Manufacturability and Reliability of a Transportable Containerized Kitchen

A Major Qualifying Project Report:

submitted to the Faculty

of

WORCESTER POLYTECHNIC INSTITTUTE

in partial fulfillment of the requirements for the

Degree of Bachelor of Science

by

Benjamin J. Campbell– Bencamp@wpi.edu

Date: April 24,2008

Approved:

1. Combat Feeding
2. Manufacturing
3. Reliability

Professor Mustapha S. Fofana

Preface

PM FSS has life cycle management responsibility for more than 45 ACAT III programs with a total budget in excess of $0.5B over the FY08-13 years. These programs provide direct and indirect life cycle support to soldiers in virtually any environment to include training, contingency and combat operations. The programs are organized into 5 different product lines: Field Feeding Equipment, Field Services Equipment, Shelter Systems, Aerial Delivery Systems, and Force Provider. They provide a broad range of soldier sustainment capability that ensures soldiers have the proper living conditions, nutrition, supply, hygiene, and clean clothing, resulting in improved combat effectiveness.

Vision/Mission Statement:
PM FSS enhances the combat effectiveness and quality of life for the soldier by providing equipment, systems, and technical support to sustain and improve the environments in which they live, train, and operate.

Abstract

Natick Soldier Research, Development and Engineering Center in Natick, Massachusetts is a facility that is part of the United States Army and supports the warfighter by enhancing equipment systems. The Food Service Equipment Team is designing a new Containerized Kitchen (CK) and needs to get it ready for the manufacturing process. Manufacturing design analysis and reliability research were conducted in order to prepare the kitchen for manufacturability. This kitchen is 8 feet by 8 feet by 20 feet and is a standard iso container. The major cooking appliances of the kitchen were focused on for manufacturability readiness. Improvements were made in the design to prepare the kitchen for production and reduce manufacturing steps.

Acknowledgements

Gregg Gildea (Supervisor Engineer)- For all his guidance and support

Joseph Jordan (Engineer)- For all his guidance and help

Josue Diaz (Engineer)- Design help and conceptual realization

Anthony Patti (Engineer)- Knowledge of appliances and advice

Ed Clancy (Equipment Specialist)- His help with understanding the system

Douglas Brown (Engineer)- Guidance and help

Glenn Doucet (Engineer)- Guidance and help

Professor M.S. Fofana- For his dedication, guidance and advice

Table of Contents

List of Tables and Figures

Figure

Chapter 1. Introduction

The Thermal Fluid Containerized Kitchen (TFCK) is an Operational Requirements Document (ORD) driven improvement of the Containerized Kitchen (CK),. The TFCK is a theatre and field transportable kitchen that can feed a large number of troops with a minimum of setup time. The kitchen shall complete its feeding mission using onboard power only; there shall be no outside source of power required. The kitchen can support at least 800 warfighters with three meals a day. The TFCK shall provide an improved cooking environment that features restaurant style cooking appliances heated by an efficient, centralized, thermal fluid heating system. The TFCK shall require minimal logistic support and operate on JP-8, the single battlefield fuel. The system shall be setup, operated, maintained and packed for transportation by 4 personnel and a supervisor. All of the equipment necessary for holding, preparing, serving and sanitation shall be carried onboard the single 8’x8’x’20’ ISO container that houses the TFCK.

Chapter 2. Background

An in-depth understanding of how U.S Army programs function was necessary in order to be able to contribute effectively. It was also vital to gain insight into how kitchens operate and to determine commonly used components in commercial kitchens.

2.1 Organization

The Thermal Fluid Containerized Kitchen (TFCK) is the next generation field kitchen for the US Army. The kitchen is meant to be an improvement of a currently fielded system, called simply the Containerized Kitchen. The CK is manufactured by SFA manufacturing of Easton MD. The US Army purchases approximately 50 CKs per year with a total procurement goal of 742 systems. The goal is to procure the improved kitchen at the expense of the base model and fill out the requirement with the TFCK.

Figure 2.1.1 Containerized Kitchen

2.2 Process

The current Containerized Kitchen provides the US Army with a flexible, transportable, mobile, quickly deployed kitchen that can supply greater than 2400 meals per day. The CK conforms to the single battlefield fuel (JP-8) concept and uses the reliable Modern Burner Unit (MBU) as the heat engine to drive the cooking process. The CK was first fielded in 2001 and over 358 have been fielded as of March, 2007, with an Army Acquisition Objective of 742 kitchens. Each CK replaces up to three outdated Mobile Kitchen Trailers (MKTs) and also eliminates the need for one Food Sanitation Center (FSC).

The CK is completely housed in an expandable 8x8x20' ISO container. The use of this certified container allows the kitchen to be transported by air (C-130 and CH 47-D), sea (by Lighter Amphibious Re-supply Cargo 60-ton and larger), rail and ground with the 5-Ton Family of Medium Tactical Vehicles (FMTV) truck. Palletized Load System (PLS) compatibility is part of the P^3I called for in the ORD, but the lack of PLS enabled prime movers may cause CASCOM to waive the requirement. PLS compatibility has been integrated into the initial prototype to evaluate technical feasibility and allow CASCOM to make an informed decision.

The CK container travels in the folded up position and upon deployment the sides fold down to form the floors for the kitchen. The added floor space virtually triples the area in which to work. Four experienced personnel and a supervisor can assemble the kitchen in 45 minutes. All of the components necessary for cooking are contained within the ISO container. The CK can be left mounted on its trailer or placed directly on level ground before it is opened for cooking. The CK can employ up to 7 Modern Burner Units to heat a variety of cooking appliances including a griddle, stock pots, tray pack heating tank, steam tray serving table, griddle racks, and a single convection oven. It is also equipped with an electric warming cabinet and two $30ft^3$ refrigerators. The appliances on the current CK were not developed for this application but were essentially non-developmental items (NDI) that were used in previous army kitchens or commercial applications. The CK can produce 800 meals (UGR-A or UGR-H&S or any combination of the two) in 3 hours using 4 cooks and a supervisor.

The CK requires electrical power to operate. The kitchen uses up to 10kW of power. That power can be supplied by the onboard 10kW tactical quiet generator or using local commercial power. The power is necessary to supply ventilation, heating/air conditioning, MBU function, refrigeration, lighting and convenience outlets. The CK uses two air conditioners, each capable of providing up to 24,000 BTUs of cooling.

Chapter 2.3 Literary Resources

The thermal fluid appliances are organized into an appliance suite, much like a commercial restaurant kitchen. These appliances provide the user with the best commercial non-stick technology, one of the items called for in the Operational Requirements Document (ORD). The more efficient use of kitchen space allows for integration of a field sanitation center onto one wing of the kitchen platform. This integration is called for in the ORD and eliminates the need for any separate sanitation centers and the associated transportation asset. The removal of powered, open air JP-8 combustion from the kitchen makes the environment less noisy and much cooler, both of these items being called for in the ORD. The improved quality of the convection ovens allows for heating the UGR-H&S polymeric trays in the oven, thereby eliminating the need for a tray pack heating tank, the improvement of that tank being called for in the Operational Requirements Document. The use of thermal fluid technology eliminates the MBU from the field kitchen, making the kitchen environment cooler, quieter, more energy efficient, and less polluted with products of combustion. It provides a better overall environment for operators and customers.

Chapter 3. Methodology

The TFCK is currently in the system demonstration phase. An initial analysis of alternatives determined that the TFCK would share as many components with the legacy CK as possible. The air conditioner and power generating systems are identical. The main difference is the elimination of the open flame Modern Burner Unit (MBU) as the heat generating appliance. The elimination of the MBU allows for a centralized thermal fluid heating algorithm to be used that is more thermally and space efficient. An initial prototype Thermal Fluid Containerized Kitchen is being assembled at the Natick Soldier Center. That system will be tested for environmental and transportability suitability in the fall and winter 2007-2008.

Successful testing of the TFCK prototype will allow the Army to move onto the next step, having a manufacturer produce TFCKs that will more closely mirror the final product. The final product will need to meet a performance specification developed here at Natick. The Army will procure two pre-production kitchens and test them against the requirements of the performance specification. It is planned at this time to have SFA Manufacturing produce these pre-production systems based on the contract currently in place for CK production. There is a short window of time in which SFA will be able to develop these pre-production systems and it is assumed they will use the prototype now being developed at Natick as the template upon which to develop their design.

What is needed is a study on ways to improve the manufacturability of the TFCK. The current prototype uses a mix of commercial items (the thermal fluid heating system, DIN 14505 compatible container, 10kW generator, refrigerators, etc) combined with prototyped equipment (steam generator, steam distribution system, exhaust gas ventilation system, etc). These prototyped items are labor and cost intensive and it is not feasible to manufacture the pre-production systems in the same manner as the prototype. A manufacturing analysis is to be conducted that will determine the best way to manufacture the pre-production TFCKs. The study will be conducted in a step wise manner, concentrating first on high risk areas that require the most change from the prototype to the next level of production.

The first step of the study will concentrate on the cooking appliances used by the TFCK. The prototype system uses modified commercial cooking appliances. These items were purchased and modified in the 1990s for a previous effort to build a thermal fluid kitchen. The appliances were of the electric heating style, using serpentine electrical resistive heating coils to provide heat to the cooking surface or cavity. The TFCK calls for removing the serpentine coil and replacing it with a serpentine tube that carries the hot thermal fluid. The manufacturability study will identify suitable appliance candidates and determine ways to modify these appliances that are cost and performance effective.

Figure 3.1 Kitchen Appliances

The second step of the study will be to determine the best way to manufacture the steam creation and distribution system. The TFCK uses steam as a means of secondary appliance heating. The thermal fluid system has no user accessible connections because of the need to prevent leakage. The thermal fluid is used to create steam and the steam is piped through user accessible connections to appliances where it is used as the heat transfer medium. This steam creation and distribution system is labor and cost intensive. The manufacturability study should focus on this steam system and determine the best way the system can be produced and inserted onto the TFCK pre-production systems.

Chapter 4. Define

Research had to be performed on the Thermal Fluid Containerized Kitchen in order to define what would be required for a manufacturability improvement. For example, the research was executed on past efforts for the CK, research was performed on other existing kitchens that provide food for a large quantity of people, and the layout of the kitchen was examined.

4.1 Efforts

The modernization strategy is a three tiered effort to include: 1) Transportability improvement, 2) Short term upgrades to the currently fielded system, and 3) Long term efforts to incorporate an improved heating system and sanitation function within the CK. The current layout dedicates one third of the floor space to the serving line.

Design changes to the current CK are focused on the equipment layout and appliances. A water heater located in the mechanical room will decrease the heat introduced into the work environment. The revised layout will provide 40% more room for meal preparation in addition to improving the work flow. Modification to the ventilation system will improve heat removal while decreasing the amount of dust infiltration. This will be accomplished by over-pressurizing the work space with filtered air, expelling heat and keeping dust from being drawn in. Although major improvements can be achieved, this version will still employ the MBU and the modifications will be relatively simple and result in minimal cost increases.

Updating the older trailers to the current configuration would improve overall transportability, eliminating the need for special handing and shoring currently required for shipment by military aircraft. The current configuration includes a recessing landing leg and rear folding step that eliminates interference with aircraft ramps. Transportability improvements are necessary to eliminate the need for shoring when loading the initial version of the CK w/trailer on C-130 aircraft. The improvements have been incorporated into the production line; however, there are a number of fielded trailers that are unimproved.

4.2 Other Large Capacity Kitchens

Other large capacity kitchens were examined to compare the layouts of the kitchens and what components were used in the kitchen. Several different restaurants were visited to observe the functions of large kitchens. It was noted how they were worked and where the components were in relation to each other.

4.3 Current Layout

The current layout of the TFCK is a task that needs to be accomplished for manufacturability purposes. Refer to appendices A for current layout. The layout is ideal for the human interaction and providing food to the soldiers, but it is not practical for manufacturing. The space that is used to have the ovens, kettle, skillet and griddle is a very compact space. The only way at this point to get commercial double-stacked ovens to fit in the provided space is to do some significant modifications to it. The controls on the side of the oven need to be taken off and moved to the middle of the oven to provide the kettle ample area to perform its tasks. This means when a commercial oven is purchased and integrated into the TFCK the modification process by the manufacturer will be significant with time and labor hours. (Refer to Figure 4.3.1 for current layout).

In depth research was performed to attempt to find a commercial oven manufacturer that had controls on the middle of the double-stacked ovens or would be willing to modify the ovens. Several were contacted but none were able to meet the footprint requirement. None of the companies contacted found it feasible to alter there manufacturing line to place the controls in between the ovens versus on the sides. This was an issue that would not be able to be rendered by the producers of the commercial ovens.

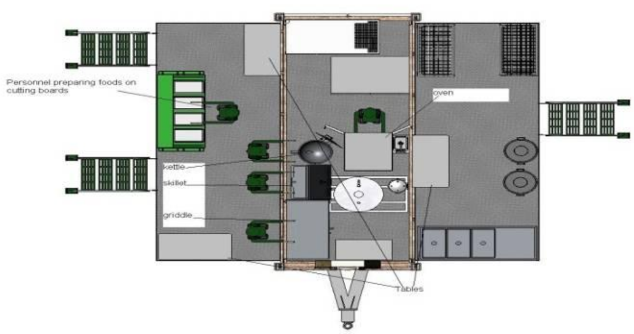


Figure 4.3.1 Lay-out of Containerized Kitchen

4.4 Transportability Specifications

The performance specifications for transportability were examined in depth to get an understanding of what is required for transportation. They are listed as follows:

1. Rail. The CK shall be capable of rail transportation without damage or degradation to the CK system or its trailer, and without damage to internal fastening devices (e.g., tiedown cables, blocking, or bracing)

2. Fixed wing. The CK shall be transportable in C-130 and larger Air Mobility Command (AMC) aircraft.
3. Helicopter Sling Load (HSL). The CK, mounted on its trailer, shall be capable of being externally transported (sling loaded) by a DoD CH-47D rotary wing aircraft. The CK/trailer combination shall be structurally capable of meeting the requirements of interface standard MIL-STD-209 and shall show no signs of damage or degradation as a result of aerial transportation.
4. Ground mobility. The CK, mounted on its trailer, shall be capable of transportation over primary roads, secondary roads, and cross-country terrain. The CK shall withstand the shocks and vibrations encountered in ground transportation without damage or degradation to the system.
5. Forklift. The CK, in transportation mode, shall be capable of being lifted onto and off of its trailer by a forklift without damage or degradation to the CK or its forklift provisions. The CK shall have forklift pockets for both loaded and unloaded containers which conform to the dimensions of forklift pockets specified in ISO Standard 1496-1.

Some tests that dealt with the transportability performance specification are listed below.

1. Rail test. Test the CK in transportation mode, with and without its trailer, in accordance with test method standard MIL-STD-810, Method 516.4, Procedure VIII, rail impact. Upon completion of the test, verify that the CK has no damage that renders it unsuitable for use.
2. Fixed wing test. Test the CK in transportation mode to determine suitability for fixed wing transportation. Upon completion of the tests, verify that the CK has no damage that renders it unsuitable for use.

3. Helicopter Sling Load (HSL) test. Test the CK in transportation mode, with its trailer, for compliance with MIL-STD-209 using a CH-47D helicopter. Upon completion of the test, verify the CK has no damage that renders it unsuitable for use. Certification that the CK meets the requirements for movement by CH-47D helicopter shall be obtained from the U.S. Army Natick Soldier Systems Center.
4. Ground mobility test. Test the CK/trailer combination by transporting it over 3000 miles of road courses simulating 30% primary roads, 65% secondary roads, and 5% cross country travel. After every 500 miles of ground mobility testing, set up the CK, inspect it for signs of damage, and verify that all components are still functional. After 3000 miles, set up the CK and operate it for a simulated meal.
5. Forklift test. Examine the CK to have forklift pockets that conform to ISO dimensional requirements for both loaded and unloaded containers. Using a forklift, lift the CK in transportation mode four feet off the ground for ten minutes. Then, lower the CK to a height of one foot above the ground, and move it 50 feet forward and 50 feet back. Repeat this process for each set of forklift pockets. Inspect the CK for damage and deformation. Minor abrasions caused by the forklift tines do not constitute failure of this test.

After investigating the current testing process for transportability it was important to take a look at what might affect the testing of the transportability specifications.

The issues that were found:

- Parts becoming loose during transport.
- The weight distribution being disproportionate throughout the CK.
- The integrity of the ISO container being compromised.

- The manufacturability issues with the location of the kettle and the postioning of the ovens.
- The drain hose for the kettle includes some ceramic material in the design.
- The frame for the griddle, kettle, and skillet allows for water to build up in the framework.

4.5 Anticipated Improvements for the TFCK

An increase in storage capacity to maintain perishable components for a 1,600 Army field menu (A-Ration) items, the TFCK will meet the minimum of 54 cubic feet of refrigeration. Improved field ovens to incorporate convection capability and to reduce the by-products of combustion, the TFCK uses modified commercial convection ovens. These ovens provide superior temperature control than the current burners allowing the cooks to different meal types in the oven. The TFCK uses two ovens in a top and bottom configuration, because the vertical space limitations of the burner fired ovens are eliminated. Also, improvements to the tray pack heater cabinet will be made. This eliminates the need for a tray pack heater tank, it was a tank filled with water that was boiled to prepare food. The commercial appliances that will be implemented will fill this need. The dual ovens provide more space for heat and serve rations and the skillet and the kettle combination provides two boiling-water appliances.

The incorporation of nonstick surfaces for cooking equipment as it becomes available, which the TFCK uses modified commercial appliances. The thermal fluid system also operates at a maximum temperature of 550 degrees Fahrenheit allowing the selection of non-stick surfaces that cannot withstand the high temperatures of an open flame combustion produced by the previously used burners.

One of the greatest benefits of the using the thermal heating centralized system is the increase in thermal transfer efficiency. The burner unit transfers 30 percent of the heat created to the appliance; the rest is lost to the kitchen environment. Thermal-fluid heating system transfers at least 70 percent of the heat created to the appliance, greatly reducing the temperatures inside the kitchen working environment. The thermal fluid system only requires one burner to be used which enables the system to be much quieter than the previous system. The combustion is contained within the combustion chamber, greatly reducing the noise in the kitchen.

The system also integrates the sanitation center capability on board, eliminating the need to bring a separate sanitation center with the kitchen. The TFCK uses an appliance suite that minimizes the room necessary to complete the cooking function. This allows for an organic sanitation center to be inserted onto the kitchen platform. The sanitation center requires hot water, and the necessary heat is supplied by the thermal fluid heating system. This capability of the onboard sanitation center reduces logistical requirements by no longer having to transport the additional sanitation center. The sanitation center also recycles water from the sanitation sinks which saves approximately 60 gallons of water per day.

4.6 Use of a Thermal Fluid System

Using a thermal fluid as the heat source in a military kitchen provides superior ration preparation algorithms. Thermal fluid heating provides more controlled and even heating to appliance surfaces and cavities. The heat transfer mechanisms are much more efficient than open combustion heating. This means more of the heat produced gets transferred to the rations and less to the kitchen environment. That results in a much cooler and quieter kitchen than currently possible. This program will integrate thermal fluid heating and six other major improvements called for in the ORD into a Thermal Fluid Containerized Kitchen (TFCK). (Refer to figure 4.5.1

for Thermal Fluid system).

Figure 4.5.1 Thermal Fluid System

The technical approach will leverage appliances that were incorporated into the Marine Rapid Deployment Kitchen (MRDK). The MRDK was a portable, thermal fluid heated kitchen developed for the Marines that used commercial thermal fluid appliances. Using the tested, commercial appliances from the MRDK saves the TFCK assembly team money and time and ensures high-level reliability and supportability metrics. Additional components for TFCK assembly (generator and ECU) were obtained from other prototype kitchens.

The TFCK incorporates a commercial, pallet mounted thermal fluid heating system. This system features a highly efficient 3-pass combustion chamber that allows for 500K BTUs of heat to be provided to the cooking appliances while occupying the minimal volume available in the container. The system is robust and uses a commercial residential burner to maximize reliability and supportability. The contract for the thermal fluid system was awarded to GTS Energy, Inc of Atlanta. The TFCK will contain a food sanitation center. The components of the center were leveraged from the AF Single Pallet Expeditionary Kitchen, again saving design time and money. Onboard sanitation significantly reduces the logistics footprint for field feeding because a separate sanitation center and its associated transportation asset are no longer necessary. Refer to appendices C for thermal fluid system.

The thermal fluid that is used has a lower heat transfer viscosity, which requires less energy to pump the fluid through the system. The thermal fluid is non-toxic and it carries an incidental food contact rating. Where conventional fluids can produce dermatitis, the fluid is not expected to cause skin irritation on contact. And unlike other heat/cool liquids, the fluid emits no pungent or noxious odors. It is plant friendly and safe to use. In the event of a release, the simple clean-up procedures used for spills of light lubrication oils can be employed. It can be recycled at a local oil recycler which is also a great benefit to using a thermal fluid system.

Chapter 5. Analyze

Additional research was needed in order to data was needed in order to depict where the manufacturing processes could be improved. In addition the materials and the manufacturing of the main cooking components were examined. This will allow a centralized focus on what issues create the greatest opportunity for improvement.

5.1 Analyzing the components

All the major cooking components were analyzed in the TFCK and were looked at to see if any possible further investigation would yield possible improvements. Refer to appendices B for appliance placements. The major components that will be closely examined are the griddle, the skillet, the kettle and the ovens. Eliminating unnecessary material and steps in the manufacturing process. Also the possibility of other commercially available products that would improve the current design and layout will be researched. The accessories also are a major factor in space and components for the kitchen. Refer to appendices D for the list of kitchen accessories.

Figure 5.1.1 Kitchen Components

5.2 Evaluating the Griddle and Skillet

First the Griddle and Skillet will be evaluated to see if there any significant opportunities for improvement. The griddle is a standard piece of steel with a serpentine running underneath it with the thermal fluid traveling throughout it. Commercial suppliers were contacted to see if there were any viable alternatives to the current griddle. No immediate improvements were discovered. The skillet was examined for possible improvements that could be done. The frame work that supports the skillet appears to have some alternative design improvements. For example, one might redesign the base so that the frame work matches with the base of the griddle support frame. This would prevent any build up of unwanted objects.

Figure 5.2.1 (Left) Griddle Appliance
Figure 5.2.2 (Right) Skillet Appliance

5.3 Evaluation of the Ovens and Kettle

The ovens and the kettle were evaluated next for any significant improvement opportunities. The most apparent issue with the ovens is that there is not enough space to purchase a commercial oven and have it fit in the available space. The current design involves removing the oven controls from the side of the ovens and positioning in between the two ovens to allow the ovens to fit in the available space. Refer to appendices L for oven dimensioning.

The kettle seems to be positioned in an ideal spot for the cook in the oven to use. The drain hose on the kettle is made with some ceramic material which would not be suitable for rough transport and durability issues may arise.

Figure 5.3.1 (Center) Double stacked ovens

5.3.1 Direct Investigation

After direct investigation into the design of the kettle layout it was discovered that the welding and draining to allow a greater amount of space for other components in the area.

5.3.1.1 Rework Area

The kettle redesign consisted of the point of weld on which the hinge of the kettle was on the radius. This allowed for the base of the kettle to be move forward to maximize the allotted space given for the kettle. With the kettle moving forward then the wall behind the kettle could proceed to move forward as well. The drain on the kettle became angled towards the skillet component which allowed better accessibility to the drain.

5.3.1.2 Space Altercations

The impact that this had on the area that was designated for the oven was it allowed six more inches of space for the oven footprint. Due to the wall being moved forward six inches. The effect it had on the griddle and the skillet were minimal with the components remaining in the same location with no space gained or no space removed. Therefore, this created more area for the ovens while not have a negative impact on the other components.

5.3.1.3 Operation Area

The operation area for the user of the major kitchen components was altered slightly with the angle in which the framing around the kettle changed. However, this did not affect the mobility of the personal using the components nor would it take away critical space for the preparation of food.

5.4 Characteristics of Kitchen

The single burner heats a thermal fluid, called Paratherm MG, that is pumped throughout the kitchen appliances that provide heat. Refer to appendices F for Paratherm MG comparasion and appendices G for Paratherm MG material safety data sheet.

- The thermal fluid system consists of a burner, combustion chamber, pump and piping
- The thermal fluid system is purchased commercially. The burner provides 625K BTU/hr of heat.
- The fluid is heated to 550°F and pumped under low pressure through each appliance. The fluid gives off its heat to the food contained in the appliance (oven, griddle, skillet, etc)

  Each appliance temperature is user controlled, set and forget.

The kitchen is designed to use a dual oven, a skillet, a large griddle, jacketed kettle and an instantaneous hot water spout. Refer to appendices H, I, and J for 3d drawings. These are commercial or modified commercial appliances that offer great flexibility in meal preparation. The TFCK also provides food refrigeration and effective air conditioning, space heating and ventilation systems. The new kitchen incorporates a sanitation center onto the platform. That means that the food sanitation center that currently accompanies each legacy CK is no longer necessary. The new kitchen shall cost the same as the legacy system plus its dedicated sanitation center. The kitchen is designed to prepare 800 rations, both UGR-A and/or UGR–H&S, within a 3-hour period. The food is served from the kitchen platform or brought to the field to supply remote field units. Refer to appendices E for operating requirements.

Chapter 6. Improve

Several recommendations were made for improvements in this particular manufacturability readiness process. For example, the kettles design altercations were recommended for this process. The drain system on the kettle that was currently used was a rigid polyvinyl chloride. A new material was chosen and implanted for the drain system, a flexible rubber hose made out of black Plioflex Synthetic Rubber. Refer to appendices K for drain hose specifications. The dual stacked ovens were researched and one was identified that would meet the performance requirements and fit in the allotted space for the ovens. There were also changes made to the framework that supported the major cooking appliances.

6.1 Modifying the Kettle

6.1.1 Pre-Modification

Currently the lid on the kettle opens directly backwards up against the wall that separates the kettle, skillet and the griddle from the thermal fluid system and the location of the ovens. The hinge on the lid is welded on and opens fully to form a ninety degree angle. Measurements were taken to determine whether the lid could open up at a different angle without creating an obstacle for the user of the kettle. Measurements were also taken to see if the point of drainage on the kettle could be altered and also evaluations were performed for ease of use when accessing the drain release on the kettle. Refer to appendices M for re-design view.

Figure 6.1.1.1 Kettle Front view

6.1.2 Reasoning for Modification

The reasoning for the modification to the kettle is to allow the base of the kettle of move away from the wall creating six more inches of space behind the kettle. This extra six inches of space allows the wall to move away from the ovens and closer to the kettle. This gains six inches of space for the area the ovens are to be placed. The controls that are currently in between the ovens require five inches of space to be able to function properly.

Figure 6.1.2.1 Oven controls

This is a significant modification to the commercially purchased ovens to put the controls in the between the ovens. However, with this additional space gained it allows the ovens to forego any significant modifications to fit in the allotted space given. The new step that is added to modify the kettle was already in place with welding the hinge to the lid of the kettle to the basin of the kettle.

Figure 6.1.2.1 View of oven location in relation to kettle

6.1.3 Improvements from Modification

The implementation of the modification will reduce significant steps and labor costs in the manufacturing process of integrating the double stacked oven into the Thermal Fluid Containerized Kitchen. This allows a commercial oven to be purchased and immediately integrated into the system. Also it does not introduce any new significant process into the assembly of the kitchen.

6.2 Drain Hose

After viewing the drain hose for the kettle it was evident that the hose could be subject to reliability issues during the life cycle of the kitchen. The drain hose was currently made out of a rigid PVC material and would be subject to significant vibrations and rough handling during transport of the containerized kitchen. Different types of drain hoses were researched to find a viable option that would be suitable for use in a kitchen environment. A rubber discharge hose was identified to replace the PVC drain system that was currently in place. The hose material consisted of a Black Plioflex Synthetic Rubber. This would enhance the durability of the drain hose and improve the reliability of the overall kitchen system.

6.3 Improvements Still In Progress

6.3.1 Frame strength of Container

Each kitchen system that produced relies on the integrity of the container that the system is housed in to endure the life cycle of all of the components inside. The iso container must withstand rigorous transport methods and system use conditions. The framing of the container is constantly being put under great stress during transport and vibrations as it is gets picked up by cranes and helicopters, carried in planes, trains and large transport vehicles. The structure must be able to withstand all of these rigors overtime. A planned analysis of the structure stresses and cross-sectional supports will be conducted to find the optimal support for the container.

6.3.2 Framework Surrounding Appliances

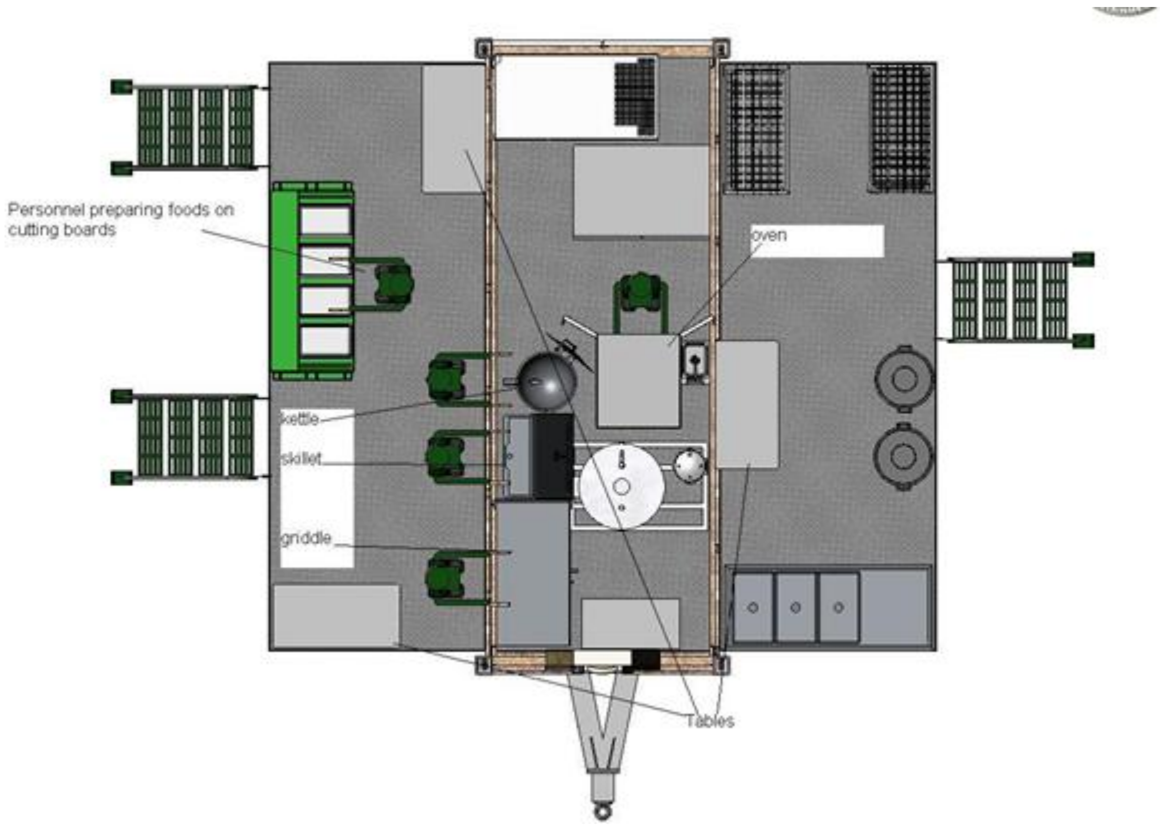
It is necessary to evaluate the frame structure that supports the kitchen appliances. Testing is going to be conducted at Aberdene, Maryland proving grounds for reliability issues during transport. Stress analysis calculations are to be performed on the framing to determine if any issues arise from the stress put on the structure during transport and use.

Chapter 7. Conclusion

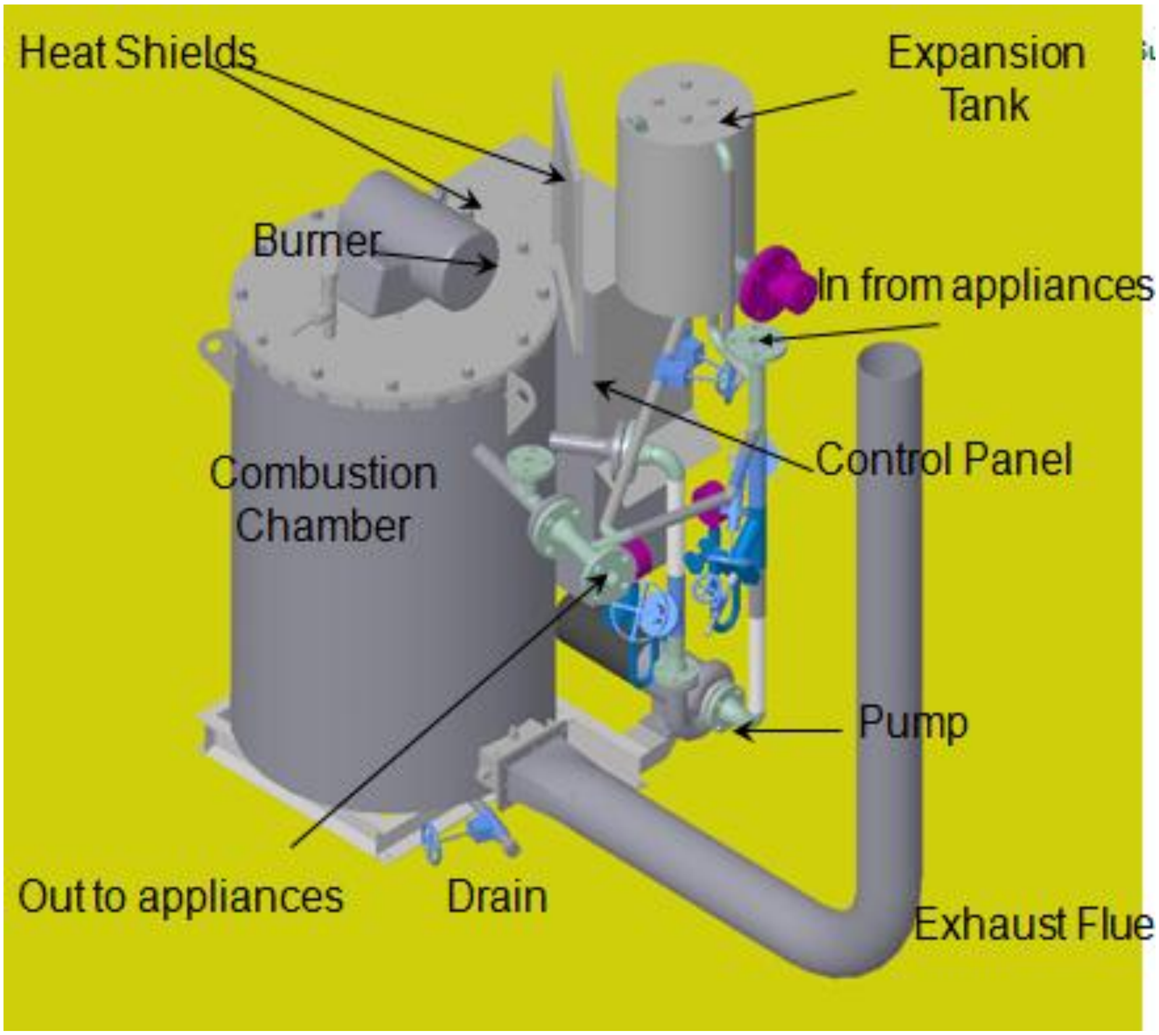
With the redesigning of the kettle it prevented other significant altercations that would have to be performed on other appliances to meet the space requirements.   Some minor changes were suggested and incorporated to potential increase the reliability of the kitchen. One of the changes was the material used for the drain pipe was rigid and had the potential to deteriorate over time. A more reliable flex hose was researched and implemented in the kitchen. With these changes the cost reduction will be significant with production labor and material reduced. Overall the project was a success by aiding in the design changes for manufacturability readiness.

Appendices

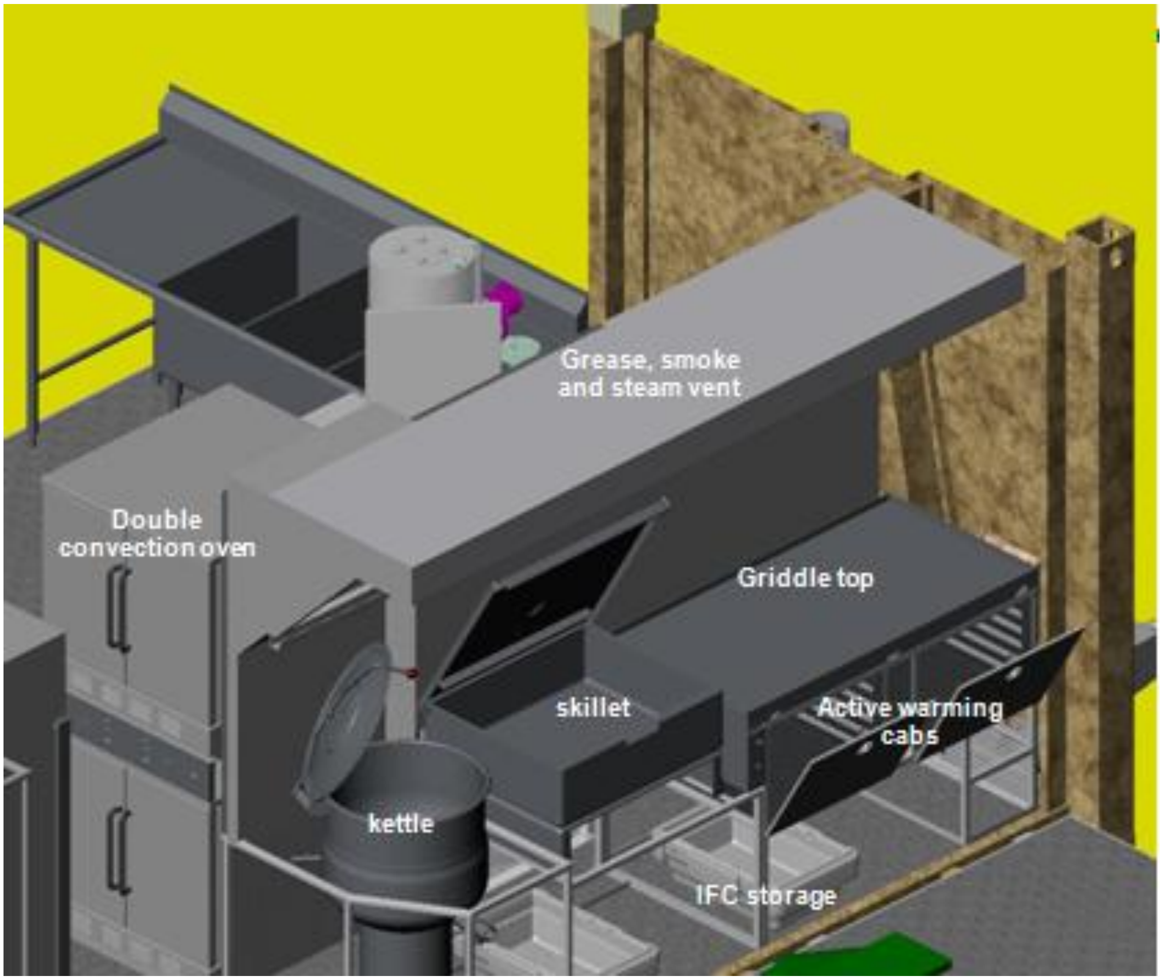
Appendix A: Current design layout



Appendix B: Thermal Fluid System



Appendix C: Appliance Placements



Appendix D: Kitchen Accessories

MIL-PRF-32026(GL)

TABLE II. Contractor-furnished NSN items

Item #	Description	Quantity	NSN
1	Cook pot cradle assembly	2	7330-01-248-9964
2	Cooking rack assembly	4	7310-01-048-2184
3	Griddle top	1	7310-01-388-6591
4	Heater tank, tray pack	1	7360-01-248-6041
5	Oven, field	2	7310-01-388-6606
6	Steam table body and adapter top	1	7310-01-388-6578

TABLE III. Contractor-furnished kitchen accessories

Item #	Description	Quantity	NSN*
1	Beverage dispenser, 5-gallon	8	7310-01-245-6937
2	Board, food slicing and chopping	2	7330-01-078-5706
3	Can, water, plastic, 5-gallon	6	7240-00-089-3827
4	Can opener, hand	2	7330-01-245-0201
5	Colander, SS, 16-quart	1	7330-00-266-7453
6	Dipper, 32-ounce	4	7330-00-272-2489
7	Eggwhip	2	7330-00-815-1458
8	Fork, 15-inch	4	7340-00-223-7791
9	Fork, 21-inch	4	7340-00-223-7792
10	Ice cream scoop, size 6	4	7330-00-197-1280
11	Insulated food container	16	7360-01-408-4911
12	Knife, boning, 10-inch	3	7340-00-197-1271
13	Knife, cook's, 14.5-inch	3	7340-00-488-7950
14	Knife, paring, 7-inch	4	7340-00-488-7939
15	Knife, steak, 10-inch	3	7340-00-197-1274
16	Ladle, 8-ounce	4	7330-00-248-1153
17	Measuring cup, 4-quart	2	7330-00-264-5368
18	Measuring set, spoons	2	7330-00-272-7876
19	Pan, baking and roasting, with cover	4	7330-00-263-8504
20	Pans, baking, full size	10	
21	Peelers, potato, hand	3	7330-00-238-8316
22	Pot cooking, 10-gallon, with cover	3	7330-00-292-2306

Appendix E: Operating Requirements

3.2 **Operating requirements**.

3.2.1 Transportation mode. When configured for transportation, the CK shall be sheltered in an 8-foot by 8-foot by 20-foot ISO container with forklift pockets (see 3.4.1.5). The CK shall meet all ISO freight container requirements related to cargo containers, including a six-high stack, and shall meet Coast Guard requirements for safe containers. In transportation mode, the CK shall meet all transportability requirements (see 3.4.1).

3.2.2 Operational mode. When configured for food preparation, the CK shall have food preparation and serving areas protected from natural elements of the environment. All food preparation equipment, the electrical supply, the environmental control system, and all related controls and instruments shall be mounted inside the CK. Sheltered floorspace shall be sufficient to perform all necessary food preparation and serving tasks, with a minimum of 390 square feet (see 6.13).

3.2.3 Meal preparation. The CK shall have a capability to prepare and serve a minimum of 550 Army field menu meals (A-Ration, Heat and Serve Ration, or any combination, see 6.8) up to three times per day. The CK shall enable cooks to prepare a meal (A-Ration) in less than three hours. The CK shall have the capability to prepare and serve meals while mounted on a towed trailer (see 6.10) and while dismounted.

3.2.4 Set up and tear down. The CK shall require not greater than 45 minutes to set up and not greater than 45 minutes to tear down by a crew of four personnel and a supervisor. If set up or tear down procedures require electrical power, backup provisions shall be provided to manually perform these tasks without power.

3.2.5 Integrated equipment. The CK system shall integrate the Government Furnished Equipment (GFE, see 6.2) listed in table I, the contractor furnished National Stock Number (NSN) items listed in table II, and the contractor furnished kitchen accessories listed in table III. Equipment in table II may be modified to meet performance or other requirements. The stock numbers listed in table III are included for reference only; all items shall be commercial food-service quality and functionally equivalent to the NSN items listed, but the source of supply does not have to be GSA.

Appendix F: Paratherm MG Comparisons

	Paratherm NF		Paratherm MG		Water		Motor Oil		Milk	
							SAE 30			
	Viscosity		Viscosity		Viscosity		Viscosity		Viscosity	
Temperature	cP	cSt	cP	cSt	cP	cSt	cP	cSt	cP	cSt
-25°F	-	-	57.3	68.1	ice	ice	-	-	-	-
0°F	1148	1296	25.3	30.5	ice	ice	-	-	-	-
70°F	40	46	5.7	7.2	1.00	1.00	352	440	3.2	4

Appendix G: Paratherm MG Material Safety Data Sheet

Material Safety Data Sheet

Paratherm Corporation
Paratherm MG™ Military Grade Heat Transfer Fluid

I. PRODUCT IDENTIFICATION

Manufacturer	Paratherm Corporation
Address	4 Portland Road West Conshohocken, PA 19428 USA
Trade Name	**Paratherm MG™**
Revision Date	July 24, 2004
Emergency Telephone No.	610-941-4900
Chemtrec (USA)	800-424-9300
Chemtrec (outside USA)	703-527-3887

CAS Number: Proprietary Hydrocarbon
NFPA Hazard Indentification

Degree of Hazard	Hazard Ratings
	0—Least
Health: 0	1—Slight
Fire: 1	2—Moderate
Reactivity: 0	3—High
	4—Extreme

II. INGREDIENTS

COMPONENT NAME	HAZARDOUS IN BLEND	PERCENTAGE	COMPONENT EXPOSURE LIMITS	UNITS
Hydrocarbon A	No	100	OSHA PEL ACGIH TLV	None established (see item III below) None established (see item III below)

III. HEALTH EFFECT INFORMATION

ACUTE EFFECTS

EYE CONTACT
May cause mild irritation on direct contact.

SKIN CONTACT
Paratherm **MG** heat transfer fluid is not expected to cause any skin irritation upon direct single or repeated and prolonged contact.

INHALATION
Caution should be taken to prevent aerosolization or misting.

INGESTION
Ingestion is non-toxic unless aspiration occurs. See Chronic Effects Section below.

CARCINOGENICITY
NTP: No IARC: No OSHA: No

CHRONIC EFFECTS

On rare occasions, prolonged and repeated exposure to oil mist poses a risk of pulmonary disease such as chronic lung inflammation. This condition is usually asymptomatic as a result of repeated small aspirations. Shortness of breath and cough are the most common symptoms. Aspiration may lead to chemical pneumonitis, which is characterized by pulmonary edema and hemorrhage, and may be fatal. Signs of lung involvement include increased respiration rate, increased heart rate, and a bluish discoloration of the skin. Coughing, choking, and gagging are often noted at the time of aspiration. Gastrointestinal discomfort may develop, followed by vomiting, with a further risk of aspiration.

IV. EMERGENCY & FIRST AID PROCEDURES

EYE CONTACT
If fluid is hot, treat for thermal burns and take victim to hospital immediately.

SKIN CONTACT
If fluid is hot, submerge injured area in cold water. If victim is severely burned, take to a hospital immediately.

INHALATION
Paratherm **MG** heat transfer fluid has a low vapor pressure and is not expected to present an inhalation hazard at ambient conditions. If vapor or mist is generated when the fluid is heated or handled, remove victim from exposure. If breathing has stopped or is irregular, administer artificial respiration and supply oxygen if it is available. If victim is unconscious, remove to fresh air and see medical attention. **Do not use compressed oxygen in hydrocarbon atmospheres.**

INGESTION
Do not induce vomiting. Drink plenty of water. Do not give anything to an unconscious victim. Seek medical attention immediately.

V. PERSONAL HEALTH PROTECTION INFORMATION

EYE PROTECTION
Eye protection is not required under conditions of normal use. If the fluid is handled such that it could be splashed into the eyes, wear plastic face shield or splash-proof safety goggles.

SKIN PROTECTION
No skin protection is required for single, short duration exposures. For prolonged or repeated exposures, use impervious synthetic rubber clothing (boots, gloves, aprons, ect.). If handling hot fluid, use insulated protective clothing.

RESPIRATORY PROTECTION
Respiratory protection is not required under conditions of normal use. If vapor or mist is generated when the fluid is heated or handled, use an organic vapor respirator with a dust and mist filter. All respirators must be NIOSH certified. **Do not use compressed oxygen in hydrocarbon atmospheres.**

VENTILATION
If vapor or mist is generated when the fluid is heated or handled, adequate ventilation in accordance with good engineering practice must be provided to maintain concentrations below the specified exposure or flammable limits.

VI. FIRE PROTECTION INFORMATION

FLASH POINT		300°F (149°C)	**TEST METHOD** ASTM D92
FLAMMABLE LIMITS IN AIR (% BY VOL).	LOWER	No data	
	UPPER	No data	

EXTINGUISHING MEDIA
Use dry chemical, foam, water fog, or carbon dioxide.

SPECIAL FIRE FIGHTING PROCEDURES
Water may be ineffective but can be used to cool containers exposed to heat or flame.

UNUSUAL FIRE AND EXPLOSIVE CONDITIONS
Dense smoke may be generated while burning. Carbon monoxide, carbon dioxide, and other oxides may be generated as products of combustion.

VII. REACTIVITY DATA

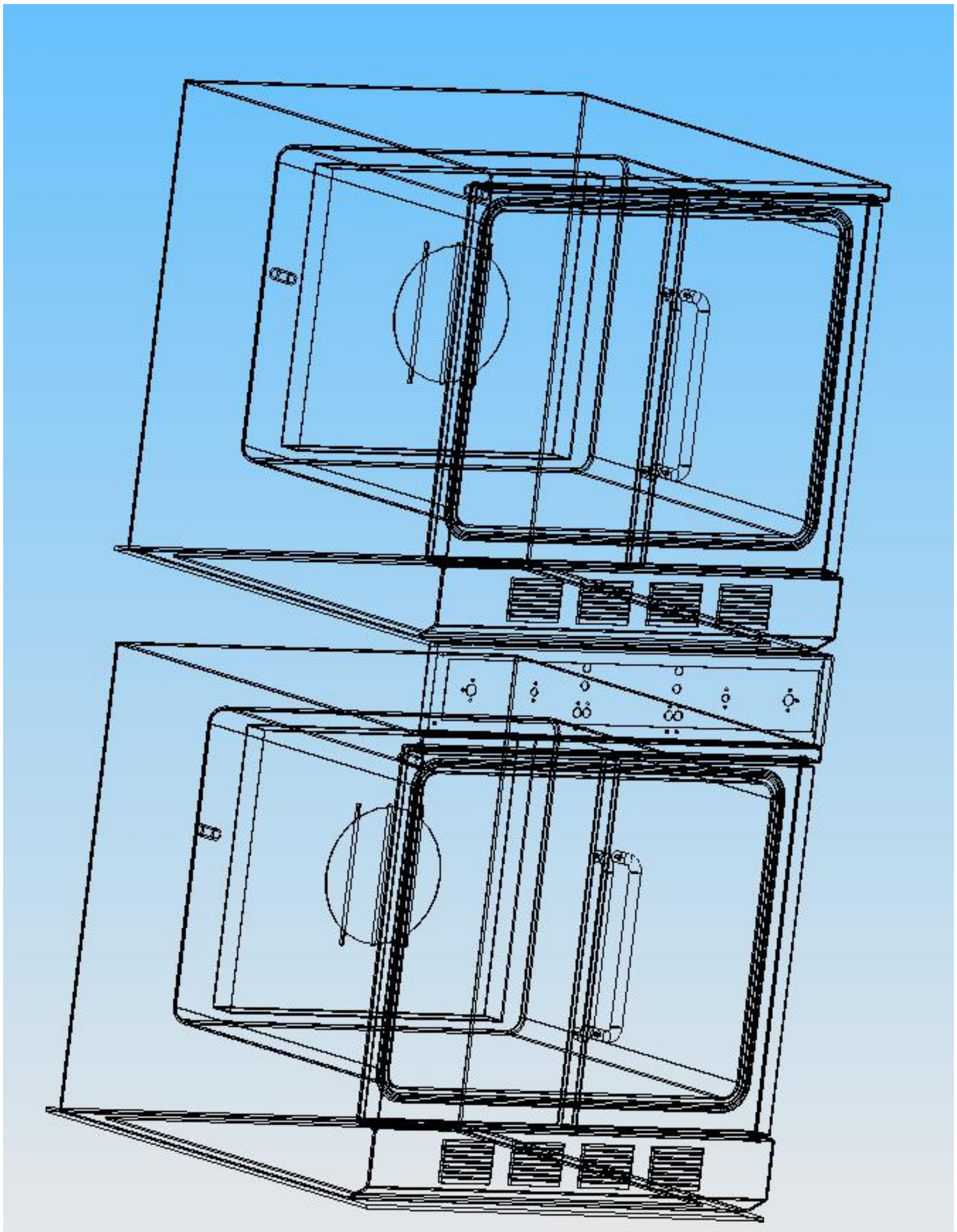
STABILITY (THERMAL, LIGHT, ETC.)	Stable
INCOMPATIBILITY (MATERIALS TO AVOID)	May react with strong oxidizing agents
HAZARDOUS POLYMERIZATION	Will not occur
HAZARDOUS DECOMPOSITION PRODUCTS	If burned, will produce carbon dioxide and carbon monoxide
CONDITIONS TO AVOID	None

VIII. ENVIRONMENTAL PRECAUTIONS

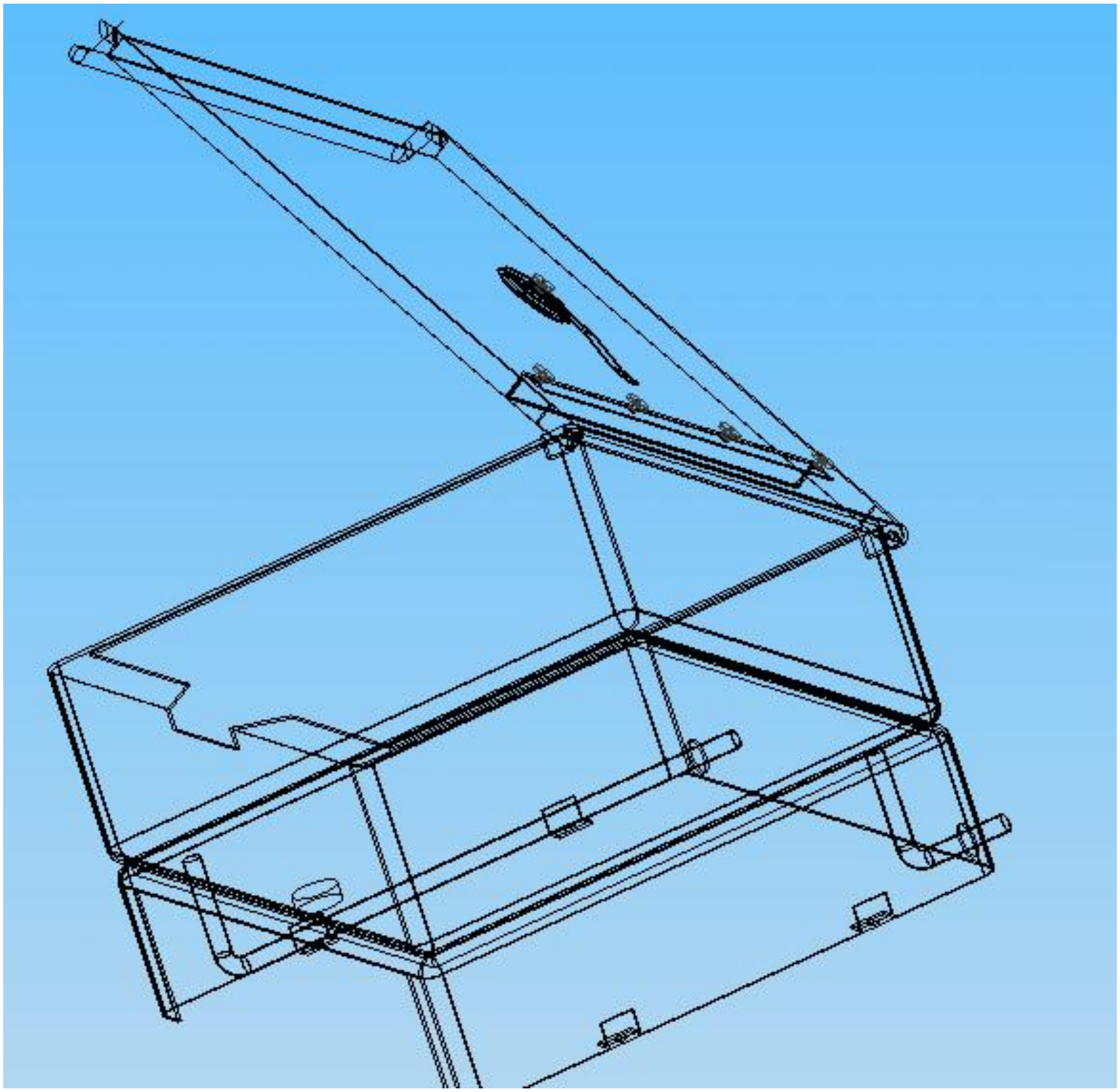
STEPS TO BE TAKEN IF FLUID IS RELEASED OR SPILLED
Consult health effect information in Section III, Personal Health Protection Information in Section V, Fire Protection Information in Section VI, and Reactivity Data in Section VII. Notify appropriate authorities of spill. Contain spill immediately. Do not allow spill to enter sewers or watercourses; remove all sources of ignition. Absorb fluid with appropriate inert materials such as sand, clay, etc. Scoop up and remove. Large spills may be picked up using vacuum pumps, shovels, buckets, or other means and placed in drums or other suitable containers.

WASTE DISPOSAL METHOD
Disposal must comply with federal, state and local regulations. The fluid, if spilled or discarded, may be a regulated waste. Refer to state and local regulations. **Caution:** If regulated solvents are used to clean up spilled fluid, the resulting waste mixture may be regulated. Department of Transportation (DOT) regulations may apply if material is spilled during transport. Waste material may be landfilled or incinerated at an approved facility. Materials should be recycled if possible. This material, as supplied, is not regulated by RCRA as hazardous waste.

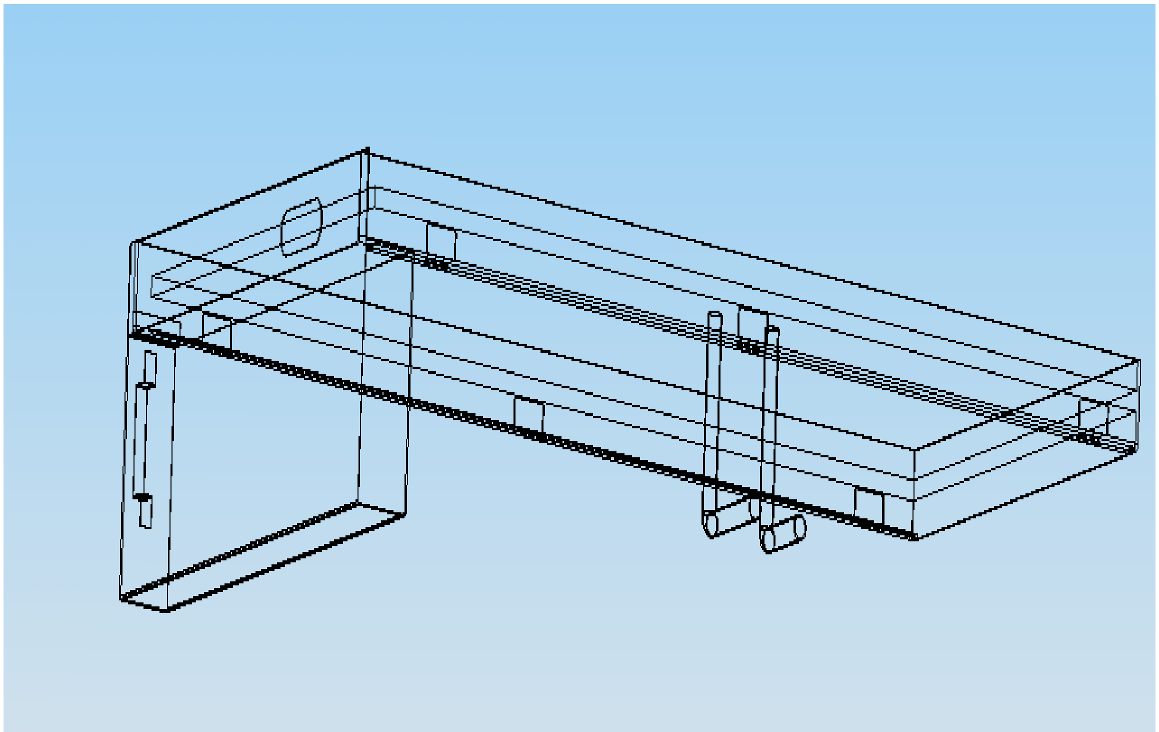
Appendix H: Stacked Ovens



Appendix I: Skillet



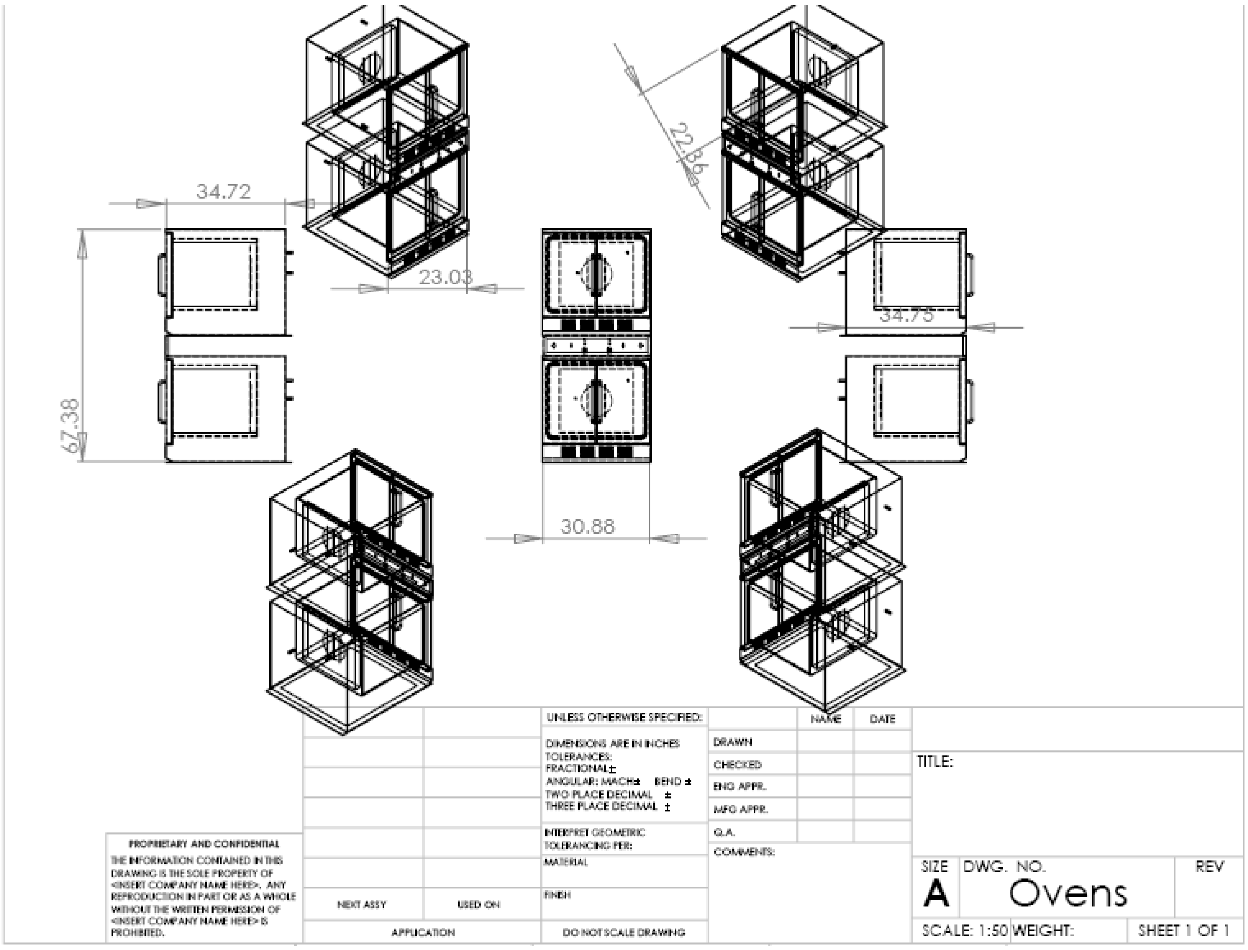
Appendix J: Skillet



Appendix K: Flexible Drain Hose

Item	Rubber Water Discharge
Hose Inside Dia. (In.)	3
Length (Ft.)	25
Max. Temp. (F)	180
Fittings	3" Aluminum Male x Female w/Brass Swivel
Hose Outside Dia. (In.)	3 17/64
Tube Material	Black Plioflex Synthetic Rubber
Reinforcement	Synthetic Fabric
Resists	Abrasion, Aging and Weathering
Max. Pressure (PSI)	125
Includes	Gasket

Appendix L: Oven Dimensioning



Appendix M: Kettle Re-Design