TECHNICAL REPORT
NATICK/TR-93/030

AD _____

DEVELOPMENT OF THE FLAMELESS RATION HEATER FOR THE MEAL, READY-TO-EAT

by
Lauren E. Oleksyk
Donald Pickard
Robert Trottier

April 1993
Final Report
October 1988 - October 1992

UNITED STATES ARMY NATICK
RESEARCH, DEVELOPMENT AND ENGINEERING CENTER
NATICK, MASSACHUSETTS 01760-5000

FOOD ENGINEERING DIRECTORATE

DISCLAIMERS

The findings contained in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

Citation of trade names in this report does not constitute an official endorsement or approval of the use of such items.

DESTRUCTION NOTICE

For Classified Documents:

Follow the procedures in DoD 5200.22-M, Industrial Security Manual, Section II-19 or DoD 5200.1-R, Information Security Program Regulation, Chapter IX.

For Unclassified/Limited Distribution Documents:

Destroy by any method that prevents disclosure of contents or reconstruction of the document.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	April 1993	FINAL OCT 88 - OCT 92

4. TITLE AND SUBTITLE
DEVELOPMENT OF THE FLAMELESS RATION HEATER FOR THE MEAL, READY-TO-EAT

5. FUNDING NUMBERS
PR MSR1534/D610

6. AUTHOR(S)
LAUREN OLEKSYK, DONALD PICKARD, ROBERT TROTTIER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
US ARMY NATICK RESEARCH, DEVELOPMENT AND ENGINEERING CENTER SATNC-WTS
NATICK, MA 01760-5018

8. PERFORMING ORGANIZATION REPORT NUMBER
NATICK/TR-93/030

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Approved for Public Release; Distribution Unlimited

12a. DISTRIBUTION/AVAILABILITY STATEMENT

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

The Flameless Ration Heater (FRH) was developed to provide an alternative method for heating the Meal, Ready-to-Eat (MRE) entree in the field. A survey of flameless heating mechanisms revealed that a water activated electrochemical pad, composed of magnesium-iron alloy dispersed in plastic powders, would most effectively heat an 8 ounce entree. A packaging system was designed to protect the heating device and function as a heater bag for the entree. The resulting system, the FRH, consists of a heater pad enclosed in a paperboard cover and sealed in a high-density, polyethylene bag with pre-printed operational instructions. The FRH was tested and evaluated extensively to determine its technical and operational capabilities. The FRH is capable of raising the temperature of an entree from 40 degrees F to 140 degrees F in 12 minutes or less; is operable in ambient temperatures from -25 degrees F to 110 degrees F; may be used by a soldier while on-the-move or in a vehicle or shelter; requires 2 ounces of water to activate; is a lightweight, cost effective and flameless alternative to the fuel bar/canteen cup method of heating; meets military requirements for safety and human factors and is logistically supportable. The Services adopted the FRH for bulk issue in May 1990, and as an MRE component in September 1991.

14. SUBJECT TERMS
FLAMELESS RATION HEATER (FRH); FLAMELESS; SELF HEATING; FLAMELESS BURNERS; HOT MEALS; HEATING; MEAL, READY-TO-EAT (MRE); MILITARY RATIONS; FIELD RATIONS

15. NUMBER OF PAGES
100

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	SAR

CONTENTS

CONTENTS (CONTINUED)

FIGURES

TABLES

PREFACE AND ACKNOWLEDGEMENTS

The following final technical report details the development of the Flameless Ration Heater (FRH) for the Meal, Ready-to-Eat from its inception through fielding and procurement by the Armed Forces. All efforts were conducted during the period of October 1988 through October 1992.

Citation of trade names in this report does not constitute an official endorsement or approval of the use of such items.

Numerous personnel from the U.S. Army Natick Research, Development and Engineering Center (Natick) deserve recognition for the successful development of the FRH. Food Engineering Directorate (FED) project officers cooperatively directed developmental efforts with superior technical and engineering support from Dr. Irwin Taub, Keith Nelson, Peter Sherman, Joel McCassie, Jay Jones, Jim Herne and Jack Barber. Special recognition is given to Andrew Taylor of the Installation Safety Office and Ruby Teng of the Individual Protection Directorate for their assistance in document preparation and coordination. Valued MANPRINT support was provided by Rose Guerra of the Behavioral Science Division, Soldier Science Directorate. Special thanks are extended to the management of FED, Mr. Philip Brandler and Mr. Gerald Darsch, for dedicating a notable amount of time and effort to keep this program on a successful track.

The authors would like to acknowledge Joint Technical Staff Army and Marine Corp representatives CPT Mark Russelburg, LTC John McNulty and MAJ Stewart Navarre for their assistance in ensuring their respective Service requirements were addressed and met.

We would also like to express our sincere appreciation for the cooperation of all external test and evaluation centers mentioned in this report, whose responsive assessments of the FRH greatly accelerated the acquisition strategy. In addition, special thanks are extended for the logistical support provided by Becky Barker, Dave Gay and Ed Grossman of the Defense Logistic Agency (HAZMAT), Mr. C.E. Radford of the Military Traffic Management Command, the Defense Personnel Support Center and the U.S. Department of Transportation, whose assistance ultimately lead to the successful fielding of the FRH.

SYMBOLS, ABBREVIATIONS AND ACRONYMS

ABNSOTBD	Airborne and Special Operations Test Board
ADEA	Army Development and Employment Agency
AFFS	Army Field Feeding System
APG	Aberdeen Proving Ground
ASD	Advanced Systems Directorate
ASTM	American Society for Testing Materials
ATCOM	Aviation and Troop Support Command
BDU	Battle Dress Uniform
BSD	Behavioral Science Division
CAA	Competent Authority Approval
CCH	Canteen Cup Heater
CCS	Canteen Cup Stand
CFFS	Combat Field Feeding System
CFR	Code of Federal Regulations
CINPAC	Cincinnati Packaging Company
CMTC	Combat Maneuver Training Center
CRH	Combat Ration Heater
CRTC	Cold Regions Test Center
CSA	Chief of Staff, Army
DASG	Department of the Army Surgeon General
DCSLOG	Deputy Chief of Staff for Logistics
DGSC	Defense General Supply Center
DLA	Defense Logistics Agency
DOD	Department of Defense
DOT	Department of Transportation
DPG	Dugway Proving Ground
DPSC	Defense Personnel Support Center
DRHD	Dismounted Ration Heating Device
FB	Fuel Bar
FED	Food Engineering Directorate
FDA	Food and Drug Administration
FDTE	Force Development Testing and Experimentation
FED-STD	Federal Standard
FRH	Flameless Ration Heater
FSC	Federal Supply Catalog
FY	Fiscal Year
GRAS	Generally Recognized as Safe
HDPE	High Density Polyethylene
HHAR	Health Hazard Assessment Report
JSR	Joint Service Requirement
JWG	Joint Working Group
LDPE	Low Density Polyethylene
MANPRINT	Manpower and Personnel Integration
MIL-H-44398	Military Specification for Heater, Ration, Flameless (for MRE)
MIL-R-44398	Military Specification for Ration Supplement, Flameless Heater For Meal, Ready-to-Eat
MORE	Meal, Operational, Ready-to-Eat
MRE	Meal, Ready-to-Eat
MRHD	Mounted Ration Heating Device
MSDS	Material Safety Data Sheet
MSR	Military Service Requirement

MTMC	Military Traffic Management Command
Natick	U.S. Army Natick Research, Development and Engineering Center
NSN	National Stock Number
NTS	National Technical Systems
ODS	Operation Desert Storm
OFIG	Operational Forces Interface Group
OSHA	Occupational Safety and Health Administration
OTSG	Office of the Surgeon General
PP	Polypropylene
QMC&S	Quartermaster Center and School
RAFCO	Right Away Foods Company
RET	Research Effort Test
RH	Relative Humidity
RHU	Ration Heating Unit
SAR	Safety Assessment Report
SEP	Soldier Enhancement Program
SHIMM	Self-Heating Individual Meal Module
SHP	Self-Heating Package
SON	Statement of Need
SSD	Soldier Science Directorate
SSRA	System Safety Risk Assessment
TECOM	Testing and Evaluation Command
TEMP	Test and Evaluation Master Plan
TEXCOM	TRADOC Test and Experimentation Command
TDP	Technical Data Package
TISA	Troop Issue Support Activity
TM	Trade Mark
UHMWPE	Ultra-High Molecular Weight Polyethylene
UN	United Nations
USAEHA	U.S. Army Environmental Hygiene Agency
USAREUR	U.S. Army Region Europe
ZT	ZestoTherm
Cl	chlorine
^{o}F	degrees Fahrenheit
Fe	iron
H_2	hydrogen gas
H_2O	hydrogen oxide (water)
Mg	magnesium
$MgCl_2$	magnesium chloride
$Mg(OH)_2$	magnesium hydroxide
NaCl	sodium chloride (salt)
O_2	oxygen gas
$\bar{X}$	mean or average
et al	and others
in	inches
g	gram
min	minute
pH	acid-base scale (log of reciprocal of hydrogen ion concn.)
i.e.	that is
S.D.	standard deviation
oz.	ounces
vs.	versus

SUMMARY

The scope of this report includes the design, fabrication, testing and document preparation for the Flameless Ration Heater (FRH) leading up to, and including, its adoption by the Joint Services. In addition, this report contains an historical background of flameless ration heating concepts that were examined between the years 1973 and 1988, prior to the development of the FRH.

The FRH for the Meal, Ready-to-Eat (MRE) Ration was developed to provide a solution to the persistent "cold ration problem" often experienced in the field. After surveying commercially available self-heating products, a chemical heating pad composed mainly of magnesium and iron was selected as the optimal heating device. A packaging system which integrated this chemical heating pad was specifically designed to heat the MRE entree. The FRH packaging system consisted of the chemical heating pad enclosed in a paperboard cover and sealed in a high-density polyethylene heater bag. Instructions for using the FRH were carefully developed and printed directly on the heater bag.

The FRH was tested and evaluated extensively for its ability to meet military users' needs. The FRH was found to efficiently and adequately heat the MRE entree in approximately 12 minutes, and could be carried in the soldier's battle dress uniform (BDU) pocket during the heating process. The FRH was operable and easy to use in a wide range of ambient temperatures and climatic conditions. It was safe, lightweight, required only 2 ounces of water to activate, and was logistically supportable. The producibility of the FRH was examined and a Technical Data Package was prepared. The performance oriented specification drew competitive bids, and the overall cost of the FRH was shown to be significantly less than the existing fuel bar method of heating. Several transportation and storage issues involving the hazardous classification of the FRH were resolved.

The FRH was adopted for issue in bulk in May 1990 and was added to the Federal Supply Catalog for Subsistence. Open-ended contracts for 51 million FRHs were awarded in April 1991. Approximately 4.5 million FRHs were shipped to Southwest Asia in support of Operation Desert Storm. In September 1991, the FRH was adopted as an integral component of the MRE. Beginning in 1993 with the assembly of MRE XIII, one FRH will be packaged with each meal to ensure that every soldier receives a hot meal in the field.

DEVELOPMENT OF THE FLAMELESS RATION HEATER FOR THE MEAL, READY-TO-EAT

INTRODUCTION

Historical Background

The need to provide soldiers with a device for heating individual military rations was recognized long before the development of the Flameless Ration Heater (FRH). Prior analyses of heating systems showed that an optimal device for heating rations in isolated areas 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. A flameless heating device could be used at night without producing a visual signature and would not be affected by wind or inclement weather.

The investigation into the design and optimization of a flameless heating device for individual rations began in 1973. The U.S. Army Natick Research, Development and Engineering Center (Natick) contracted Power Applications Inc., Long Island, NY to determine the feasibility of using their patented self-contained electrochemical heat source, Hot Sheet™, as a means of heating the Meal, Ready-to-Eat (MRE) entree.[1] Hot Sheet was a nontoxic, electrochemical heating element which consisted of a magnesium anode, a carbon electrode and an electrolyte salt. Patent claims suggested that it could be used to heat a pan of food by simply adding water to the Hot Sheet assembly. At the completion of this contract, it was determined that the Hot Sheet heating element geometry and configuration would have to be modified, optimized and integrated into a package to effectively heat the packaged entree.

In 1980 Natick learned that the Navy's Civil Engineering Laboratory was also conducting research on electrochemical reactions for marine release devices, buoyancy devices and heated diving vests. The Navy's technology, based on powder metallurgy, was thought to be more cost effective than the Hot Sheet technology. Since the Navy had a related ongoing contract with the University of Cincinnati, Natick provided additional funds to expand the university's contract. This contract resulted in the development of a portable electrochemical heater for the MRE entree, referred to as the Dismounted Ration Heating Device (DRHD).[2]

The DRHD utilized chemical heating pads composed of supercorroding magnesium-iron (Mg-Fe) alloy powder dispersed in a porous polyethylene matrix. The DRHD consisted of an insulated pouch, two heating pads attached to the inside surfaces of the insulated pouch, and a separate pouch, containing a saline solution, which was glued to the outside of the insulated pouch. To use the DRHD, the MRE entree was inserted into the insulated pouch between the two heating pads, and the saline solution was added to initiate the heating reaction. Two thousand DRHDs were manufactured and delivered to the U.S. Army for testing.

In 1982 the DRHD was evaluated during a Force Development Testing and Experimentation (FDTE) of the Combat Field Feeding System (CFFS) at Fort Hood, TX. Other devices for heating the MRE entree were also evaluated, including the Mounted Ration Heating Device (MRHD) and the canteen cup heater (CCH). The MRHD was designed to operate off a vehicle's power supply. It consisted of a fabric pouch containing five electrical resistance heating elements which could heat four MRE entrees at a time. The CCH consisted of a metal stand, a canteen cup and trioxane fuel bars. The fuel bars were used to boil approximately 12 ounces of water in the canteen cup and the entree was heated by hot water submersion. The heating devices evaluated during the FDTE are shown in Figure 1. The DRHD was found to heat the MRE entree to an acceptable level in 3 to 11 minutes and was well accepted by the soldiers. However, it was also considered to be too bulky and too fragile to use in an operational environment.[3]

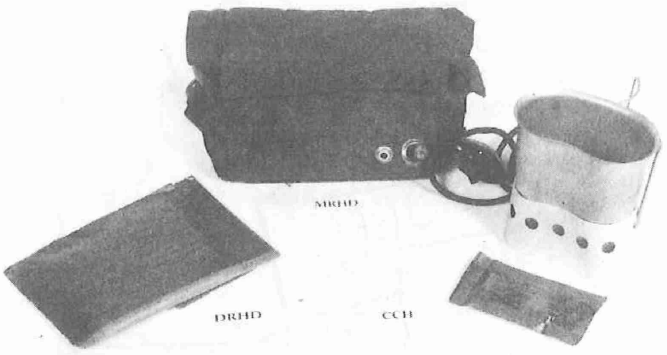


Figure 1. FDTE Heating Devices

Between 1983 and 1986 the inventors of the chemical heating pads used in the DRHD obtained a patent on the construction of the flexible heating pad material for food heating and medical applications.[4] Soon after the patent was filed, the principal inventor formed a corporation called ZestoTherm Inc. in Cincinnati, Ohio. ZestoTherm continued to modify the heating pad by adding sodium chloride directly to the pad matrix so that plain water could be used to activate it instead of salt water. This heating pad later became a commercially available food heater called the ZT Energy Pad™. ZestoTherm also developed several cooking pouches for heating prepackaged foods with ZT Energy Pads.

In 1986 the U.S. Army Development and Employment Agency (ADEA) conducted an evaluation of the effectiveness of two types of Ration Heating Units (RHU) for heating the MRE entree: the flameless Combat Ration Heater (CRH), which was

the ZT Energy Pad (heated in the MRE meal bag), and the CCH. Both RHUs were found to be marginally effective in heating the MRE entree. The CRH did not always generate enough heat to adequately heat the entire entree and left an unappealing residue (magnesium hydroxide) on the entree pouch. It was also suggested that the CRH should be made an integral part of the MRE to facilitate use.[5]

In February of 1988 the Human Factors Branch of the Soldier Science Division (SSD) conducted MRE Focus Groups at Fort Carson, CO to elicit opinions on three types of individual ration heaters: two versions of a Canteen Cup Stand (CCS) with trioxane fuel bars, and the CRH. The two versions of the CCS differed in the stand height and width, and the CRH utilized the MRE meal bag as a container for heating the entree (Figure 2). The majority of soldiers preferred the CRH system over the canteen cup with the CCS, mainly because the CRH was compact and disposable, whereas the canteen cup with CCS was just "one more piece of equipment" to carry and clean after use.[6]

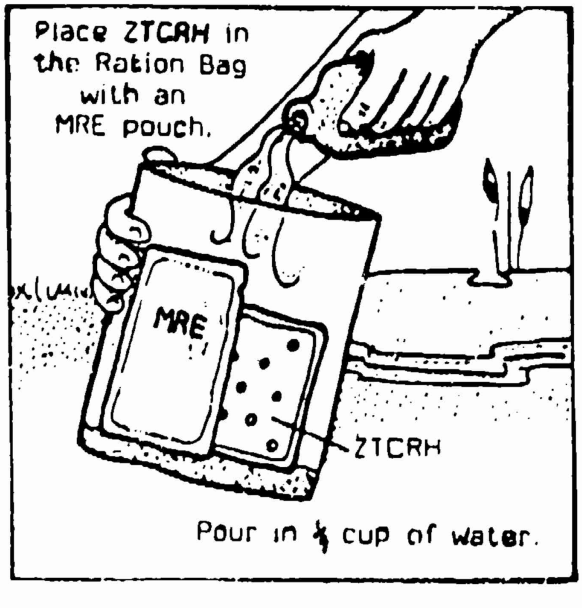


Figure 2. Flameless CRH in MRE Meal Bag

From April 30 through May 7, 1988, the Quartermaster Command and School (QMC&S) conducted a field evaluation of the CRH during the Market Square II field exercise at Fort Bragg, NC. Again, the CRH consisted of the ZT Energy Pad and an instruction card, with the MRE meal bag being used as the heating container. Twenty-six soldiers of the 82nd Airborne Division completed questionnaires on the CRH. The CRH was generally well received, and 100% of the respondents said they preferred heating the MRE with the CRH more than any other method.[7]

When surveyed on methods used to heat entrees in previous field exercises, soldiers frequently reported they ate their MREs cold because of time constraints or the lack of a heat source. When asked what methods they used to heat the MRE entree, soldiers reported using the canteen cup with fuel bars, the canteen cup stand with the canteen cup and fuel bars, a squad, yukon or Optimus Ranger™ stove, or Sterno™. Mounted soldiers reported that they would sometimes heat the entree by placing it on the vehicle's engine block or exhaust manifold. It was evident from these preliminary evaluations that a flameless, disposable, fast and easy method for heating the MRE entree was strongly desired by soldiers as an alternative to the canteen cup stand. However, it was also evident that significant modifications to existing flameless heater prototypes would be required to effectively heat the MRE entree. Specifically, prototypes could be improved by providing a convenient method to accurately add the activating water, reducing heater by-products such as white residue and chemical odors, and designing a lighter, less bulky and easy-to-handle packaging system.

Program Initiation

Following the successful development and type classification of the canteen cup stand, the U.S. Marine Corps (USMC) continued to have concerns regarding the overall effectiveness of the canteen cup stand/fuel bar method of heating MRE entrees. The USMC's primary concern pertained to the logistical availability of the trioxane fuel bar and the time it took to heat the entree, particularly in cold weather. In October 1988, the USMC sponsored a Military Service Requirement (MSR) to evaluate the possible use of chemical heaters. The success of a prototype heater demonstrated in a preliminary field exercise galvanized Army interest, and the MSR became a Joint Service Requirement (JSR) in August 1989.

In response to the MSR, the "Self-Heating for the Year 2001" program was initiated in FY89 and managed by the Food Engineering Directorate (FED). The main objective of the program was to provide a more convenient and effective method of heating the MRE entree than the trioxane fuel bar and canteen cup stand method. In addition, the method of heating would provide a flameless alternative to the standard trioxane fuel bar. A two phase Requirement Technical Plan for "Self-Heating for the Year 2001" was developed.[8] The objective of Phase I was to develop a flameless heating mechanism for the MRE which would be integrated as a primary package component or as an adjunct to the meal. Phase II involved the development of an entirely new shelf-stable ration in a self-heating package (SHP), which later evolved into the Self-Heating Individual Meal Module (SHIMM). The scope of this report is limited to efforts conducted under Phase I, which involves the development of the Flameless Ration Heater (FRH) for the MRE.

ACQUISITION STRATEGY

The Chief of Staff, Army (CSA) issued a challenge to all involved with the Army Field Feeding System (AFFS) to develop a simple, easy method to provide hot meals to front line soldiers. The CSA saw this as a key AFFS issue and requested that initiatives be taken immediately and efforts intensified to make 1989 the year of the hot ration. The stage was set to expedite the "Self Heating for the Year 2001" program. An acquisition strategy was developed that would lead to adoption of the FRH one and a half years after the program was initiated. First Unit Equipped occurred September 1990 during the onset of Operation Desert Shield, 13 months after the Army issued its Statement of Need (SON). A complete integrated program schedule is outlined in Appendix A.

To expedite the schedule, the requirements of AR 70-1 were selectively tailored. The FRH was categorized as an expendable, nonaccountable item. Therefore, it did not require type classification and the need for a formal Required Operational Capability was avoided. The acquisition strategy called for adoption of the item from Engineering Development (category 6.3) on the basis of the SON provided by the Quartermaster Center and School (QMC&S). Exceptional cooperation was provided by the independent technical testers (Cold Regions Test Center and Dugway Proving Ground), technical evaluators (Test and Evaluation Command), operational testers (Airborne and Special Operations Test Board), and combat developer (QMC&S). Normal lead times for tests were cut from years to months and independent assessments were equally responsive. The introduction of the Soldier Enhancement Program (SEP) provided funding to conduct producibility tests so that when the technical data package was transitioned to the Defense Personnel Support Center (DPSC), the first procurements were accomplished in accordance with cost projections.

DEVELOPMENTAL APPROACH

To initiate the "Self-Heating for the Year 2001" program, a detailed technical approach to develop a suitable FRH for the MRE was formulated. It included conducting a market investigation of potentially applicable self-heating devices, selecting the most suitable device, designing a prototype packaging system to integrate the heating device with the MRE entree, examining the requirements of military users, testing and evaluating prototypes, finalizing the FRH design, preparing procurement documents, and performing extensive technical and operational tests. The ultimate goal was to incorporate the FRH as an integral component of the MRE to ensure all soldiers would obtain a hot meal in the field.

Market Investigation

A market investigation of commercially available self-heating devices and/or self-heating meals was initiated in October 1988. Samples of chemical heaters, which released heat through hydration, thermite, neutralization and oxidative reduction (electrochemical) reactions, were obtained and evaluated for their potential ability to heat the MRE entree. Figure 3 depicts the variety of self-heating items obtained from the market search. A literature search and subsequent evaluation of various self-heating principles are outlined in Table 1.

Figure 3. Market Investigation of Self-Heating Devices

Table 1. Evaluation of Self-Heating Principles

Reactants	H^{o}_{rxn} kcal/mol	Heat Output Btu/lb	Comments
$MgCl_2 + H_2O$	-38.13	721	no strong acid or base
$Mg + H_2O$	-84.88	5643	produces hydrogen gas
$KOH + H_2O$	-13.77	442	strong base
$CaO + H_2O$	-15.95	501	commonly used, low cost, high weight and bulk
$SrO + H_2O$	-21.78	322	no advantage over $CaO + H_2O$
$BaO + H_2O$	-52.92	302	no advantage over $CaO + H_2O$
$CaO + HCL$	-50.00	411	strong acid
$NaOH + HCL$	-23.99	565	strong acid and base
$Mg(OH)_2 + HCL$	-27.22	373	strong acid
$Fe + O_2$	-197.00	3169	difficult to control
$Fe + KMnO_4$	-131.80	554	no water required
$Al/KClO_3/CaSO_4$	------	1058	many reactions possible
$H_3PO_4 + KOH$	-80.99	644	strong acid and base

Selection of Heating Mechanism

The heating mechanism most capable of heating the MRE entree was determined to be the electrochemical ZT Energy Pad™ produced by ZestoTherm (Figure 4). Preliminary field evaluations had already proven the Energy Pad's ability to heat the entree to some extent. The challenge would lie in improving the convenience and efficiency of the ZT Energy Pad by integrating it into a packaging system specifically designed for heating the MRE entree and in resolving previous user complaints regarding residue and odor by-products of the chemical reaction.

ZT Energy Pads were procured from ZestoTherm to further examine their chemical properties and functional capabilities. The Energy Pads consisted of two components--an outside paperboard cover and a flexible chemical heater pad. The paperboard cover was folded and stapled around the heater pad to provide rigidity and protect the heater pad from crumbling. The chemical heater pad was composed of the following nontoxic ingredients: magnesium metal powder, iron powder, ultra-high molecular weight polyethylene (UHMWPE), high-density polyethylene (HDPE), fumed silica and linear alcohol alkoxylate. The ingredients were blended, formed into pads and sintered at approximately 135°C.

The electrochemical heater pads are activated by the addition of water. After reacting with water, a nontoxic residue is produced which consists of a weak solution of magnesium hydroxide [$Mg(OH)_2$] in a saline solution. The reactions and reaction products between the magnesium anode and iron cathode are divided into three types:

1. Electrochemical Reaction:
   Air Cathode: $O_2 + 2H_2O + 4e \longrightarrow 4OH^-$
   Anode: $2Mg \longrightarrow 2Mg^{++} + 4e^-$
   Net Electrochemical Reaction: $2Mg + O_2 + 2H_2O \longrightarrow 2Mg(OH)_2$

2. Corrosion Reaction:

$$Mg + 2H_2O \longrightarrow Mg(OH)_2 + H_2$$
$$Mg^{++} + 2Cl^- \longrightarrow MgCl_2$$

3. Hydrolysis Reaction:

$$MgCl_2 + H_2O + OH^- \longrightarrow Mg(OH)Cl - (H_2O) + Cl^-$$

The resulting reaction by-products are magnesium hydroxide, hydrated magnesium hydroxy chloride and hydrogen gas. After full activation of a 20 gram heater pad, the residual material consists of NaCl, $Mg(OH)_2$, iron oxide powder, UHMWPE, HDPE and small amounts of silica and linear alcohol alkoxylate. The resulting magnesium hydroxide and saline residue has no adverse affect on polymeric materials such as mylar or polyester. Therefore, the heater pad will not damage the outer layer of the MRE entree retort pouch, which it directly contacts during the heating reaction.

Figure 4. ZT Energy Pad™

Design of a Prototype Packaging System

The FRH packaging system was designed to serve two purposes; provide protective packaging for the heater pad prior to use, and function as a heater bag for the 8 ounce MRE entree. The FRH package would be designed to be lightweight, compact and easier to use than previously tested flameless heater prototypes, i.e., DRHD and CRH. Since the heater pad was designed to be activated by the addition of water, it was critical that the FRH package would prevent accidental activation of the heater pad during shipping, handling and storage.

In addition to the ZT Energy Pad, ZestoTherm produced a line of insulated cooking pouches and trays including the Zesto Food Warmer™, Side Kik™, SofPak™ and the Zesto Kitchen™. After evaluating the cooking pouches, it was determined that they were too intricate, bulky and costly to be issued with each MRE. Also, they did not provide protective packaging for the heater pad.

A variety of packaging films were considered for the construction of a heater bag. The film would require the properties necessary to withstand the temperatures achieved during the heating reaction (up to 212°F) and the chemical constituents of the heater pad by-products ($Mg(OH)_2$, salt water, steam and H_2). A transparent film was desired so that the amount of activating water, which would be added to the heater pad inside the heater could be measured according to fill-lines printed directly on the bag. This would eliminate the need for the soldier to premeasure the amount of activating water. For this reason, an opaque film, such as aluminum foil or a trilaminate material containing foil, was not chosen as the heater bag material.

High-density polyethylene (HDPE) film was ultimately selected as the heater bag material based on its mechanical, thermal and chemical resistant properties. HDPE film is produced by blown film extrusion and, in addition to having great tensile strength, has anisotropic properties that allow it to tear evenly in one direction only. Such characteristics have great utility in a package that must protect the heater pad and safely heat the MRE entree. As the density of the polyethylene increases, the melting point of the film and its chemical resistance increases. Thus, a heater bag constructed of HDPE film would be able to withstand the temperatures encountered during the heating reaction as well as the chemicals contained in the heater and its by-products. HDPE films also provide an excellent barrier to moisture or water vapor, but a relatively poor barrier to other gases. An HDPE bag would sufficiently prevent water vapor (from humidity or condensation) from permeating the bag during storage, which will help prevent accidental activation of the heater pad.

A prototype heater bag was constructed of HDPE film that met the Food and Drug Administration (FDA) requirement for plastics in contact with food under FDA Regulation 121.2501. The prototype configuration allowed room for the addition of the MRE entree and approximately two ounces of activating water at time of use. The required inside dimensions of the bag were 14 inches in length and 5 inches in width. A range of film thicknesses between 1 and 5 mils were tested. It was found that a film thickness of less than 2.5 mils did not withstand the heat produced by the reaction, due to the formation of small holes in the film. A film thickness greater than 2.5 mils was very stiff and inflexible, and did not provide any advantages over the thinner gauge. A film thickness of 2.5 mils was determined to be optimal for the heater bag.

A contract was awarded to TUFPAC, Inc., Ossipee, NH to manufacture prototype heater bags for in-house testing and evaluation. It was necessary that heater bags be manufactured with side seals so that tear notches could be placed in the side seal areas to facilitate opening the bag at time of use. Because of the anisotropic properties of HDPE film, tubular bags that are formed via blown film extrusion would tear only in the machined direction (from top to bottom). In order to manufacture bags that would tear in the transverse direction (across the width of the bag), the extruded tube was collapsed into a flat film, re-oriented in a direction perpendicular to the machine direction, then formed into bags on a side-weld machine. Tear notches were applied in two locations on the side seal; one at the top of the bag for initial opening, and the other in the middle of the bag to remove the hot MRE entree after heating. Two fill-lines were printed on the bottom of the bag; the top line at a location equivalent to approximately 2 ounces of water. A volume of water added to a level between the lines would activate the heater pad (Figure 5).

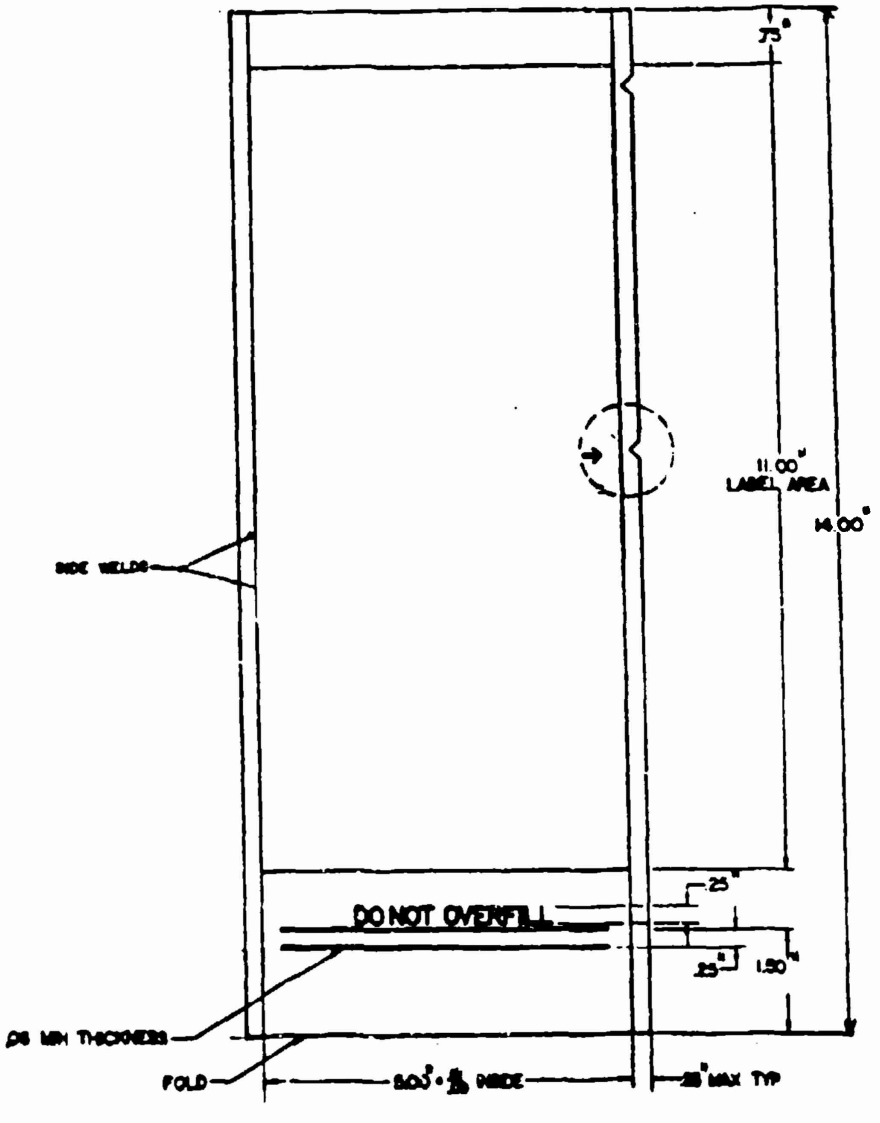


Figure 5. FRH Heater Bag

The heater pad, enclosed in a paperboard cover and sealed in the heater bag, constituted the first prototype of the FRH packaging system (Figure 6). Prior to opening, the heater bag adequately prevented water from accidentally entering the bag and activating the heater pad since it was hermetically sealed on all sides. The paperboard cover was originally stapled closed on three sides and folded on the fourth side around the heater pad, and had nine holes to allow water penetration into the pad. However, the cover was later modified with the addition of a polyethylene coating so that it could be heat-sealed rather than stapled around the heater pad (to avoid puncturing the heater bag), and a variety of hole patterns were allowed.

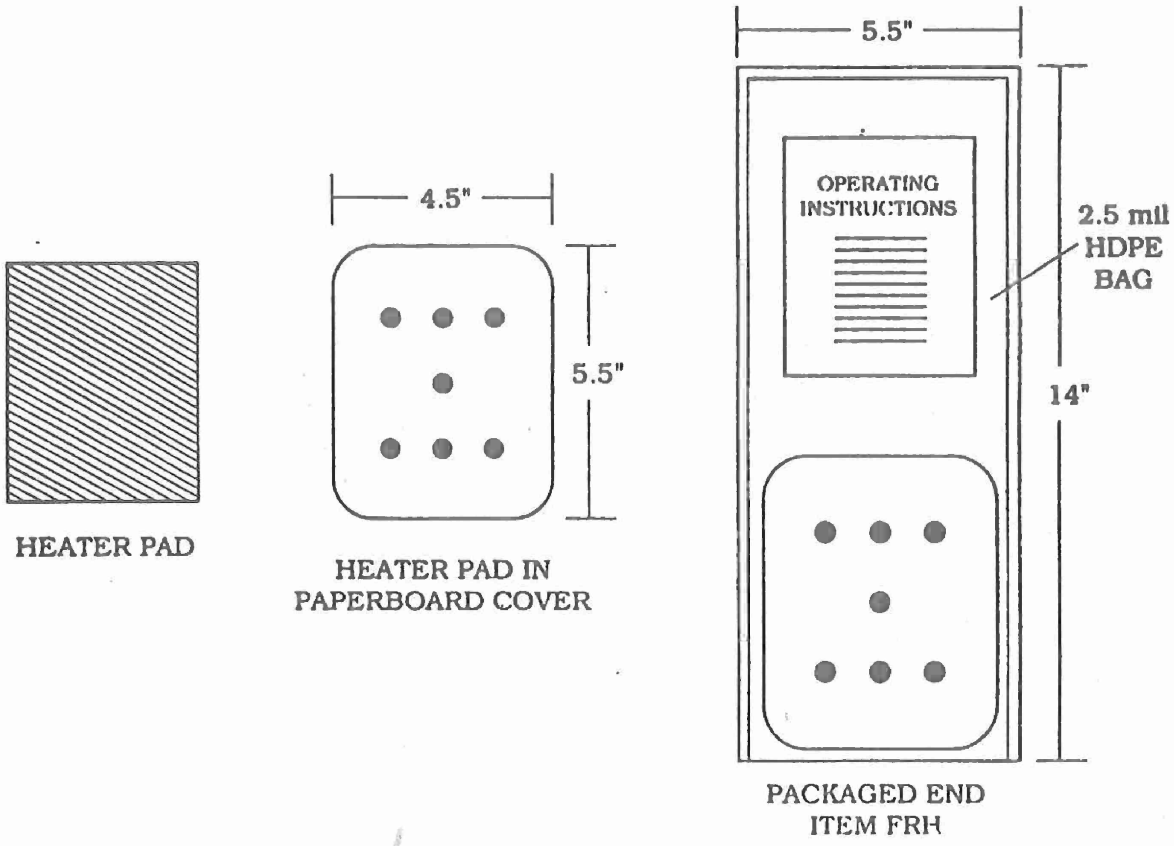
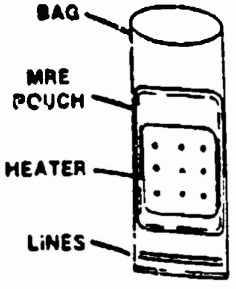


Figure 6. FRH Packaging System Prototype

The Human Factors Branch of the Behavioral Sciences Division, SSD, assisted in the development of operational instructions which were flexographically printed on the heater bag. The instructions were simple pictorials with accompanying written instructions demonstrating how to use the FRH to heat the MRE entree (Figure 7).

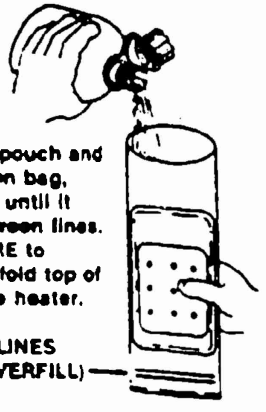
OPERATING INSTRUCTIONS

1 Remove MRE pouch from carton and save carton



2 Tear off top of bag. Place MRE pouch in bag with water.

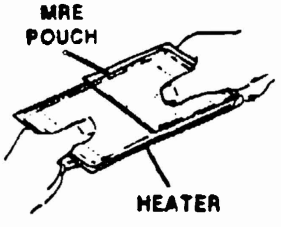
3



While holding MRE pouch and heater above lines on bag, pour water into bag until it reaches a level between lines. Slide heater and MRE to bottom of bag, and fold top of bag to side opposite heater.

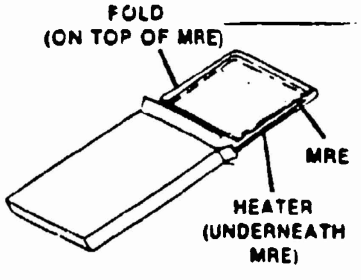
FILL TO LINES (DO NOT OVERFILL)

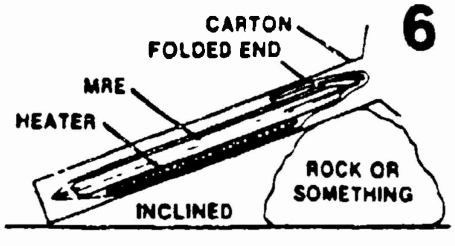
↑ TEAR HERE TO REMOVE MRE



4 With heater UNDERNEATH MRE, hold bag level for a few minutes to let heater soak up water.

5 When heater becomes warm, stuff assembly into carton with top of bag folded over top of MRE and heater underneath.





6 To prevent water from escaping and to maximize heat output, always keep:

- HEATER located UNDERNEATH MRE;
- BAG folded OVER TOP of MRE; and
- CARTON INCLINED, with FOLDED END of bag UP.

After fifteen minutes top half of bag can be torn off and the MRE can be removed and eaten

Figure 7. FRH Operational Instructions

Joint Service Requirements for the FRH

By August of 1989, the Chief of Staff, Army, and the Army Food 2000 Task Force recognized the urgent need for a safe, reliable method for dismounted soldiers to heat MRE entrees, and that a hot meal was essential for maintaining a soldier's morale and warfighting capability. They recognized that the FRH system would ensure that dismounted soldiers would have a safe, reliable and resource efficient means of heating the MRE entree. Thus, the original Marine Corps MSR became a Joint Service Requirement (JSR), and the U.S. Army Quartermaster Center and School (QMC&S) provided Natick with a Statement of Need (SON) for the FRH packaging system. The SON outlined the required technical and operational characteristics of the FRH.[9] The need for the FRH was justified by identifying the deficiencies of the method of heating the MRE entree which existed at the time. The dismounted soldier's method for heating the entree required the use of the canteen cup, canteen cup stand, 12 ounces of water, two to three 15 gram trioxane fuel bars and matches. The procedure was time consuming, water consuming, required the soldier to suspend his mission, and produced a signature flame which could possibly identify the soldier's position. Moreover, the soldier was often unable to get fuel bars because they are purchased and issued separately from rations (i.e., the motor sergeant instead of the mess sergeant). Efforts to package the fuel bars with the MRE had been unsuccessful due to regulatory provisions preventing the packaging of fuel with food.

The SON listed the following required technical and operational characteristics for the FRH. The following criteria were considered to be preliminary and subject to change by the combat developer:

(1) The FRH must be capable of raising the temperature of an 8 ounce entree to 80°F, or to a temperature of 140°F, in 20 minutes or less from an ambient temperature of 40°F. (This requirement was later modified to increase the temperature by 100°F in 12 minutes or less). The ability to heat a canteen cup of water was not considered to be a critical requirement for the FRH. However, this was recognized as a serious drawback of the FRH system.

(2) The FRH must be operable in ambient temperatures from -25°F to 110°F, provided that at low temperatures the heater and MRE are not frozen so as to cause the activating water to freeze. However, procedures were later developed for heating frozen MRE entrees with two FRHs.

(3) The FRH and its by-products must be nontoxic and nonhazardous as required for use with food and air, ground and sea transportation and storage, and must comply with applicable safety and health design requirements.

(4) The FRH shall weigh no more than the current method (i.e., two trioxane fuel bars weigh 30 grams).

(5) The FRH shall require no more water than the current method (i.e., canteen cup requires 12 ounces of water).

(6) The FRH shall have an effective shelf life of at least 3 years when held under any environmental condition.

(7) The FRH shall be capable of meeting Manpower and Personnel Integration (MANPRINT) requirements in the areas of logistics, supportability, safety and human factors engineering.

Test and Evaluation Issues and Criteria for FRH performance, compatibility with the MRE, safety, human factors engineering, effective operation by representative personnel and logistics supportability were also itemized.

Testing and Evaluation

The FRH prototype was subjected to a series of tests and evaluations to ensure all of the required technical and operational criteria outlined in the SON were met. A Test and Evaluation Master Plan (TEMP) for the Adoption of an Integral Heater for the MRE was prepared, and included a review of previous tests and an outline of proposed tests.[10] Specifically, a combination of in-house and outside agency tests and evaluations would address the following criteria: FRH operability in a range of ambient temperatures; technical criteria including weight, water and shelf life requirements; FRH and by-product safety and toxicity; and MANPRINT requirements in the areas of logistics, supportability, safety and human factors engineering. Issues relative to hazardous transportation and storage were addressed briefly at the time. However, this later became a critical area of concern when federal regulations were updated and revised.

a. OPERABILITY: The performance requirement for the FRH to increase the temperature of the entree to 140°F was based on prior research into the optimal serving temperature of food. Assuming a scenario in which a soldier received an MRE between 32 and 40°F, the FRH was required to heat the entree to the optimal serving temperature of 140°F. In-house tests revealed that the FRH was capable of increasing the temperature of the 8 ounce entree from an initial temperature of 40°F to a final temperature of 140°F in 12 minutes or less.

To determine the performance of the FRH in environmental temperature extremes ranging from -25°F to 110°F, in-house tests were conducted at controlled temperatures of 0°, 40° and 110°F. Tests were not conducted at -25°F due to the unavailability of a testing chamber. However, data obtained from tests conducted at 0°F were considered to sufficiently reflect FRH operability at low temperature extremes, provided the MRE entree and activating water were not frozen. With the exception of the test conducted at 0°F, the FRH heater pad, activating water and MRE entree were all conditioned at the same controlled room temperature (i.e., the FRH, activating water and MRE entree were conditioned to the temperature of the room). At 0°F, the activating water was conditioned to 35°F to prevent it from freezing, since in actual use the water will be in its liquid state. A frozen MRE required two FRHs to increase the entree by 100°F. The first FRH reaction thawed the MRE in approximately 10 minutes. When a second FRH was added after the first reaction (in the same heater bag), the second FRH increased the entree 100°F in less than 12 minutes. Special operating instructions were developed for heating frozen MREs (Figure 8). When the test was conducted at 40°F controlled room temperature, only one FRH was required to increase the entree (also at an initial temperature of 40°F) by 100°F. It appeared that cold

activating water slowed the initial activation of the heater pad. However, once the pad absorbed the water within the first 2 minutes, the reaction progressed at a normal rate. At 110°F, the reaction was accelerated by the addition of hot water, and it took less than 5 minutes to bring the entree to an optimal serving temperature.

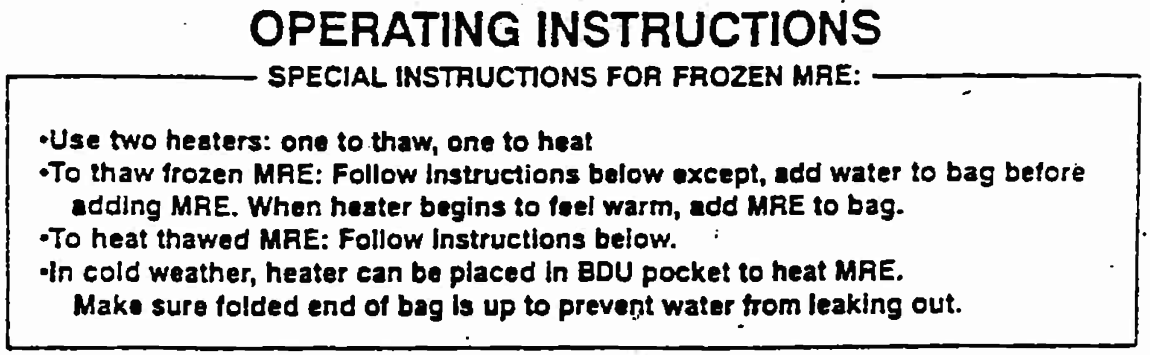


Figure 8. Frozen MRE Operational Instructions

b. TECHNICAL CRITERIA: In addition to meeting the operational criteria, the FRH also met technical criteria for weight, water and shelf life requirements. The U.S. Army required that the FRH weigh less and require less water than the current method. Compared with the 30 gram weight and 12 ounces of water required with the trioxane fuel bar and canteen cup stand respectively, the FRH weighed 30 grams (including bag) and required two ounces of water, or less, to activate. As discussed in the background of this report, previous evaluations also indicated that the FRH was desired over any other method of heating, including the canteen cup stand, since it required less water, was less bulky and easier to handle, and did not require cleaning after use. The shelf life requirement of a minimum of 3 years was addressed by the manufacturer's claim and Natick's accelerated storage tests. When requested by Natick, ZestoTherm provided the following statement regarding shelf life:

> "Given our available data, ZestoTherm certifies the FRH will maintain its required performance specifications for a minimum of five years after the unit's production date. This certification assumes that the 2.5 mil polyethylene bag which encases the FRH has not been damaged and that the product is maintained under normal storage conditions."[11]

Natick conducted accelerated storage tests at high and low temperatures and saw no adverse effects on the heater performance. However, FRHs stored for 3 months at high temperature and high humidity (100°F/90%RH) increased the temperature of the entree an average of 12.6°F less than FRHs stored under controlled, standard conditions. It is theorized that this decrease in heater performance is due to slow water vapor permeation through the heater bag which is held in a very humid environment over time. The water vapor slightly activates and expends the surface magnesium particles in the heater pad, leaving less reactive material at time of use.

c. FRH AND BY-PRODUCT SAFETY: The U.S. Army required that the FRH and its by-products comply with the applicable safety requirements with respect to basic usage by the soldier and when used in enclosed shelters and vehicles. Hydrogen gas is a by-product of the chemical reaction and has a relative density of 0.0695 (air=1). Hydrogen gas is easily ignited and its flammability limits in air are 4.0%-75.0% by volume. In a report provided to Natick, ZestoTherm summarized safety information relative to the hydrogen gas by-product produced by the heater pad reaction. In general, the report stated that the reaction of each pad releases approximately 8 liters of hydrogen (0.28256 cubic feet) which is relatively harmless in terms of detonation or flammability because it rapidly disperses as it is produced.[12] Calculations were made for the volume of air which, homogeneously mixed with hydrogen, would produce the lower flammable limit of hydrogen. For purposes of the calculations, it was assumed that each soldier used two FRHs to heat the MRE entree, and that each soldier's body displaces three cubic feet of space. The calculations produced the following maximum enclosure (vehicle/shelter) sizes that would contain a flammable air/hydrogen homogeneous mix:

One soldier, using 2 FRHs = 17.128 cubic feet (a 3'x 3'x 1.9' room)
Four soldiers, using 8 FRHs = 68.512 cubic feet (a 4'x 4'x 4.3' room)
Thirteen soldiers, using 26 FRHs = 222.67 cubic feet (a 6'x 6'x 6.2' room)

As can be seen from the calculations, a flammable homogeneous air/hydrogen mix would only occur if the FRHs were used in a very small enclosure with no ventilation.

The heater bag was designed to remain open after the heater pad is activated to allow steam and H_2 gas to escape. The user is also instructed to insert the FRH into the entree carton to restrict the volume of air in the heater bag, thereby preventing flammable or detonable gases from accumulating in the heater bag. Although hydrogen was flammable outside of the heater bag if ignited at the points where the hydrogen gas escapes to the atmosphere, tests showed the flame was barely self-sustaining. ZestoTher stated that ignition could occur only if a flame is held where a high concentration of hydrogen flow is restricted, and that a hazard does not exist if food packages are heated in a ventilated area.[13]

Tests were conducted in enclosed shelters and vehicles to address concerns regarding flammability. The results revealed that the threat of explosion due to the emission of hydrogen gas would be improbable, as would the threat of asphyxiation due to the displacement of air (and oxygen).[14] In addition, calculations performed by the Test and Evaluation Command (TECOM) indicated that the levels of hydrogen emitted by FRHs used in tanks would be below the lower flammable limit (i.e., <4%).[15] Nevertheless, since there was always the possibility that a flammability or oxygen depletion situation may exist, the Manpower and Personnel Integration Division (MANPRINT), SSD, developed precautionary warnings which were placed on the FRH heater bag instruction label (Figure 9).

WARNING

1. Vapors released by activated heater contain hydrogen, a flammable gas. Do not place an open flame in the vapor.

2. Vapors released by activated heater can displace oxygen When ten or more heaters are used inside a vehicle or shelter, ensure the ventilation system is operating or a top hatch or door is open.

Figure 9. FRH Warning Label

d. FRH AND BY-PRODUCT TOXICITY: The U.S. Army required that the FRH and its by-products must be nontoxic and must comply with applicable health requirements. Toxicity tests were conducted on the FRH and its by-products by ZestoTherm, and by the U.S. Environmental Hygiene Agency (USAEHA) at Aberdeen Proving Ground (APG), MD. ZestoTherm's toxicity tests were conducted in accordance with the Federal Hazardous Substances Act (16 CFR et al), and included tests for primary skin irritation, acute oral toxicity and eye irritation. Based on the results of these tests, ZestoTherm concluded that the FRH heater pad materials were not classified as toxic following oral, dermal or ocular exposure.[13] The USAEHA also assessed the ZestoTherm heater pad for health concerns including residual water contamination, food contamination, toxic gases in enclosed spaces and asbestos. These findings, which were reviewed by the Office of The Surgeon General (OTSG) and endorsed by the DA Surgeon General (DASG), are published in the Health Hazard Assessment Report (HHAR) on the ZestoTherm Chemical Flameless Heater.[16] Regarding water contamination, USAEHA determined that the residual water remaining in the heater bag following the reaction contains magnesium hydroxide [$Mg(OH)_2$] precipitate, commonly referred to as milk of magnesia, and reduced iron, a common source of iron enrichment in foods. The FDA lists $MG(OH)_2$ and reduced iron as food additives that are generally recognized as safe (GRAS) for human consumption. Natick noted that the high pH of the residual water contributed to $Mg(OH)_2$ precipitate, and experimented with various acids to lower the pH to keep the $Mg(OH)_2$ in solution. The addition of adipic acid to the heater pad decreased the amount of precipitate. Other by-products present in trace concentrations in the residual water are traces of plastic powders, silicon dioxide and the wetting agent. The plastic polymers are considered nontoxic when taken orally, and silicon dioxide is approved as a direct food additive by the FDA. The wetting agent, linear alcohol alkoxylate, may be consumed but has been demonstrated to cause diarrhea and hypoactivity. Overall, accidental ingestion of the residual water remaining in the heater bag following the heating reaction is considered safe. Regarding food contamination, it was determined that as packaged in the heater bag, there is little possibility of contamination of other food items in the MRE from the FRH heater pad. However, if this should occur, food is still safe to eat because all the ingredients used in the heater pad are FDA approved food additives or exhibit low toxicity.

Regarding toxic gases in enclosed spaces, USAEHA tests determined the average volume of gas generated by the FRH reaction was 7.9 liters, but of that amount, the average percentage of hydrogen gas was only 56.0% or 4.4 liters.

They predicted the level of oxygen in various vehicles assuming all passengers/crew members were using the FRH. None of the predicted levels were less than the Occupational Safety and Health Administration (OSHA) allowable minimum of 19.5% oxygen. USAEHA concluded that heating the FRH in enclosed locations does not present an oxygen depletion or asphyxiation hazard, but precautions should be taken to provide natural or mechanical ventilation. The FRHs were also tested for asbestos because ZestoTherm used asbestos in the original formula but claimed to have since removed it. When analyzed for the presence of asbestos, none was found.

Based on the findings of the safety and toxicity analyses of the FRH and its by-products, a Safety Assessment Report (SAR) was prepared by Natick and approved by the Natick Installation Safety Office.[17] The purpose of the SAR was to outline any potential safety and occupational health hazards to user personnel resulting from the operation of the FRH, and to show that adequate precautions have been taken through designs, training and warnings in the operating instructions. The SAR was also used as a reference to minimize, as much as possible, any danger to troops using the FRH during future TECOM and Airborne Board Tests.

e. MANPRINT REQUIREMENTS: In accordance with the criteria listed in the SON, the FRH had to meet MANPRINT requirements in the areas of logistics, supportability, safety and human factors engineering. Safety and toxicity were previously addressed in the HHAR and the SAR, in which the FRH was determined to be safe for use by the soldier. However, several other issues in the areas of logistics, supportability and human factors needed to be addressed.

Since the possibility that FRHs may be used for heating meals on board aircraft, Natick conducted tests to determine the effects of rapid decompression on an FRH in the process of activation.[18] If an FRH was being used on an aircraft at high altitude and there was a sudden loss of cabin pressure, the sudden decompression would cause an instantaneous expansion of the liquids and gases in the FRH. The concern was that the sudden expansion of the liquids and gases might rupture the heater bag and possibly burn the user. To examine the validity of this concern, the FRH was activated in a vacuum chamber and a vacuum drawn to simulate sudden decompression at approximately 23,000 feet above sea level. The MRE carton containing the FRH and the MRE entree was observed to have expanded and a slight amount of steam exited the heater bag during sudden decompression. No rupturing of the heater bag occurred and it was determined that there was no danger to the user.

Technical Document Preparation

A Technical Data Package (TDP) was developed for FRH production procurements. The TDP contained the requirements for the FRH design, performance and packaging. The resulting specification for the Heater, Ration, Flameless (For MRE), MIL-H-44398 emphasized heater performance rather than detailed composition and design.[19] This would encourage competition and creativity among manufacturers, since they were not restricted on the composition of the FRH as long as the end item met the performance criteria. The heater pads were required to be composed of the supercorroding alloy Mg with five atomic percent Fe. However, all other alloy additives, such as

fillers, binders, wetting and flow agents could be used at the manufacturer's discretion to enhance the performance of the heater. In order to meet military requirements for weight, the heater pad was required to weigh 20 ± 2 grams. The paperboard cover for the heater pad, the heater bag and the instruction label were specified in detail. Drawing 6-1-8920 depicted the instruction label and was referenced in the specification.

End item testing included tests for leakage, heater performance and by-products, and label legibility following the reaction. FRHs were required to pass leak tests for several operational and safety reasons. The heater bag had to be leak-proof when the soldier received it in order to hold the water necessary for heater activation. Heater bags which leaked might also allow accidental activation during transportation and storage, which not only could present a safety hazard due to the emission of hydrogen gas, but could also expend the single-use heater pad. A heater bag which leaked could also allow accidental spillage of water containing heater by-products into a soldier's eye if held up to facilitate reading of the fill lines. The specification was later amended to require leak testing following rough handling to account for the abuse which occurs during shipping and handling. Heater performance and by-products tests were designed to examine basic heater performance in a laboratory setting. Performance requirements included the heater's ability to provide a 100°F minimum temperature rise in a water filled MRE pouch in 12 minutes or less. If heaters could pass these stringent tests under optimal laboratory conditions, it was expected that FRHs would perform to an acceptable level in the field. Restrictions were placed on the by-products produced by the heating reaction. These restrictions prohibited the emission of objectionable odors and limited the amounts of magnesium hydroxide precipitate and residual water. Testing of the heater bag label and instruction markings were required to ensure that important instructions for removing the MRE following the reaction were legible.

As cited in the SON, the Operational Concept was to initially make bulk packs of FRHs available to supplement existing supplies of MREs. The decision to package one FRH within each MRE had not yet been made. Therefore, a shipping container designed to contain bulk quantities of FRHs was incorporated into the TDP. The bulk pack contains 288 FRHs with each FRH individually packaged in a hermetically sealed heater bag (Figure 10). Since a palletized unit load of MREs consisted of 576 MREs, two bulk packs of FRHs would adequately supplement a unit load of MREs. The 288 prepackaged FRHs were broken down into 24 shrink-wrapped unit packs. Each unit pack contained 12 FRHs. Thus, to provide each soldier with an FRH, one unit pack would be distributed with each case of MREs at the time of issue. The bulk pack design withstood military rough handling tests as well as post-rough handling leakage tests.[20] Hazardous markings were not required on bulk pack shipping cases at the time the TDP was prepared because the magnesium alloy in the FRH did not contain the required amount of magnesium powder to be classified as a hazardous material. Research into the exact classification of the FRH is discussed later in this report in the Transportation and Storage section.

The military specification for the Heater, Ration, Flameless (For MRE), MIL-H-44398 was later renamed as the Ration Supplement, Flameless Heater, For Meal, Ready-to-Eat, MIL-R-44398, to make the FRH available through the Class I field supply system (Appendix B).

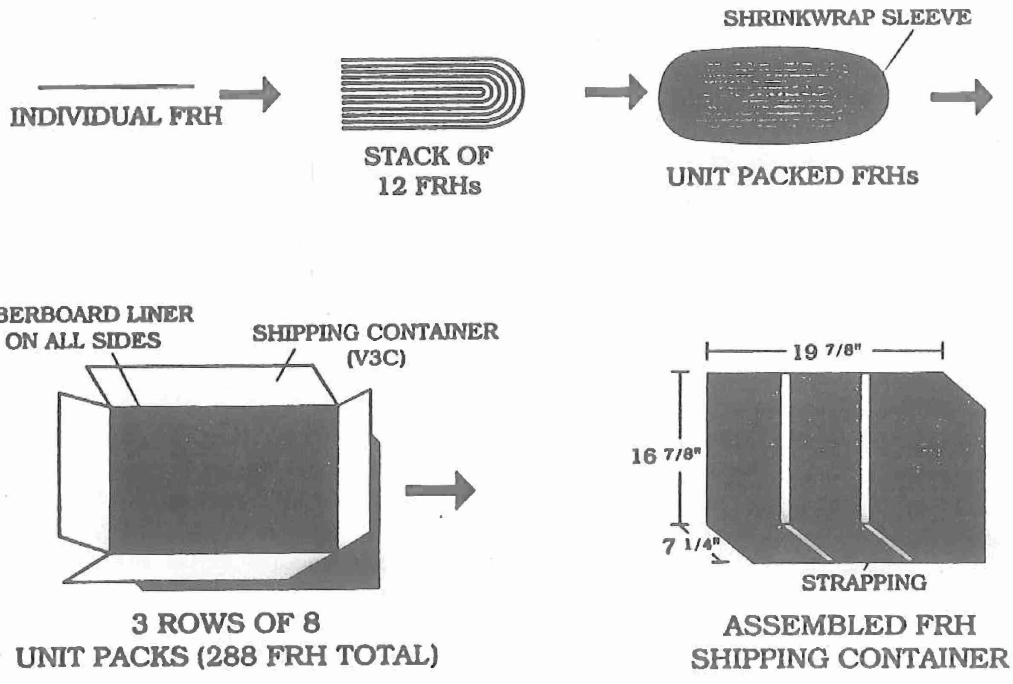


Figure 10. FRH Bulk Pack

Technical and Operational User Tests

Heater pads and heater bags were procured from separate manufacturers and FRHs were assembled in-house for a series of technical and operational tests. In January 1989 a Cold Weather Feeding Study was conducted at Fort McCoy, WI to determine the effect of FRHs on acceptability and consumption of the MRE in a cold weather environment. The study was conducted during a five day period with 125 Marines who were participating in the Alpine Warrior winter training exercise. The Marines were separated into three groups; one group was issued trioxone fuel bars and canteen cup stands (CCS), another was issued an early prototype of the FRH (MRE meal bag was used as the heater bag), and the third group used their Optimus Hiker stoves as a control. Results showed that each of the three groups had significant body weight loss, but that more frequent heating of entrees was associated with greater consumption. Average acceptance ratings for breakfast, lunch and dinner entrees was highest for the FRH group compared to the CCS and control groups. The CCS and the FRH were both rated as easier to use than the Optimus Hiker™ stove. However, limitations of each were cited. The CCS limitations included the need for a substantial supply of fuel bars and that heating must take place in open areas. FRH limitations included an undesirable foam by-product and the inability to heat water.[21] The FRH was later modified with a nondetergent wetting agent to eliminate foaming and adipic acid to keep the $Mg(OH)_2$ by-product in solution.

During September through December 1989, a Customer Test of the FRH was conducted by TEXCOM Airborne and Special Operations Test Board (ABNSOTBD) in a

tactical environment at Fort Bragg, Camp McKall and Troy, NC. The test was conducted to collect user data on the effectiveness of the FRH, and to provide Natick with the findings to support the evaluation of operational issues. In TEXCOM's final letter report, it was concluded that if given a choice, 78% of test personnel would choose the FRH over alternate methods of heating.[22] The remainder would continue to use their current method which included squad stoves, Sterno™ and canteen cup stands with heat tabs. Other test findings included: FRH instructions were easily read and understood by 99.5% of all personnel; the heater bag was easy to open; the FRH performance reliability was 99.89%; some fluid spillage occurred while heating during which nine personnel were burned (all burns were attributed to human error and none required medical treatment); less than 1% of test participants thought the FRH was unsafe; the FRH heated 81% of the MREs to either hot or extremely hot in an average time of 8 minutes and 50 seconds for one group and 11 minutes and six seconds for another, and personnel were able to carry the FRH while heating.

During the period of 1-30 November 1989, the U.S. Army Region Europe (USAREUR) conducted an operational feasibility test of the AFFS in Hohenfells, West Germany. The overall test objective was to demonstrate and evaluate new products being considered for adoption by the AFFS. A total of 20,000 MREs, each containing a FRH packed directly within the meal bag, were issued to Army personnel from the 3rd Infantry Division at the Combat Maneuver Training Center (CMTC). The FRH was found to be very convenient and effective for heating the MRE entree.[23] The FRH was also issued with the Meal, Operational Ready-to-Eat (MORE) but was found to be less effective due to the larger entree size and primary package (i.e., 10 ounces in a deep polymeric tray).

Between November 1989 and January 1990, the U.S. Army Test and Evaluation Command (TECOM) conducted a Research Effort Test (RET) of the FRH at the Cold Regions Test Center (CRTC), Fort Greely, AK. The objective of this test was to evaluate all issues and criteria identified in the SON. The FRH was tested by soldiers from the 6th Infantry Division for environmental performance, human factors, safety, health, compatibility with the MRE and logistic supportability. Testing was conducted at temperatures ranging from -23°F to 40°F. The heating ability of the FRH was compared to that of the standard canteen cup stand and trioxane fuel bars. As stated in the CRTC final letter report, the FRH proved to be a simple, effective and resource-efficient method for heating MRE entrees.[24] When examined for its ability to meet the issues and criteria outlined in the SON, the FRH was found to have met the criteria outlined in Table 2. CRTC recommended that additional warnings were needed to caution the user about the dangers of contact with water in cold weather. The concern was addressed by placing additional warnings on the heater bag which stated the following: "Hot water leakage can burn and cause a cold-weather injury. Use caution if carrying activated heater in pocket." and, "After heating, the heater bag and MRE pouch will be very hot. Use caution when removing MRE pouch from bag." The potential environmental, disposal and health hazards of the FRH were not addressed during the CRTC study, but were evaluated and proven safe at the U.S. Army Dugway Proving Ground (DPG).[25]

Table 2. Issues and Criteria FRH Met

Issues	Criteria	Remarks
Weight	FRH shall weigh ≤30 grams	Met
Climatic Temperatures	FRH shall operate in ambient temperatures from -25°F to 110°F	Met; two FRHs will heat frozen entrees
Water Requirement	FRH shall require ≤12 oz water	Met; two ounces water required
Human Factors	FRH must meet human factors engineering design requirements of MIL-STD-1472D and 1474B	Met
	FRH must be operated by 5th-95th percentile MOS personnel dressed in appropriate climatic clothing	Met
	Instructions must be adequate to operate FRH	Met
Safety	FRH and by-products must be non-toxic and nonhazardous	Met
	MRE shall be safe to eat after heated with FRH	Met
	MRE entree pouch material shall function as an effective barrier against chemical reaction of FRH	Met
Logistics and Supportability	FRH shall be compatible with standard load carrying systems	Met; FRH fits in uniform pocket/packs
	FRH must be logistically supportable when deployed and during test	Met

In June 1991, Natick's Operational Forces Interface Group (OFIG) conducted a user evaluation of the FRH to determine soldier acceptability, usage rates and preferred packaging format.[26] Participating units were chosen from various climates and represented the different services within the U.S. Armed Forces. Subjects included 226 soldiers and 27 airmen assigned to units in Hawaii, Colorado, Missouri, Florida, Washington, New York and Southwest Asia.

The FRHs were issued to personnel who would use them for at least one week and consume at least one MRE per day. The data was collected through mail-in questionnaires or by visiting the sites for direct data collection. FRHs shipped to Southwest Asia were evaluated by Operation Desert Storm (ODS) forces, however, very little data was obtained from users in this area because FRHs were not packaged, stored or distributed with MREs. Regarding usage rates, subjects from all climates used the FRH an average of 12 times to heat the MRE during this mission. The most commonly stated reason for not using the FRH was that the mission did not allow extra time for heating. However, if given a choice, 77% of the respondents would choose to use the FRH or retain it for future use. Regarding functional qualities, the FRH received very positive ratings for the criteria listed in Table 3. When asked to indicate which packaging method they would prefer (i.e., packaged with the MRE or separately), 90% of the respondents preferred the FRH to be packaged with the MRE. Respondents felt uncertain that FRHs would consistently be issued with MREs in the field if they were packaged separately.

Table 3. Mean Ratings For FRH Functional Qualities

Criteria	$\bar{X}$	SD
Taste of the heated MRE entree vs. the cold entree (1=much worse, 7=much better)	6.5	0.77
Temperature of MRE entree after being heated (1=cold, 5=hot[a])	4.5	0.53
Speed of heating the MRE entree (1=very slow, 7=very fast)	5.1	1.30
Ease of heating the MRE entree (1=very difficult, 7=very easy)	6.3	1.00
Overall acceptability for field use (1=very bad, 7=very good)	6.6	0.71

[a] This factor was rated on a 5 point scale; the others on a 7 point scale

PRODUCIBILITY

Before September 1990, the only known manufacturer of the FRH heater pads was ZestoTherm. During early development and testing of FRH prototypes, Natick purchased ZestoTherm heater pads separately from preprinted heater bags. The FRH "packaging system" (i.e., paperboard covered pad sealed in heater bag) was assembled in-house for subsequent tests and evaluations. In September 1990, Natick awarded the first contracts to obtain completely assembled FRHs to examine the producibility of manufacturing large quantities of FRHs and procure enough FRHs for OFIG's user evaluations (Figure 11). In response to Natick's initial solicitations, two companies were awarded contracts--ZestoTherm Inc. manufactured 3.6 million FRHs at a cost of $0.54 each, and a new company, Truetech Corp., manufactured 1.2 million FRHs for $0.47 each. The unexpected low bid from a company other than ZestoTherm Inc. highlighted the beneficial impact that competition has on providing cost savings to the government.

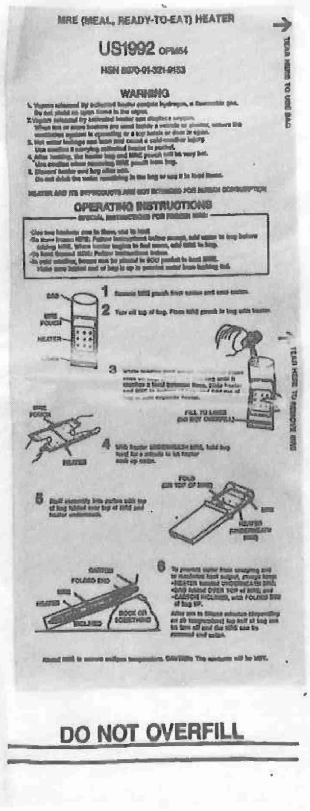


Figure 11. Producibility Test End-Item

Natick conducted first article testing on FRH samples produced by both manufacturers. Minor problems were encountered with FRHs manufactured by both companies. ZestoTherm was not manually expelling enough air prior to sealing the heater bag, and the shrink-wrapped unit packs were too large to fit into the outer shipping case. ZestoTherm's careful attention to sealing eliminated this problem. ZestoTherm was previously able to eliminate the excessive foam created during the heating reaction by coating the bottom edge of the heater pads with food grade adipic acid. Problems encountered with FRHs manufactured by Truetech Corp. included heater pad fragility, the production of an objectionable metallic odor during the heating reaction and a gritty residue produced during the reaction. Through undisclosed means, Truetech was able to improve the cohesiveness of the heater pad to improve its strength and eliminate the gritty residue. The firm was also successful in eliminating the objectionable metallic odor produced during the heating reaction. Both ZestoTherm and Truetech FRHs met heater performance, leakage and by-product requirements outlined in the specification.

COST ANALYSIS

The FRH system, consisting of the heater pad in a paperboard cover, sealed within the heater bag, was estimated from the producibility contracts to cost approximately $0.49 each. However, when examining the overall cost of the FRH in comparison to other ration heating devices, both the tangible costs as well as the intangible costs had to be considered. The most likely item to compare the FRH to was the trioxane fuel bar (FB). In order to compare both tangible and intangible costs, the basic characteristics outlined in Table 4 were considered for each item.

Table 4. Comparison of FRH and FB Characteristics

Characteristic	FRH	FB
Water Required to Heat	2 oz	12 oz
Heater Weight	20 g	30 g
Ancillary Equipment	none	stand
Time to Heat	12 min	20 min
Heat-on-the-Move	yes	no
Heat in Shelters	yes	no
Packaged with MRE	yes	no

Tangible costs included the actual cost of the item and the number of items required in specific climates. The actual cost of the FRH was greater than the FB ($0.49/FRH vs. $0.21/FB). However, this difference in cost was dependent on the climate in which the item is used. In a temperate climate, the cost of using the required two FBs nearly equaled the cost of using one FRH, and in a cold climate (assuming the MRE entree is not frozen), the cost of using the required three FBs exceeded the cost of using one FRH.

Intangible costs included the amount of time it takes to heat the food, weight and volume of water required for heating, convenience or inconvenience of the item, and the personal safety of the soldier using the item. The FRH clearly had benefits over the FB regarding intangible costs. For example, using the FRH saved the soldier considerable time particularly in cold weather. The FRH heats the MRE entree in 12 minutes or less, but the FB may take anywhere from 15 to 30 minutes depending on the ambient temperature. The FRH also saved the soldier from having to carry or expend an extra 10 ounces of water to heat the entree. Regarding convenience, the FRH may be used in shelters or vehicles, offers heat-on-the-move capability, and keeps the entree warm for a longer period of time. The FB had the convenience of heating water and/or beverages as well as the MRE entree. The issue of savings in terms of personal safety could not be overlooked. The FRH did not produce the detection characteristics associated with the FB, such as the visual flame, odor or infrared signature.

When considering the climate, cost of distribution, heating time, weight and cost of additional water, and the intangible benefits, the overall cost of the FRH was significantly less than the FB. The total cost of the FRH was determined by subtracting the intangible benefits (cost reducers) from the tangible costs (cost drivers). Assuming the MRE entree is not frozen when issued, Table 5 compares the total costs of the FRH and the FB after all tangible and intangible costs are taken into account.

Table 5. Total Cost Analysis of FRH vs. FB

Operational Climate	Tangible and Intangible Costs	
	FRH	FB
Cold	$0.30	$0.70
Temperate	$0.32	$0.47
Hot	$0.37	$0.42

TRANSPORTATION AND STORAGE

A criterion in the Statement of Need required that "The FRH and its by-products must be nontoxic and nonhazardous as required for use with food and air, ground and sea transportation and storage." The Health Hazard Assessment previously conducted by OTSG determined that the FRH is safe for use and transportation with food. However, proper classification of the FRH regarding its hazardous nature, and the regulations that govern its transportation and storage were much more complicated issues.

During the development of the FRH, the 1990 edition of Title 49 of the Code of Federal Regulations (49 CFR) was referenced to determine if the FRH should be classified as a hazardous material. Table 172.101 lists those materials which the Department of Transportation (DOT) has designated as hazardous for the purpose of transportation.[27] Although magnesium powder is listed in this table, the FRH contained only 40% magnesium (Mg) and did not exhibit the characteristics of pure magnesium powder when tested. Also listed in the table were magnesium alloys. However, to be classified as hazardous, magnesium alloys must contain at least 50% magnesium powder, which the FRH did not. All other components of the FRH were not listed in the hazardous materials table. Part of the confusion regarding the classification of the FRH was due to the fact that the FRH was a new item that consisted, in part, of a hazardous ingredient (Mg) but did not have the characteristics of pure Mg. In the 1990 edition, 49 CFR did not list "mixtures of components" that were deemed hazardous, nor did it rely on specific test parameters to determine the hazardous nature of a material. This edition was based instead on written definitions for flammable solids, spontaneously combustible and dangerous when wet materials. If a material met any of these definitions it was classified as hazardous.

Hazardous Classification

In the 1990 edition of 49 CFR, the definition for a flammable solid required that the material ignite readily, and burn vigorously and persistently. Since test methods were not provided in 49 CFR, Natick first subjected the FRH to an in-house adaptation of ASTM D635 (Standard Test Method for Rate of Burning and/or Extent and Time of Burning). Results of this test showed that the burning rate of the heater pads was slower than the burning rate of the materials used to package the FRH i.e., the paperboard cover and HDPE bag. The test also showed that the heater pads did not maintain a flame as long as the packaging materials did.[28] In addition to Natick's test, contracts were awarded to SRS Technologies and Blazetech Corp to conduct more extensive flammability tests. SRS conducted flammability tests on individual FRHs and simulated bulk packed FRHs. Their results, published in a System Safety Hazard Analysis Report on the FRH for the MRE, concluded that the packaging materials were more flammable than the actual heater pad material and that extraordinary precautions for storage of FRHs were not required.[29] SRS recommended that a Material Safety Data Sheet (MSDS) be developed for the FRH to accompany it during transportation. Blazetech found that single FRHs, unit packed FRHs and FRHs packed in MRE meal bags were not flammable. However, Blazetech determined that a bulk pack of FRHs partially met the definition for

flammable solids because, although it did not ignite readily or burn vigorously, it did burn persistently.[30] Blazetech also determined which extinguishing agents should be used in case a bulk pack fire occurs (Table 6).

Table 6. Extinguishing Agent Testing on FRH Bulk Packs

Extinguishing Agent	Results
Water (solid stream)	Mg flares
Water (steady spray/fog)	Effectively extinguished Mg
Carbon Dioxide, Foam	Not effective
Sand	Very effective
Metal Guard, Lith-X	Very effective
Sodium Carbonate, Met-L-X	Effective

Based on all test results, Natick concluded that a single FRH did not meet the definition for a "flammable solid, spontaneously combustible or dangerous when wet material" and should not be classified as hazardous. However, the FRH should be classified as a flammable solid when packed in bulk quantities based on Blazetech's findings. Bulk pack shipping cases would therefore require hazardous markings which state "Magnesium Metal Mixture, Flammable Solid, UN 1869" when shipped by air, highway, rail or water. At this time, it was unclear what impact the flammable solid case markings would have on the storage of FRH bulk packs. Department of Transportation flammable solid labels would not be required on shipping cases because of the "limited quantity exception clause" of 49 CFR. Future MRE shipping cases containing FRHs would not require any hazardous markings or labels because of the "small quantity exception clause" of 49 CFR.

Material Safety Data Sheet (MSDS)

Because the FRH contained a potentially hazardous chemical (Mg), a MSDS was required to accompany all FRH shipments. The purpose of the MSDS was to identify the primary chemicals contained in the heater pad and provide safety precautions and/or procedures in case of accidental spillage, ingestion, fire, etc. In addition to accompanying all shipments of FRHs, the MSDS is provided to all depots and TISAs where FRHs are stored. The MSDS is accessible on the Hazardous Materials Information System (HMIS) database which is overseen by DGSC. The manufacturer of the item is generally responsible for preparing an accurate MSDS. However, Natick assisted both FRH manufacturers by providing data obtained from SRS and Blazetech's flammability tests. The MSDS was prepared in accordance with FED-STD-313 and listed the item's ingredients, the hazardous classification of the item, and procedures for fire fighting, storage, handling and disposal of the item (Appendix D). Blazetech provided fire, explosion and extinguishing data. When examined in accordance with 40 CFR, Subpart 261.20 through 261.23, expended FRHs were not considered to be a hazardous waste and the recommended method of disposal was landfill or incineration.

In accordance with 29 CFR 1910.1200, any item that requires a MSDS must conform to OSHA marking requirements. Therefore, the OSHA markings shown in Table 7 were developed for bulk pack and MRE shipping cases containing FRHs. The exact wording of the markings for both shipping cases was determined with the assistance from the Natick Installation Safety Office and approved by OSHA representatives. The markings were carefully worded to identify the potentially hazardous nature of the FRH (i.e., water reactive) and, in the case of bulk packs, what action should be taken if FRHs were involved in a fire. By referencing the NSN number, DGSC is able to disseminate any MSDS information requested on the FRH through the HMIS

Table 7. OSHA Case Markings

Shipping Case	Marking
FRH Bulk Pack	"Note: WATER ACTIVATED, In case of fire involving magnesium, flood with large amounts of water with a fog nozzle (not a solid stream)"
MREs with FRHs	"Note: WATER ACTIVATED Flameless Ration Heater, NSN 8970-01-321-9153, supplied in each MRE meal bag"

System Safety Risk Assessment (SSRA)

Even with an attached MSDS outlining safe storage and fire fighting procedures, the Army still requested a document stating that it was safe to store FRHs in general purpose (subsistence) warehouses. TISAs were still unable to store bulk packs, even before the flammable solid markings were applied, because of the "hazardous nature" of the item. In February 1992, Natick initiated a System Safety Risk Assessment (SSRA) document which identified risk codes and details storage and handling procedures. The SSRA applied to both bulk packed and future MRE packed FRHs. Once the SSRA was approved by QMC&S (March 92) and the Aviation and Troop Support Command (ATCOM April 92), it served as the Army's acceptance document for storing FRHs in general purpose warehouses (Appendix E). The SSRA allowed TISAs to store and distribute FRHs.

Revision of Hazardous Classification

Natick soon discovered that marking bulk pack shipping cases as "Flammable Solid" to meet transportation regulations had an enormous impact on military and commercial warehouse storage, regardless of informative MSDS and SSRA documents. DPSC informed Natick that under DOD regulation 4145.19-R-1, the governing document for storage and handling of DOD stock items, materials classified as flammable solids required special facilities for storage, specifically flammable solid warehouses. Not only were flammable solid warehouses scarce and had limited space, but segregating the storage of FRHs from MREs would create logistical problems when attempting to distribute the items together as was seen in Southwest Asia.

As Natick began to examine possible solutions to this problem, DOT revised the 1990 edition of 49 CFR to meet United Nation (UN) standards. The resulting new 1991 edition of 49 CFR listed test criteria for a greater variety of hazardous materials, including chemical "mixtures" such as the FRH. No longer could the FRH be classified based on definition only. The FRH now had to be classified through accurate testing for flammability, combustibility and water reactivity in its "commercial form", i.e., stripped of all packaging. Natick awarded a contract to National Technical Systems (NTS) to determine the proper classification of the FRH in accordance with the new version of 49 CFR. NTS concluded that the FRH was not a flammable solid nor spontaneously combustible, however, it was determined to be water reactive.[31] A single FRH in its commercial form produced a significant quantity of flammable gas (hydrogen) at a fast enough rate to be classified as a Packing Group I, Division 4.3 (Dangerous When Wet) material. Since packaging could not be considered when classifying an item under the new regulation, DOT would now require hazardous "Dangerous When Wet" marking and labels on not only bulk packed FRHs, but also on future MRE cases containing FRHs. Classification of the FRH as "Dangerous When Wet" posed an even greater storage crisis than the "Flammable Solid" classification. Special warehouses for "Dangerous When Wet" items were virtually nonexistent, and future MREs containing FRHs could not be stored with subsistence items.

The 1991 edition of 49 CFR allowed a two year transition period to comply to the new regulations. Therefore, beginning on 1 Oct 1993, all shipping cases of FRHs would require new hazardous markings and labels. This would include MRE XIII shipping cases, which would be assembled in Spring 1993 but distributed in October 1993. All shipping cases containing FRHs, including bulk and MRE, would be marked with the proper shipping name "Substances which in contact with water emit flammable gases, solid, n.o.s" and labeled "Dangerous When Wet." Unlike the 1990 edition, this version of 49 CFR did not allow limited or small quantity exceptions for dangerous when wet materials. The implications this would have on storage and supply of FRHs was serious enough to potentially warrant the termination of the FRH program.

Department Of Transportation Exemptions

Natick requested assistance from the Military Traffic Management Command (MTMC) which acts as the government liaison between military agencies and DOT. MTMC suggested that Natick prepare a request for Competent Authority Approval (CAA) from DOT, which would provide exemptions from all hazardous marking, labeling and placarding provisions of 49 CFR for both domestic and international shipments. Separate CAA petitions were prepared for bulk packed and MRE packed FRHs in the event that DOT would grant CAA for one package but not the other. Natick based the CAA requests on the ability of the high quality of FRH and MRE packaging to prevent hazards from occurring during transportation.[32] The CAA petitions were supported by test reports on hazard classification tests conducted by NTS, and reports generated by Natick on vibration, drop, compression and water spray testing of damaged and undamaged FRH shipping cases. The complete package was reviewed by DLA-HAZMAT, approved by Commander, ATCOM, and forwarded through MTMC to DOT in May 1992.

On 7 July 1992, DOT responded to Natick's request in a letter coordinated through MTMC (Appendix D). Their decision was two-fold. First, the quantity of FRHs in MRE shipping cases was so small (12 FRHs/96 g Mg) that DOT decided the FRH in the MRE meal bag was not subject to any hazardous material regulations. Essentially, DOT "deregulated" the FRH in the MRE from 49 CFR. Therefore, a CAA for this package was not required. Future MRE shipping cases containing FRHs would not require hazardous markings or labels. However, the OSHA case markings would remain. Secondly, regarding the CAA petition for bulk packed FRHs, DOT denied granting a CAA or deregulation due to the quantity of FRHs (288 FRHs/2306 g Mg) contained in the bulk pack shipping case. However, DOT understood the impact of hazardous markings/labels on the military storage and supply system, and agreed to discuss their opinion before making a final decision.

In July 1992, representatives from Natick, DPSC, DLA, QMC&S and MTMC met at DOT to discuss the status of marking and labeling bulk packed FRHs. DOT's main concern was if an accident occurred during transport, unmarked FRH cases would not identify the potential hazards to emergency response crews. Natick stated that OSHA case markings and accompanying MSDS documents identify the hazard. A superb compromise was reached when DOT agreed to allow exemption of hazardous markings/labels on bulk pack shipping cases and pallets, provided that transportation vehicles are properly identified with placards as carrying hazardous cargo. This exemption would apply only to domestic shipments of bulk packed FRHs and it would be the decision of each foreign country on whether or not to accept unmarked cases under the DOT exemption. Natick prepared formal exemption request documents and coordinated them through MTMC. The DOT exemption for bulk pack FRHs was granted on 26 October 1992 (Appendix F). This exemption from hazardous marking and labeling allowed storage of bulk packed FRHs with rations in general purpose warehouses.

RESULTS AND DISCUSSION

Adoption and Fielding Strategy

As outlined in the Statement of Need, the operational concept was to initially make FRH bulk packs available through the existing Class I field supply system. It was envisioned that one FRH would eventually be packaged inside each MRE. Ultimately, the FRH would be available to every soldier on the battlefield on an individual level. Based on prior technical and operational tests, TECOM provided their position on the adoption of the FRH in an Independent Assessment Report in May 1990.[15] TECOM assessed the FRH in terms of performance, compatibility with the MRE, safety and health concerns, human factors, environmental factors and logistic supportability.

a. BULK PACKED FRHs: The FRH, for issue in bulk quantities, was adopted in May 1990. In July 1990, a Joint Working Group (JWG) meeting was held at Natick to discuss the fielding strategy for the FRH. The military specification for the Heater, Ration, Flameless (for MRE), MIL-H-44398 was modified to become the "Ration Supplement, Flameless Heater for MRE, MIL-R-44398," and the Federal Stock Catalog (FSC) number was changed from 9110 (fuels) to 8970 (subsistence) to make the FRH available through the existing Class I field supply system. DPSC was selected to be the item manager, specification documents were coordinated, and a National Stock Number (NSN) 8970-01-321-9153 was assigned to the FRH. Bulk packed FRHs were added to the FSC as a ration supplement. They would be procured to supplement existing stocks of MREs, and to supplement MREs in arctic environments when more than one FRH may be required for thorough heating. Fielding of bulk packed FRHs was projected to include distribution in FY91 on a limited basis as part of the Soldier Enhancement Program (SEP).[33] This would be followed by more general distribution through the TISAs towards the end of FY91. However, in response to a request from DCSLOG, Natick was able to accelerate the FRH development in order to make the initial production buy for bulk pack FRHs by the end of FY90.

b. COMPONENT OF THE MRE: To ensure that every soldier receives an FRH with an MRE, JWG members discussed initiatives for packaging the FRH directly with the MRE. The Office of the Surgeon General already determined that it was safe to make the FRH an integral component of the MRE. Shock and vibration tests were conducted to determine the best placement of FRHs in the MRE shipping case; either one FRH inside each meal bag or laying 12 FRHs on top of the 12 meal bags. Test results showed that either placement was acceptable from a package integrity standpoint. However, there were more advantages to packaging the FRH directly inside each meal bag (Figure 12). Packaging the FRH inside the meal bag would provide additional protective packaging, control distribution, and eliminate the possibility of "hoarding" several FRHs upon opening the MRE shipping case. JWG opposition to making the FRH an integral component came mostly from service representatives concerned with the additional cost (i.e., $0.49/MRE) for MREs. The QMC&S developed a marketing strategy to include requisitioning and operational procedures. It was initially decided to collect data from military-wide user evaluations between 1-2Q FY91 to quantitatively establish the need, so that in April 1991 a decision would be made on packaging the FRH with the MRE. However, the

occurrence of ODS resulted in further delays, and the decision to adopt the FRH as an integral component of the MRE could not be made in April 1991. In September 1991 a Joint Services MRE Forum was held at which the results from the military-wide user assessments on the FRH were presented. The Services voted to adopt the FRH as an integral component of the MRE, beginning with the MRE XIII assembly in January 1993.

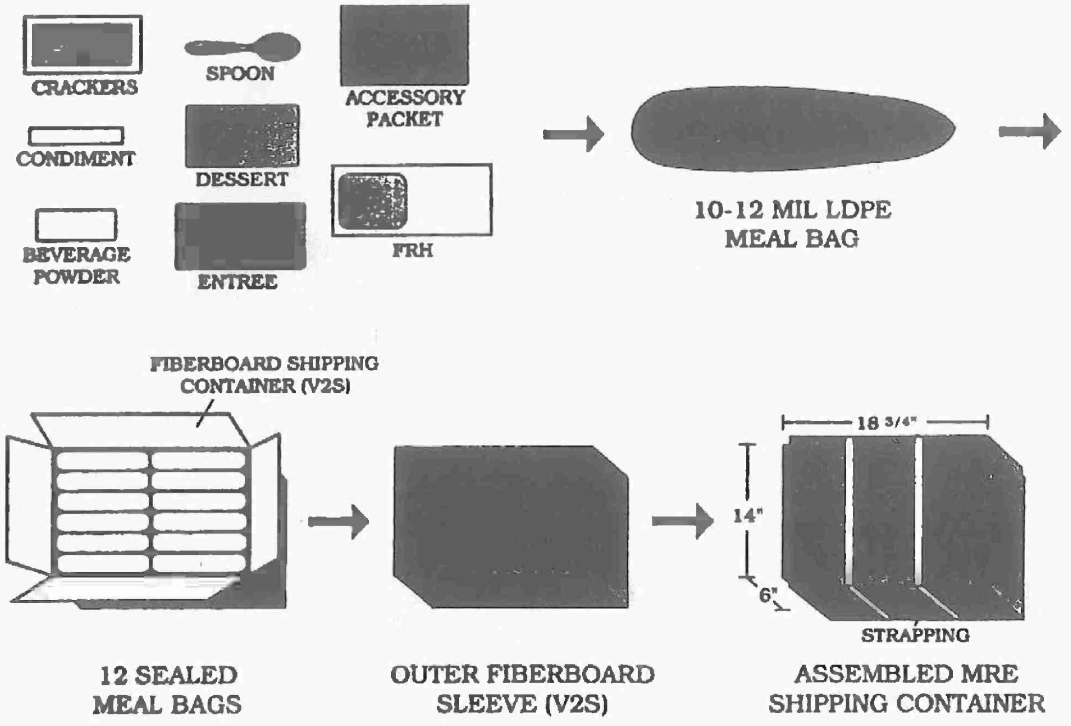


Figure 12. Packing the FRH as a Component of the MRE

Procurements

a. BULK PACK FRHs: Shortly after the completion of large scale FRH producibility tests, Natick awarded two bulk pack contracts for a total of 4.8 million FRHs with deliveries from September 1990 through July 1991. The first of these contracts was awarded to ZestoTherm Inc., Cincinnati, OH, to produce 3.6 million FRHs at $0.54 each. The second contract was awarded to Truetech Corp., Riverhead, NY to produce 1.2 million FRHs at $0.47 each. In February 1991, DPSC awarded the first indefinite quantity production contracts for bulk packed FRHs. A total of 51 million FRHs was procured from ZestoTherm Inc. and Truetech Corp. at a cost of $25,000,000. Approximately 4.5 million FRHs obtained from these contracts were sent to Southwest Asia in support of ODS (Figure 13), and remaining bulk packs are currently stocked in the supply depots.

Figure 13. Use of FRH in Operation Desert Storm

b. COMPONENT OF THE MRE: Following the Services' decision to make the FRH an integral component of the MRE, DPSC conducted an initial MRE XIII assembly production test in June 1992. The purpose of this limited test was to examine the impact of assembling the FRH and several other new items with the MRE, prior to the actual production of MRE XIII. DPSC awarded two limited assembly contracts to Cincinnati Packaging Company (CINPAC) and Right Away Foods Company (RAFCO) to pack and assemble MRE menus with the following new items: FRH, pork chow mein, smokey links, sugar free beverage base, potato sticks, chow mein noodles and pound cake. Approximately 9,600 of the 50,000 MRE shipping cases assembled contained FRHs.

For this production test, the MRE meal bags were slightly wider than regular meal bags to facilitate the packing of additional components. Nevertheless, meals containing new components were tighter and more difficult to pack, and an additional 1/8" allowance in the width of the meal bag was recommended. During menu assembly, RAFCO's production department found that packing meals with the FRH required one additional stocker on each menu sub-assembly line. Packing meals with the FRH was determined to be slightly

less efficient than assembly of MREs without FRHs, whose rate of production occurred at 30 cases per minute. During final assembly of meals into the MRE shipping case, significant numbers of meals popped out of position prior to case closure making the case assembly very difficult. Although resizing the shipping case was not deemed necessary at the time, two assembly personnel were added for each case top sealer in order to prevent damage to meals and their components. OSHA markings were stenciled on the MRE shipping case side panel following case closure, and the cases containing FRHs were distributed to Fort Bragg, Fort Benning, Memphis Depot, Tracy Depot, DPSC and Natick.

In July 1992 a Value Engineering Change Proposal (VECP) was submitted by RAFCO to Natick that involved a reconfiguration of the MRE shipping case. The new case design still contained 12 MREs but provided an additional 0.03 cubic feet of interior space while maintaining 48 cases per pallet. The reconfigured case easily accommodated the FRH as well as additional components should the Services require them. The new shipping case was successfully tested to ensure appropriate stacking and compressiong strength, and the VECP was adopted in October 1992 after obtaining Military Service approval. Routine assembly of MRE XIII with FRHs in the new shipping case is scheduled to begin in January 1993.

CONCLUSIONS

The successful development of the Flameless Ration Heater (FRH), a small, inexpensive, water activated, chemical heater, provides a solution to the Armed Forces' historical and persistent "cold ration problem." The incorporation of the FRH into the standard operational ration, the Meal, Ready-to-Eat (MRE) ensures that every soldier will have a safe, reliable and resource efficient means of obtaining a hot meal.

The FRH has been specifically designed to heat the MRE entree. The FRH consists of a 40/60 mixture of active magnesium-iron powder and inert plastic powders molded into a stable 4.5 by 3.5 by 0.12 inch pad, weighing less than one ounce, and packaged in a bag sized to hold the MRE entree. The FRH is activated by two ounces of water and will raise the temperature of the eight ounce entree 100^{o}F in 12 minutes or less. The FRH takes a fraction of the time and water required by previous heating methods, is flameless, produces no noxious combustion products, and can be activated in shelters or in the soldier's pocket while on-the-move. It will also keep the entree warm for approximately one hour if the tactical situation prevents the soldier from eating immediately.

Although the basic chemical heater was developed during an earlier research effort, the FRH program provided several innovative changes in packaging, presentation, chemical make-up, and human factors that made the FRH a success. Because the FRH was comprised of a new material and was being used in a new application, extensive work was conducted to resolve transportation and storage safety issues. The program has produced a Military Specification, MIL-R-44398, that was production tested and transitioned to the Defense Personnel Supply Center for full adoption completion. The FRH was added to the Federal Supply Catalog 8970 for subsistence to enable the mess sergeant to order the item through the Class I supply system. Since transition there have been several large production contracts that have yielded millions of FRHs and to date, there have been no cost increases due to a deficiency in the specification.

Perhaps the most significant aspect of the FRH program was the aggressive development of an acquisition strategy that condensed the requirements of the Army Life Cycle Management Model and Army Regulation 70-1, which typically take four to six years, into a program that resulted in the development and adoption of the FRH by the Services in approximately one year. Moreover, contracts were in place prior to and in anticipation of adoption, so that First Unit Equipped was accomplished within four months of adoption. This coincided with immediate support to Operation Desert Shield.

The FRH has been widely recognized in defense and commercial publications, and through numerous awards including TROSCOM's Competitor of the Quarter Award and Natick's Silver Pin for Development. In 1991, the FRH received the prestigious R&D 100 Award from R&D Magazine which recognizes innovative new products that are successfully marketed. The FRH is considered by all to be a major innovation that provides a significant improvement to field feeding and will, for the first time in history, ensure that the soldier can enjoy a hot operational meal anytime, anyplace.

This document reports research undertaken at the US Army Natick Research, Development and Engineering Center and has been assigned No. NATICK/TR-93/030 in the series of reports approved for publication

REFERENCES

1. Power Applications, Inc. 1973. Design and Optimization of Electrochemical Device for Heating Military Rations, Natick TR-74-44-GP, USANRDEC, Natick, MA.

2. Kuhn, W. E. 1983. Optimization of an Electrochemical Heater for Warming Military Field Rations, Naval Civil Engineering Laboratory Technical Memorandum No. 43-83-07CR, Port Hueneme, CA.

3. TRADOC Combined Arms Test Activity. 1983. Combat Field Feeding System, TCATA Test Report FT 458, Fort Hood, TX.

4. Kuhn, W. E. et al. 1985. Flexible Electrochemical Heater, U.S. Patent No. 4,522,190, University of Cincinnati, Cincinnati, OH.

5. U.S. Army Development and Employment Agency. 1986. Ration Heating Units Evaluation Report, Fort Lewis, WA.

6. Engell, D. B. 1988. MRE Focus Groups, Fort Carson, Colorado, Memorandum for Record, SATNC-YBH, USANRDEC, Natick, MA.

7. Engell, D. and Popper, R. 1988. Evaluation of Meal, Ready-to-Eat VIII at Market Square II, Natick TR-88/078, USANRDEC, Natick, MA.

8. Root, J. A. 1989. Self-Heating for the Year 2001, Requirement Technical Plan No. M 89-14, USANRDEC, Natick, MA.

9. U.S. Army Quartermaster Center and School. 1989. Statement of Need for the Flameless Ration Heater, Memorandum for USANRDEC, ATSM-CDM, Fort Lee, VA.

10. U.S. Army Natick RD&E Center. 1989. Test and Evaluation Master Plan for an Integral Heater for the Meal, Ready-to-Eat, SATNC-WAE, USANRDEC, Natick, MA.

11. Holwadel, D. K. 1992. Flameless Heater, Ration Supplement, Information Letter, ZestoTherm Inc., Cincinnati, OH.

12. Kuhn, W. E. 1989. Safety of Chemical Heaters, Information Letter, ZestoTherm Inc., Cincinnati, OH.

13. Kuhn, W. E. 1984. Safety and Toxicity of ZT-Energy Paks, ZestoTherm Inc., Cincinnati, OH.

14. Guerra, R. and Nelson, K. 1990. Flameless Ration Heater Enclosed Vehicle and Shelter Testing, SSD/FED Memorandum Report, USANRDEC, Natick, MA.

15. U.S. Army Test and Evaluation Command. 1990. TECOM Independent Assessment Report for the Flameless Ration Heater, Memorandum for USANRDEC, AMSTE-TA-G, Aberdeen Proving Ground, MD.

REFERENCES (CONTINUED)

16. U.S. Army Environmental Hygiene Agency. 1989. Health Hazard Assessment Report on the ZestoTherm Chemical Flameless Heater, Report No. 69-37-4758-89, Aberdeen Proving Ground, MD.

17. Pickard, D. 1989. Safety Assessment Report for the Flameless Ration Heater, SATNC-WAE, USANRDEC, Natick, MA.

18. Trottier, R. 1990. Effects of Sudden Decompression on Activated Flameless Ration Heaters, Memorandum for Record, SATNC-WAE, USANRDEC, Natick, MA.

19. U.S. Army Natick RD&E Center. 1990. Heater, Ration, Flameless (For MRE), Military Specification MIL-H-44398, USANRDEC, Natick, MA.

20. Trottier, R. 1990. Leak Testing of Rough Handled Flameless Ration Heaters, Memorandum for Record, SATNC-WAE, USANRDEC, Natick, MA.

21. Lester, L. et al. 1989. Evaluation of the Canteen Cup Stand and Ration Heater Pad: Effects on Acceptability and Consumption of the Meal, Ready-to-Eat in a Cold Weather Environment, Natick TR-90/008L, USANRDEC, Natick, MA.

22. Hammond, T. R. 1989. Customer Test of the Flameless Ration Heater, TRADOC Final Letter Report No. 89-CT-960, TEXCOM ABNSOTBD, Fort Bragg, NC.

23. Saren, D. J. et al. 1989. Trip Report to Hohenfels Combat Maneuver Training Center, SATNC-WES, USANRDEC, Natick, MA.

24. Todd, W. E. and Richardson, H. 1990. Research Effort Test of the Flameless Ration Heater, USA Cold Regions Test Center, Final Letter Report No. 8-ES-765-FRH-002, U.S. Army TECOM, Aberdeen Proving Ground, MD.

25. U.S. Army Dugway Proving Ground. 1990. Data Package for FRH, Memorandum for TECOM, STEDP-MT-TM-CB, Dugway, UT.

26. Shearer, V. M. et al. 1991. User Evaluation of the Flameless Ration Heater, Geo-Centers Inc., Soldier Science Directorate, USANRDEC, Natick, MA.

27. Department of Transportation. 1990. Code of Federal Regulations, Title 49, Transportation, National Archives and Records Administration, Washington, DC.

28. Trottier, R. 1990. Burn Test of Individual Flameless Ration Heater Components, Memorandum for Record, SATNC-WAE, USANRDEC, Natick, MA.

29. SRS Technologies. 1991. System Safety Hazard Analysis Report on the Flameless Ration Heater for the Meal, Ready-to-Eat, Report No. SEDCOS-90-R212, Colorado Springs, CO.

30. Moussa, N. A. and Jordan, W. D. 1992. Fire Hazard Testing and Evaluation of the Flameless Ration Heater, Contract Report No. DAAK60-91-P-0791, BlazeTech Corporation, Winchester, MA.

31. Boyce, D. M. 1992. Environmental Testing of Flameless Ration Heaters and Heater Pad Material, National Technical Systems, Report No. 535-3091, Hartwood, VA.

32. U.S. Army Natick RD&E Center. 1992. Request for Competent Authority Approval for the Flameless Ration Heater for the Meal, Ready-to-Eat, Memorandum for MTMC, SATNC-WTS, Natick, MA.

33. Oleksyk, L. E. 1991. Flameless Ration Heater for the MRE, Requirement Technical Plan No. MAAFN 89-14, USANRDEC, Natick, MA.

APPENDIXES

APPENDIX A

FLAMELESS RATION HEATER
INTEGRATED PROGRAM SCHEDULE

ACQUISITION STRATEGY

Flameless Ration Heater
Integrated Program Schedule

Phase I (make chemical heater available)

Event	Date	Agency
FDTE of CFFS	Oct 82	QMC&S
Market Square Demo	May 88	QMC&S
Market Investigation	1-2Q FY89	Natick
Cold Weather Feeding Study	Jan 89	Natick
JWG Meeting	Feb 89	
Preliminary HHAR	Apr 89	OTSG
AFFS/ATCOM Shakedown	Mar 89	ATCOM
In-house design, test & evaluation	2-3Q FY89	Natick
TIWG Meeting	May 89	
Independent Assessment Plan	Aug 89	TECOM
Statement of Need	Aug 89	QMC&S
Procure Prototypes	4Q FY89	Natick
Prepare Mil-Spec	1-2Q FY90	Natick
User Test	1Q FY90	TEXCOM
JWG Meeting	Oct 89	
Test & Evaluation Management Plan	Nov 89	TECOM
AFFS USAREUR Evaluation	Nov 89	ATCOM
Technical Research Effort Test	1-2Q FY90	DPG/CRTC
User Test Report	Jan 90	TEXCOM
Technical Test Report	Mar 90	DPG/CRTC
Proponent Assessment	May 90	QMC&S
Technical Assessment	May 90	TECOM
Decision Coordinating Paper	May 90	Natick
JWG Adoption	May 90	
Production Contract Award	Jun 90	Natick
Bulk Pack Distribution	1-2Q FY91	Natick
Collect Usage Data	2Q FY91	Natick/OFIG
Coordination/Transition of Mil-Spec	Aug 90	Natick/DPSC

Phase II (add FRH to MRE)

Event	Date	Agency
Secondary Package Design	1Q FY91	Natick
Consolidated Assessment Report	Jun 91	Natick/SSD
Revise MRE Technical Data Package	3Q FY91	Natick
Final HHAR	Aug 91	OTSG
Cost Analysis	Aug 91	Natick
Decision Coordinating Paper	Sep 91	Natick
JWG Adoption of FRH as MRE Component	Sep 91	
Resolve Classification, Transportation and Storage Issues	1-2Q FY92	Natick/DLA MTMC/DOT
Limited Production Contract Award (MRE XIII)	2Q FY92	DPSC

APPENDIX B

MIL-R-44398
RATION SUPPLEMENT, FLAMELESS HEATER,
FOR MEAL, READY-TO-EAT

INCH-POUND

MIL-R-44398A
10 July 1990
SUPERSEDING
MIL-H-44398
30 March 1990

MILITARY SPECIFICATION

RATION SUPPLEMENT, FLAMELESS HEATER, FOR MEAL, READY-TO-EAT

This specification is approved for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification covers a water activated exothermic-chemical heater packaged in a plastic heating bag which functions as a container for heating the Meal, Ready-to-Eat (MRE).

2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation (see 6.2).

SPECIFICATIONS

FEDERAL

PPP-B-26	-	Bag, Plastic (General Purpose)
PPP-B-636	-	Boxes, Shipping, Fiberboard

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be used in improving this document should be addressed to: U.S. Army Natick Research, Development, and Engineering Center, Natick, MA 01760-5014 by using the Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

AMSC N/A FSC 8970

DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.

STANDARDS

FEDERAL

FED-STD-313 - Material Safety Data Sheets Preparation and the Submission Of
FED-STD-595 - Colors

MILITARY

MIL-STD-105 - Sampling Procedures and Tables for Inspection by Attributes
MIL-STD-129 - Marking for Shipment and Storage
MIL-STD-147 - Palletization Requirements
MIL-STD-731 - Quality of Wood for Containers and Pallets

(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Standardization Documents Order Desk, Bldg. 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.)

2.1.2 Other Government documents, drawings, and publications. The following other Government documents, drawings, and publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues are those cited in the solicitation.

Federal Regulations:

Food and Drugs Administration, Department of Health and Human Services (Title 21 CFR Parts 174-178)

(The Code of Federal Regulations (CFR) and the Federal Register (FR) are for sale on a subscription basis by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402-0001. When indicated, reprints of certain regulations may be obtained from the Federal agency responsible for issuance thereof.)

DRAWINGS

U.S. ARMY NATICK RESEARCH, DEVELOPMENT, AND ENGINEERING CENTER

6-1-8920 - Bag, Ration Heater

(Copies of drawings are available from the U.S. Army Natick Research, Development, and Engineering Center, ATTN: STRNC-EMSS, Natick, MA 01760-5014.)

2.2 Non-Government publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted are those listed in the issue of the

DODISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS are the issues of the documents cited in the solicitation (see 6.2).

NATIONAL MOTOR FREIGHT TRAFFIC ASSOCIATION, INC., AGENT

National Motor Freight Classification

(Application for copies should be addressed to the American Trucking Association, Inc., Traffic Department, 2200 Mill Road, Alexandria, VA 22314.)

UNIFORM CLASSIFICATION COMMITTEE, AGENT

Uniform Freight Classification

(Application for copies should be addressed to the Uniform Classification Committee, 222 South Riverside Plaza, Suite 1120, Chicago, IL 60606.)

2.3 Order of precedence. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless specific exemption has been obtained.

3. REQUIREMENTS

3.1 First article. When specified (see 6.2), a sample shall be subjected to first article inspection (see 6.3), in accordance with 4.3.

3.2 Materials and components. The materials and components shall be as specified herein and on the applicable drawings. Where materials are not definitely specified, they shall be of the quality normally used for the purpose in commercial practice provided the end items comply with all requirements of this specification and do not degrade the operational suitability or effectiveness of the heater. It is encouraged that recycled and/or degradable material be used when practical as long as it meets the requirements of this specification.

3.2.1 Supercorroding alloy. The supercorroding alloy shall be Mg-5atomic%Fe produced from magnesium metal powder and food grade electrolytic iron powder by solid state blending in a vibratory ball mill. The alloy shall be of such purity that the performance of the finished ration heater will meet all requirements of this specification.

3.2.2 Alloy additives. Fillers, binders, and additives, including electrolytes, wetting agents, and flow agents used in the heater construction shall be of such purity that the performance of the heater will meet the requirements of this specification.

3.2.3 Paperboard cover. After forming, each pad shall be contained within and protected by a folded paperboard cover. The cover shall have nine 1/4-inch diameter holes in each side. The holes shall be spaced 1-1/4 inches apart in a 3 by 3 pattern. The color of the cover shall be either a natural tan color like unbleached kraft paper or shall be colored a light green approximating color number 34089 of FED-STD-595.

3.2.4 Plastic bag. The plastic bag shall be a clear, high density polyethylene bag that will function as protective packaging for the heater and serve as a container to hold both the heater and the MRE pouch while the heating process takes place. The bag shall conform to the requirements shown on Drawing 6-1-8920.

3.3 Design of heater pad. The heater pad consists of a supercorroding Mg-Fe alloy powder and an electrolyte together with flow and wetting agents dispersed throughout a porous matrix formed from polymeric powders. The magnesium and iron function as anode and cathode respectively. The electrolyte is activated by the addition of water, which initiates a rapid corrosion of the magnesium particles within the matrix. The products of the chemical reaction are heat, magnesium hydroxide, and gaseous hydrogen.

3.4 Heater construction.

3.4.1 Heater pad. The supercorroding alloy powder shall be blended with the other components indicated in 3.2.2 and then formed into pads and sintered. Each heater pad shall have approximate dimensions of 4-1/2 by 3-1/2 by 1/8 inches, and shall weigh 20 $\pm$ 2 grams when examined as specified in 4.4.1.2.

3.4.2 Heater pad covering. The formed pad shall be inserted in the folded paperboard cover specified in 3.2.3. The folded cover shall then be sealed on its three open sides so as to contain and protect the heater pad.

3.4.3 Insertion in bag. The heater pad with protective paperboard cover shall be sealed within the plastic bag specified in 3.2.4. The seals of the finished bag shall be of adequate strength and integrity to withstand the leakage test specified in 4.4.4 without leaking. If the method of opening the finished bag is to be different from that shown on Drawing 6-1-8920 the method shall be such that the bag can be easily torn open across the width of the bag perpendicular to the side weld of the bag when tested as specified in 4.5.5.

3.5 Peformance requirements.

3.5.1 Heating performance. The heater shall be capable of providing a 100°F minimum temperature rise in water filled MRE pouch in 12 minutes or less, when tested as specified in 4.4.4.

3.5.2 Heater by-products. The finished heater shall operate without emission of any unusual foreign odors as specified in 4.5.4.1. After the MRE pouch is removed, but still wet, there shall be no evidence of the white precipitate

magnesium hydroxide on at least 80 percent of the pouches inspected, except at the location of the 1/4 inch diameter holes in the cover. The amount of residual water shall be not greater than 10 milliliters.

3.6 Label. One side of the plastic heating bag shall be legibly printed using a flexo-graphic printing process (or equal) with black characters on a light green background. The light green background shall approximate color number 34089 of FED-STD-595. The label shall be as shown on Drawing 6-1-8920. The label shall be clearly legible after testing as specified in 4.4.4.

3.7 Food grade certification. The contents of the heater and the heater bag itself must be safe for incidental contact with food. The contractor shall certify that the materials used are generally recognized as safe in or on food in accordance with Code of Federal Regulations (CFR), Title 21, Parts 174-178.

3.8 Material safety data sheets. A material safety data sheet shall be prepared in accordance with the requirements of FED-STD-313 (see 6.5).

3.9 Workmanship. The heaters shall be uniform in composition and texture, and not broken or separated. The heating bag shall fit around the heater so as to allow enough space for an MRE to be placed inside, on top of the heater (see 4.5).

4. QUALITY ASSURANCE PROVISIONS.

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the contractor is responsible for the performance of all inspection requirements (examinations and tests) as specified herein. Except as otherwise specified in the contract or purchase order, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in this specification where such inspections are deemed necessary to ensure supplies and services conform to prescribed requirements.

4.1.1 Responsibility for compliance. All items shall meet all requirements of sections 3 and 5. The inspection set forth in this specification shall become a part of the contractor's overall inspection system or quality program. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility of ensuring that all products or supplies submitted to the Government for acceptance comply with all requirements of the contract. Sampling inspection, as part of manufacturing operations, is an acceptable practice to ascertain conformance to requirements, however, this does not authorize submission of known defective material, either indicated or actual, nor does it commit the Government to accept defective material.

4.1.2 Responsibility for dimensional requirements. Unless otherwise specified in the contract or purchase order, the contractor is responsible for ensuring that all specified dimensions have been met. When dimensions cannot be examined

on the end item, inspection shall be made at any point, or at all points in the manufacturing process necessary to ensure compliance with all dimensional requirements.

4.2 Classification of inspections. The inspection requirements specified herein are classified as follows:

a. First article inspection (see 4.3)
b. Quality conformance inspection (see 4.4)

4.3 First article inspection. When a first article is required (see 3.1 and 6.2), it shall be examined for the defects specified in 4.4.2 and 4.4.3 and tested for the characteristics specified in 4.4.4.

4.4 Quality conformance inspection. Unless otherwise specified, sampling for inspection shall be performed in accordance with MIL-STD-105.

4.4.1 Component and material inspection. In accordance with 4.1, components and materials shall be inspected in accordance with all the requirements of referenced documents unless otherwise excluded, amended, modified, or qualified in this specification or applicable purchase document.

4.4.1.1 Material certification. A certificate of compliance may be acceptable as evidence that the heater and bag materials conform to the requirements specified in 3.7.

4.4.1.2 Heater pad weight examination. Heater pads, prior to insertion in the paperboard covers and plastic bags, shall be weighed as specified in 4.5.1. The lot size shall be expressed in units of heater pads. The sample unit shall be ten heater pads. The inspection level shall be S-2. Any sample unit average weight failing to meet the weight requirement specified in 3.4.1 shall be cause for rejection of the lot.

4.4.2 End item visual examination. The end items (heater pad sealed in heater bag) shall be examined for the defects listed in table II. The lot size shall be expressed in units of end items. The sample unit shall be one end item. The inspection level shall be I and the acceptable quality level (AQL), expressed in terms of defects per hundred units, shall be 1.5.

TABLE II. End item visual defects.

Defect	Classification Major
Heater pad not formed as specified	101
Heater bag not formed as specified	102
Tear, hole, or open seal (visible channels)	103
Required marking missing, incorrect, or illegible	104
Not material specified	105

TABLE II. End item visual defects. (cont'd)

Defect	Classification Major
Not clean	106
Tear notch (or tear method) missing	107
Tear notch not located as specified	108
Heater pad broken (protruding from cover)	109
Paperboard cover not securely sealed	110
Paperboard cover holes not as specified	111
Heater pad crumbling (separated chunks of heater which have fallen to bottom of bag)	112
Color of heater pad cover not as specified	113
Color of heater bag label not as specified	114

4.4.3 End item dimensional examination. The end items shall be examined for conformance to the dimensions specified on Drawing 6-1-8920 and in 3.4.1. Any dimensions not within the specified tolerance shall be classified as a defect. The lot size shall be expressed in units of end items. The sample unit shall be one end item. The inspection level shall be S-3 and the AQL, expressed in terms of defects per hundred units, shall be 4.0.

4.4.4 End item testing. The end items shall be tested for the characteristics listed in table III. The lot size shall be expressed in units of end items. The sample unit shall be one end item. The inspection level shall be as specified in table III and the AQL, expressed in terms of defects per hundred units, shall be 1.0.

TABLE III. End item tests.

Characteristic	Requirement paragraph	Test paragraph	Inspection level
Leakage	3.4.3	4.5.2	S-2
Heating performance	3.5.1	4.5.3	S-2
Heater by-products	3.5.2	4.5.4	S-2
Label	3.6	4.5.4	S-2

4.4.5 Packaging examination. The fully packaged end items shall be examined for the defects listed below. The lot size shall be expressed in units of shipping containers. The sample unit shall be one shipping container fully packaged. The inspection level shall be S-2 and the AQL, expressed in terms of defects per hundred units, shall be 2.5.

Examine	Defect
Marking	Omitted; incorrect; illegible; of improper size, location, sequence, or method of application
Materials	Any component missing, damaged, or not as specified
Workmanship	Inadequate application of components, such as: incomplete sealing or closure of flap, improper taping, loose strapping, or inadequate stapling Bulged or distorted container
Content	Number of unit packs per container is more or less than required Number of heaters per unit pack is more or less than required Number of heaters per container is more or less than required

4.4.6 Palletization examination. The fully packaged and palletized end items shall be examined for the defects listed below. The lot size shall be expressed in units of palletized unit loads. The sample unit shall be one palletized unit load, fully packaged. The inspection level shall be S-1 and the AQL, expressed in terms of defects per hundred units, shall be 6.5.

Examine	Defect
Finished dimensions	Length, width, or height exceeds specified maximum requirements
Palletization	Pallet pattern not as specified Load not bonded as specified
Weight	Exceeds maximum load limits
Marking	Omitted; incorrect; illegible; of improper size, location, sequence, or method of application

4.5 Methods of inspection.

4.5.1 Heater pad weight. Ten heater pads shall be weighed to the nearest 1 gram and the heater pad average weight shall be calculated and reported to the nearest 1 gram.

4.5.2 Leakage test. The heater shall be removed from the plastic bag. Fill the bag 3/4 full with water and fold over the top of the bag. Gently apply light pressure to sides of bag while holding the top of bag closed to contain water. Observe any dripping or steady flow of water through the bag's surfaces or seams. Failure to meet the requirements in 3.4.3 shall constitute a test failure.

4.5.3 Heater pad performance test. The heater pad shall be placed in a plastic tray no less than 7.5 inches long, 4.75 inches wide, and 1.75 inches deep with not more than 0.03 inch thick tray walls. An MRE pouch shall be filled with not less than 8 ounces of water, fitted internally with a temperature measuring device, and placed on top of the heater pad. One end of the pouch shall be lifted and a quantity of water equal to or less than the amount used in 4.5.4 and no warmer than 72°F shall be poured on top of the heater pad. A lid shall then be placed on the tray and the time and temperature rise recorded for at least 15 minutes. Failure to meet the requirements of 3.5.1 shall constitute a test failure.

4.5.4 Heater by-products. Following the instructions provided on the label of the bag, an 8-ounce MRE pouch (see 6.4) shall be inserted in the bag and the bag filled with water to the top indicator line to activate the heater. The MRE pouch shall be placed on a 15° incline during the heating process. After 12 minutes the heater bag shall be opened and the contents of the bag and the label shall be inspected as specified below.

4.5.4.1 Foreign odor. While the heating process takes place and after the bag has been opened, the emission of any unusual foreign odors shall constitute a test failure.

4.5.4.2 Residue. While the MRE pouch is still wet, it shall be inspected for white residue (magnesium hydroxide). Failure to meet the requirement in 3.5.2 shall constitute a test failure.

4.5.4.3 Residual water. After the MRE pouch has been removed, the residual water shall be poured out of the bag and measured. Failure to meet the requirement in 3.5.2 shall constitute a test failure.

4.5.4.4 Label and markings. The heater bag label and markings shall be inspected for legibility, tackiness, and separation from the bag. Failure to meet the requirement in 3.6 shall constitute a test failure.

4.5.5 Bag tear test. If the method to be used for tearing open the bag is to be different from the tear notch method shown on Drawing 6-1-8920, the acceptability of the method shall be determined by grasping the bag between the thumb and forefinger of each hand on either side of the arrow indicated on Drawing 6-1-8920 and pulling the bag apart in one pull. Failure to meet the requirement in 3.4.3 shall constitute a test failure.

5. PACKAGING

5.1 Preservation. Preservation shall be level A.

5.1.1 Level A. Twelve heaters shall be arranged in a single stack, with heater pads positioned at the same end of the stack and the ends of the bags opposite the heater pads folded together underneath the stack. The stack of 12 heaters shall be unit packed in a close-fitting polyethylene bag conforming to

type II, style 1 of PPP-B-26. Excess air shall be manually expelled from the bag just prior to closing to maintain a close fit between the bag and contents. The bag shall be closed by heat sealing as specified in PPP-B-26 and shall be provided with tear notch located halfway along either short side of the bag. As an alternate to the polyethylene bag, the stack of twelve heaters may be inserted into a sleeve composed of a suitable heat shrinkable material and subsequently shrink wrapped.

5.2 Packing. Packing shall be level B or C as specified (6.2).

5.2.1 Level B packing. Two hundred and eighty-eight heaters, preserved as specified in 5.1, shall be packed in a snug-fitting fiberboard shipping container conforming to style RSC-L, grade V3c of PPP-B-636. Twenty-four unit packs shall be packed on end and arranged eight in length, three in width and one in depth, with the face of each pack against the box width panels. The top and bottom of the box shall be fitted with pads made of the same material as the box, with length and width dimensions not more than 1/4 inch shorter than the inside length and width of the box. When metal fasteners are used in the box manufacturer's joint, the fasteners shall be completely covered with pressure-sensitive tape. The approximate inside dimensions of the shipping container shall be 18-1/2 inches in length, 16-5/8 inches in width, and 7 inches in depth. Approximate dimensions are furnished as a guide only. Each shipping container shall be closed and reinforced with nonmetallic strapping or pressure-sensitive adhesive, filament reinforced tape in accordance with the appendix of PPP-B-636.

5.2.2 Level C packing. Not more than 250 heaters shall be packed in a manner to ensure carrier acceptance and safe delivery at destination at the lowest transportation rate for such supplies. The shipping container shall be in accordance with the National Motor Freight Classification or the Uniform Freight Classification, as applicable, except fiberboard containers shall be closed in accordance with method II, as specified in the appendix of PPP-B-636. When metal fasteners are used in the manufacturer's joint or set up of the fiberboard box, the fasteners on the inside of the box shall be covered with tape or paperboard to protect contents from mechanical damage.

5.3 Palletization. When specified (see 6.2), heaters packed as specified in 5.2.1, shall be palletized on a 4-way entry pallet in accordance with load type Ia of MIL-STD-147. Pallet types shall be type I (4-way entry), type IV, or type V in accordance with MIL-STD-731. Each prepared load shall be bonded with primary and secondary straps in accordance with the bonding means C and D or film bonding F or G. Pallet pattern shall be number 95 in accordance with the appendix of MIL-STD-147.

5.4 Marking. In addition to any special marking required by the contract or purchase order, unit packs, shipping containers, and palletized unit loads shall be marked in accordance with MIL-STD-129. The top of the shipping container shall be clearly marked as follows:

OPEN CAREFULLY IF USING KNIFE TO AVOID SLITTING CONTENTS

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use. The heater is intended for use in heating the Meal, Ready-to-Eat.

6.2 Acquisition requirements. Acquisition documents must specify the following:

a. Title, number, and date of this specification.
b. Issue of DODISS to be cited in the solicitation, and if required, the specific issue of individual documents referenced (see 2.1.1 and 2.2).
c. When first article is required (see 3.1, 4.3, and 6.3).
d. Level of packing (see 5.2).
e. When palletization is required (see 5.3).

6.3 First article. When a first article is required, it shall be inspected and approved under the appropriate provisions of FAR 52.209. The first article should be a preproduction sample. The contracting officer should specify the appropriate type of first article and the number of units to be furnished. The contracting officer should also include specific instructions in acquisition documents regarding arrangements for selection, inspection, and approval of the first article.

6.4 Samples. For access to samples of MRE pouches, address the contracting activity issuing the invitation for bids or request for proposal.

6.5 Material safety data sheets. Contracting officers will identify those activities requiring copies of completed Material Safety Data Sheets prepared in accordance with FED-STD-313. The pertinent Government mailing addresses for submission of data are listed in FED-STD-313.

6.6 Subject term (key word) listing.

Exothermic-chemical
Heating bag
Operational rations

6.7 Changes from previous issue. Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the extensiveness of the change. However, it should be noted that the title and FSC class were changed. The previous issue had a FSC class of 9110 and was titled; Heater, Ration, Flameless (FOR MRE).

INCH-POUND

MIL-R-44398A
AMENDMENT 1
19 February 1992

MILITARY SPECIFICATION

RATION SUPPLEMENT, FLAMELESS HEATER, FOR MEAL, READY-TO-EAT

This amendment forms a part of MIL-R-44398A, dated 10 July 1990, and is approved for use by all Departments and Agencies of the Department of Defense.

PAGE 2

2.1.2: Under Federal Regulations, line 2, delete "174-178" and substitute "170-189".

PAGE 3

2.2: Add the following:

"AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

D 775-80 - Drop Test for Loaded Boxes
D 999-86 - Vibration Testing of Shipping Containers

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103-1187.)"

3.1, line 2: Delete "4.3" and substitute "4.3 and 4.3.1".

PAGE 4

3.2.3, line 6: Delete "34089" and substitute "of the instruction label as specified in 3.6, or green in the range of 34127 through 34159 (excluding 34138) or 34226 through 34258 or 34583".

3.2.4, line 1: After "clear" add "natural".

3.5.2, line 2: Delete "foreign odors" and substitute "objectionable odors such as burning plastic/metal or sulfurous odors,".

PAGE 5

3.6, line 4: Delete "34089" and substitute "34583".

PAGE 5

3.7: Delete and substitute:

"3.7 Material certification. The material used in the heater and in the heater bag itself shall be safe in the event of incidental contact with the food being heated. The contractor shall certify that the materials used are safe in or on food by reference to, and in accordance with Title 21 CFR Parts 170-189, applicable Material Safety Data Sheets, or other recognized health standards and regulations."

3.8, line 2: After "(see 6.5)" add "The material safety data sheets (MSDS) shall be securely attached to the palletized unit loads of Level B and C packing as specified in 5.3."

PAGE 6

4.2a: Delete "(see 4.3)" and substitute "(see 4.3 and 4.3.1)".

4.3: Delete and substitute:

"4.3 First article inspection. When a first article is required (see 3.1 and 6.2), one fully packed case of end items (level B or C as specified in the contract) shall be tested for rough handling in accordance with 4.3.1, and the first article shall be examined for the defects specified in 4.4.2 and 4.4.3, and tested for the characteristics specified in 4.4.4."

4.3: Add the following:

"4.3.1 Rough handling. Individual shipping containers shall be dropped in accordance with ASTM D 775, Objective B and Annexes. Constant height drop procedure and drop sequence described in A1.3 for a cycle of 10 drops shall be followed. The drop height shall be 21 inches. Vibration shall be conducted in accordance with ASTM D 999, Method A. Sample units shall be vibrated for one hour at 268 cycles per minute."

4.4.1.2, line 4: Delete "ten heater pads" and substitute "one heater pad".

4.4.1.2, line 4: After "sample unit" delete "average weight".

PAGE 7

4.4.4, in Table III, line 5: Delete "S-2" and substitute "S-3".

4.4.4, in Table III, line 7: Delete "4.5.4" and substitute "4.5.4.4".

PAGE 8

4.5.1: Delete and substitute:

"4.5.1 Heater pad weight. Each heater pad shall be weighed to the nearest 1 gram."

PAGE 9

4.5.3: Delete and substitute:

"4.5.3 Heater performance test. The heater shall be placed in a plastic tray not less than 7.5 inches long, 4.75 inches wide and 1.75 inches deep with not more than 0.03 inch thick tray walls. An MRE pouch shall be filled with not less than 8 ounces of water in the temperature range of 35°F to 45°F, fitted internally with a temperature measuring device, and placed on top of the heater. One end of the pouch shall be lifted and a quantity of water equal to or less than the amount used in 4.5.4 and no warmer than 72°F shall be poured on top of the heater. A lid shall then be placed on the tray and the time and temperature rise recorded for at least 15 minutes. Failure to meet the requirements of 3.5.1 shall constitute a test failure."

4.5.4.1, line 2: Delete "foreign odors" and substitute "objectionable odors such as burning plastic/metal or sulfurous odors,".

PAGE 10

5.2.1: Delete lines 10-14, "The approximate ...PPP-B-636." and substitute:

"The approximate inside dimensions of the shipping container shall be 19-1/2 inches in length, 16-3/8 inches in width and 7 inches in depth. Approximate dimensions are furnished as a guide only. Each shipping container shall be closed in accordance with method III, taped in accordance with method V, and reinforced with nonmetallic strapping or pressure-sensitive adhesive filament-reinforced tape in accordance with PPP-B-636."

5.3: Delete and substitute:

"5.3 Palletization. When specified (see 6.2), heaters, packed as specified in 5.2.1, shall be pallletized on a 4-way entry pallet in accordance with load type Ia of MIL-STD-147. Pallet types shall be type I (4-way entry), type IV, or type V in accordance with MIL-STD-731. Each prepared load shall be bonded with primary and secondary straps in accordance with the bonding means C and D or film bonding F or G. A bottom pad and top pad or cap, conforming to MIL-STD-147, shall be used on each unitized load. Storage aid 29 shall be used when bonding method G is employed. Each palletized unit

PAGE 10 (cont'd)

load shall be provided with a MSDS securely attached to adjacent sides inside a clear plastic sleeve with tape or by using a self-adhering clear plastic sleeve. Pallet pattern shall be number 95 in accordance with the appendix of MIL-STD-147."

5.4: Delete and substitute:

"5.4 Marking. In addition to any special marking required by the contract or purchase order, unit packs, shipping containers, and palletized unit loads shall be marked in accordance with MIL-STD-129. Unit packs shall be clearly marked with the lot number, contract number, and the date of pack. The top of the shipping container shall be clearly marked as follows:

OPEN CAREFULLY IF USING KNIFE TO AVOID SLITTING CONTENTS"

PAGE 11

6.2c: After "4.3" add ",4.3.1".

PAGE 12

At end of document under Custodians: Delete "Air Force - 68" and substitute "Air Force - 50".

At end of document under Custodians: Add "Navy - SA".

At end of document under Review activities: Delete "Army - ME" and substitute "Army - QM".

At end of document under Review activities: Delete "DLA - GS" and substitute "DP - SS".

At end of document under Review activities: Add "Navy - MC".

Custodians:

Army - GL
Navy - SA
Air Force - 50

Review activities:

Army - MD, QM
Navy - MC
DP - SS

Preparing activity:

Army - GL

(Project 8970-0166)

APPENDIX C

MATERIAL SAFETY DATA SHEET FOR FRH

Material Safety Data Sheet

Ration Supplement, Flameless Heater (FRH), for Meal, Ready-To-Eat (MRE)

NSN 8970-01-321-9153

SECTION I

Manufacturer's Name: CAGE:

Address:

Emergency Telephone Number: (513) 772-3066 (Weekdays 8:00 am - 5:00 pm)

Date Prepared: 10 February 1992

SECTION II - HAZARDOUS INGREDIENTS

Ingredients (all are food grade material)	Weight
Magnesium (Mg) - Iron alloy Sodium Chloride, Silica, Wetting agent	8 grams per FRH
Plastic Pad (Matrix)	
Polyethylene Matrix (Ingredients dispersed throughout pad)	12 grams per FRH

SECTION III - PHYSICAL DATA

Boiling Point (F)	N/A	Specific gravity	N/A
Vapor Pressure	N/A	Melting Point (F)	1202 (Mg)
Vapor Density	N/A	Evaporation Rate	N/A
Solubility in water	N/A	Percent Volatile by Weight	N/A

Appearance and Odor: The heater element is a flat, grayish metal imbedded plastic pad consisting of the above described ingredients. The FRH system consists of the heater element packaged in a paperboard cover and is sealed within a high density polyethylene (HDPE) bag.

SECTION IV - FIRE AND EXPLOSION HAZARD DATA

Flash Point: N\A Flammability Limits: N\A LEL: N\A UEL: N\A

Extinguishing Media:

Use class-D agents at any stage of the fire (sand, MetalGuard, LITH-X, sodium chloride, sodium carbonate (soda ash), or other extinguishing agents specifically intended for Magnesium fires).

If class D agents are insufficient to cover fire the proper action to follow is dependent on the stage and size of the fire:

If detected before Mg starts to burn:
Use extinguishing agents intended for Type A, B, or C fires.

If Mg is burning (extremely intense fire with white sparks):
(1) Flood the fire with large amounts of water with a fog nozzle (not a solid stream) or foam. The fire may intensify before coming under control.
(2) Move burning material outdoors if possible, allow to burn completely or spread material out to extinguish. Individual FRH's are self extinguishing.
(3) Abandon the attack and use water to protect other structures/materials from exposure to the fire.

Special Fire Fighting Procedures:

Fire Fighters should use Self Contained Breathing Apparatus due to hazardous off-gassing from burning fiberboard and polyethylene.

Unusual Fire and Explosion Hazards:

Individual FRH's are self extinguishing. If cases of FRH are ignited, fiberboard and plastic will burn initially as a class A fire. Bulk packs (288 FRH per case) will sustain initial fire due to the fiberboard and plastic packaging. Bulk packs will transition from initial class A fire to flammable solid fire (class D) if fire is not brought under control in initial stages.

SECTION V - HEALTH HAZARD DATA

Acute Effects: [Requires exposure to FRH pad due to damaged or no packaging]

Causes eye irritation.
Causes skin irritation with prolonged contact.

Emergency First Aid Procedures:

In case of contact:
Eyes - Flush eyes with water for at least 15 minutes.
Broken skin - Wash skin with soap and water.

Carcinogenicity: Unknown

Signs and Symptoms of Exposure: Irritation of the eyes, nose or throat. Dermatitis of the skin.

Medical Conditions Generally Aggravated by Exposure: Small cuts, abrasions

Other:
Manufacturer certifies that all FRH ingredients are non-toxic, and by-products of reacted FRHs are non-toxic and harmless. See Section VII for list of byproducts.

Individual FRHs are packaged with labels warning that "Heater and its By-products are not intended for human consumption."

SECTION VI - REACTIVITY DATA

Stability: Water Activated

Incompatibilities: (Specifically Magnesium contained within FRH)

Acids, Acid Chlorides, Strong Oxidizing agents

Reacts Violently With:

Halogens, Chlorinated Solvents, Ammonium nitrate, Carbonates, Arsenic, Cupric oxide, Cupric Sulfate, Mercuric Oxide, Inorganic Phosphates

Hazardous Decomposition or By-products: If packaging is penetrated, saturation of one FRH by water slowly produces trace amounts of hydrogen gas (Max 9 liters).

Hazardous Polymerization: Will not occur

SECTION VII - SPILL OR LEAK PROCEDURES

Steps to be Taken in Case Material is Released or Spilled:

Collect spilled FRHs and inspect polyethylene bags:

- If bag is cracked, punctured, torn, or interior material is wetted, discard as waste as described below.
- If bag is undamaged, dry surfaces and repackage.

Waste Disposal Method

Used FRHs (i.e. heaters reacted with water) may be disposed of as ordinary waste.

Unused and undamaged FRHs may:

(1) Be reacted with water in accordance with instructions, then disposed of as ordinary waste, or

(2) Be incinerated in a waste facility, ensuring that all material is burned thoroughly.

Unused but damaged FRHs should be disposed of in accordance with (1) or (2) directly above. In all circumstances, FRHs must be disposed of in accordance with all applicable municipal, state and federal waste disposal regulations.

FRH byproducts (reacted with water):

Magnesium Hydroxide (Milk of Magnesia - common antacid, FDA listed food additive)
Elemental Iron (food enrichment grade - FDA listed food additive)
Polyethylene
Silicon Dioxide (FDA listed food additive)
Wetting agent (Trace amounts only - alcohol derivative, has been shown to cause diarrhea and hypoactivity)

SECTION VIII - SPECIAL PROTECTION EQUIPMENT

Fire Fighters should use Self Contained Breathing Apparatus due to hazardous off-gassing from burning fiberboard and polyethylene.

Bulk Handlers (personnel involved in handling multiple FRH either in cases or individually) must wear appropriate protective gloves.

SECTION IX - SPECIAL PRECAUTIONS

Precautions to be Taken in Handling and Storage

Warehouses where large quantities of FRHs are stored should provide:

- Protection against physical damage, especially the puncturing of cases during operation of fork lifts.
- Protection against water including leaks, snow, rain or flooding.
- Wrapping of FRH pallets to prevent water damage.
- Coverings for small quantities of FRHs (i.e. tarps, polyethylene, etc.)
- Storage in a general purpose warehouse or dry goods storage area.
- End bays reserved for the storage of FRHs where possible. Stacks of FRHs should be arranged for access to the stack's interior and/or for removal to the outdoors for fire fighting .
- Equipment for fighting Class-D and Class-A fires where FRHs are present.
- Quick response fire detection and fire fighting capabilities.
- Segregation from strong oxidizers, flammable materials or munitions.

Other Precautions:

This MSDS shall be made readily available to the local Fire Department or Emergency Response Crew in case of an emergency.

DISCLAIMER

The information, data, and recommendations contained herein are believed to be correct at the time of writing. All materials and mixtures may present unknown hazards and should be used with caution. When necessary or appropriate, independent opinions regarding the risk of handling or exposure should be obtained from trained professionals.

APPENDIX D

SYSTEM SAFETY RISK ASSESSMENT

SYSTEM SAFETY RISK ASSESSMENT
FOR THE
FLAMELESS RATION HEATER (FRH)
NSN 8970-01-321-9153

Part I

1. Item/System Identification:

The Flameless Ration Heater (FRH) is a water activated exothermic chemical heating device designed to heat the entree in the standard individual combat ration, the Meal, Ready-to-Eat (MRE). The FRH system consists of a 20 gram chemical heater pad enclosed in a paperboard cover, and sealed within a high density polyethylene (HDPE) heater bag. The heater bag functions as both an envelope for the heater pad and MRE entree during the heating reaction and as protective packaging for the heater pad during transportation and storage. The entire FRH system weighs approximately 30 grams and when activated by 40 to 50 milliliters of water, will raise the temperature of an eight ounce MRE entree by 100°F in 12 to 15 minutes, and generates 1/3 Ft^3 of Hydrogen gas.

The chemical heater pad within the FRH is a mixture of magnesium and iron powders, sodium chloride and a wetting agent, dispersed throughout a mixture of polyethylene powders and heat sintered or pressed into a porous, stable, metal imbedded polyethylene matrix. Approximately eight grams of Magnesium is contained within each heater pad.

Twelve FRHs are unit packed into a plastic shrink wrap sleeve, and 24 of these unit packs (288 FRHs total) are contained within a shipping container (bulk pack). The FRH shipping case is constructed of 350 lb test, grade V3C (weather resistant) fiberboard. One palletized load consists of 30 shipping containers and totals 8640 FRHs. Palletized loads of bulk packed FRHs are wrapped in polyethylene, covered with a top cap, and strapped to further contain the shipping cases.

2. Source Documents:

a. Safety Assessment Report for the Flameless Ration Heater, dated 16 August 1989.

b. 5th End, AMCSG, 10 April 1989, Subject: Health Hazard Assessment on the "Zesto-Therm" Chemical Flameless Heater.

c. Memorandum, AMSTE-TA-G, 3 May 1990, Subject: TECOM Independent Assessment Report for the Flameless Ration Heater.

d. System Safety Hazard Analysis Report on the Flameless Ration Heater for Meal, Ready-to-Eat, SRS Technologies, 22 March 1991.

e. Fire Hazard Testing and Evaluation of the Flameless Ration Heater, Blazetech Corporation, January 1992.

f. Material Safety Data Sheet for the Ration Supplement, Flameless Heater for the Meal, Ready-to-Eat, ZestoTherm Inc., 10 February 1992.

g. Material Safety Data Sheet for the Ration Supplement, Flameless Heater for the Meal, Ready-to-Eat, Truetech Inc., 25 February 1992.

3. Residual Hazards:

a. **Hazard Topic: Flammability of Palletized Loads of FRH bulk packs.**

(1) **Hazard Description:** Progression of a warehouse fire to the extent that it engulfs palletized bulk packs of FRHs, and penetrates through shipping cases and inner polyethylene packaging. Fire duration must be long enough so that a high enough temperature is reached to sustain the burning of the magnesium contained within each FRH. Fire would then be considered a difficult to suppress, Class D, combustible metal fire.

(2) **Hazard Classification:** Individual FRHs are self extinguishing and do not represent the hazards associated with palletized bulk packs. If palletized bulk packs are allowed to burn freely, with no attempt to control the fire, then the fire will eventually transition to a Class D fire. This hazard assumes a fire of sufficient strength is occurring with direct contact to the palletized bulk packs. This is a remote possibility. This also assumes that no attempt is made to extinguish fire, or the fire is not noticed in it's early stages. An automatic fire alarm, sprinkler system, or early visual identification of the fire would reduce the possibility of the fire transitioning to a Class D fire. The fire sequence proceeds from a Class A fire, in which the shipping cases and inner polyethylene packaging sustains the fire, to a Class D, in which the magnesium contained within the FRH heater pad starts to be consumed. Burning magnesium is identified as an extremely intense fire with white sparks. A fire at this stage is extremely distracting due to the bright flare-ups within the pockets of magnesium.

Activation of a warehouse sprinkler system will serve to extinguish any burning fiberboard and polyethylene and cool the fire below the temperature at which magnesium will burn. Water from a warehouse sprinkler system onto non-burning palletized FRH bulk packs will have minimal adverse effect due to the quality of packaging. Water onto burning FRHs in which the Magnesium is burning will not be sufficient to put the fire out, but will slow the fire till fire fighters can approach with proper equipment. With proper procedures, practices, and knowledge of the item, this hazard can be classified as a catastrophic/improbable hazard (RAC IE, Medium Risk).

(3) **Alternative Actions to Reduce Hazard Level**: As recommended in the FRH MSDS, the following precautions should be taken during handling and storage.

- Quick response fire detection and fire fighting capabilities should be available. Extinguishing the initial class A fire before the Magnesium starts to burn is much simpler, and safer than fighting the subsequent class D fire.
- End bays should be reserved for storage where possible.
- Stacks of palletized bulk packed FRHs should be arranged for access to the stack's interior and/or for removal to the outdoors for fire fighting.
- Equipment for fighting Class D and Class A fires should be available where FRHs are present.
- Storage of palletized bulk packs of FRHs should be in a general purpose warehouse or subsistence storage area and segregated from strong oxidizers, flammable materials or munitions.
- The MSDS should be made readily available to the local Fire Department of Emergency Response Crew in case of an emergency.
- Fire fighters should use self contained breathing apparatus due to hazardous off-gassing from burning fiberboard and polyethylene.

(4) **Recommendation**: It is recommended that this risk be accepted. For this hazard to be feasible, an ongoing warehouse fire must be present, the automatic sprinkler systems must fail, the fire department would have to fail to respond in a timely manner, and the palletized FRHs would have to be inaccessible for fire fighting. FRHs are not spontaneously combustible and will not initiate a fire. This hazard scenario is highly unlikely. To further reduce the hazard, all personnel associated with the bulk storage of FRHs should be properly trained, and fire department personnel should be informed of the location and proper response techniques required to fight a fire involving palletized FRHs. All information required for fire fighting and storing palletized bulk packed FRHs' is written in the Material Safety Data Sheet.

b. **Hazard Topic: Generation of Hydrogen gas during accidental activation.**

(1) **Hazard Description**: Release of sufficient quantities of hydrogen gas, which would then pose a fire hazard within a warehouse or other storage facility. For palletized loads of FRH bulk packs to present a hydrogen gas generation risk, there must be a severe amount of damage to the palletized loads. Large quantities of individual FRHs must have a breach in their packaging.

(2) **Hazard Classification**: For palletized FRH bulk packs to present a hydrogen gas generation hazard, a severe amount of damage to the palletized loads is required, specifically the puncturing or other damage to multiple FRH bulk packs, and to the heater bags contained within. Damage, severe enough to pose a hazard, would be readily identifiable to any personnel who sees the palletized bulk packs within a warehouse. The hydrogen must accumulate to pose a problem. Proper ventilation would automatically expel the majority of gases generated to the outside atmosphere and reduce the hydrogen gas hazard.

In addition to severe damage to multiple FRH bulk packs and individual heater bags, large quantities of water must be present to trigger FRH accidental activation. Possible scenarios that could lead to this type of accidental activation are flooding in excess of 5 inches, severe leakage of water through the warehouse roof, or by activation of a sprinkler system by accident or during a fire within the warehouse.

There is a limited probability that a large quantity of water could penetrate FRH shipping cases with subsequent saturation of multiple FRHs. Flooding of the storage area would have to exceed 5 inches before water would touch the base of FRH bulk pack stack. All loads of FRHs are palletized. Water leakage from the roof or a sprinkler system, saturating the palletized loads of FRH bulk packs, would present a minimal hazard. FRHs are individually sealed in a HDPE bag, unitized (packs of 12) in a plastic shrink wrap sleeve, and then packed in a shipping container constructed of weather resistant fiberboard. Presently, all FRH manufacturers are wrapping palletized FRH bulk packs in polyethylene, and are covering the tops of all palletized loads with a fiberboard cap. Intact cases of FRHs have been immersed in water for an extended period of time with no degradation in performance or activation of FRHs. Individual FRHs have been immersed for over a week without accidental activation occurring.

FRHs that have been involved in a fire and saturated with water pose a hazard from hydrogen generation that could possibly reignite the fire. Each FRH generates 1/3 Ft^3 of gas over a period of 15 minutes. Fire damaged FRHs should be continually soaked for this period of time to reduce the hazard of hydrogen gas generation. All FRHs that have been directly involved in a fire should be spread out and reacted as soon as possible after the fire is brought under control. As a safety precaution, personnel involved should be instructed to maintain a steady fog of water on the FRHs until total reaction has occurred (15 -20 minutes). Water is a natural inhibitor for the hydrogen gas fire hazard. A fog nozzle should

be used on the FRH until reaction has been completed. This will reduce the hazard associated with the gas. If the individual FRH packaging was not damaged during the fire, then the FRH will not have reacted during subsequent water saturation. All FRHs must therefore be inspected and disposed of as needed.

The guidelines for storage and handling, located in the FRH MSDS, identifies the requirements for protection of the FRHs from water damage. Specifically, the MSDS calls for the protection against physical damage to FRH bulk packs, protection against water in all forms, and wrapping of FRH pallets to prevent water damage. By following these recommendations, and by following normal warehouse storage protection procedures, this hazard can be classified as a marginal/remote hazard (RAC IIID, Low Risk).

(3) **Alternative Actions to Reduce Hazard Level:** By following the storage and handling guidelines for palletized FRHs, as described in the FRH Material Safety Data Sheet (MSDS), the level of risk associated with any of the above described scenarios will be lessened. These guidelines include:

- Wrapping of FRH pallets to prevent water damage.
- Coverings for small quantities of FRHs (i.e. tarps, polyethylene, etc.).
- Inspection for damage to stored palletized loads of FRH bulk packs and the removal/repackaging of damaged items.
- Protection against physical damage, especially the puncturing of cases during operation of fork lifts.
- Protection against water including leaks, snow, rain or flooding.
- Storage in general purpose warehouses or subsistence storage area.
- Making the MSDS readily available to the local Fire Department or Emergency Response Crew in case of an emergency.
- Disposing of damaged FRHs and the repackaging of undamaged FRHs to prevent the risk of any of the above occurrences.

(4) **Recommendation:** It is recommended that this risk be accepted. This hazard is controllable by following the storage and handling guidelines set forth in the FRH MSDS. The hazard is unlikely to occur considering the sequential occurrence of events necessary to culminate in this hazard. All events are highly visible and controllable.

Prepared by

Robert L. Trottier
Physical Scientist, Packaging
Subsistence Protection Branch
Food Engineering Directorate

Date: [illegible] 1992

Lauren Oleksyk
Physical Scientist, Packaging
Subsistence Protection Branch
Food Engineering Directorate

Date: 3 March 1992

2 March 1992

SYSTEM SAFETY RISK ASSESSMENT

Part II

There are two hazards for the Flameless Ration Heater (FRH), they are:

1. Flammability of Palletized Loads of FRH bulk packs. RAC IE Medium Risk

Individual Flameless Ration Heaters are not flammable. A Bulk pack (288 FRH) is considered flammable. A bulk pack of FRH will initially burn as a Class A fire, at this stage the packing material is sustaining the fire, if the fire is left unattended the fire will transition into a Class D fire. The FRH itself will not initiate a fire. For a FRH bulk pack to pose a fire hazard, it would require a fire of sufficient size, intensity, and duration to initiate fire in FRH bulk pack. The fire in the initial stages can be fought with Class A material (water). Activation of a warehouse sprinkler system will serve to extinguish any burning fiberboard and polyethylene and cool the fire below the temperature at which magnesium will burn. Water from a warehouse sprinkler system onto non-burning palletized FRH bulk packs will have minimal adverse effect due to the quality of packaging. Water onto burning FRHs, in which the Magnesium is burning, will not be sufficient to put the fire out, but will slow the fire till fire fighters can approach with proper equipment. If the fire is allowed to burn for an extended period of time and the Magnesium has started to burn, then the appropriate Class D fire fighting agent would be large quantities of sand.
This material will pose a slightly greater risk to store. Small (20-30 pallets) and Medium (30-100 pallets) quantities will not pose a greater risk, but should follow guidelines laid out at the end of this section. Large quantities (100 + pallets) should be:

- Stored in warehousing with an active sprinkler system.
- Broken into small lots with access between lots.
- Fire alarm for early detection of fire.
- Class D agents should be present (sand pile).
- Care should be taken to not damage the packaging.
- Damaged material should be taken out and repacked.
- End bays should be reserved for storage where possible.

2. Generation of Hydrogen gas during accidental activation. RAC IIID Low Risk

Hydrogen gas generation hazard will occur only if three actions occur:

(1) Major damage to bulk packs with individual FRH pads exposed.
(2) Large quantity of water coming in contact with Flameless Ration Heater pad.
(3) Enclosed space with no ventilation.

The FRH reaction gives off Hydrogen gas as part of the reaction (1/3 Ft^3 of gas per FRH). Each FRH is packed in a plastic sealed plastic bag, twelve FRHs are then unit packed into

a plastic shrink wrap sleeve, and 24 of these unit packs (288 FRHs total) are contained within a shipping container (bulk pack). The FRH shipping case is constructed of 350 lb test, grade V3C (weather resistant) fiberboard. The damage required to tear open enough FRHs to pose a problem is unlikely to occur during transportation or storage. An accident would possibly damage the exterior packaging, but the individual FRH packaging would protect the FRH pad. The most probable way that multiple FRHs could come in contact with water after a breach in packaging is a fire. The fire would pose a greater hazard than the limited quantities of Hydrogen given off. The danger of Hydrogen gas can be reduced by following these guidelines:

- Wrapping or covering (i.e. tarps, polyethylene, etc.) of FRH pallets to prevent water damage.
- Inspect palletized loads of FRHs for damage.
- Remove/repack damaged items.
- Disposing of damaged FRHs.

The above hazards are acceptable if the guidelines set forth are followed. FRHs are not a hazard at the unit level. Individual FRH bulk packs are not hazardous (1-4 packs). Palletized bulk packs do contain sufficient mass (Magnesium, polyethylene, packing material etc.) and bulk to pose a problem. The hazard of transporting and storing the FRH is based on the quantity on hand. One pallet of FRHs contains 31.5 lb of magnesium spread out in a 4ft X 4ft X 5ft (or 80 Ft^3) of space. Even if the Magnesium is ignited large quantities of water will put the fire out. If the quantity of FRHs on hand is large enough, breaking the large lots into smaller lots will limit the hazard exposure. A fire in a warehouse will initiate at one point and spread out from that point. FRHs, if broken into lots, will burn stack by stack therefore at any point in time sections of the fire may be in the Class A, paper and plastic etc., or Class D, metal burning, stage depending on how long the fire has gone unnoticed or with no action. The fire, if approached as a Class A, can be put out for all Class A fire sections and then Class D sections can be attacked with more emphasis. All actions assume a fire is present in sufficient size, duration without action. The highest danger from Hydrogen exists in a FRH fire situation. If FRH packaging is breached then from the time water contacts it till all hydrogen has been given off is 15 to 20 minutes. If water from sprinkler system or other source is showered on the FRHs for 30 minutes after the fire, and fire site is ventilated then the hydrogen will not pose a hazard. If the fire site is closed with no ventilation then the Hydrogen, if no water is sprayed on fire after initial quantity, will momentarily intensify the fire for 5 - 15 minutes till reaction has completed. If fire was put out, no water was subsequently sprayed, the gas would float to ceiling with eventual escape to outside. This quantity of hydrogen would be very limited and would not pose a risk greater than the normal gases from any fire.

Date: 3 March 1992

Paul G. Angelis
Chief, Installation Safety Office

The flameless ration heater presents two residual hazards but the recommendation of the Quartermaster Center and School as the user's representative is to accept the reduced risk.

The first hazard is the flammability of bulk quantities of the FRH. Individual FRHs have been subjected to a flame and the heating pad melts without sustaining a flame. The polyethylene bag that replaced the original one has a higher resistance to ambient temperatures but it burns at a lower temperature. The change was made as a result of Desert Storm lessons learned, where the original polyethylene would melt under local ambient temperatures rendering the heaters unusable. The bulk pack or more of the FRHs, when ignited, burn as a class A fire with packaging providing the fuel. If the fire is not extinguished within 20 minutes it will change to a class D fire where agents such as sand have to be used. Measures are recommended in part I and II of this document, such as stacking the FRH in areas easily accessible for fire fighting and for removal of smoldering/burning FRHs, prestocking class D fire fighting agent such as sand. Water sprinklers and water fog hose nozzles will put the fire out in the class A fire stage and will slow the fire down in the class D stage. Using a high pressure water hose with a concentrated stream on a class D fire will only spread the burning debris and spread the fire.

The second residual hazard is the generation of hydrogen gas. The hydrogen gas generated during intentional use of the FRH is of no danger if the instructions on the packet are followed. Some possibility exists that damage may occur to the pallet loads during packing, transport and forklift operations. If water would come in contact with these damaged cases, hydrogen generation would result. The water would have to be over 5 inches deep to go above the bottom of the cases resting on a pallet. Shipping the FRH in a watertight container would preclude this problem. If the moisture got into the pallet load prior to loading the container, some hydrogen generation would take place within the container. Care should be taken to sufficiently ventilate such containers prior to working in or around them when reopened. No smoking should be done in the vicinity of the FRH. Accidental hydrogen generation may be occurring. When possible the FRH in bulk should be stored in a well ventilated area to preclude buildup of hydrogen, if accidentally generated. The chain of events leading to dangerous level of hydrogen is unlikely because of the multiple packaging layers and ventilation. Generation of hydrogen can occur during fire fighting. Water used to fight the class A fire may come in contact with the fire damaged FRH and initiate the reaction. If the fire location is closed the fire will flare up until the hydrogen burns off. If the fire is put out and no further water is sprayed, the hydrogen will float up and escape into the

atmosphere. If the water is sprayed for 30 minutes and the site is ventilated the damaged FRHs will react and the hydrogen will dissipate without a problem.

Adam J. Janczewski DATE 18 MAR 92

ADAM J. JANCZEWSKI
System Safety Engineer
QMC&S, DCD

APPROVED / ~~DISAPPROVED~~

John J. Cusick DATE 31 March 92

JOHN J. CUSICK
Brigadier General, U. S. Army
Commanding

SYSTEM SAFETY RISK ASSESSMENT

Flameless Ration Heater

PART IV

I have reviewed the previous parts of this System Safety Risk Assessment and concur with the risk categories assigned to the two residual hazards. Recommendations in Parts I, II, and III to accept the risk associated with these hazards are approved.

THOMAS L. PRATHER, JR.
Major General, USA
Commanding

APPENDIX E

DEPARTMENT OF TRANSPORTATION
LETTER OF DEREGULATION

U.S. Department
of Transportation

Research and
Special Programs
Administration

400 Seventh Street S.W.
Washington, D.C. 20590

JUL 07 1992

Mr. Arnold Daxe, Jr.
Colonel, U.S. Army
Deputy Chief of Staff for Safety
Security, and Intelligence
Department Of The Army
Headquarters, Military Traffic Management Command
5611 Columbia Pike
Fall Church, VA 22041-5050

Dear Mr. Daxe:

This is in response to your letter of May 28, 1992 requesting a competent authority approval for the shipment of a flameless ration heater (FRH) shipped in full pack quantities or in single units as components of meals, ready-to-eat (MRE). In addition, information and samples were submitted on the functioning and packaging of FRHs.

Based on a technical review of a FRH single unit packed with a MRE, we have determined that this unit is not subject to the Department's Hazardous Materials Regulations (HMR). This determination is based on the small quantity of hazardous material (maximum quantity of 8 grams of magnesium powder per single unit) in relation to the total mass of each MRE package.

With regard to the shipment of full pack quantities of FRHs, it is our preliminary opinion that a substantial quantity of the hazardous material would be present, particularly in full freight container or transport vehicle shipments, and that application of the full scope of the HMR is appropriate. We recognize the importance of authorizing the shipment of FRHs in quantities other than single units and are willing to discuss our opinion further before making a final determination.

Because of the UN meetings and other commitments, the individuals necessary to be in attendance at any discussions on this subject will not be available before July 24. Please confirm this date with Joseph Herring of my staff who may be reached at (202) 366-4511.

Sincerely,

Alan I. Roberts
Associate Administrator
for Hazardous Materials Safety

APPENDIX F

DEPARTMENT OF TRANSPORTATION
EXEMPTION FOR BULK PACKED FRHs

US Department
of Transportation

Research and
Special Programs
Administration

400 Seventh Street S W
Washington D C 20590

OCT 2 6 1992

DOT-E 10897

1. U.S. Department of Defense, Washington, DC, is hereby granted an emergency exemption from certain provisions of this Department's Hazardous Materials Regulations to offer packages prescribed herein of the hazardous materials described in paragraph 3 below for transportation in commerce, subject to the limitations and special requirements specified herein. This exemption authorizes the transportation of a water reactive material in special packaging without being labeled or marked with the proper shipping name, and provides no relief from any regulation other than as specifically stated.

2. BASIS. This exemption is based on Military Traffic Management Command's application dated September 5, 1992, submitted in accordance with 49 CFR 107.113 based on a statement that it is vital to national interest.

3. HAZARDOUS MATERIALS (Descriptor and class). Flameless ration heaters (FRH), Class 4.3.

4. PROPER SHIPPING NAME (49 CFR 172.101). Substances which in contact with water emit flammable gases, solid, n.o.s.

5. REGULATION AFFECTED. 49 CFR 172.301 and 172.400.

6. MODES OF TRANSPORTATION AUTHORIZED. Motor vehicle, rail freight, cargo vessel, cargo aircraft only.

7. SAFETY CONTROL MEASURES. Packaging prescribed is as follows:

a. Each FRH is hermetically sealed in a 2.5 mil high density polyethylene bag.

b. Twelve of these units are shrink wrapped in a polyethylene sleeve.

c. Twenty-four shrink-wrapped packs are assembled in three rows of eight into a fire-retardant fiberboard box. This packaging is shown in detail in Attachment 3 to the application.

d. The gross weight of the bulk pack unit may not exceed 30 pounds.

e. Palletized unit loads of bulk pack units are strapped tightly to the pallet base, capped with weather resistant fiberboard and wrapped in polymeric stretch or shrink wrap material.

8. SPECIAL PROVISIONS.

a. A copy of this exemption must be carried aboard each cargo vessel and aircraft used to transport packages covered by this exemption.

b. Persons who receive packages covered by this exemption may reoffer them for transportation provided no modifications or changes are made to the packages, all terms of this exemption are complied with, and a current copy of this exemption is maintained at each facility from which such reoffering occurs.

c. The placarding requirements of 49 CFR Section 172.504 pertaining to Division 4.3 materials are applicable to shipments made under the terms of this exemption.

9. REPORTING REQUIREMENTS. Any incident involving loss of packaging contents or packaging failure must be reported to the Associate Administrator for Hazardous Materials Safety as soon as practicable. (49 CFR 171.15 and 171.16 apply to any activity undertaken under the authority of this exemption.)

10. EXPIRATION DATE. September 15, 1994.

Issued at Washington, D.C.

OCT 2 6 1992

Alan I. Roberts
Associate Administrator for
Hazardous Materials Safety

Date

Address all inquiries to: Associate Administrator for Hazardous Materials Safety, Research and Special Programs Administration, Department of Transportation, Washington, DC 20590. Attention: Exemptions Programs.

Dist: FHWA, USCG, FRA, FAA.

BIBLIOGRAPHY

Code of Federal Regulations, Titles 16 and 29, Office of the Federal Register, National Archives and Records Administration, Washington, DC.

Decision Coordinating Paper for the Flameless Ration Heater, USANRDEC, Natick, MA, May 1990 and September 1991.

Hanlon, J. F. Handbook of Package Engineering, McGraw-Hill Book Company, New York, NY, 1983.

The Wiley Encyclopedia of Packaging Technology, John Wiley & Sons, Inc., New York, NY, 1986.

The Merck Index of Chemicals and Drugs, Merck & Co., Inc., Rathway, NJ, 1960.

U.S. Army Natick RD&E Center, Laboratory Notebook No. 8770, Natick Form 554-1, USANRDEC Technical Library, Natick, MA, 1989.

U.S. Army Natick RD&E Center, Laboratory Notebook No. 9055, Natick Form 554-1, USANRDEC Technical Library, Natick, MA, 1991.

U.S. Army Natick RD&E Center, Planning and Accomplishment Reporting System (NPARS), MSR 1511 Self-Heating for the Year 2001 (FY89-FY90); MSR 1534 Flameless Ration Heater for the MRE (FY91-FY92).

DISTRIBUTION LIST

	NO. OF COPIES
Administrator Defense Technical Information Center ATTN: DTIC-FDAC Alexandria, VA 22304-6145	2
Technical Library U.S. Army Natick RD&E Center Natick, MA 01760-5000	4
Commander U.S. Army Natick Research Development and Engineering Center ATTN: SATNC-WTS (Laurie Oleksyk) Natick, MA 01760-5018	33
DOD Joint Technical Staff U.S. Army Natick RD&E Center ATTN: SATNC-TR/SATNC-TI/SATNC-TL/SATNC-TN/SATNC-TM Natick, MA 01760-5000	5
OASD(HA)/PA&QA ATTN: LTC Toni Hagey, AN, USA, Pentagon, Room 3D368 Washington, DC 20302-1200	1
Naval Health Research Center CODE 50 ATTN: Dr. Tamsin L. Kelly ATTN: Dr. Steven Gomez P.O. Box 85122 San Diego, CA 92138-9174	2
Commander U.S. Aviation and Troop Command ATTN: AMSAT-E/AMSAT-R-B 4300 Goodfellow Boulevard St. Louis, MO 63120-1798	2
Commander U.S. Army Test and Evaluation Command ATTN: AMSTE-EV-S/AMSTE-TA-G/AMSTE-TA-T Aberdeen Proving Ground, MD 21005-5055	3
Commander U.S. Army Cold Regions Test Center ATTN: STECR-TM APO Seattle 98733-7850	1

DISTRIBUTION LIST (CONTINUED)

	NO. OF COPIES
Commander U.S. Army Environmental Hygiene Agency ATTN: HSHB-MD-A (Mr. Gross) Aberdeen Proving Ground, MD 21010-5422	1
Commander U.S. Army Operational Evaluation Agency ATTN: CSTE-ZX 5600 Columbia Pike Falls Church, VA 22041	1
Commander U.S. Army Training and Doctrine Command ATTN: ATCD-S Fort Monroe, VA 23651	1
Commander U.S. Army TRADOC Combined Arms Test Activity ATTN: ATCT-PO Fort Hood, TX 76544	1
Commander U.S. Army Materiel Command ATTN: AMCQA-S/AMCDE-S/AMCSM-ID/AMCSF/AMCSM-W 5001 Eisenhower Ave Alexandria, VA 22533-0001	5
Commander U.S. Combined Arms Center ATTN: ATZL-TIE/ATZL-CAT-EO Fort Leavenworth, KS 66207	2
Director Defense Logistics Agency ATTN: DRSO-M/DLA-OWP Cameron Station Alexandria, VA 22304	2
Department of the Army Office of the Surgeon General ATTN: DASG-DBD/DASG-RDZ 5109 Leesburg Pike Falls Church, VA 22041-3258	2

DISTRIBUTION LIST (CONTINUED)

	NO. OF COPIES
HQDA Deputy Chief of Staff for Logistics ATIN: DALO-TST (LTC Casio) Pentagon, Room 1E 569 Washington, DC 20310-5000	1
Commander U.S. Army TRADOC Test & Experimentation Command ATIN: ABNSCTBD (ATCT-ABT-T) Fort Bragg, NC 28307-5000	1
Commandant U.S. Army Quartermaster Center and School ATIN: ACES-S/ATSM-CDT/ATSM-CDM/ATSM-CES-AF/ATSM-SFS-FM Fort Lee, VA 23801	5
Commandant U.S. Army Troop Support Agency ATIN: DALO-TAF Fort Lee, VA 23801	1
Commander John F. Kennedy Special Warfare Center ATIN: ATSU-CD-TE/ATSU-CD-ML-M/DOCD-M-L Fort Bragg, NC 28307-5000	3
Commanding General Warfighting Center ATIN: Major Puckett Marine Corps Combat Development Command Quantico, VA 22134-5080	1
Commanding General Marine Corps Research, Development & Acquisition Command Code SSC-GPB Rosslyn, VA 22209	1
HQ US Marine Corps Code LFS-4 Washington, DC 20380-0001	1
Commanding General Second Marine Division Camp Lejeune, NC 28542-5500	1
Commanding General 1st Marine Division Camp Pendleton, CA 92055-5500	1

DISTRIBUTION LIST (CONTINUED)

	NO. OF COPIES
Commander Defense Personnel Support Center ATTN: DPSC-HS/DPSC-HP/DPSC-HPPR/DPSC-HQ/DPSC-HO/DPSC-HOND 2800 South 20th Street Philadelphia, PA 19101-8419	6
HQDA Military Traffic Management Command ATTN: MTSS (Mr. Radford) 5611 Columbia Pike Falls Church, VA 22041-5050	1
PM Soldier ATTN: AMCPM-SDR (Mr. Hodges) 14050 Dawson Beach Road Woodbridge, VA 22191-1419	1
Commander U.S. Army Dugway Proving Ground ATTN: STEDP-MT Dugway, Utah 84022	1
Commander U.S. Army Belvoir RD&E Center ATTN: AMCPM-AFF/SATBE-Z Ft. Belvoir, VA 22060-5606	2
Commanding Officer Navy Food Service Systems Office 901 M Street, SE Washington, DC 20374-5049	1
U.S. Department of Transportation Office of Hazardous Materials ATTN: Chief, Exemptions & Approvals Division ATTN: Joe Horning, Exemption Department 400 Seventh St., S.W. Washington, DC 20590	2
ZestoTherm Inc. ATTN: Mr. Dave Holwadel 311 Northland Blvd. Cincinnati, OH 45246	1
TUFPAC, Inc. ATTN: Mr. Frank J. de Ramer P.O. Box 249 Ossipee, NH 03864	1