components could not be determined

Therefore the thermal disposal of the cartridge munitions, Hoffmann Devices, and the FRH components can be influenced by the following limits:

- o overall dust
- o organic substances, identified as carbon
- o gas-forming inorganic chlorides, identified as hydrochloric acids
- o sulphur dioxide and sulphur trioxide, identified as sulphur dioxides
- o nitrogen dioxide and nitrous oxide, identified as nitrogen dioxide
- o antimony and its components, identified as Sb
- o lead and its components, identified as Pb
- o copper and its components, identified as Cu
- o PCDD and PCDF

### 2.3.2 Emission Relevant Substances

Calculation of emission of harmful substances, on the basis of the above mentioned components, was weighted according to their relevance in connection to harmful substance - emissions. From that, representative substances were concluded for emission calculations on basis of their quantity, or their stoichiometric reaction during thermal disposal contribute to higher harmful emissions (Table 2-3, 2-4). All other listed substances are either unproblematic in connection with the flue gases, or they do not contribute in great quantity to the relevant harmful emissions compared to the burning of normal household garbage.

Due to this the Flameless Ration Heaters were also not considered separately for the calculations because they generally consist of magnesium which does not influence the overall dust component and is within permit limitations (quantity relationships). In the case of additives,

fillers and binders, one must conclude that none of the components are different from the consistency of normal household garbage.

Therefor only inorganic chlorides such as hydrochloric acid, sulphur dioxide, sulphur trioxide, nitrous oxide, nitrogen dioxide, as well as lead and its components were considered in the calculations (see also chapter 2.5).

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**Table 2-3: Overview of the Components of the Signalmunition and Pyrotechnical Hoffmann Devices**

Substance Group	Munitions Type	Components	Substances
Propellant Powder	Propellants	black powder potassium nitrate, graphite, sulphur) dibasic propellant powder on nitrocellulose- nitroglycerine-Basis analog blank rounds	black powder (10% S, 75% KNO <sub>3</sub> , 15% C)
Black Powder and Additives	discharge charge	black powder	black powder (10% S, 75% KNO <sub>3</sub> , 15% C)
	transfer charge	black powder	
	accelerator charge	aluminum, potassium nitrate, black powder, sulphur	
	initiator charge	aluminum, barium nitrate, black powder, (potassium nitrate, sulphur, graphite), magnesium, cuprous (II) oxide, sulphur	
	report charge	black powder	
Igniters	Igniter charge	lead nitrate, SINOXID (lead tri"zinate", barium nitrate, lead oxide, antimony trisulfide), potassium chlorate, glass powder, calcium silicate, hydrazine, antimony	lead nitrate Pb(N <sub>3</sub> ) <sub>2</sub>
Illuminants	illuminating charge	aluminum, barium nitrate, magnesium, sodium nitrate, PVC, strontium nitrate, paraffins	magnesium Mg, barium nitrate Ba(NO <sub>3</sub> ) <sub>2</sub>
Smoke charge	smoke charge	diamino anthraquinone, n- hexane, potassium chloride, magnesium, sodium nitrate, PVC, stearic acid, strontium nitrate	potassium chloride KClO <sub>3</sub> , diamino anthraquinone C <sub>14</sub> H <sub>10</sub> N <sub>2</sub> O, n-hexane C <sub>6</sub> H <sub>6</sub> Cl <sub>6</sub>

Table 2-4: Overview of the "Blank" Munitions Composition

Substance Group	Munitions type	Components	Substances
Propellant Powder	propellant	nitrocellulose, nitroglycerin	nitrocellulose ( $C_6H_7N_3O_{11}$ ) <sub>n</sub>
	stabilizers	akardit I, akardit II, diphenylamine	
	muzzle-fire inhibitor	potassium sulfate	
Ignitors	ignitor charge	lead nitrate, SINOXID (lead tri"zinate", tetrazene, barium nitrate, lead oxide, antimony trisulfide	lead nitrate $Pb(N_3)_2$
Tracer Material	illuminating charge	aluminum, barium nitrate, lead stearate, chlorine carrier "HCl", potassium perchlorate, magnesium, sodium oxalate, silicon, strontium nitrate, strontium peroxide, zinc stearate	magnesium Mg, barium nitrate $Ba(NO_3)_2$

### 2.3.3 Calculation of Harmful Emissions

After estimates made by the leader of the US Office of MISSION-SAFETY and the IABG, the following maximum values of contamination can be expected

- o 1 cartridge / 10 tons of garbage
- o 1 Hoffmann Device / 20 tons of garbage

With the munitions and munition parts there are exclusively small caliber weaponry, pistols-, storm guns-, and machine gun- munitions of 5.56mm caliber, 7.62mm caliber, 9mm caliber, and 12.7mm caliber (cal50) as well as munitions for flare-guns.

The overall garbage quantity of the training areas Grafenwöhr, Vilseck and Hohenfels in 1996 was 10,413 t. Taken this amount, one reaches the results indicated in table 2-5 in 1 ton of garbage.

Assessment regarding the possibilities of the disposal of the accumulating household garbage of the training area Grafenwöhr (Süd- and Ostlager) and Hohenfels Areas.  
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Table 2-5: Effects of Munitions on Garbage Composition

Substance Group	Substances	Daily values [g/d]	Concentration per 1 ton garbage [g/t]
Signal Munitions and Pyrotechnical Hoffmann Devices			
Propellant powder	black powder (10% S, 75% KNO <sub>3</sub> , 15% C)	0.75	0.0151
Black powder and Additives	black powder (10% S, 75% KNO <sub>3</sub> , 15% C)	175	3.5292
Ignitors	lead nitrate Pb(N <sub>3</sub> ) <sub>2</sub>	0.09	0.0018
Illuminators	magnesium Mg barium nitrate Ba(NO <sub>3</sub> ) <sub>2</sub>	130	2.6217
Smoke "screens"	potassium chlorate KClO <sub>3</sub> , diamino anthraquinone C <sub>14</sub> H <sub>10</sub> N <sub>2</sub> O, n-hexane C <sub>6</sub> H <sub>6</sub> Cl <sub>6</sub>	24	0.4840
"Blank" rounds (Munitions)			
Propellant powder	nitrocellulose (C <sub>6</sub> H <sub>7</sub> N <sub>3</sub> O <sub>11</sub> ) <sub>n</sub>	19	0.3832
Ignitors	lead nitrate Pb(N <sub>3</sub> ) <sub>2</sub>	0.2	0.0040
Tracer material	magnesium Mg barium nitrate Ba(NO <sub>3</sub> ) <sub>2</sub>	3.95	0.0797

MKW Schwandorf has a capacity of 450,000 t per year. In 1996 approximately 380,000 t garbage was processed. According to the 1996 yearly report of the ZMS 6000m<sup>3</sup> of air is needed to burn 1 ton of garbage. Not including the volume of the flue gas products developed during the thermal disposal, additional contributions to the emissions is listed in table 2-6.

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Table 2-6: Supplementary Emissions from Munition Components

	SO <sub>2</sub> (mg)	NO <sub>2</sub> (mg)	Pb (mg)	HCl (mg)
black powder (10% S, 75% KNO <sub>3</sub> , 15% C)	280.90	1513.14	-	
lead nitrate Pb(N <sub>3</sub> ) <sub>2</sub>	-	5.54	4.16	-
magnesium Mg barium nitrate Ba(NO <sub>3</sub> ) <sub>2</sub>	-	870.08	-	-
potassium chlorate KClO <sub>3</sub> , diamino anthraquinone C <sub>14</sub> H <sub>10</sub> N <sub>2</sub> O, n-hexane C <sub>6</sub> H <sub>6</sub> Cl <sub>6</sub>	-	112.91	-	89.48
nitrocellulose (C <sub>6</sub> H <sub>7</sub> N <sub>3</sub> O <sub>11</sub> ) <sub>n</sub>	-	104.88	-	-
maximum harmful emissions per ton of garbage (mg)	280.90	2606.55	4.16	89.48
supplementary maximum harmful emissions [mg/m <sup>3</sup> ]	0.0468	0.4344	0.0007	0.0149

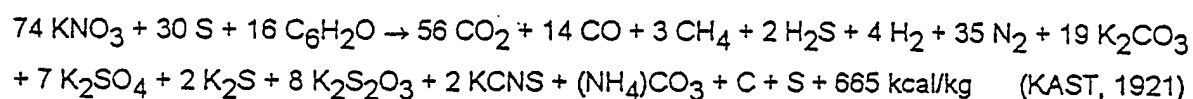
On the basis of the limits listed in chapter 2.6.1 as well as operator measured emission values of MKW - Schwandorf, one can conclude that no significant changes of emissions result in the disposal of the garbage of the TrÜbPI Grafenwöhr, Vilseck, and Hohenfels in consideration of Chapter 0 and in Phase 1, in connection with the garbage quantity and consistency.

## 2.4 Examination of the Potential Self-ignition of the Garbage Contaminated with Black Powder or Propellant

### 2.4.1 Dangers from Black Powder

Black powder is produced through the mechanical mixture of Potassium nitrate (75%), Charcoal (15%), and Sulphur (10%) by: (RÖMPP, 1992).

During detonation the following reaction products (shown in the chemical equation) develop:



Black powder is not sensitive to impact or friction, but is easily ignited through flame or spark (STETTbacher, 1948). The powder does not detonate but burns quickly and is therefore not a risky, explosive substance. The ignition temperature is approximately 300°C (STETTbacher, 1948; URBANSKI, 1967).

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## 2.4.2 Dangers from Propellant Powder

### 2.4.2.1 *Smokeless Powder*

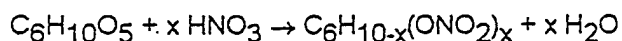
Smokeless powder is used as a propellant. Depending on the consistency they are subdivided into

- o monobasic propellant powder on the basis of nitrocellulose
- o dibasic propellant powder
  - mixtures of nitrocellulose and nitroglycerin (nitroglycerin powder)
  - mixtures of nitrocellulose and diethyleneglycoldinate
- o tri-basic propellant
  - mixtures of di- or triethyleneglycoldinate and cellulosenitrate, to which nitroguanidin is added as a third component

On the training areas of Grafenwöhr and Hohenfels the munitions and Hoffmann Devices used as propellants, in addition to black powder, are monobasic and dibasic propellants with a nitroglycerin-nitrocellulose base.

### 2.4.2.2 *Nitrocellulose*

Nitrocellulose is developed by the estrification of cellulose with nitrate of saltpeter (URBANSKI, 1965).



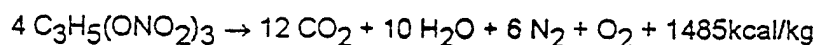
To use it as an explosive substance, nitrocellulose has a nitrogen content of a least 12.6%. In dry condition pure nitrocellulose is explosive and has a flamepoint of 12°C (SORBE, 1997) therefore it is stabilized (eg. diphenylamine, akardit, centralit, diphenylurethane, aniline) to be used as propellant. Non-stabilized nitrocellulose is worked and transported in a damp, moist condition (URBANSKI, 1965).

The type and consistency of the reaction products is dependent of the degree of nitration and the reaction conditions. Generally, carbon monoxide, carbon dioxide, nitrogen, water, and hydrogen are formed (RÖMPP, 1991).

#### 2.4.2.3 Nitroglycerin

Nitroglycerin is produced through the estrification of glycerin with nitrite of saltpeter and sulfate (STETTACHER, 1948).

During detonation, nitroglycerine oxidizes after the following formula:



Additional, heat or impact produce other nitrogen oxides as reaction products (URBANSKI, 1965). The ignition temperature of nitroglycerin is 200 - 205°C. Pure nitroglycerin is susceptible to friction or flame. Nitroglycerin ignited by a match burns slowly with a pale flame. The ignition by flame is explosive only if confined in a narrow container (eg. glass tube, cartridge, empty casing) (STETTBACKER, 1948).

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#### *2.4.2.4 Characteristics of Monobasic Propellant Powder*

Monobasic propellant powder is formed of nitrocellulose plus stabilizers and additional additives. Substances such as diphenylamine, akardit, centralit, diphenylurethane, and aniline are used as stabilizing agents.

Smokeless powders are overall harder to ignite and burn much slower than black powder. Sensitivity to flame increases with increasing heat or dryness (STETTBACKER, 1948). In addition mono and dibasic propellant powders have a low sensitivity to friction or impact (URBANSKI, 1967). The detonation temperature of nitrocellulose-powder is approximately 200°C. Burned powder also flame quickly without explosion. Danger of detonation only occurs due to increasing pressure because of hindered drainage of the burning gases (STETTBACKER, 1948).

Numerous tests were developed and scientific experiments were performed under various conditions in connection with the stability of propellant powders during production and storage. There are measurement by F. Volk on mono and dibasic propellant powders in the 60-95°C temperature range. During this, an increase of NO<sub>2</sub>-development, as a measure of degradation, was noted after 800 days (VOLK, 1976). Also noted was a reduction of stability through exposure to water (URBANSKI, 1967). No aging effects could be noticed with nitrocellulose-powder that, in connection with war activities, was sank in the ocean (after several years).

#### *2.4.2.5 Characteristics of Dibasic Propellant Powders*

Nitroglycerin-powder is produced from nitrocellulose and nitroglycerin plus stabilizers and additional additives. Substances such as camphor, butylthiolate, akardit, centralit, and diphenylurethane.

During reaction dibasic propellant powders develop more heat than black powders. Depending on its composition, the values are in the range of approximately 900 to 1250 kcal/kg. The burning process is two step. Initially gas-like substances form from the solid body, which in turn react with one another (URBANSKI, 1967).



Dibasic propellant powders or similar to monobasic powders, harder to ignite and slower burning than black powder, but increasing sensitivity with rising heat or dryness (STETTbacher, 1948). Because the sensitivity of powders made with nitroglycerin and nitrocellulose is somewhat low, practical usage of a primer (eg. blackpowder) is needed for ease of ignition (URBANSKI, 1967). In addition they have a low sensitivity to friction or impact.

The ignition temperature of nitroglycerin/nitrocellulose base propellant powders is approximately 180°C (URBANSKI, 1967). Stabilizing agent are added to the propellant powders to prevent decomposition at higher temperatures. As with monobasic powders, there is only danger of explosion if the draining of the burning gases is hindered (STETTbacher, 1948). Stabilizing test have demonstrated that quality powders can be exposed to temperatures of 80°C for a least 500 hours without any decomposition (URBANSKI, 1967).

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The previous tests concerning the stability of the propellant powders were conducted by F. Volk (VOLK, 1976). As with monobasic propellant powders, the stability does decrease with increasing moisture (URBANSKI, 1967).

### 2.4.3 Assessment of the Danger

A potential danger from mono and dibasic propellant powders, as well as black powder, during transportation of the garbage and storage of the garbage in the dump can be excluded on the basis over the previous described substance-characteristics and the estimated quantities. Through the shredding of the garbage, the cartridge munitions and Hoffmann Devices are destroyed and thus the danger of detonation. Additionally, the shredding process partially mixes the garbage which leads to a reduction of the local concentrations of explosive substances and thus the potential danger.

### 2.5 *Examination of the possible Corrosion to the Facility Components of the MKW - Schwandorf from HCl*

During the thermal destruction of the chlorine containing garbage, chlorine compounds can form as gas reaction products eg. hydrogen chloride. The munitions such as the signalling munitions and the pyrotechnical Hoffmann Devices can contain chlorine compounds in the following munition components:

- o Illuminating charges
- o Igniter charges
- o Smoke charges
- o additional components

In particular, the following components can basically play a role (see table 2-7):

- o PVC
- o n-Hexane
- o Chlorine carriers
- o Potassium chlorate (which is basically converted into Potassium chloride)

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Table 2-7: Influence to the Composition of the Garbage from Munitions

Substance Group	Amount per 1 ton collected garbage [g/t]	Components	Chlorine-containing components
<b>Signal Munitions and Pyrotechnical Hoffmann Devices</b>			
Propellant Powder	0.0151	blackpowder, dibasic propellant powder in nitrocellulose- nitroglycerin-base	—
Blackpowders and Mixtures	3.5292	aluminum, barium nitrate, potassium nitrate, cuprous (II) oxide, magnesium, blackpowder, sulphur	—
Igniter Charges	0.0018	lead nitrate, SINOXID (lead tri"zinate", tetrazine, barium nitrate, lead oxide, antimony trisulfide), potassium chlorate, sulphur, glass powder, calcium silicate, hydrazine, antimony	potassium chlorate
Illuminating Charges	2.6217	aluminum, barium nitrate, magnesium, sodium nitrate, PVC, strontium nitrate, paraffins	PVC
Smoke Charges	0.4840	diamino anthraquinone, n-hexane, potassium chlorate, magnesium, sodium nitrate, PVC, stearic acid, strontium nitrate	n-hexane, potassium chlorate, PVC
<b>Blank "rounds" Munitions</b>			
Propellant Powder	0.3832	nitrocellulose, nitroglycerin, akardit I, akardit II, diphenylamine, camphor, dibutylthiolate, diethylthiolate, potassium sulfate	—

Igniter Charges	0.0040	lead nitrate, SINOXID (lead tri"zinate", tetrazine, barium nitrate, lead oxide, antimony trisulfide)	—
Tracer Material	0.797	aluminum, barium nitrate, chlorine carriers, potassium perchlorate, magnesium, sodium oxalate, sulphur, silicon, strontium nitrate, strontium peroxide	chlorine carriers, potassium perchlorate

On the basis of the fact that the cartridge munitions and the Hoffmann Devices containing quantities of chlorine compounds (see table 2-7), one does not need to presume that the HCl formed during their thermal destruction leads to a relevant additional corrosive burden on the facility components. Furthermore, one cannot assume all the chlorine compounds contained in these substances ultimately is turned into HCl.

## 2.6 Legal Considerations to the "Planfeststellungsbeschuß" (operating standards - rules - permits) and to the DeNO<sub>x</sub>- Permit

In connection with the legal considerations the following licences-permits were examined to determine any impact on the appropriate facility. The goal of the examination was to answer the question in how far, or what extent the disposal of the garbage from the training areas Grafenwöhr and Hohenfels would have on the permitted values (listed within the permits-licences). The following documents were closely examined:

- o "Planfeststellungsbeschuß" (operating standards - rules - permits) MKW - Schwandorf from 03/27/92
- o DeNO<sub>x</sub>-Permit from 07/03/93
- o "Planfeststellungsbeschuß" (operating standards - rules - permits) from 08/09/84 for the construction and the operation of a disposal site for remaining substances (Mathiasgrube) from the MKW - Schwandorf
- o "Planfeststellungsbeschuß" (operating standards - rules - permits) from 10/14/81 and 04/05/82 Reloading Station Neumarkt i.d.OPf. (in the Oberpfalz).
- o "Planfeststellungsbeschuß" (operating standards - rules - permits) from 08/05/82 Reloading Station Amberg
- o "Planfeststellungsbeschuß" (operating standards - rules - permits) from 01/20/82 Reloading Station Weiden i.d.OPf. (in the Oberpfalz).

### 2.6.1 "Planfeststellungsbeschuß" (operating standards - rules - permits) and DeNO<sub>x</sub> - Permit - Air Emissions

The following "Planfeststellungsbeschuß" (operating standards - rules - permits) of the government of the Oberpfalz from 03/27/92 for the MKW - Schwandorf refers to the extension of a fourth incinerator line and the upgrading of the existing fume abatement equipment.

The DeNO<sub>x</sub>-Permit contains, in addition to the approval of the upgrade of MKW - Schwandorf with catalytic de-NO<sub>x</sub>ing equipment with an integrated de-dioxin(?ator?) (De-Dioxin Facility), additional regulations which are to be followed during start-up and operation of the De-NO<sub>x</sub> Facility. These additional regulations have priority before the original standards with respect and contrast to the DeNO<sub>x</sub> Facility.

On sides with the contractor, it is assumed that the last valid "Planfeststellungsbeschuß" and the last valid DeNO<sub>x</sub>-Permit have not changed (with respect to the original except for the one single description).

To be examined was whether the disposal of the garbage of the training areas Grafenwöhr and Hohenfels was violating the "Planfeststellungsbeschuß" or DeNO<sub>x</sub>-Permit. Statements are to be made whether the critical limits (of the permits) are reached or to what extent the garbage influences the approved limits

### *2.6.1.1 Garbage of the Training Areas Grafenwöhr and Hohenfels*

#### **2.6.1.1.1 Garbage from the Living Areas**

The garbage from the living area Vilseck, Grafenwöhr Main Post and the Hohenfels Housing Area of the training areas Grafenwöhr and Hohenfels is in its overall consistency similar to that of normal household garbage. However, within the areas, separation of the garbage is not yet fully accepted by the people living there, so that we still have a garbage separation potential. Through currently initiated action of the US-Army, this standard will be certainly improving so that in the near future there will be no difference to the usual German standard of garbage separation.

#### **2.6.1.1.2 Garbage from the Field Camps Grafenwöhr and Hohenfels, the Firing Ranges Grafenwöhr and from the Training Areas Hohenfels**

The garbage sampling found constant contamination of the garbage with FRH components. In relatively rare cases, illegally disposed gun- and MG-munitions were found in the garbage. Furthermore, in the scope of Phase 1 of the report, sampling revealed Hoffmann Devices. Like the munitions these were illegally disposed of in the garbage. By means of the recent change of regulations, (SOP), sampling conducted during Phase 2 of the report found only one Hoffmann Device (which was probably already in the garbage for sometime). The munitions found during Phase 2 of the report ( 3 cartridges, 12.77mm caliber ), were illegally disposed of in a garbage container in the Motorpool.

#### **2.6.1.1.3 Contamination of the Garbage with Munitions and Hoffmann Devices**

The quantity of munitions found during Phase 2 of the report is below that determined during Phase 1 of the report, one cartridge per 10 Mg garbage, by approximately a factor of 3 (see also Report to Phase 1). Reasons for the miscalculation were errors in estimates, etc. from the US-Army.

Also the Hoffmann Devices discovered in Phase 1 of the report and the resulting estimate of one Hoffmann Device per 20 Mg of garbage is over estimated. This is due to a similar error as with the cartridge munitions and results in an estimate reduction factor of 3 according to the calculated contamination.

During the evaluation of the garbage samples an additional security factor of 2 was calculated into the estimates. This was because not all the garbage was inspected, and not all contamination with munitions and Hoffmann Devices could be accounted for and additional contamination by these substances, in scope of the operation in the training areas, has to be calculated in.

Therefore, one can proceed from this fact that

- o one cartridge per 30 Mg
- o one Hoffman Devices per 60 Mg

of garbage is present.



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Large caliber munitions or other combat materials (handgrenades, mines, anti-tank weaponry, rockets, etc.) or munition parts were not found.

#### 2.6.1.1.4 Potential Danger of the Garbage

The potential danger of the garbage from the TrÜbPl Grafenwöhr and Hohenfels, after pre-treatment as explained in Chapter 4.3 of this report, is that of ordinary household garbage or household trash. The suggested pre-treatment will eliminate the potential danger, especially from the FRH. The pre-treatment also eliminates any risks associated with illegally disposed munitions and Hoffmann Devices.

On basis of the samplings conducted (Phase 1 and Phase 2 of the Assessments) a pre-treatment of all of the garbage without exception is suggested. Because of reason of facility security at the reloading stations and the "garbage works"(garbage bunkers) a high degree of FRH-free garbage must be reached. Currently, this can only be obtained through the pre-treatment of the garbage.

#### 2.6.1.1.5 Disposability of the Garbage at the ZMS

According to the "Planfeststellungsbeschluss" (operating standards - rules - permit) from 03/27/92, paragraph 2.6, the following garbage can be burned in the "garbage works" MKW - Schwandorf of the ZMS:

- o household garbage
- o "household-like" garbage from industry and trades
- o trash and
- o clarified slurry/sludge

In the scope of the examination of the garbage to be burned a MKW - Schwandorf during Phase 1 and Phase 2 of the assessment, it was found the garbage consisted of:

- o household garbage (greatest amount approximately 90%)
- o "household-like" garbage (similar to garbage from industry in the area, approximately 5%)
- o trash (approximately 5%)

Clarified slurry/sludge and other garbage could not be determined or else they were disposed of by other means (eg. disposal requiring supervision).

The garbage to be disposed of corresponds to the garbage which may be burned according to "Planfeststellungsbeschuß" (operating standards - rules - permit) issued to MKW - Schwandorf on 03/27/92. Therefore, there are no restrictions concerning the garbage fractions against disposal in MKW - Schwandorf.

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#### **2.6.1.2 Emission of MKW - Schwandorf ("Planfeststellungsbeschuß" (operating standards - rules - permit) and DeNO<sub>x</sub> - Permit)**

These documents serve as main sources for the listed data and statements in the following paragraphs:

- o "Planfeststellungsbeschuß" (operating standards - rules - permit) about the expansion and upgrade of MKW - Schwandorf from 03/27/92 as well as the revisions from 06/09/94
- o the DeNO<sub>x</sub> - Permit from 06/07/93
- o emission reports from the years 1995 and 1996 (edited)
- o measured emission values 1997 (January to April)

##### **2.6.1.2.1 Limits According to the "Planfeststellungsbeschuß" (operating standards - rules - permit) from 03/27/92**

The "Planfeststellungsbeschuß" (operating standards - rules - permit) from 03/27/92 requires daily average values, half-hour averages, and sampling times dependent upon average values for certain emissions, and emission limits of certain single substance concentrations.

The State Office for Environmental Protection and the Government of the Oberpfalz proceed from the fact that the regulations of the 17 BImSchV (valid after 03/01/94) with the exception of DeNO<sub>x</sub> and possibly mercury are met by MKW - Schwandorf.

#### 2.6.1.2.1.1 Daily Average Values

The following daily average values per incinerator line are not to be exceeded according to the "Planfeststellungsbeschluss" (operating standards - rules - permit) from 03/27/93, number 3.16, paragraph 1:

o	overall dust [dust <sub>total</sub> ]	10	mg/m <sup>3</sup>
o	organic substances, shown as total carbon [C <sub>total</sub> ]	10	mg/m <sup>3</sup>
o	gas-forming inorganic chlorine-compounds, shown as hydrogen chloride [HCl]	10	mg/m <sup>3</sup>
o	gas-forming inorganic fluorine-compounds, shown as hydrogen fluoride [HF]	1	mg/m <sup>3</sup>
o	sulphur dioxide and sulphur trioxide, shown as sulphur dioxide [SO <sub>2</sub> ]	50	mg/m <sup>3</sup>
o	nitrous oxide and nitrogen dioxide, shown as nitrogen dioxide [NO <sub>2</sub> ]	0.50	g/m <sup>3</sup>
	after 03/01/94 (according to 17. BImSchV)	0.20	g/m <sup>3</sup>

#### 2.6.1.2.1.2 Half-hour Average Values

The following half-hour average values per incinerator line are not to be exceeded according to the "Planfeststellungsbeschluss" (operating standards - rules - permit) from 03/27/92, number 3.16, paragraph 2:

o	overall dust [dust <sub>total</sub> ]	20	mg/m <sup>3</sup>
o	organic substances, shown as carbon [C <sub>total</sub> ]	20	mg/m <sup>3</sup>
o	gas-forming inorganic chlorine-compounds, shown as hydrogen chloride [HCl]	60	mg/m <sup>3</sup>
o	gas-forming inorganic fluorine-compounds, shown as hydrogen fluoride [HF]	4	mg/m <sup>3</sup>

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o	sulphur dioxide and sulphur trioxide, shown as sulphur dioxide [SO <sub>2</sub> ]	0.10	g/m <sup>3</sup>
o	nitrous oxide and nitrogen dioxide, shown as nitrogen dioxide [NO <sub>2</sub> ]	1.00	g/m <sup>3</sup>
	after 03/01/94 (according to 17. BImSchV)	0.40	g/m <sup>3</sup>

#### 2.6.1.2.1.3 Sampling Time-Dependent Average Values for certain Emissions

No average value, which is formed by the time-dependent sampling times, may exceed the following values according to the "Planfeststellungsbeschluss" (operating standards - rules - permit) from 03/27/92, number 3.16, paragraph 3:

o	cadmium and it's compounds, shown as Cd thallium and it's compounds, shown as Tl	total	0.05	mg/m <sup>3</sup>
o	mercury and it's compounds, shown as Hg		0.05	mg/m <sup>3</sup>
o	antimony and it's compounds, shown as Sb, arsenic and it's compounds, shown as As, lead and it's compounds, shown as Pb, chromium and it's compounds, shown as Cr, cobalt and it's compounds, shown as Co, copper and it's compounds, shown as Cu, manganese and it's compounds, shown as Mn, nickel and it's compounds, shown as Ni, vanadium and it's compounds, shown as V, tin and it's compounds, shown as Sn	total	0.50	mg/m <sup>3</sup>

#### 2.6.1.2.1.4 Limit - Values of Dioxin and Furane

No average value which is formed by the time-dependent sampling times, may exceed the following values according to the "Planfeststellungsbeschluss" (operating standards - rules - permit) from 03/27/92, number 3.16, paragraph 4, the value as stated in 17 BImSchV, Dioxin and Furane- given as total values as an extension of 17. BImSchV and determined as 0.1 ng/m<sup>3</sup>.

#### 2.6.1.2.1.5 Sampling Times

The sample taking time, according to the "Planfeststellungsbeschluß" (operating standards - rules - permit) from 03/27/92, number 3.16, paragraph 4, *the measurement, to determine substances* according to Chapter 2.6.1.2.1.3 of the report is ; at least half an hour and not to exceed 2 hours. For determination of substances in Chapter 2.6.1.2.1.4 (Dioxin and Furane) the time is at least 6 hours and should not exceed 16 hours. For these substances the limits of the analysis method should not exceed 0.005 ng/m<sup>3</sup>.

#### 2.6.1.2.1.6 Emission Limits of Single Substance Concentrations

- |   |   |    |                   |
|---|---|----|-------------------|
| o | gas-forming chlorine-compounds,<br>shown as hydrogen chloride [HCl] | 50 | mg/m <sup>3</sup> |
| o | gas-forming fluorine-compounds,<br>shown as hydrogen fluoride [HF]  | 2  | mg/m <sup>3</sup> |
-

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o	sulphur dioxide (SO <sub>2</sub> and SO <sub>3</sub> ), shown as sulphur dioxide [SO <sub>2</sub> ]	50	mg/m <sup>3</sup>
o	nitrous oxide, shown as nitrogen dioxide [NO <sub>2</sub> ]	0.50	g/m <sup>3</sup>
o	organic substances, shown as total Carbon [C <sub>total</sub> ]	20	mg/m <sup>3</sup>
o	overall dust [dust <sub>total</sub> ]	10	g/m <sup>3</sup>
	from dust generating, organic substances, such as generated from the burning of		
	Class I: (cadmium, mercury)	0.20	mg/m <sup>3</sup> *
	Class II: (nickel)	1.00	mg/m <sup>3</sup>
	Class III: (lead, chromium, copper)	3.00	mg/m <sup>3</sup>

\* including damp- and gas-forming Hg-fractions

Of those Class I and II substances present, the maximum total concentration in the flue gases must not exceed 1 mg/m<sup>3</sup>.

#### 2.6.1.2.2 Maximal Values Allowed, DeNO<sub>x</sub> - Permit from 06/07/93

##### 2.6.1.2.2.1 Daily Average Values / Half-hour Average Values / Time-dependent Sampling Average Values

The DeNO<sub>x</sub>-Permit from 06/07/93, which allowed the upgrading of the MKW - Schwandorf with catalytic DeNO<sub>x</sub>-ing" equipment with an integrated De-dioxin "ator" (DeNO<sub>x</sub>-equipment), contain the following emission limits according to number 2.2:

The SCR-Facility is to be constructed and operated as to maintain (in the off-gases)

1. No Daily Average Values to exceed the following Emission Limits:

o	overall dust [dust <sub>total</sub> ]	10	mg/m <sup>3</sup>
o	organic substances, shown as total carbon [C <sub>total</sub> ]	10	mg/m <sup>3</sup>

o	gas-forming inorganic chlorine-compounds, shown as hydrogen chloride [HCl]	10	mg/m <sup>3</sup>
o	gas-forming inorganic fluorine compounds, shown as hydrogen fluoride [HF]	1	mg/m <sup>3</sup>
o	sulphur dioxide and sulphur trioxide, shown as sulphur dioxide [SO <sub>2</sub> ]	50	mg/m <sup>3</sup>
o	nitrous oxide and nitrogen dioxide, shown as nitrogen dioxide [NO <sub>2</sub> ]	0.20	g/m <sup>3</sup>

2. No Half-hour Average Values to exceed the following Emission Limits:

o	overall dust [dust <sub>total</sub> ]	30	mg/m <sup>3</sup>
o	organic substances, shown as total carbon [C <sub>total</sub> ]	20	mg/m <sup>3</sup>
o	gas-forming inorganic chlorine-compounds, shown as hydrogen chloride [HCl]	60	mg/m <sup>3</sup>

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o	gas-forming inorganic fluorine-compounds, shown as hydrogen fluoride [HF]	4	mg/m <sup>3</sup>
o	sulphur dioxide and sulphur trioxide, shown as sulphur dioxide [SO <sub>2</sub> ]	0.20	g/m <sup>3</sup>
o	nitrous oxide and nitrogen dioxide, shown as nitrogen dioxide [NO <sub>2</sub> ]	0.40	g/m <sup>3</sup>
o	ammonium [NH <sub>3</sub> ]	20	g/m <sup>3</sup>

Demands indicated by the "Planfeststellungsbeschluss" (operating standards - rules - permits):

The MKW - Schwandorf (ZMS) must, according to the DeNO<sub>x</sub>-Permit from 06/07/93. (page 12, number 2.2), to everything possible to ensure the average values for overall dust (20 g/m<sup>3</sup>) and sulphur dioxide (0.10 g/m<sup>3</sup>) listed in the "Planfeststellungsbeschluss" (operating standards - rules - permit) of the Government of the Oberpfalz from 03/27/92 are met.

3. No Average Values formed during the Time-dependent Samplings are to exceed the limits of:

o	cadmium and it's compounds, shown as Cd thallium and it's compounds, shown as Tl	total	0.50	mg/m <sup>3</sup>
o	mercury and it's compounds, shown as Hg		0.50	mg/m <sup>3</sup>
o	arsenic and it's compounds, shown as As		0.1	mg/m <sup>3</sup>
o	antimony and it's compounds, shown as Sb, arsenic and it's compounds, shown as As. lead and it's compounds, shown as Pb, chromium and it's compounds, shown as Cr, cobalt and it's compounds, shown as Co, copper and it's compounds, shown as Cu. manganese and it's compounds, shown as Mn, nickel and it's compounds, shown as Ni, vanadium and it's compounds, shown as V tin and it's compounds	total	0.50	mg/m <sup>3</sup>

4. No Average Values formed during the Time-dependent Samplings are to exceed the limits set in 17. BImSchV *Dioxin and Furane*, named as total values in 17. BImSchV of 0.1 ng/m<sup>3</sup>.



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#### 2.6.1.2.2.2 Evidence/Record of Compliance with Emission Limits

The Emission Limits for the continually measured substances noted in the DeNO<sub>x</sub>-Permit from 06/07/93, number 2.15 must be recorded during all operating hours for one calendar year, and

- o no daily average values, according to number 1 (Chapter 2.6.1.2.2.1, paragraph 1 of the report) and
- o no half-hour average values, according to number 2 (Chapter 2.6.2.2.1, paragraph 2 of the report)

is to be exceeded.

#### 2.6.1.2.3 Comparison of the Emission Data

Table 2-8 shows the approved Limits of the DeNO<sub>x</sub>-Permit from 06/07/93. These are still to be observed as valid limits. The actual measured values are taken from ZMS documentation (excerpts from the Emission Reports of the corresponding time periods).

The values indicated for "measured values 1995 and 1996" is the arithmetic means of the average values from incinerator lines 1 to 4. The NO<sub>2</sub>- and NH<sub>3</sub>- values were similarly obtained (measured at the 3 SCR-lines).

The values indicated for "measured values 1997" is the arithmetic means of the average values from incinerator 1 to 4. The months January thru April were evaluated. First the mean values for each month was determined, then the arithmetic mean for all four months was obtained. The values were similarly obtained for the NO<sub>2</sub>-values.

HCl, SO<sub>2</sub>, C<sub>total</sub>, CO, dust, and NO<sub>2</sub> values were measured continuously. All others values were measured as needed.

The measuring procedures (techniques) including the definition of the Time-dependent Samplings, correspond to the regulations of the "Planfeststellungsbeschuß" (operating standards - rules - permit) and those of the DeNO<sub>x</sub>-Permit relevant for compliance.

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Table 2-8: Emissions, Limits, Daily Averages (up to #7 ), Time-dependent Average Values  
(from # 8 on)

No.	Emission	Unit	Limit	Measured Values 1995	Measured Values 1996	Measured Values 1997	TrÜbPl 1)
1	gas-forming inorganic chlorine- compounds, shown as hydrogen chloride [HCl]	mg/ m <sup>3</sup>	10	5.175	6.425	5.833	0.0149
2	sulphur dioxide and sulphur trioxide, shown as sulphur dioxide [SO <sub>2</sub> ]	mg/ m <sup>3</sup>	50	4.05	3.35	5.010	0.0468
3	organic substances, shown as total carbon [C <sub>total</sub> ]	mg/ m <sup>3</sup>	10	0.925	0.525	0.379	--
4	carbon monoxide [CO]	mg/ m <sup>3</sup>	50	15.25	11.55	13.954	--
5	overall dust	mg/ m <sup>3</sup>	10	1.275	1.175	1.066	--
6	nitrous oxide and nitrogen dioxide, shown as nitrogen dioxide [NO <sub>2</sub> ]	mg/ m <sup>3</sup>	200	64.20	62.833	62.999	0.4344
7	gas-forming inorganic fluorine- compounds, shown as hydrogen fluoride [HF]	mg/ m <sup>3</sup>	1	<0.07	<0.1	--	--
8	cadmium and it's compounds, shown as Cd thallium and it's compounds, shown as Tl	mg/ m <sup>3</sup>	0.05	<0.011	<0.011	--	--
9	mercury and it's compounds, shown as Hg	mg/ m <sup>3</sup>	0.05	0.0245	0.0245	--	--
10	arsenic and it's compounds, shown as As	mg/ m <sup>3</sup>	0.1	--	--	--	--

11	antimony, arsenic, lead, chromium, cobalt, copper, manganese, nickel, vanadium, tin, and their compounds [Sb - Sn]	mg/ m <sup>3</sup>	0.5	0.03	0.03	--	0.0007
12	ammonium [NH <sub>3</sub> ]	mg/ m <sup>3</sup>	20	0.0666	0.0666	0.0666	--
13	dioxin and furane [PCDD/F]	ng/ m <sup>3</sup>	0.1	0.00157	0.00157	--	--

1) additional emission burdens from substances in munition cartridges and Hoffmann Devices will approach maximum limits (see also Chapter 2.3)

all substances were not taken into account because they correspond with the "household garbage and household-like garbage" standards and thus a lack of harmful substance potential.

Table 2-9: Measured Emissions for the Months of January, February, March, and April 1997  
(Daily Averages)

Month	HCl	SO <sub>2</sub>	C <sub>total</sub>	CO	Dust	NO <sub>2</sub>	Unit
January	5.775	5.475	0.425	14.475	0.95	62.6	mg/m <sup>3</sup>
February	5.275	5.025	0.425	14.125	0.975	64.833	mg/m <sup>3</sup>
March	6.133	5.166	0.366	11.766	1.175	62.4	mg/m <sup>3</sup>
April	6.15	4.375	0.3	15.45	1.175	62.4	mg/m <sup>3</sup>
Total	5.833	5.010	0.379	13.954	1.066	62.999	mg/m <sup>3</sup>
Permit/ Limit	10	50	10	50	10	200	mg/m <sup>3</sup>

The total values were calculated in table 2-9 as "measured values".

The values TrÜbPI demonstrate the additional emissions burden on MKW - Schwandorf which could exist through the incineration of munitions and Hoffmann Devices. The basis of this was the Phase 1 report of calculated contamination. The values include a 100% threefold security factor to ensure that even in the most severe situations (high contamination with munitions and Hoffmann Devices), the emissions of the MKW - Schwandorf would not be greatly influenced by the garbage of the training areas Grafenwöhr and Hohenfels.

#### 2.6.1.2.4 Legal Consequences of the Disposal of the Garbage of the TrÜbPI Grafenwöhr and Hohenfels on the Emissions Permits

As described in the composition of the garbage samples (Chapter 1 of this report) and the short description on the chapter, the garbage to be disposed (of) consists exclusively of household or "household-like" garbage and trash. The additional contamination and potential danger of the illegally dumped munitions and Hoffmann Devices is relatively slight based on their low concentration. Even an increase in their quantity would not noticeably increase the emission values.

With this one can proceed to the conclusion that the emissions produced by the disposal of the garbage of the TrÜbPI Grafenwöhr and Hohenfels neither

- o the valid section of the "Planfeststellungsbeschuß" (operating standards - rules - permit) from 03/27/92 (MKW - Schwandorf) nor
- o the valid section of the approval from 06/09/94 (MKW - Schwandorf Incinerator Line 4) nor
- o the valid section of the DeNO<sub>x</sub>-Permit from 06/07/93 nor
- o the valid section of the "Planfeststellungsbeschuß" (operating standards - rules - permit) from 08/09/84 (Mathiaszeche) or the DeNO<sub>x</sub>-Permit from 06/07/93

will be exceeded. Therefore no legal consequences should develop with respect to the section *Emissions in the Off-gases and Substances in Off-gas Scrubbing*, even if there was a substantial increased contamination of garbage by munitions, munition parts, or Hoffmann Devices, or an increase in garbage production of TrÜbPI Grafenwöhr and Hohenfels.

Therefore, the "Planfeststellungsbeschuß" (operating standards - rules - permit) from 03/27/92, the notice from 06/09/94 (concerning the upgrade/rebuild of incinerator line 4), the DeNO<sub>x</sub> Permit from 03/07/93 and the "Planfeststellungsbeschuß" (operating standards - rules - permit) from 08/09/84 (Mathiaszeche) are not negatively effected by the disposal of the garbage, and need no re-approval.

#### 2.6.2 "Planfeststellungsbeschuß" (operating standards - rules - permit) from 03/27/92, DeNO<sub>x</sub> - Permit from 03/07/93 and the "Planfeststellungsbeschuß" (operating standards - rules - permit) of the Re-loading Station - Lärmemissionsstoffen

In addition to and in connection with the examination of emission gases, noise emissions must be addressed. Noise emissions can develop through the re-loading and transport of the garbage. Noise emissions from the detonation of illegally dumped munitions or Hoffmann Devices can be excluded due to their pre-treatment.

In addition to the "Planfeststellungsbeschuß" (operating standards - rules - permit) for the MKW - Schwandorf and the DeNO<sub>x</sub>-Permit, the following "Planfeststellungsbeschlüsse" (operating standards - rules - permits) also contain regulations concerning noise emissions:

- o "Planfeststellungsbeschuß" (operating standard - rules - permit) from 10/14/81 and 04/05/821 Re-loading Station Neumarkt i.d.Opf. (in the Oberpfalz)
- o "Planfeststellungsbeschuß" (operating standard - rules - permit) from 08/05/82 Re- loading Station Amberg
- o "Planfeststellungsbeschuß" (operating standard - rules - permit) from 01/20/82 Re-loading Station Weiden i.d.Opf. (in the Oberpfalz)

#### 2.6.2.1 Guidelines and Limits Concerning Noise Reduction - "Planfeststellungsbeschuß" (operating standard - rules - permit)

Due to the overall noise, produced by VAW (Association of Aluminum, "Works") as with that produced by MKW - Schwandorf, "Planfeststellungsbeschuß" (operating standard - rules - permit) number 5.12, defined *Emission-type* (IO), the degree of noise emissions of the "Planfeststellungsbeschuß" (operating standard - rules - permit) allow the noise produced by MKW - Schwandorfs not exceed the following values:

IO 1:	Emissions guideline	Daytime:	50 dB (A)
		Night-time:	35 dB (A)
IO 2:	Emissions guideline	Daytime:	50 dB (A)
		Night-time:	35 dB (A)

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Single maximum values which develop during normal operation are <sup>not</sup> allowed to exceed 60 dB (A) at night for both IO's. Maximum levels allowed to exist during the lifting of safety valves cannot exceed 70 dB (A).

Similarly, the noise generated by the DeNO<sub>x</sub> Facility cannot lead to a situation where (according to number 5.1.5 of the "Planfeststellungsbeschuß" (operating standards - rules - permit)) the regulated values of the MKW are exceeded. As usual, all other noises produced by the operating machinery should be minimized.

#### 2.6.2.2 Regulatory Limits concerning Noise Reduction - DeNO<sub>x</sub> - Permit

According to number 5.2.27 of the DeNO<sub>x</sub>-Permit, the maximum noise levels at the job site in working rooms and from noises outside the location cannot exceed:

- o at mostly "intellectual activities" 55 dB (A)
- o at simple or most mechanical office activity and similar activity 70 dB (A)
- o at all other activities 85 dB (A)

These values can only be exceeded by 5 dB (A) even if all possible measures have been taken. The VBG "noise" values are to be followed.

#### 2.6.2.3 Regulatory Limits of the "Planfeststellungsbeschuß" (operating standard - rules - permit) Concerning Noise Reduction - Reloading Stations

The relevant noise-situation and regulations for all the reloading stations is the same. For example, the "Planfeststellungsbeschuß" (operating standard - rules - permit) from 01/20/82. for the construction and operation of the planned reloading station for household garbage and "household-like" garbage and trash at Weiden i.d. Opf. (in the Oberpfalz) was examined in this report. Therefore the noise levels in the working rooms are to be kept as low as possible for this type of operation.

The maximum noise levels at the job site in working rooms and from noises outside the location cannot exceed:

- o at mostly "intellectual activities" 55 dB (A)
- o at simple or most mechanical office activity and similar activity 70 dB (A)
- o at all other activities 85 dB (A)

These values can only be exceeded by 5 dB (A) even if all possible measures have been taken.

#### *2.6.2.4 Consequence of the Disposal of the Household Garbage from Grafenwöhr on the Noise Situation at MKW - Schwandorf and the Reloading Stations*

According to the report (Chapter 4.3) a two stage pre-treatment facility, to reduce the size of the garbage from the TrÜbPI into small pieces, is planned for construction. This pre-treatment facility will incorporate an integrated ferro-magnetic separation facility and a coarse particle expeller has been suggested.



The suggested pre-treatment facility, with the coarse particle expeller and integrated ferro-magnetic separator, can reduce the delivered garbage to a relatively small grain-size. This grain-size allows the garbage to be classified as high density. Due to the coarse particle expeller and the integrated ferro-magnetic separator, all the noise-causing materials are eliminated before transition to the responsibility of the ZMS.

As all experiments on the garbage depot Grafenwöhr - Haderbühl showed, the shredded garbage had a high bulk density without hard objects and an elastic effect during reloading. Due to this, it is unlikely that the approved noise levels will be exceeded during disposal (transport and reloading) with regards to the garbage of the TrÜbPl.

From a legal viewpoint, the approved noise levels of the "Planfeststellungsbeschluss" (operating standard - rules - permit) for the MKW - Schwandorf, the Reloading Station - Neumarkt i.d.Opf. (in the Oberpfalz), Amberg and Weiden i.d.Opf. (in the Oberpfalz) or the DeNO<sub>x</sub>-Permit will not be exceeded by disposal of the garbage and re-approvals are not needed.

#### 2.6.3 "Planfeststellungsbeschluss" (operating standards - rules - permit) from 08/09/84 Waste Depot "Mathiaszeche"

According to number 2.1 of the "Planfeststellungsbeschluss" (operating standards - rules - permit) from 08/09/84, only the following garbage can be stored at the facility:

- o waste from the MKW - Schwandorf
- o construction garbage, broken pavement, and ground fills
- o stabilized, decomposed, clarified sediments "waste", with a minimum of 25% dry materials
- o oil saturated soils with <3% by weight of petroleum substances, based on a dry sample
- o household garbage and "household-like"garbage in the event of non-operation of MKW - Schwandorf

The garbage for disposal in MKW - Schwandorf from the TrÜbPI Grafenwöhr and Hohenfels is exclusively:

- o household garbage
- o "household-like" garbage
- o trash

These types of garbage, and their components are allowed to be stored on the garbage depot "Mathiaszeche" according to the "Planfeststellungsbeschuß" (operating standards - rules - permit).

The "Planfeststellungsbeschuß" (operating standards - rules - permit) is not violated by the garbage to be disposed from the TrÜbPI Grafenwöhr and Hohenfels and no re-approval is required.

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### 3 Organizational and Administrative Solutions

#### 3.1 Problem and Initial Solution

The unreacted and unused FRH components present a high potential danger during disposal in the garbage streams. This potential danger is increased when a high number of unreacted, unused FRH components simultaneously react or are simultaneously burned.

The reasons are:

- o FRH components, upon contact with moisture, reach a temperature up to 95°C. Therefore they are an ignition source for the other garbage.
- o FRH components contain magnesium which reaches a temperature up to 3000°C when burned. This presents a danger for the "grills" of the incinerator lines.

#### 3.2 Examination of Administrative and Organizational Measures

In order to follow rules of garbage separation and reduction and therefor eliminate the FRH from the garbage, all relevant administrative and organizational measure must be taken.

Due to the fact that the unused and unreacted FRH components must be treated in a special way during disposal, faction of the US-Army need to develop appropriate collection and especially avoidance concepts.

But due to extraordinary reasons, these concepts cannot be used and thus any planned "avoidance" schemes cannot be realized

Furthermore, it appears that any planned, separate collection system for the FRH components (eg. separated collection of FRH components in the Field Camps) is no solution to the problem because one can conclude from the samples that all garbage streams are contaminated with FRH components.

Because of these reasons, administrative or organizational measurements could not be used.

### 3.3 Field Tests with various Shredding Equipment

Due to the fact that from the beginning it appeared that administrative and organizational solutions to the FRH component problem could not be realized, an overall technical solution to the problem was developed. Planned field tests with various shredding equipment, to destroy illegally disposed of gun- and MG-munitions as well as the destruction of Hoffmann Devices were not done. During sampling it became apparent that FRH components and not munitions represented the real disposal problem. Furthermore, the modified SOP for the handling of Hoffmann Devices noticeably reduced the contamination and thus a contamination by Hoffmann Devices is no longer present.

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## 4 Technical Solution

### 4.1 Problem and Initial Solution

The fact that unused and unreacted FRH components presented a problem during disposal was already shown within this report. That these FRH components are present as loose FRH packets as well as FRH packets still contained in open MRE packages was also mentioned several times. Furthermore, it was discussed that approximately 50% of the FRH packets present were still reactive. A differentiation of used and un-used FRH packets can only be accomplished by manual inspection during sampling because only then can it be determined whether the FRH packet is fully reacted or not. General technical pre-conditioning (either mechanically or some other procedure) for sorting out FRH packets or MRE packages is not known.

Another problem is the illegally disposed of gun- and MG-munitions and Hoffmann Devices found in the garbage. These objects despite all caution and precautions, continually get into the garbage, and can only be removed by a relatively complicated technique or by hand and once again, under strict security.

To summarize, it has to be determined:

- o Sorting of FRH components from the garbage is only possible by hand; necessary technical facilities are not available or known.
- o Sorting out of munitions or Hoffmann Devices would require a relatively high technical burden and/or would require a high degree of security.
- o The approved-required law for sorting munitions or FRH components by hand are relatively high due to job security/safety concerns.

To circumvent the associated problems and still reach a secure elimination of the FRH components, munitions, and Hoffmann Devices, the experts suggest a two-step shredding of the entire garbage at both locations.

#### 4.2 Marginal Conditions and Organizational Measures

In order to prevent contact with moisture (required for reaction) and prevent loss of the component, the FRH is sealed in a rip-proof plastic bag. Therefore, to destroy the FRH component, every plastic bag has to be ripped open. Furthermore within the shredding process, it must be assured that adequate moisture be available to sprinkle the FRH fragments with liquid in order to reach through hydrolytic reaction and neutralization of the FRH material.

As determined during sampling, it must proceed from the fact that the entire garbage from both locations is contaminated with FRH components to varying degrees. Because of facility security/safety reasons of the ZMS it is therefore suggested to shred the whole garbage. By doing this any apparent differences with the Phase 1 report on garbage content and collection are eliminated.

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Furthermore, a separate disposal of the FRH components from the field camps can be eliminated because a garbage separation at this location is not feasible.

#### 4.3 Documentation of Technical Concepts

As previously mentioned, the FRH components are sealed in rip-proof plastic bags. The destruction of the FRH components is further complicated because the FRH is often still in the relatively thick foil of the MRE packages. An additional factor for the difficult destruction is that the FRH packets, including their foil, are very flat and smooth in their original condition. The shredding experiments showed that a single step shredding of the FRH components was inadequate to completely destroy them with certainty (see also the conversation-note # 05/97 as well as the photo-documentation in the appendix of this report).

The size of the gun- and MG-munitions, and Hoffmann Devices require a relatively small grain-size during shredding in order to securely destroy these objects and make them unusable.

However, the collected garbage can reach measurements up to 3 meter in original size (trash). Additionally, parts of the garbage can become very compacted and therefore afford great resistance to destruction.

These demonstrated original parameters (size and compactibility) require a 2-step shredding process which leads to the required grain-size ensuring a secure destruction of the FRH components, munitions, and Hoffmann Devices which cannot be obtained in a single step shredding process due to technical reasons.

Therefore the following rough concept of a shredding facility is suggested (see Illustration 4-1 and Photo-documentation in appendix 1):

- o coarse shredding with a low rpm shredder
- o fine shredding with a high rpm shredder
- o ferro-magnetic separation after coarse shredding

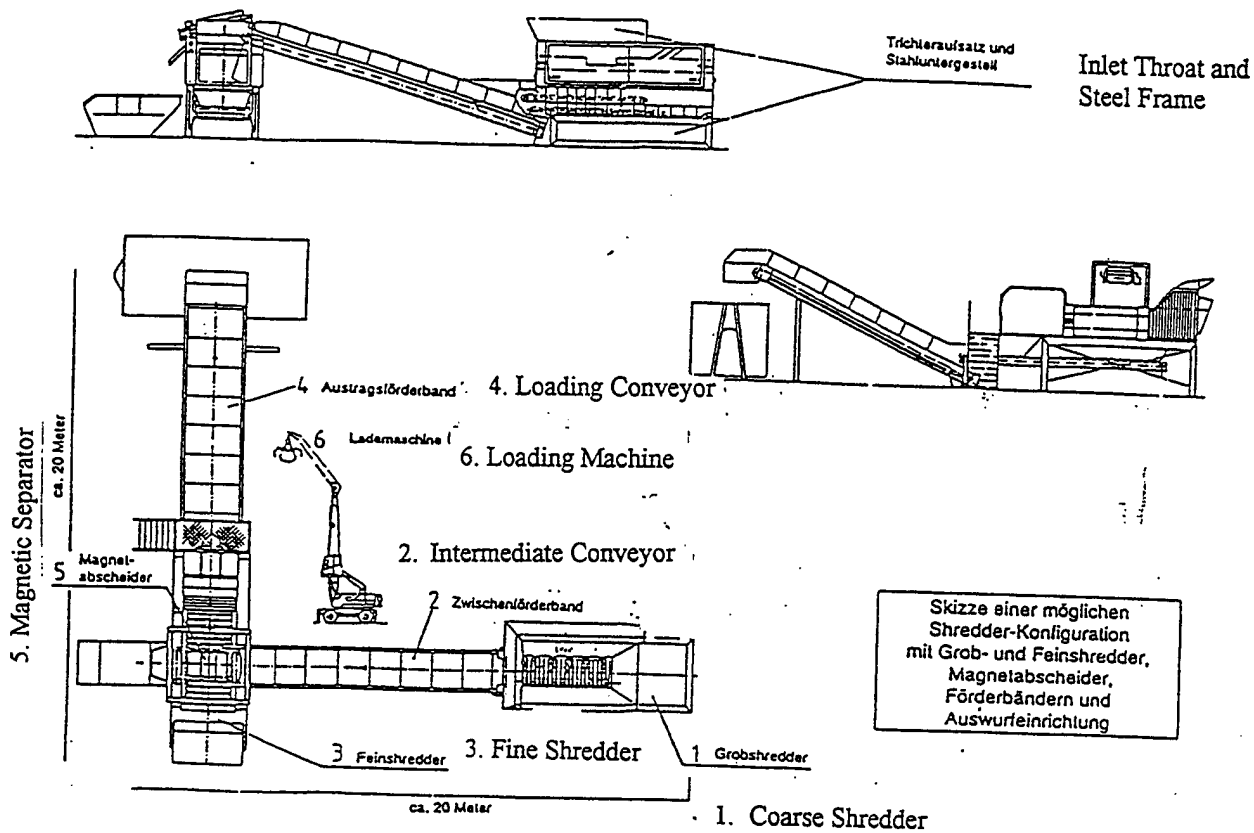
- o sprinkling device for misting of shredded material from fine shredder in order to reduce dust-formation and initiation of a reaction of the FRH component
- o loader with a raised-cabin for loading and simultaneously supervising the whole facility
- o large container with flexible roof material or pre-stressed skin type container in various configurations



# Sketch of Possible Shredder Configuration with Coarse and Fine Shredder, Magnetic Separator, Conveyors, and Discharge Chute

Gutachten über die Möglichkeiten der Entsorgung des anfallenden Hausmülls der Truppenübungsplätze Grafenwöhr (Süd- und Ostlager) und Hohenfels  
Bericht zur Phase 2

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A short description of the single components of the rough concept follows:

### 1. Coarse Shredder

Basically the two following systems are a choice:

- o Rotary-Scissor principle
- o ? Hammer ?- Mill principle

With the rotary-scissor principle, sets of parallel knives, are rotating at different speeds and in opposite directions. These knives are exchangeable to varying degrees according to the desired amount of shredding desired. The clearance developed between the blades determines the grain size of the garbage shredded. Here the garbage is cut, broken or smashed. A press assists in moving the garbage into the blades if necessary. Materials which cannot be shredded are automatically expelled. The cutting tool are easily changed by the operator. The cutting tools are easily reconditioned by either the manufactor or other specialized companies. Power to the shredding blades is provided by indirect-inter-switched hydraulic motors. The hydraulic pumps are powered by electric motors. Rotary Scissors are well designed and dependable. Because of the technique, they provide a high output of shredded garbage. Various interlocks and safety devices provide security against damage to the rotary scissors.

The Walzen-shredder, uses a tooth equipped drum to push the garbage through a hydraulically adjustable comb. During this process, the garbage is broken, smashed, and torn. The drum and comb are constructed of non-rusting steel. To extend the operating time the teeth can be equipped with hard-facing. This hard-facing can be replaced by the operator. In order to prevent an overload, the comb withdraws allowing the oversized item to be expelled. Power to the drum is provided through a hydraulic-clutched electric motor or diesel engine. Walzen shredders, by design, are very durable and dependable. Various interlocks and switches prevent damage to the machinery in the event of overload.

On the garbage depot Grafenwöhr - Haderbühl a Walzen-shredder is currently used for pre-shredding of the garbage.

Both types of shredders are low rpm equipment and are generally considered very stable and dependable.

## 2. Ferro-magnetic Separation

In order to prevent a possible ignition source in the fine-shredder, the ferro-magnetic objects must be removed from the pre-shredded garbage before being loaded into the fine-shredder.

After coarse-shredding the pre-shredded garbage is transported by a conveyor belt near a magnet. The magnet removes the steel parts from the garbage. These parts are put into a collection container and can be disposed of separately. In order to ensure that the ferro-magnetic separation removes all appropriate objects, the bulk size cannot exceed a certain measurement.

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The material must be continuously moved by the conveyor-belt without interruption.

### 3. Fine-Shredder

The goal of the fine-shredder is a reduction to a relatively small grain-size of the pre-treated problematic garbage for disposal by the MKW - Schwandorf Facility. Simplified, this is accomplished by destroying the garbage until a sufficiently small grain-size is reached that the garbage can be smashed through an appropriate grating or it falls through on its own. Basically, the low rpm scissors can be used for fine shredding because the clearances can be adjusted to obtain the desired grain-size. But whether this is economically feasible is not in the scope of this investigation and remains to be discussed during the design of the facility.

In order to obtain an appropriate size of the shredded materials, fine-shredders are always designed as high rpm equipment so that the inertial forces can be used for the destruction of the materials. The technique is relatively simple and consists of an impact mill with changeable points. With the help of a "screen" basket or sieve, the grain-size of the fine-shredder can be adjusted. Similar techniques are used in a hammer-mill, but the basic technique is always the same.

The technique of high rpm shredders has an important disadvantage which must be kept in mind during configuration of the facility. Highly stable materials will be difficult to destroy and will be impacted repeatedly. The heat generated by the repeated impact of steel materials can lead to hot, glowing metal and provide a source of ignition (of the garbage). In order to prevent this the garbage to be shredded must be free of ferro-magnetic material.

### 4. Sprinkling System in the Fine-shredder

In order to secure a reaction of the FRH-fragments, the garbage must have a certain moisture content. It must be insured that the garbage has direct contact with moisture. Shredders, independent of design, are already equipped with sprinkling systems to reduce dusting. These sprinkling systems are suitable after re-design for sprinkling of FRH-fragments without neglecting their original purpose. It is suggested to install these sprinkling systems in the fine-shredder in a way as to spray the garbage during fine-shredding. Through adjustment of the

nozzles, it can be assured that a minimum amount of liquid is used and therefore the waste-water burden can be kept low.

#### 5. Loading Machine

The loading of the facility must be permanently supervised due to operating- and facility security. The continuous supervision of the facility should, due to economic reasons (an automatic or technical supervision of the facility would be technically desirable) be possible by the operating personnel of the facility.

As the sampling revealed, contained within the garbage, despite precautions taken during garbage collection, are objects which must be sorted-out as not being shredable.

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As already stated, the output of the coarse-shredder to the inlet of the fine-shredder, with the help of the conveyor belt, cannot exceed a certain material size to ensure separation of ferro-magnetic materials.

From the current point of view of the restrictions and pre-conditions shown, the loading of the facility with the help of a loading machine is suggested because,

- o the operator of the loading machine could be the operator of the entire facility (seating height of 4-5 m over the ground affording a overall view of the facility)
- o the loading and throughput of the facility can be continuously maintained and therefore accumulation of pre-treated garbage before ferro-magnetic separation is prevented
- o the garbage to be shredded (garbage bunker is next to the facility), and the loading of the inlet of the coarse-shredder is in plain view of the operator and therefore any sorting out of non-shredable objects is possible
- o the loading machine can be used to fill the shredded material in the storage containers without damage to the containers. Damage to the container by the loader must be avoided (see 6. Containers)

## 6. Large Containers

The shredded garbage is transported by container belts out of the facility and is filled into available containers. The operation of the conveyor belt is by the operator of the facility.

As the shredding experiment demonstrated, the shredded material is in a loose condition, similar to loose bulk material, and therefore relatively light. For economical transport to the reloading stations of the ZMS, compaction of the material should be examined during the planning stage of the facility. In connection with this, it must be considered whether a pressure-container must be used or whether later compaction with the loading machine is sufficient.

To ensure there was full reaction of the FRH-fragments, it is suggested to cover the full containers and allow them to stand at the facility for a few days before being transported to one of the reloading stations for disposal.

## 4.4 Performance of Tests by the Manufacturer

#### 4.4 Performance of Tests by the Manufacturer

During development of Phase 2 of the report, several shredder-manufacturers were asked whether they have a two-step shredder in operation. It became apparent that a two-step shredder facility, as is necessary for the shredding of the garbage of the TrübPI Grafenwöhr and Hohenfels, was not available.

The assembly and set-up of a single component (coarse-shredder, fine-shredder, etc.) for available manufacturers would have resulted in additional costs and as a consequence would have required a relatively high early determination to use that particular manufacturer. For this reason, a test by any particular manufacturer was not conducted.

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Only a visit by a few manufacturers coarse-shredders (rotary-scissor type) was done to determine if the rotary-scissor type of shredder would yield similar results as the drum-shredder used at the garbage depot Grafenwöhr and Haderbühl.

The outcome of these visits and the questions asked each single manufacturer, as well as the operators were very informative and positive. The conclusion showed it could be assumed that either type, whether a rotary-scissor or the drum shredder yield similar results during the pre-shredding of the garbage. Furthermore it appeared that the desired results could not be reached without fine-shredding.

Because of this reason, an experiment with a fine-shredder (high rpm) was urgently needed in order to check whether the result of a fine-shredding would be acceptable. Due to the fact that the basic techniques of high rpm shredders are similar, only one nearby manufacturer was asked to make a fine-shredder available for an experiment.

The final results of the experiment proved positive and useful. On the basis of the experiments conducted a final planning phase can be initiated. However, further experiments to determine the quality of results by any single manufacturer's equipment, from an expert's point of view, is suggested before any further planning.

The description of the experiments conducted and their results can be taken from the conversational notes # 05/97 in the appendix of this report. However, it must be kept in mind that the statements with regard to

- o technical concepts
- o costs
- o optimal shredder-configuration can be revised or optimized in the final version of Phase 2 of the report

#### 4.5 Economic Considerations



As already shown, at this time no complete reference appendices exist. Due to this, any economic considerations can only be sporadically and partially done (incomplete). Precise statements concerning the investment and operating costs are only possible within the scope of the planning phase because an exact configuration of the facility is not complete.

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To take the "technical concept" of the described facility into account, the following investment costs for the facility, including the necessary construction measures are calculated as this.

1. Coarse-Shredder	600.000,-- DM
2. Ferro-magnetic Separator	60.000,-- DM
3. Fine-Shredder inc. Sprinkler	450.000,-- DM
4. Conveyor Belts, Operation, Set-up, Steel Framing, etc.	190.000,-- DM
5. Loading Machine	350.000,-- DM
6. Container approximately 40m <sup>3</sup> capacity, 10 @ 15.000,-- DM ea.	150.000,-- DM
7. Electrical Equipment (Transformers, etc.)	200.000,-- DM
8. Construction Investment (Area, Foundations, Garbage Storage De-watering System, Fencing, etc.)	600.000,-- DM
OVERALL:	<u>2.600.000,-- DM</u>

The operating costs are exclusively dependent on the facility configuration and cannot be estimated at this time. However it can be assumed there is no increase of personnel costs occur, which means, additional personnel for the operation of the facility or for operating the loading machine is not needed. Only simple instructions and short training (a few days) is necessary.

Because of the fact that the repair and maintenance of the shredder system is low (according to questions asked the operators), except the replacement of worn parts, it can be assumed this can be accomplished by the current personnel. However, if the shredder is operated with diesel engines vs electric motors, additional maintenance, probably not within the skills of the available personnel, would be required.

#### 4.6 Overall Evaluation of the Solution

The suggestions, according to the assessment, provide a definite solution to the disposal problem of the garbage of the training areas Grafenwöhr and Hohenfels. Because it cannot be excluded that the practicing troop dispose their garbage properly, from reasons of security to the facility of the ZMS (reloading stations and garbage bunker) the entire garbage must be shredded.

The "technical solution" introduced is a , a two-step shredding facility with a ferro-magnetic separator and a sprinkling system in the fine-shredder, constructed from available components and proven techniques. Developmental risks are not existent with any of the suggested components. The facility is basically conventional machinery with steel construction and electrically operated.

With the help of the suggested loading machine, several tasks can be accomplished simultaneously. The view afforded by the operator will allow supervision of the facility and the machine can assist with compressing the garbage in the containers. However, during pre-planning additional methods should be investigated (winches, compactors, etc.).

According to the suggestion, the shredded garbage is filled in large containers and remains there in covered condition for a few days to ensure complete reaction of the FRH-fragments. First a compression of the garbage with the help of the loading machine is planned. Should the material not be able to be compressed with the loader, a test experiment to develop an economic evaluation using pressure-containers (compactors) is suggested.

Whether transportation of the containers from the facility to the reloading stations is to be accomplished by the operators or some other economic (technical) means has yet to be determined. The necessary licences would need to be available for the personnel.

The operation of the facility can be accomplished by the available personnel with little re-training. The same is true regarding the maintenance and repair of the facility equipment. The facility operators can change any worn components themselves. However, rebuilding of the components must be done by a special company or the manufacturer. All other operations regarding maintenance are restricted to control-, lubrication, and cleaning activities. Because of the relatively simple techniques used, most repairs can be done by a mechanic or electric repair shop. Pre-conditions for this are appropriate maintenance schedules and repair manuals.

Necessary construction measures within the realization of the "technical solution" restrict themselves to area-stabilization, inc. de-watering (drainage), foundations, necessary measures for electrical installations (ECR), fencing, containment of the garbage (bunkers for approximately 400 m<sup>3</sup> of garbage), and stabilization of roads to and from the facility. High construction cost associated with the erection of a building, etc. is not considered necessary.

Overall it can be determined that

- o a safe disposal can only be realized by a "technical solution"
- o the suggested "technical solution" has little developmental risks
- o no additional personnel are needed
- o the maintenance and repair can be done by the operator

- o little instruction and training of the available personnel is needed (3-5 days for the operation and repair personnel, loading machine, and shredder)
  - o therefore, the operation, maintenance and repair costs can be kept within limits
  - o high construction costs, from current point of view, are not necessary
  - o all other construction measures are thus also without additional risks
  - o the "technical solution" should be quickly realized in order not to get into an emergency situation in the event of garbage depot closure
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## Appendix

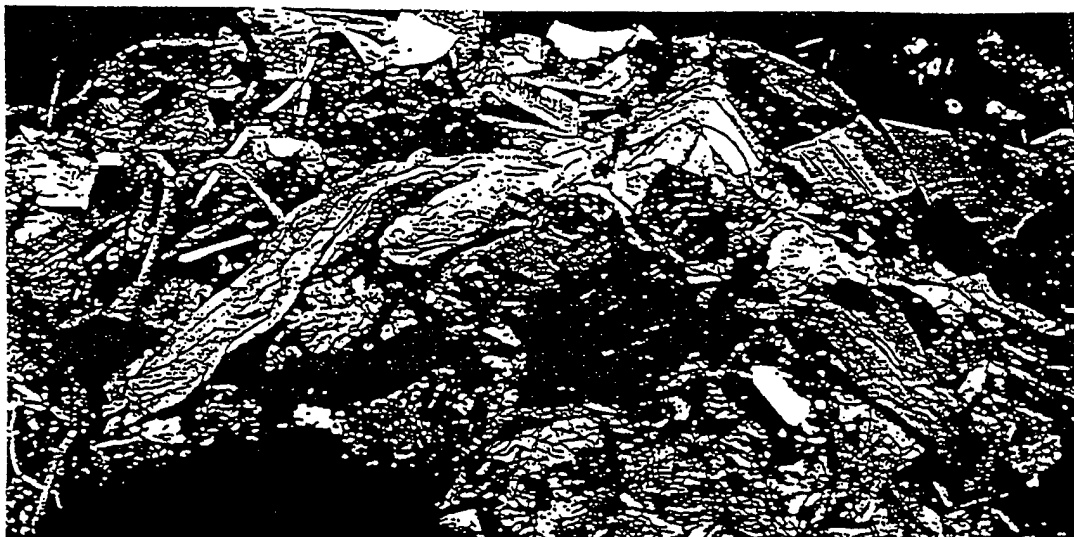
1. Photo-documentation of the shredder trials and demonstration at the Grafenwöhr/Häderbühl Garbage Depot
2. Conversational Notes 01/97 from the discussion at the OFD Nürnberg

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Appendix 1: Photo-documentation of the Shredder Trial and Demonstration on  
the Grafenwöhr/Haderbühl Garbage Depot



Appendix A1: Un-shredded Garbage.



Appendix A 2: Garbage after Coarse-Shredding



Appendix A 3: Garbage after Fine-Shredding



Appendix A 4: Loading of Shredder Machine