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MOBILE NUCLEAR POWER PLANTS 1960-1970 (U)

CECD 59-7

PREPARED BY THE
COMBAT DEVELOPMENTS GROUP
NOVEMBER 1960

CDOG-FA-59-7

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FOREWORD

This study was coordinated with interested agencies through distribution of a review draft dated March 1960. Until specifically approved, this document represents only the views of the preparing agency and not necessarily the opinion of the Chief of Engineers, Commanding General, USCONARC, or the Department of the Army.

D. M. McCLAIN
Colonel CE
Director

[redacted]

ABSTRACT

(C) The purpose of this study is to determine the requirements for mobile nuclear power plants to support the Army in the Field in the 1960-1970 decade. The objective is the eventual substitution of nuclear power for conventional power with the resultant reduction in POL consumption by the Army in the Field.

a. It was determined that the greatest potential for POL reduction (70%) lies in the application of nuclear power to vehicle propulsion. Treatment of this subject in detail is beyond the stated scope of the problem. However, potential savings in POL are so great that indirect application of nuclear power for charging battery or fuel cell powered vehicles is discussed. Except for application to very large vehicles, prior to realizing the benefits of nuclear power for ground vehicle propulsion in the next 10 years, a breakthrough is required in the development of rechargeable energy storage devices.

b. Of second importance in reducing the POL burden (25%) is the application of nuclear power to space heating; however, the development of a satisfactory heat distribution system must precede this application.

c. Of third magnitude (3%) is the application of nuclear power for production of electrical energy. Although significant local reductions in POL consumption can be realized and operational capabilities improved, full benefit of nuclear power for electricity for the Army in the Field cannot be realized until a satisfactory electrical power distribution system is developed or low power (10-50 KWE) nuclear plants are feasible.

d. Pending the above mentioned collateral developments, priority of development of mobile nuclear power plants in the 1960-70 period should be to provide electrical power to meet concentrated demands such as those imposed by Army and Corps Tactical Operations Centers (TOC) and for the Field Army Ballistic Missile Defense System (FABMDS). It is concluded that the state of the art in the time frame will permit the development of mobile nuclear power sources to meet TOC and FABMDS power requirements and environmental conditions.

[redacted]

MOBILE NUCLEAR POWER PLANTS 1960-1970

(CECD 59-7)

TABLE OF CONTENTS

MOBILE NUCLEAR POWER PLANTS (U)

1. (U) PROBLEM: To determine the requirements for mobile nuclear power and heat sources, exclusive of requirements for vehicular propulsion, within the Army in the Field for the period 1960-1970.

2. (U) SCOPE: This study considers the need for mobile nuclear energy sources for all Army forces in an active Theater of Operations including both Combat and Communications Zones. The Study Directive is appended as Annex B.

3. (U) ASSUMPTIONS: Within the Army in the Field during the 1960-1970 time frame:

a. Sufficient nuclear material will be available for any practicable controlled nuclear energy program.

b. POL requirements for the Army in the Field will increase throughout the time frame of this study.

c. The organizations to be supported are those described in current series TOE of units contained in TTMCFO up to 1965, and MOMAR organizations from 1965 to 1970.

d. Equipment will become operational as indicated in Department of the Army's Transition Plan for Period 1959-1965 and U.S. Continental Army Command's Combat Development Analysis Chart.

4. (U) FACTS BEARING ON THE PROBLEM:

a. POL products constitute approximately 40% of the total logistical burden for the Army in the Field.

b. The use of nuclear energy as a source of power and heat has the potential of drastically reducing POL requirements.

c. No mobile nuclear power plants are now (1960) available for use in the Field.

5. (U) APPROACH TO THE PROBLEM:

a. Guidelines: The directive initiating this study recognized that considerations involving mobile nuclear power are inalterably allied with the funds and personnel available. At the outset it was recognized by those charged with monitoring this study that the present outlook for mobile nuclear power funding is pessimistic. However, while it may have been realistic to gear this study to the practicable limits dictated by current funding such a limitation would have been unnecessarily restrictive. In fact, a study so inhibited would have generated little in the way of findings that is not already apparent. To counter this restrictive factor, the study directive increased the degree of latitude permitted the study agency by authorizing treatment of the funding consideration in two aspects:

(1) Optimum Funding: The first aspect gives the study free rein; that is, requirements for nuclear power plants should be developed in an atmosphere of optimum dollar and personnel availability. This, then, is the conceptual framework which the reader should apply when appraising the merits of the study's conclusions and recommendations listed under the term optimum funding.

(2) Less than Optimum Funding: While a condition of optimum funding is desirable from the Army's standpoint, it does not exist now nor can it be expected to apply in the near future. Whatever funds are obtained will be something less than optimum. This study recognizes this fact and separate conclusions and recommendations, relating to less than optimum funding, are listed and pinpointed as such. Within the area of less than optimal funding, there arises the nebulous question of how much money will (or should) be made available. The study does not profess to answer this question. Instead, conclusions and recommendations are listed according to a series of priorities delineating the work which should be accomplished progressively. Some guidance to

reasonable conclusions and recommendations under conditions of less than optimum funding can be obtained indirectly from the funding which the Army and the Atomic Energy Commission have been able to obtain for the Army Nuclear Power Program in the past, and in the present attitude of American industry toward the future of nuclear power through the next ten years.

b. Research: Requirements for nuclear power and heat are necessarily based on present and future requirements for conventional power and heat. Accordingly, the initial step in gathering data for this study was to make a comprehensive Army-wide survey of present and future power and heat requirements. This survey was made among Army agencies representing all the major arms and services both in CONUS and in the overseas theaters. The resulting survey data constituted the most important segment of the raw data contributing to study of the basic problem.

c. Methodology: To arrive at a solution employing an approach that can be readily followed by the reader, the subject is developed along these lines:

(1) Current requirements for heat and electrical power are tabulated.

(2) The characteristics of currently proposed mobile nuclear power plants are described.

(3) Requirements for heat and electrical power which can be reasonably satisfied by mobile nuclear energy sources are determined.

(4) The capability of proposed mobile nuclear power plants to meet requirements of the Army in the Field is examined.

(5) Finally, a critical appraisal is made to determine the specific areas where mobile nuclear power plants offer practicable advantages to the Army in the Field.

[redacted]

6. (U) DISCUSSION: See Annex A (Discussion).

7. (C) CONCLUSIONS:

a. General: The following conclusions are general in nature, are independent of funding considerations, and are applicable to mobile nuclear energy requirements for the Army in the Field without regard to the 1960-1970 time frame.

(1) The three primary areas where the greatest POL requirements exist and the percent of total POL demand represented generally by each area are as follows:

(a) Vehicular propulsion (70%).

(b) Heating (25%).

(c) Electrical power (3%).

(2) Though specifically excluded from the terms of reference of this study, it is apparent from the preceeding data that application of mobile nuclear energy to the field of vehicular propulsion offers the greatest possibility for reducing POL requirements.

(3) Nuclear power will have limited application to general heating and electrical requirements until one of the following occurs:

(a) Practical means are developed to distribute heat and electrical energy to dispersed users; or

(b) Nuclear energy sources are developed with useful outputs suited to small lighting sets and shelter heating; or

(c) Energy storage devices of useful output are developed which are chargeable by nuclear power plants.

[redacted]

(4) Mobile nuclear power plants can produce significant local reductions in POL requirements if used to provide power and/or heat for (facilities are listed in order of overall priority for application of nuclear power):

(a) Missile systems.

(b) Tactical Operations Centers.

(c) Hospitals and convalescent centers.

(d) Communications Centers.

(e) Base development installations.

(f) Major logistical installations.

(g) Rock crushing operations.

(h) Airfields.

(i) Emergency assistance to indigenous populace.

(5) The future of mobile nuclear energy, other than that used directly for propulsion of vehicles, depends primarily on its successful application to:

(a) Charging energy storage devices.

(b) Heating of personnel.

(c) Practical transmission of power.

b. Time Frame 1960-1970, Optimum Funding: The following conclusions relate to the advantages which may accrue to the Army in the Field during the period 1960-1970 by employing mobile nuclear power plants, given optimum conditions of funding and personnel:

(1) There is a requirement to develop a propulsion system which will use an energy source chargeable by a mobile nuclear plant.

(2) There is a requirement to develop a practical energy distribution system such that most heating requirements in the field can be filled by energy from mobile nuclear reactors.

(3) There is a requirement to develop a family of mobile nuclear power plants ranging in capacity up to 3000 KWE.

(4) Development and utilization of mobile nuclear plants for support of the areas listed below should be in the following priority:

(a) Field Army Ballistic Missile Defense System.

(b) Tactical Operations Centers.

(c) Improved NIKE-HERCULES Missile System.

(d) Headquarters.

(e) Other missile systems.

(f) Hospitals.

(g) Base development installations other than those included immediately above.

c. Time Frame 1960-1970, Less than Optimum Funding:

(1) Proposed Mobile Nuclear Power Plants: The following conclusions relate to the advantages which may accrue to the Army in the Field during the period 1960-1970 by employing currently proposed mobile nuclear power plants, given conditions of funding and personnel less than optimum. It is concluded that:

(a) There is a requirement for a power plant of 500 KWE capacity for use in a Tactical Operations Center expected to be operational in 1965. Either the proposed 500 KWE Military Compact Reactor (MCR) or a future development of the ML-1 type nuclear power plant can satisfy this requirement. (See Table I, page A-4)

(b) There is a requirement for a power plant for the Field Army Ballistic Missile Defense System which is expected to be operational in approximately 1965. While specifications for this system are not yet firm, it appears that this requirement can be satisfied by the 500 and 3000 KWE capacity versions of the MCR nuclear power plant. A nuclear power plant to satisfy FABMDS power requirements must be compatible to the proposed FABMDS operational requirements.

(c) There is a continuous requirement for electrical power for base development installations in various amounts up to 1500 KWE. The ML-1 nuclear power plant, capacity 300-500 KWE, despite certain inherent operational disadvantages, can be applied to this requirement.

(d) There is a requirement for a barge mounted power plant to supplement the Corps of Engineers' electric power barges. This requirement can be satisfied by the MH-1A nuclear power plant now under development.

(e) There will be a period, from 1962 to 1966, when the only mobile nuclear power plant which can be made immediately available for field use will be the ML-1 plant. It should be used to gain experience in the field.

(2) Mobile Nuclear Power Plants in General: The following conclusions relate to the employment by the Army in the Field of any mobile nuclear power plants which may be developed during the period 1960-1970, given conditions of funding and personnel less than optimum. It is concluded that:

(a) The use of mobile nuclear power plants to provide electric power will be limited by:

1. The minimum capacity (300 KWE) of practical nuclear power sources which can be developed in the time frame.

2. The characteristics of energy distribution systems which the Army can feasibly employ.

3. The number of compact installations having large power requirements.

(b) The use of mobile nuclear power plants to provide heat will be limited by the lack of a heat distribution system suitable for field use.

(c) The present rate of development and procurement of mobile nuclear power plants indicates that the ever-rising requirements for heat and electric power must continue to be serviced primarily by POL fueled generators and heaters.

8. (C) RECOMMENDATIONS: The following recommendations pertain to application of mobile nuclear power and heat sources to the needs of the Army in the Field.

a. General: It is recommended:

(1) That the Army Nuclear Power Program emphasize the application of nuclear energy to reduce POL requirements in the following areas, listed in order of priority:

(a) Vehicular propulsion.

(b) Heating.

(c) Production of electricity.

(2) That, in addition to the POL aspects of the problem, the Army Nuclear Power Program consider the following special areas of energy application:

(a) Missile systems.

(b) Energy storage devices.

(c) Distributive heating of personnel.

(d) Beam transmission of power.

(e) ADPS and grid system communications.

b. <u>Specific, Funding Immaterial</u>: It is recommended:

(1) That a Qualitative Materiel Requirement for a 500 KWE mobile nuclear power plant for use in a Tactical Operations Center be submitted to Department of the Army for approval. (See Annex C)

(2) That a Qualitative Materiel Requirement for a rechargeable propulsion system for military vehicles, utilizing mobile nuclear power plants, be submitted to Department of the Army for approval. (See Annex D)

(3) That a Qualitative Materiel Requirement for a field heating system be submitted to Department of the Army for approval. (See Annex E)

(4) That a Qualitative Materiel Requirement for a field electrical distribution system which will capitalize on the advantages of nuclear power be submitted to Department of the Army for approval. (See Annex F)

(5) That, upon approval of Military Characteristics for the Field Army Ballistic Missile Defense System, a Qualitative Materiel Requirement for a suitable mobile nuclear power source for this system be submitted to Department of the Army for approval.

(6) That the Army Nuclear Power Program give particular attention to developments in energy distribution systems, including those systems employing energy storage devices, and sponsor appropriate developments in this field which might enhance the application of mobile nuclear power plants to Army field requirements.

[redacted]

c. Specific, Optimum Funding: Given optimum conditions of funding and personnel for the Army Nuclear Power Program, it is recommended:

(1) That the Army develop a family of mobile nuclear power plants up to 3000 KWE.

(2) That procurement of this family of plants begin in 1964 and that these plants be applied in the priority shown in paragraph 7b(4) above.

(3) That the Army develop by 1965 a practicable distribution system which will enable field heating requirements to be met by energy from mobile nuclear power plants.

(4) That the Army develop by 1965 a practicable vehicular propulsion system using rechargeable energy storage devices which obtain their energy from mobile nuclear power sources and propel most of the vehicles and aircraft in the Army in the Field.

(5) That, upon development of the distribution and propulsion systems described in (3) and (4) above, procurement of mobile nuclear power plants be initiated to meet Army heating and propulsion needs.

d. Specific, Less Than Optimum Funding: Given less than optimum conditions of funding and personnel for the Army Nuclear Power Program, it is recommended:

(1) That the prototype ML-1 300-500 KWE trailer mounted nuclear power plant be completed as scheduled and that, appropriate extensive user tests be conducted to insure that ML-1 capabilities satisfy sufficient power requirements to justify quantity procurement.

(2) That the Military Compact Reactor nuclear development program be scheduled so that production models can be procured as follows:

(a) The 500 KWE MCR type to be available in 1966.

[redacted]

(b) The 2000-3000 KWE MCR type to be available in 1968.

(3) That the MH-1A floating nuclear power plant be designed and procured as an in service unit, pending requirements for additional units.

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ANNEX A

DISCUSSION

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SECTION I. BACKGROUND

1. (S) INTRODUCTION: The problem is to determine the requirements for mobile nuclear power plants practicable for use by the Army in the Field during the time frame 1960-1970. A statement of requirements is necessary so that appropriate QMR can be submitted for these plants. The objective of the QMR is to encourage concentration on those development projects in this area which are considered most important to the Army in the Field. The terms of reference state that the study should develop the extent to which nuclear power plants might be utilized based on optimum conditions of funding and personnel, but, since such conditions are rarely obtained, the study should develop priorities for development and utilization of such plants. In order to have a proper foundation for a listing of such priorities, it is necessary to consider the state of the art of development of mobile nuclear power plants and the basic requirements for power and heat. For this study a survey was taken in July 1959 of present and future requirements for power and heat. The survey questionnaire was sent to Combat Developments agencies representing the users of energy sources in the Army in the Field. Overall power and heat requirements and specific power and heat requirements determined from this study and other research will be matched against the capability of mobile nuclear power plants to satisfy these requirements. In satisfying a requirement, the use of a nuclear plant must be justified by the advantages it offers; that is, an energy source relatively free of continuous fuel supply, and a high capacity power plant in a relatively small package. However, before considering requirements and capabilities, the reader should bear in mind some pertinent information concerning the status of nuclear power in general.

a. Economics of Nuclear Power: The substitution of nuclear energy for fossil fuel energy results in a fuel weight reduction ranging from 1/15,000 to 1/1,000,000. Costwise, as fossil fuels become more expensive, the more economically feasible becomes nuclear power. Herein lies the major advantage of nuclear power as applied to military needs. However, the capital cost of nuclear power plants is still so high that nuclear power plants are not commercially feasible throughout most of the world.

Although there have been many plans put forth for development of commercially competitive stationary nuclear power plants, it is unlikely that by 1970 any commercially competitive plants will be constructed except in remote areas where fuel supply is extremely costly. Compared to stationary nuclear power plants, mobile nuclear plants are even more expensive to develop and procure and their cost is far greater than that of conventional mobile plants of the same capacity. This high cost has limited development of mobile nuclear plants to government sponsored projects for military application.

b. Army Nuclear Power Program: The Army has a nuclear power program under the direction of the Chief of Engineers. Besides the needs of the Army, this program is also responsible for meeting Air Force and Navy requirements for design and development of nuclear power plants other than those plants designed for propulsion of ships, planes and missiles, and those plants designed for use in space vehicles. The program has been pointed primarily at development work, with the manpower emphasis on fixed plants for remote stations and the funds emphasis on gas cooled reactors suitable for small plants. A summary of the present status of the Army Nuclear Power Program is shown in Table I. The summary shows that only two plants, the ML-1 and the MM-1, are mobile overland, while one, the MH-1A, is barge mounted.

c. POL Requirements: The major advantage of nuclear power plants is their freedom from dependence on POL supply. As POL requirements rise, the importance of nuclear energy as a substitute for fossil fuel energy becomes increasingly apparent. The expected rise in POL requirements for active Theaters of Operation is shown in Table II. There are numerous CDOG projects dealing with shipping, off-loading, storing, piping and hauling POL in quantities sufficient to meet the rising requirements brought on by mechanization, and there is serious concern about the ability of the Armed Services to supply the vast quantities of POL shown in the table.[1] This concern is the basis for some of the statements in subparagraph e below.

1/ The Quartermaster Board, Petroleum Supply for the Army in the Field, (Draft), August 1959

TABLE I - SUMMARY OF ARMY NUCLEAR POWER PROGRAM PROJECTS, 1960

Project	Location	Net Output (Electrical & Heat in equivalent KW)	Funding Agency	Status of Project
MOBILE REACTORS				
MH-1A	Mobile (Floating)	10,000 minimum	Army	Design soon to be initiated.
ML-1	Mobile	400	AEC & Army	Final design and Fabrication underway. Begin operation April 1961.
MCR (MM-1)	Mobile	500-800 (1966) 2,000-3,000 (1968)	AEC & Army	Feasibility studies being conducted by development contractor.
PORTABLE REACTORS (PREPACKAGED)				
PM-1	Sundance AFS, Wyoming	1,500	AEC & Air Force	Under construction. Begin operation September 1961.
PM-2A	Camp Century, Greenland	1,560	Army	Construction completed, under test operation.
PM-3A	MacMurdo Sound, Antarctica	1,500	AEC & DOD	Site under construction, to be completed March 1962.
PL-1	Undetermined	300	AEC & Army	Contract guidance plans completed. Final design to be completed March 1961.
PL-2	Undetermined	1,000	Navy	Contract guidance plans completed. Final design to be completed March 1961.
STATIONARY REACTORS				
SM-1	Fort Belvoir, Virginia	1,855	AEC & Army	In operation since April 1957.
SM-1A	Fort Greely, Alaska	4,000	Army	Under construction. Begin first full power operation January 1961.
SL-1	AREA, NRTS Idaho	300	AEC	In operation since October 1958.

Notes - ANPP Project Designation:

1. First letter - Degree of mobility:

   S - Stationary - Permanent type construction.
   P - Portable - Prepackaged at the factory, in several packages, for transportability and rapid assembly at site.
   M - Mobile - Can be moved intact, or virtually intact, may or may not operate in transit.

2. Second letter - Power range:

   L - Low - 100 to 1,000 KWE
   M - Medium - 1,000 to 10,000 KWE
   H - High - 10,000 KWE or higher

3. Arabic Numeral - Order of initiation projects with same two letter designation.

4. Capital Letter - Order of initiation of field plants whose designations do not include this final letter are prototype or pilot plants.

Military Compact Reactor - MCR

Army Reactor Experimental Area - AREA

TABLE II

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ESTIMATED ARMY POL REQUIREMENTS IN A THEATER OF OPERATIONS

Estimated Requirement	Date of Applicability of Estimate	Source and Date of Estimate
3.4 gal/man/day	1959	FM 101-10, 1959
3.5 gal/man/day	1960	TTMCFO-61, 1959
3.1 gal/man/day 1/	Mid-Range (1961-1965)	POL Logistical Support Study, QM Bd, 1957 (taken from "Logistics Policy Committee Memorandum 2176/54". (1956)
5.9 gal/man/day 2/	Mid-Range	POL Logistical Support Study, QM Bd, 1957
7.5 gal/man/day 2/	Long Range (1966-1970)	POL Logistical Support Study, QM Bd, 1957
6.2 gal/man/day 3/	Long Range	TAPFA Evaluation, USCONARC, 1959
5.8 gal/man/day	Long Range	Petroleum Supply for the Army in the Field, 1959 (based on PENTANA Army)

1/ Includes Tac Air
2/ Includes Tac Air and Air Line of Communications
3/ Based on divisional consumption for division in attack.

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d. POL Sources: In the past thirty years there has been much information published on the impending shortage of fossil fuels and a significant amount of argument published to show how very far in the future this shortage lies. The most often quoted source of information1/ indicates that there is indeed an impending POL shortage and that rapidly increasing worldwide per capita use of energy demands that new and different sources of energy be found. There is no question that nuclear energy will someday become economically feasible in the United States because of increased costs of extracting oil and coal and technical advances in production of nuclear energy. The military, too, will eventually have to consider non-fossil fuel sources to meet its energy requirements. These factors, however significant they may be, are beyond the terms of reference of this study. In the 1960-1970 time frame, the question is not one of availability of fuel per se; rather it is a question of whether the logistical system can transport, store and issue the ever-increasing quantities of POL which will be required if an alternate source of energy is not available.

e. Planning for Nuclear Power: Included below are statements taken from various studies or agencies concerned with the problem of organizing and equipping the Army of the future. These statements give an idea of the status of controlled nuclear power as reflected in long range planning. In general they support the use of nuclear power to reduce POL requirements and to make electricity more universally available in the field. Despite this affirmation, these references have not generated specific Qualitative Materiel Requirements for nuclear power.

(1) USCONARC: "A family of nuclear power plants (is required) for the three armed services capable of producing power and heat in the range from a few KW to 40,000 KW. The plants are to provide power in remote and inaccessible locations, devastated areas, combat zones

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1/ P. C. Putnam, Energy in the Future, D. Van Nostrand Company, Inc., 1953 and CONUS disaster areas. The plants will be capable of use in areas where logistical support to meet conventional fuel requirements is difficult, costly or vulnerable to interruption by enemy action. Smaller plants are to be developed as mobile or transportable compact power plants to be mounted on or transported by aircraft, trailers, barges, ships or railroad cars for support of military operations and for emergency requirements."[1]

(2) Secretary of the Army: "In spite of the high cost of nuclear power plants I believe the Army should now take advantage of this important military resource...The Army will include the necessary funds (for procurement and construction of four mobile nuclear plants) in budget requests."[2]

(3) DCSLOG: "Atomic propulsion is the ultimate requirement...We must press forward with the development of atomic powered engines to drive the atomic logistical train and then our main battle tank...Special attention must be given to the reduction of fuel consumption and maintenance requirements of mechanical and electronic equipment...It is possible that no deep penetration will be possible until we achieve, in our large units, a capability to fight and move and fight again and move again without resupply."[3]

(4) QM Board: Nuclear energy "appears to be the most promising field" wherein POL consumption can be reduced.[4]

1/ Department of the Army, Combat Development Objectives Guide

2/ Secretary of the Army, (from a letter approving a program to develop and procure eight nuclear power plants for the Army), 25 July 1958

3/ The Program of the Deputy Chief of Staff for Logistics, 1 June 1959

4/ The Quartermaster Board, op, cit.

(5) USACGSC: "The following constitutes some development objectives for energy and motive power:

(a) Nuclear engines suitable for appropriate tactical equipment.

(b) Nuclear generators suitable for tactical use.

(c) High capacity storage batteries chargeable by solar energy or broadcast power.

(d) Fuel cells for direct production of electrical power." 1/

(6) USACGSC: "In order for TASS (Theater Administrative Support System) to perform its mission satisfactorily under the conditions anticipated for 1970-1975, it is obvious that new or greatly improved supplies or equipment must be developed. Some of the more important of these developments are summarized below:

...A nuclear powered VTOL air vehicle carrying up to 30 tons of cargo...

...A nuclear powered logistical land train...

...Application of nuclear energy to propel selected special purpose ground vehicles. Limited Application of nuclear power to high density vehicles...

...Portable nuclear power plants in small packages...

"After evaluation and approval, the concepts of the (TASS) study will become the Army's very long range

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1/ U.S. Army Command and General Staff College, Initial Concepts for the Very long Range Field Army, 1970-1975, August 1959 requirements plan for operational, organizational and research and development planning for the theater administrative support system."1/

(7) USAWC: "...according to data presently available, petroleum fuels will have begun to dwindle in availability by that date (1975) and...high energy solid fuels will probably not become available much before 1980."2/

(8) USALMC: In the "far future" nuclear power will result in many benefits to the Army, including "increased availability of electricity in the field."3/

(9) USACGSC: "Lightweight, mobile, nuclear electric power generators (are required) for air defense systems and major command posts." An Air Defense Division will require 196 of these.4/

2. (U) TECHNICAL DATA: The units of measure and equivalents used in this study are presented here along with estimated use and logistical factors to give the reader a better feel for the quantities involved. The values shown, while considered valid for this study, are often averages and are not necessarily scientifically exact.

a. Energy:

1/ U.S. Army Command and General Staff College, Initial Concepts for the Theater Administrative Support System, 1970-1975, August 1959

2/ U.S. Army War College, Very Long Range Strategic Forecast, September 1959

3/ U.S. Army Logistics Management Center, A Current Appraisal of the Effect of Non-Destructive Nuclear Energy Upon Logistics Systems and Doctrines, Sept 1959

4/ U.S. Army Command and General Staff College, Tactical Atomic Plenty Field Army, June 1958

1 Kilowatt-hour (KWHr) = 3413 British thermal units (BTU).

1 pound of POL has a heat content of 18,000 BTU.

1 gallon of POL has a heat content of 112,000 BTU.

b. Power:

1 Kilowatt (KW) = 3413 BTU/Hr.

1 Kilowatt = 1.34 horsepower.

KWE refers to electrical power output.

c. Estimated Use Factors:

(1) 0.9 pound of fuel burned in the average motor generator set produces one kilowatt hour of electrical energy, giving the set a 21% efficiency.

(2) One pound of fuel burned in a space heater produces an average of 16,000 BTU of heat, an efficiency of 89%. Thus the typical 45,000 BTU/Hr space heater requires 2.8 pounds of fuel per hour when operating at rated capacity.

(3) To produce heat electrically from a motor generator set implies an efficiency of only 21% in production of electricity from fuel (see (1) above) and an 80% efficiency in the heating circuit, or a total efficiency of 17%. Thus, to produce the equivalent capacity of a 45,000 BTU/Hr space heater by electrical power requires 45,000/0.17 or 260,000 BTU/Hr worth of fuel. This amount of fuel is 14.5 lb/hr. As a result, heating with electricity is only 20% as efficient as heating directly with POL fired heaters. Consequently, to replace 45,000 BTU/Hr of POL fired space heater capacity requires 16.5 KW of electrical capacity.

(4) The average generator runs the equivalent of six hours a day at rated capacity.1/

(5) The average heater runs the equivalent of eight hours a day at rated capacity over a year's time.

(6) Estimated POL requirements:

(a) For heating purposes in temperate zone: 2/

0.5 gal/man/day, summer.
1.0 gal/man/day, spring and fall.
1.5 gal/man/day, winter.
1.0 gal/man/day, average.

(b) For mess purposes using field ranges and immersion heaters:

0.1 gal/man/day.

(c) For electrical power generation:

0.08 gal/man/day.

(7) A reactor which can supply one unit of energy as electricity could supply as an alternative four times that much energy as heat. For example, a reactor rated at 3,000 KWE could supply a rated 4 x 3000 x 3413 or 41 million BTU/Hr if designed for space heating, with the same expenditure of reactor fuel.

d. Logistical Factors: The following rules of thumb apply to conventional engine generator sets:

1/ Compiled from estimates submitted by users.

2/ Office of the Deputy Chief of Staff for Operations, Theater Type Mobilization Corps Force (Objective) 1961, December 1958

(1) Daily fuel consumption (continuous operation): 3.5 gal/KW.

(2) Weight: 150 lb/KW.

(3) Cost: $150/KW.

3. (U) MEETING POWER AND HEAT REQUIREMENTS: This paragraph examines the needs of the Army in the Field for electrical power and for heat and describes how these requirements are currently met. Trends in electrical power and heat requirements in the future Army are also covered. Much of the information was compiled from a survey of user energy requirements taken in July 1959 by the U.S. Army Engineer School.

a. Electrical Power: The availability of electricity for administrative use in military units has become so habitual that it is taken for granted by the users. Sufficient generators to accommodate the increasing requirements are provided by appropriate entries in TOE. Presently, there is approximately one generator for every 60 men. This provides about 100 watts of generating capacity per man in the Field Army. High assurance of having some electricity when absolutely necessary is provided by relying on a multiplicity of generators in units requiring this high assurance. Because of the growing dependence of the Army on electronically operated weapons and weapons systems, more and more essential operations such as air defense, tactical control, and surveillance depend on constant availability of electric power.

(1) Nature of the Demand: Most of the electrical power requirements in a Theater of Operations are so dispersed that there are comparatively few small physical areas which need large amounts of power. The continuing emphasis on mobility and dispersion would tend to keep reducing the number of such locations if it were not for the increased use of complex equipment and electrically operated creature comforts. Regardless of the trends in density of power requirements, there will continue to be critical needs for large amounts of reliable

power for specific units and functions. These areas include missile systems components, hospitals, operation centers, communications stations, rock crushing operations, and some base development installations. These requirements are now adequately met by using generators in multiples. (Adequate is used in the sense that sufficient kilowatts are provided; it does not mean that the present day generator concept is acceptable either now or in the future). One possible solution for the equipping of units which need large amounts of power (over 100 KWE) is the provision of one or two large power sources instead of the several 30 to 60 KWE generators now in use. However, this would be undesirable in some cases for the following reasons:

(a) Flexibility in dispersion is reduced.

(b) Ability to displace in leapfrog fashion keeping some part of the unit always in operation, is impaired.

(c) Larger power distribution systems with their attendant installation and maintenance problems are introduced.

(d) The probability of the entire electrical power source of a unit being eliminated at one time is increased.

(2) Generator Population: Table III below shows the TOE generators found in the typical Field Army described in FM 101-10, a force of three corps, each consisting of three infantry divisions and one armored division. The total force is 387,000, with a division slice of slightly over 32,000. No logistical command is included. The TOE used was that authorized as of September 1959.

TABLE III

GENERATOR POPULATION IN TYPICAL FIELD ARMY

Generator Size KW	Total Number in Field Army	Total KW in Field Army
1.5	3,664	5,500
3	877	2,600
5	726	3,600
10	65	700
15	87	1,300
30	86	2,600
45	408	18,500
60	15	900
TOTALS	5,928	35,700

These figures show that there are about 500 generators per division slice. The figures do not include the so called "hidden" generators; that is, those generators which do not appear as end items because they are integral components of other major items. Inclusion of hidden generators would add about 10% to the totals in Table III in the 1.5 to 5 KW classes and an insignificant amount to the rest.

(3) Future Trends: The previously mentioned survey of future electrical power requirements, based on proposed TOE authorizations, shows a trend toward an increase in numbers of generators and total generating capacity per unit, and a trend away from the larger, less mobile general purpose generators. This survey also indicates a trend toward more complex high powered electronic equipment in the fields of missiles, battlefield surveillance, communications and data processing. The attitude of those responsible for development of electrically powered equipment is that acceptable power sources can be made available for any equipment which is practical for military use. In 1959, the Army accepted gas turbine generator sets as standard for special applications.1/ Gas turbine generators have a decided weight advantage over conventional diesel engine driven generators. For example, it has been estimated at USAERDL that the development of a 300 KW gas turbine generator set weighing six tons is feasible. This six tons can be contrasted to the 20 ton weight of its diesel driven counterpart. In addition, the ability of the turbine set to reach peak power rapidly is greatly superior to that of a piston driven generator set. The technology of gas turbine generator sets is relatively new and improvements can be expected; however, their present fuel consumption, in comparison to conventional sets, is about as much higher as their weight is lower. For example, a 45 KWE turbine generator set requires 11.5 gal/hr of fuel compared to 6.5 gal/hr for a gasoline driven set and even less for a diesel driven set. High powered turbines make more noise than their piston engine counterparts but can be silenced to a comparable level by sacrificing some of their weight advantage.

b. Heating: This subparagraph considers the problems of providing space heating, hot water, and heat for cooking purposes.

1/ R&D Directive Nr 30, 13 Nov 1959, "Engine Generators and Gas Turbine Driven Generators"

(1) Space Heating:

(a) Nature of the Demand: Gasoline and diesel fueled space heaters are provided in TOE for CP tents, squad tents and maintenance tents. The standard space heaters are the 45,000 BTU/Hr tent stove and the 250,000 BTU/Hr maintenance tent heater. For many applications, such as, command posts, troop camps and maintenance installations, being without the heat from space heaters would be little more than a nuisance, provided the weather were not too severe and the lack of heat were not extended too long.

(b) Heater Population: The determination of the number of space heaters authorized and expected to be used is difficult to obtain accurately because of present EML[1/] and WAB TOC[2/] authorizations. If all space heaters were converted to the two standard types, the 387,000 man typical field Army would require approximately 15,000 of the 45,000 BTU/Hr heaters and 2500 of the 250,000 BTU/Hr heaters. This amounts to a capacity of 3400 BTU/Hr/man.

(c) Fuel Consumption: Planning figures for Theater of Operations fuel consumption in 1961 indicate an average yearly space heating fuel requirement of one gallon per man per day, as compared to a total theater Army POL requirement of 3½ gallons per man per day.[3/] Another document covering proposed future organizations indicates POL requirements which approach seven gallons per man per day.[4/] Although the total POL requirement may approach seven gallons per man per day, there is no reason to believe that the individual space heating

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1/ EML: Equipment Modification List

2/ WAB TOC: When authorized by Theater Commander

3/ TTMCFO-61, op, cit.

4/ Petroleum Supply for the Army in the Field, op, cit.

requirements will increase much over the one gallon per man per day which is currently used in computing logistics requirements.

(d) Distribution Problems: There is no equipment operationally feasible for use by the Army in the Field to enable units with a multitude of space heaters to utilize central heating. Conventional central heat systems would be a handicap to units which expect to move more often than (say) once a month, because of the difficulty of installing such systems in temporary installations. The only possible advantage would be an expected savings in fuel. If central heating were provided which permitted the use of an energy source which uses virtually no fuel, the savings in POL could be significant and might outweigh the disadvantages of putting in and maintaining a system of hot water pipes or heat ducts throughout an installation. Before adopting such a system the economics and logistics involved would have to be weighed against its operational practicability. To date there is no known work underway to reduce the overall consumption of heating fuel, nor is there any expressed user interest in central heating systems for field units.1/ However, there is a central heating system for field installations which is more operationally practicable than piping hot air or liquid. This system involves electrical distribution and heating. Electric heaters which derive the necessary power from standard generators are now used by the Army, particularly in vans. Their use has two disadvantages. First, the high amperage required for heaters is poorly transmitted over distances exceeding a few hundred meters. This could be alleviated by the use of transformers, at the expense of adding more items to the supply system, and making installation more difficult. Second, electric heaters are only 20% as efficient as gasoline or diesel heaters in use of fuel. The main advantages of heating with electricity as opposed to conventional heat distribution systems are the smaller size of distribution lines from source to user and the added convenience of electric heaters because they are smaller and more portable than fuel burning heaters and need no exhaust outlets.

1/ USAES, Energy Requirements Survey

(2) Mess and Sanitation: The fuel requirement for mess and sanitation in the field is 0.1 gallon per man per day, which, in an average company size unit, is consumed in three field ranges and three immersion heaters. The heating produced by this equipment could be provided electrically. However, to run the ranges and heaters simultaneously at high heat would require an electrical capacity of approximately 45 KW. Centralization of power sources for mess and sanitation purposes would interfere with the desirable capability of many units to split their mess sections to serve widely separated platoons. No serious consideration is now being given to provide central power sources for field mess use.

(3) Special Hot Water Requirements: Certain units, such as field hospitals and Quartermaster bath companies, have exceptionally high demands for hot water. These demands are currently met by oil fired water heaters, but could be met by electrical heating. The energy distribution problem in these applications is simplified considerably from messing requirements but is still formidable.

c. Summary: Electrical power and heat requirements in the Army in the Field are generally met by a multitude of small generators and heaters. Centralization of energy sources is seldom used. The dispersion of requirements and desire for mobility and "fragmentability" of units is such that centralization of sources and use of commercially feasible distribution systems are not generally favored by the users. There are certain exceptions which will be considered later in this discussion.

4. (C) CAPABILITIES OF MOBILE NUCLEAR POWER PLANTS:

a. General: Nuclear power plants of any desired electrical or heat capacity can be designed and constructed. However, within the present state of the art, there are economic and technological limitations in the size of the mobile nuclear plants which can be made acceptable to the Army in the Field. Although projected mobile nuclear power plants or those under construction are designed for generation of electrical power exclusively, there is no technical reason why a mobile plant could not provide space heat and electricity or just space heat alone. Mobile plants could also be used to heat large quantities of water for hospitals and bath units.

b. <u>Small Energy Sources</u>: Considerable publicity has been given to the Systems for Nuclear Auxiliary Power (SNAP) program, a series of USAF sub-programs designed to produce nuclear power sources for space applications. Some of these sub-programs have been quite successful, but the power levels produced, while acceptable for space purposes, are too low to be considered practicable for use in the Army when compared to the cost of these reactors. An exception might be the use of such a reactor for specific missions vital to national security. Although feasibility is doubted, Special Forces has expressed a desire for a man-portable nuclear power source. The SNAP program is also concerned with non-reactive nuclear sources in which the energy is provided by the decay of radioactive isotopes. Energy sources of this type are presently limited to a capacity of a few kilowatts because of shielding problems involved and technological problems in converting the available energy into useful forms. Although it is difficult at this date to estimate the future capabilities of non-reactive nuclear energy sources, the eventual possibility of successful application of such sources to Army energy needs should not be overlooked.

c. <u>Prototype Mobile Nuclear Power Plants</u>: The Army has under construction a prototype trailer mounted nuclear power plant designated the ML-1. It will have a capacity of 300 to 500 KWE and can provide space heat through the addition of a heat exchanger. This plant typifies the mobile nuclear plant which can be produced in the time frame within the state of the art. The ML-1 will have the following characteristics:

(1) It will weigh 30 tons; this will require mounting on a flat bed trailer.

(2) Two or three auxiliary trucks will accompany the reactor; these trucks will carry such items as the start-up generator, cables, coolant make-up and spare parts.

(3) The range of dangerous radiation from the reactor while in operation will be about 150 meters. This brings out at least two undesirable operating features:

(a) Personnel will not be able to remain within 150 meters of the reactors for more than a few hours without receiving an undesirable dose of radiation.

(b) In most cases there will be a requirement for transmission lines of at least 150 meters between the reactor and the equipment for which it provides electricity.

(4) The safety radius can be reduced to 50 meters or less but this will require operating the reactor behind expedient shielding such as, a slot dug in the ground or in a location such that there is a hill mass between the reactor and its control personnel.

(5) The reactor will require about 12 hours to become operational after a halt and 24 hours to diminish sufficiently in radioactivity to be moved.

(6) It will require a conventional 45 KW generator for starting.

(7) The production cost of this plant is estimated at $2,000,000 to $3,000,000; this is about fifteen times the cost of conventional plants of the same capacity.

Despite some undesirable features, this reactor represents several notable firsts. Most significantly, it will operate at full power for an estimated 10,000 hours without refueling and it will be the first truly mobile reactor capable of producing more than a few kilowatts of power.

d. Projected Mobile Nuclear Power Plants: The above discussion of the ML-1 indicates what can be expected from mobile nuclear power in the near future (1961-1962). This subparagraph indicates the direction of projected developments:

(1) Guidelines: The following guidelines are indicated based on experience thus far with the ML-1:

(a) Because of present technical limitations, a major reduction in capacity will not bring about a major reduction in weight, size or initial cost.

(b) Effort should be placed on improving the characteristics of the reactor, e.g., by eliminating "cool off" time, by providing sufficient shielding so that little or no safety radius is necessary, and by attaining a rapid start up time. Effort is already being placed on reducing the required shut down time and safety radius.

(2) Military Compact Reactor (MCR): Development of a compact, light weight, mobile nuclear power plant is planned which will be suitable for a wider variety of field applications than the ML type plants. A number of design studies of compact reactor plants have been completed by the Army Nuclear Power Program. It is estimated that the 500-800 KWE MCR field plant can be available in 1966, with a 2000-3000 KWE plant available in 1968. The Military Compact Reactor is being developed to provide a compact, light weight mobile source of power for a variety of military applications, including propulsion of the overland train. It is expected to be the fore-runner of the power plant for a nuclear powered combat vehicle. The 500-800 KWE MCR would have all the characteristics of the 2000-3000 KWE MCR but the smaller capacity of this reactor may permit a slightly lighter shield. Its cost would be somewhat less than the heavier model.

(3) The MH-1A: Another type of mobile nuclear plant under active consideration is a floating plant, the MH-1A, which will produce at least

10,000 KWE. Such a plant would be available for use as needed on major waterways, harbors, and beachhead areas in a Theater of Operations. The Corps of Engineers already has three conventional power barges of this size or larger, all with diesel driven engine generators. The design and construction of a nuclear counterpart to these will not be as technically difficult as design and construction of a trailer mounted plant.

e. Summary of Capabilities: Mobile nuclear power plant capabilities applicable to the Army in the Field through 1970 can be summarized as follows:

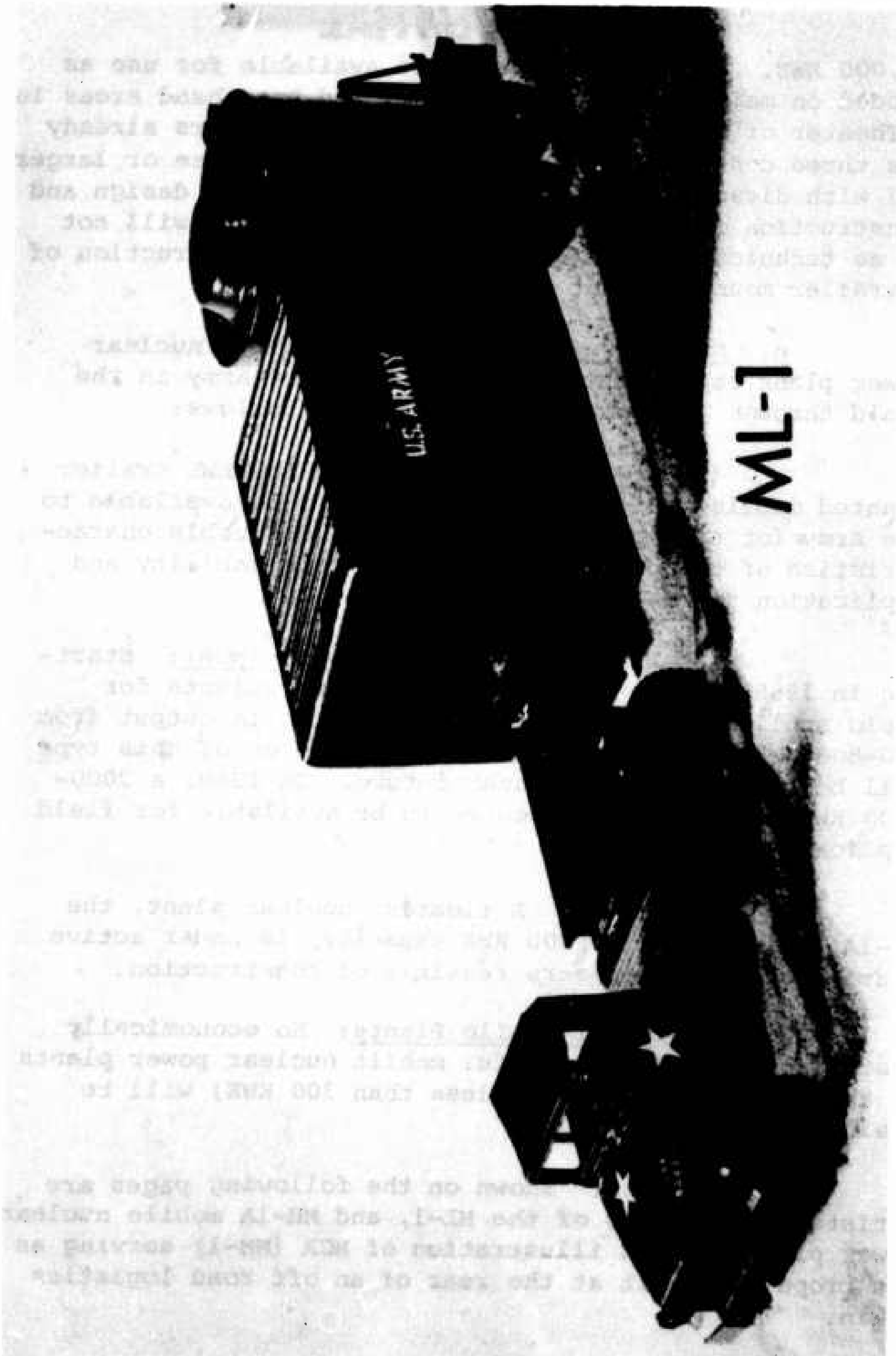
(1) ML-1: A prototype 300-500 KWE trailer mounted mobile nuclear plant (ML-1) will be available to the Army for test purposes in 1961. Undesirable characteristics of the plant may limit its acceptability and application to the Army in the Field.

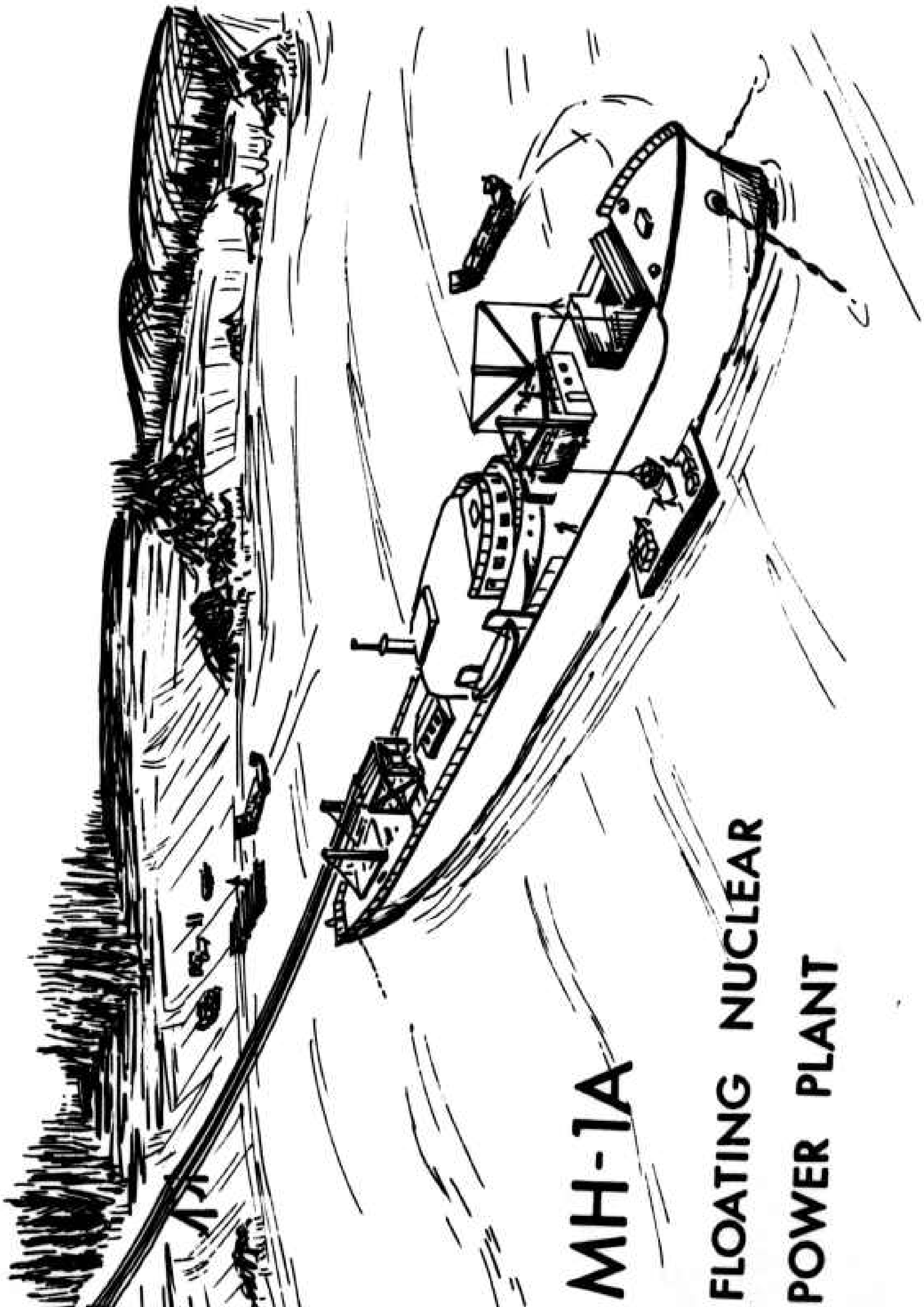
(2) Military Compact Reactor (MCR): Starting in 1966, compact mobile nuclear power plants for field application can be produced ranging in output from 500-800 KWE. Design of a prototype reactor of this type will be initiated in the near future. In 1968, a 2000-3000 KWE MCR plant is expected to be available for field application.

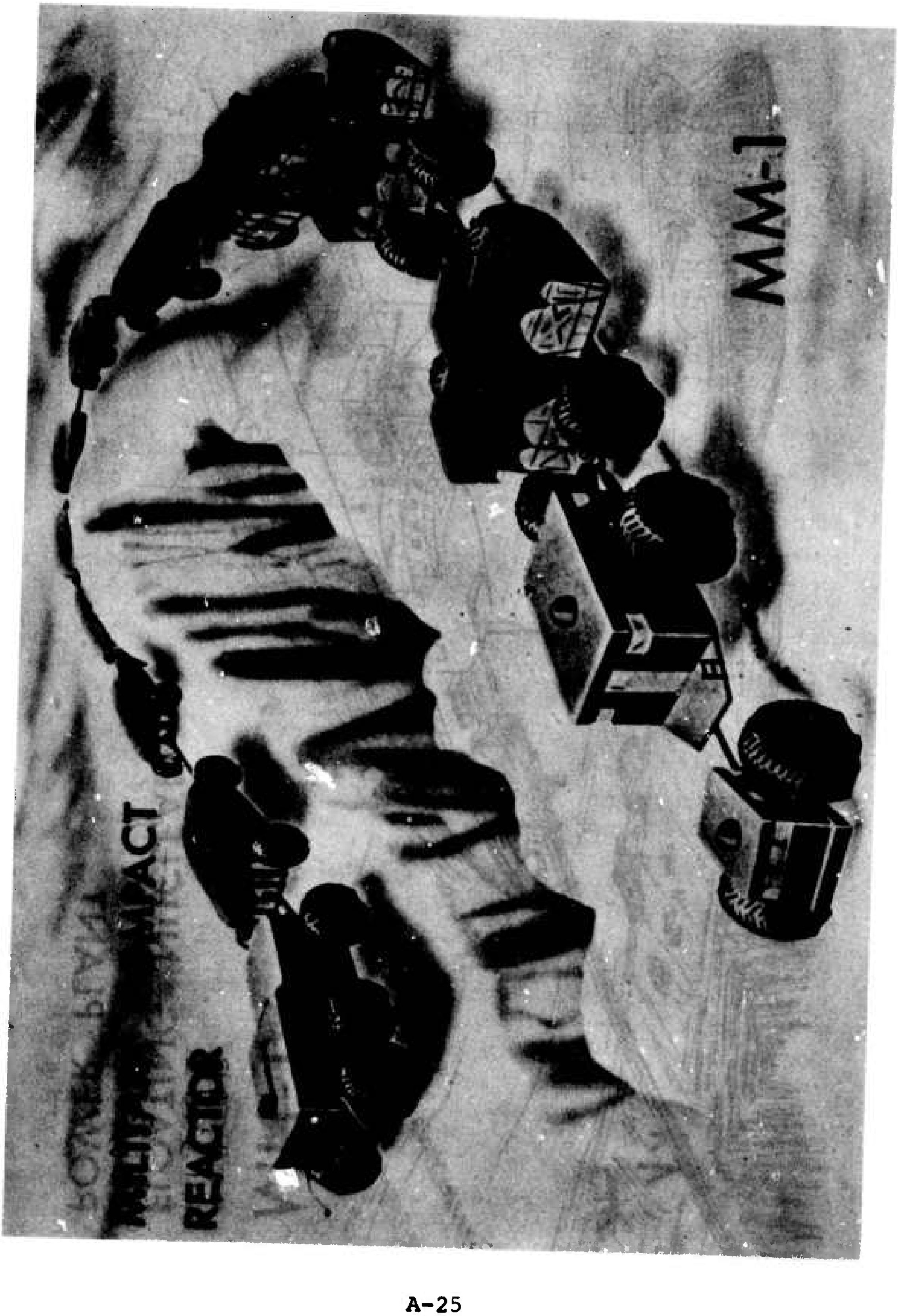
(3) MH-1A: A floating nuclear plant, the MH-1A, of at least 10,000 KWE capacity, is under active consideration and appears feasible of construction.

(4) Small Mobile Plants: No economically justifiable and field useful mobile nuclear power plants in the lower power ranges (less than 300 KWE) will be available prior to 1970.

f. Figures: Shown on the following pages are artists' conceptions of the ML-1, and MH-1A mobile nuclear power plants and an illustration of MCR (MM-1) serving as the propulsion unit at the rear of an off road logistics train.


U.S. ARMY
ML-1


MH-1A
FLOATING NUCLEAR
POWER PLANT


REACTOR
MM-1

SECTION II. APPLICATION

5. (U) GENERAL PRACTICABILITY OF MOBILE NUCLEAR POWER PLANTS: This paragraph discusses the advantages and disadvantages of nuclear energy in place of conventionally fueled energy in the Army in the Field. The first step is to consider complete substitution of nuclear reactors for conventional power and heat sources of all types, including those used for propulsion. However, to replace with nuclear power the total temperate zone winter POL expenditure of four gallons per man per day, a 500,000 man Theater Army force would require theoretically the generating capacity of at least 470 power plants of 3000 KWE each, or their equivalent. The actual generating capacity required to replace all of the POL consumed for heating, electric power generation, and vehicular propulsion to the extent possible could vary up to twice this number of plants, due to the energy conversions and dispersion factors involved. The advantages and disadvantages of this "across-the-board" proposal are discussed below.

a. Advantages:

(1) Fuel: A 100% substitution of nuclear energy for conventionally fueled energy in a 500,000 man theater Army force would provide a savings of two tanker loads of POL a week.

(2) Manpower: In a force of 500,000 troops, approximately 4300 are directly involved in some phase of POL logistics in units such as Quartermaster petroleum distribution companies and Engineer pipeline companies, while thousands more are involved on a part time basis. Provision of nuclear power for all POL fueled requirements would free most of these troops for other tasks but would require, in return, trained operators for the large number of nuclear power plants. At best, perhaps 2000 troops could be freed for other duties.

(3) Storage and Distribution: If POL storage must be available for 30 days supply for a consumption rate of four gallons per man per day, a 500,000 man force

requires 60,000,000 gallons of storage capacity using 5000 tons of material. An even larger burden is the requirement for 18,000 tons of pipeline material per 100 miles of theater depth. Significant savings in pipeline and storage requirements will accompany any sizeable reduction of POL consumption.

(4) Mobility: The ML-1 represents the largest mobile power plant the Army will have in the near future. Rail mounted and barge mounted conventional generators of larger capacity could be made available, but they do not have the flexibility of employment of a roadable power plant. Some of the larger conventional power plants are skid mounted, and may be easily transported in the beds of large trucks and trailers. However, they are designed for off vehicle operation. The time required to load and off load these generators would place them at a disadvantage compared to the ML-1 if it were not for the long start up and shut down times of this reactor. It is believed that this problem can be essentially eliminated in future reactors such as the MCR (MM-1). On the other hand, gas turbine motor generator sets will provide a mobile capability for POL fueled generators in the 300-500 KWE or ML-1 range. Thus the mobility advantage of the smaller nuclear reactors will diminish.

(5) Underground Capability: A reactor-generator set is not an air breather like conventional power plants, and is thus well suited for underground applications. This advantage may not completely eliminate detection of an underground installation by heat sensing devices because disposal of waste heat will be a serious problem, but it may be of considerable importance if the nature of future warfare is such that underground installations become commonplace.

b. Disadvantages: Nuclear reactors also have some significant disadvantages in comparison with conventional heat and power sources. As time passes, most of these disadvantages can be expected to decrease in magnitude.

(1) Cost: The initial cost of nuclear power plants is many times that of generator sets of similar capacity and can be expected to remain high, even if reactors are produced in quantity. In addition, reactors are and will be for several years undergoing development processes for which funds must be made available. To date, reactors can be justified economically only for extended application in remote installations where the delivered price of POL is extremely high.

(2) Training Requirements: Training personnel to operate and maintain nuclear reactors is far more difficult than training personnel to operate and maintain conventional power plants. This problem is being attacked at Fort Belvoir where an extensive one year training program has been underway since the Army's first reactor became operative there in 1957. As nuclear power comes of age, the technological problems of training nuclear power operators and maintenance personnel should decrease, but the number of personnel requiring training will increase.

(3) Disposal of Expended Fuel Elements: Expended reactor fuel elements are highly radioactive and therefore must be heavily shielded. In addition, they normally contain sufficient nuclear material to warrant processing to reclaim this material. This means the expended elements, upon removal from the reactor, must be shipped to a processing plant. If the fuel elements are to be disposed of in the field without reprocessing, some safe and workable system for disposal must be found. This problem of handling and disposing of burned out fuel elements must be considered along with any definite plans to have large scale application of nuclear power to military needs.

(4) Radioactivity: Dangerous radioactivity is inseparable from reactors in operation and personnel and some equipment will require extensive protection from it. The amount of shielding required to give adequate protection is the major factor in determining weight and size of a reactor-generator system. Presently, the radiation hazard of the nearly completed ML-1, with all

the shielding it is praçtical to include, requires a safety distance for the operating crew of approximately 150 meters. However, it is believed possible to build a mobile nuclear power source of up to 3000 KW capacity (the MM-1) with integral shielding sufficient to reduce the radiation problem by a marked degree.

6. (S) <u>APPLICATION OF MOBILE NUCLEAR ELECTRICITY SOURCES</u>: Discussed below are the implications of application of mobile nuclear power plants to general and specific requirements for electrical power in the Army in the Field. (This discussion excludes direct vehicular porpulsion.)

a. <u>"Across-the-Board" Application</u>:

(1) <u>Basic Considerations</u>: Requirements for <u>electrical power</u> are so dispersed throughout the Army in the Field that any discussion of a new system of power generation must be accompanied by consideration of a compatible power distribution system. Substitution of mobile nuclear power sources for all conventional generators in a 500,000 man Theater Army force could be accomplished by only 17 MM-1 3000 KWE power plants, but to distribute electrical power from only 17 plants to a force this large is completely unreasonable within presently foreseeable technology. Supplying the power from 170 reactors of 300 KWE capacity would still require a staggering distribution task. All the effort which might go into such a project would only replace a maximum of 3% of the total force POL requirement.

(2) <u>Nuclear Application</u>: An across-the-board substitution of energy from mobile nuclear power plants for conventionally generated electrical energy can only be achieved by a complete breakthrough in energy distribution techniques or development of a practical family of mobile nuclear power plants down to one kilowatt capacity. Until such time, mobile nuclear power will be applicable only to areas with high localized energy requirements such as missile systems, operations centers, large hospitals, other base development installations, rock crushing operation and energency power for indigenous populations.

(3) Conclusions: It is not feasible for mobile nuclear power plants to furnish complete substitution for all conventional electrical power generators prior to 1970.

b. Missile Systems:

(1) Basic Considerations: Field missile systems with high power requirements are the HAWK, NIKE-HERCULES and REDSTONE. The MISSILE MONITOR fire distribution system used with ADA (Air Defense Artillery) missile systems adds to the power requirements at missile batteries, operations centers and command posts. Of the missile systems listed, the REDSTONE is being superseded by the PERSHING and the NIKE-AJAX by the NIKE-HERCULES; the latter, in turn, is being modified to an improved NIKE-HERCULES. Therefore, the REDSTONE, NIKE-AJAX and unimproved NIKE-HERCULES will not be considered further for application of nuclear power. In addition, there is being planned a completely mobile missile system, the Field Army Ballistic Missile Defense System (FABMDS), which is destined to replace the improved NIKE-HERCULES. The FABMDS supersedes the once planned PLATO and supplements improved HAWK systems. The military characteristics of FABMDS have not been finally approved; hence, power requirements can only be estimated. However, this system is designed to defeat incoming IRBM's and must have such a rapid response time that an estimated 2500 KWE must be kept "on line" at all times. The power requirements of FABMDS and other missile systems components of interest to this study are shown in Table IV. The power requirements shown in the table include both 60 cycle and 400 cycle power. Presently, there are technical difficulties in attaining two different electrical frequencies from one prime mover but it can be accomplished at the expense of added weight to the generator set. However, recent technological breakthroughs have indicated that it will be possible within a few years to take any desired frequency from a high speed generator.[1/]

1/ Corps of Engineers Long Range Technical Forecast, (Draft), February 1960.

TABLE IV

MISSILE SYSTEMS POWER REQUIREMENTS

Missile System and Component	Generator Capacity (KWE)	Estimated Power Need (KWE)	Single Distribution System Possible?
HAWK			
Battery Area	270	140	Yes
Battery Area*	315	160	Yes
AADCP*	145	100	Yes
NIKE-HERCULES (Improved)			
Battery Control Area*	750	350	Yes
Launching Area	225	130	Yes
AADCP*	145	100	Yes
FABMDS			
Battery Area*	7,500 (est)	5,000	Yes
AADCP*	300 (est)	200	Yes

*Includes Fire Distribution Equipment (Missile Monitor)

(2) Nuclear Application: The need for a mobile source of estimated 5000 KWE for the FABMDS is well suited to the capabilities of 500-3000 KWE MCR power plants. One of these plants alone would supplant the 15,000 gallons of fuel per day which would be required to keep a 2500 KWE gas turbine or its equivalent "on line" at all times. In addition, the two nuclear plants would replace the caravan of trailer mounted conventional plants which would be required to meet the power demand. The 500 KWE MCR plant will fit the power requirements of the Improved NIKE-HERCULES Battery Control Area. Nuclear power for the HAWK is of doubtful advantage and should not be sought until FABMDS and Improved NIKE-HERCULES requirements are met.

(3) Conclusions: There is a firm requirement for development of a mobile nuclear reactor with characteristics of the 500-3000 KWE MCR for use with each firing battery of the FABMD System. There is also a requirement for the MCR or two ML-1 type plants in parallel to provide power for the Battery Control Area of the Improved NIKE-HERCULES.

c. Tactical Operations Center:

(1) Basic Considerations: There is a requirement for a mobile electronic tactical operations center (TOC) in 1963. (The TOC for a Field Army has been designated AN/MSQ-19.) Electric power generation for electronic gear, lighting and air conditioning will be supplied by eight generators of 100 KWE capacity each. Four of these will be spares. The Army TOC will be dispersed over an area less than one square kilometer. Similar but smaller TOC's will be made available for Corps and Division headquarters. Present rate of development indicates the TOC will not be available until 1964 or 1965.

(2) Nuclear Application: A nuclear power plant would be able to support a TOC far better than a multiplicity of 100 KW generators which would have a fuel requirement of at least 1000 gallons per day and, under the present state of the art, would make far more noise than a nuclear plant. The requirement for TOC's can be met by either the MCR or ML-1 type plant. However, the radiation safe exclusion area of the ML-1 may limit plant location in comparison with the small exclusion area of the MCR within the TOC and add to the electrical distribution problem.

(3) Conclusions: A definite requirement exists for the MCR or the ML-1 type of nuclear power plant for support of the Field Army TOC. The ML-1 type field plant should be available in 1964 and the 500 KWE MCR type in 1966. There may be further requirements for these plants for Corps and Division TOC's. The ML-1 could fulfill these requirements as an interim measure if necessary.

d. Large Hospitals:

(1) Basic Considerations: The largest hospital (TOE 8-551) found in the Army in the Field has a generator authorization with approximately 500 KWE operating capacity. For this hospital the fuel demand for generators operating at rated capacity is approximately 800 gal/day. Considered in isolation, this is a substantial requirement which the Medical Corps would like to see eliminated. However, since field hospitals with their multiplicity of 45 KW generators have the capability of sectional deployment, the Medical Corps is reluctant to have its hospitals tied to a central power system unless some method is available to maintain the present deployment capability. An exception exists in those general hospitals established in the Communications Zone which do not move for the duration of hostilities. Here, a centralized power source free of heavy POL requirement would be welcome.

(2) Nuclear Application: The use of a mobile nuclear power plant in a general hospital is difficult to justify. This is true because there is no requirement for mobility and the standby generators so necessary for any hospital would still be necessary. Moreover, a power tie-in to the local transmission system, if one exists, is often available to most of these hospitals. A more convincing case for hospital application can be made for a few mobile nuclear power plants in the Theater of Operations which can be made available temporarily to those hospitals whose power sources fail, whose storage capacity of POL for standby generators is limited, and whose requirement for 800 gallons per day of POL would be a local logistic burden.

(3) Conclusion: Mobile nuclear electrical power plants appear impractical for normal use by field hospitals and appear unnecessary for use by general hospitals. Non-mobile packaged nuclear power plants might be practical for general hospitals, but non-mobile plants are beyond the scope of this study.

e. <u>Base Development</u>:

(1) <u>Basic Considerations</u>: There are many fixed or relatively fixed installations in the Communications Zone with high power requirements. TM 5-301, Staff Tables of Engineer Functional Components System, lists the following base development facilities with high connected electrical loads:

Basic Facilities	Connected Loads
Radio Transmitters	280 to 930 KWE
Relay Stations	145 to 280 KWE
Telephone Dial Office	205 KWE
Terminal Station	155 KWE
Ordnance Artillery and Fire Control Shop	180 KWE
Ordnance Tire Rebuild Shop	220 KWE
Refrigeration Warehouse 80' x 200'	140 KWE
Hospitals, 100 to 1000 bed	135 to 700 KWE
POW Camps, 200 to 4000 men	0 to 430 KWE
Electric Generating Plants	15 to 1500 KWE (output)

The Army plans to procure 36 skid mounted 300 KWE conventional generators for base development in FY 1964 and 1965. In addition to these plants, the Corps of Engineers has recommended procurement of two floating nuclear power plants for general use. Conventional diesel electric power barges were used in World War II and in the Korean War.

(2) <u>Nuclear Application</u>: All of the facilities listed above are permanent or semi-permanent and the arguments stated above concerning the justification of mobile power plants for the general hospitals also apply to them. Electrical power for these installations may be furnished in any manner locally available, or the appropriate size of electric generating plant may be requisitioned. The number of such installations depends not only on the size of the US forces but the location of the

Theater of Operations and the type of warfare encountered. The barge mounted plant is a relatively advantageous application of nuclear power because it can replace a significant amount of fuel (over 30,000 gallons per day for a 10,000 KWE plant) and could be profitably used in peacetime as well as in an active Theater of Operations.

(3) <u>Conclusion</u>: It is granted that a mild case for nuclear power can be developed on the basis of combinations of a number of any of the above installations. However, in cases where nuclear plants could conceivably be required, the use of stationary plants rather than the more expensive mobile type is indicated. There is no pointed requirement for a mobile nuclear power plant for any of these applications. However, since the Army is planning procurement within the next five years of 36 large power plants for base development, consideration should be given to procuring a small number of mobile nuclear power plants in place of the same number of conventional plants. These plants could be put in use where conventional plants are now in operation and thereby fill a power need, provide a considerable fuel savings over a period of years, give needed experience in operating nuclear power plants, and still be available in event of war. For this purpose it is considered that three ML-1 plants will be adequate through FY 1963. For the barge mounted application, the design of an MH-1A nuclear plant should proceed as rapidly as funds will permit. Procurement of the nuclear barge mounted plants should be based on requirements for power in the 10,000 KWE range which would otherwise require procurement of conventional generation equipment.

f. <u>Rock Crushing Operations</u>:

(1) <u>Basic Considerations</u>: The Army is standardizing on mobile quarrying equipment with two plants, a 75 ton per hour crushing and screening plant and a 75 ton per hour washing and screening plant. Engineer construction units in a Theater Army force of 500,000 troops will require approximately thirty generators of 100 KWE capacity to operate these plants. Each generator will require 350 gallons of fuel daily for around-the-clock operation.

(2) Nuclear Application: Each plant requires two power sources so that the sections of any plant, i.e., washing, screening, or crushing, can operate independently of each other. It is undesirable, therefore, to combine the two power sources into one of 200 KWE in order to justify a requirement for mobile nuclear power sources. In addition, it should not be difficult to supply one ton of diesel fuel per day to a plant which sends out 75 tons of crushed rock per hour.

(3) Conclusion: When small mobile reactors in the 100 KWE range are practical, this area appears to offer possibilities. However, so long as the individual item demand does not exceed 200 KWE, there will be no practical requirement for nuclear power because the using Engineer units must maintain an inherent capability to operate each item on an individual basis.

g. Indigenous Requirements:

(1) Basic Consideration: Whether or not the US Army should plan to provide emergency power for consumption by indigenous personnel is a political consideration beyond the purview of this study. In many cases some electrical power in urban areas will be almost a prerequisite for keeping the population under control and for otherwise reducing the burden created by civilians on combat forces. In large urban areas electricity is essential for most water supply, communications, adequate care of the sick and injured, and fire fighting.

(2) Nuclear Application: Requirements may exist for provision of emergency electrical power to indigenous populations by the military, and these can be adequately filled by mobile nuclear power plants. The concentration of power in one or two sources, characteristic of present and planned nuclear application, is advantageous for this use since these plants could be tied in to existing transmission systems.

(3) Conclusion: It is impossible to pinpoint the exact amount of auxiliary power which the Army will be inclined to provide to indigenous personnel under

wartime conditions, and it is difficult to justify procurement of reactors or conventional generators for this purpose until more pressing requirements are met.

7. (C) APPLICATION OF MOBILE NUCLEAR HEAT SOURCES: Discussed below are the implications of the application of mobile nuclear power plants as the energy sources for areas of highest heating requirements. Heating requirements now met with electric heaters, such as are installed in vans, are excluded from this discussion. However, it should be noted that any heating requirement could be met by the use of electricity if desired.

a. "Across-the-board" Application:

(1) Basic Considerations: Substitution of nuclear powered heating for conventional heating on an overall basis for a 500,000 man Theater Army force would reduce POL requirements by 25%, averaged over a year. The energy represented by this reduction could theoretically be supplied by 300 mobile nuclear power plants of 3000 KWE capacity, or their equivalent. This energy output would be spread thinly throughout the entire Theater of Operations.

(2) Nuclear Application: The across-the-board substitution of mobile nuclear power plants for fossil fueled heaters demands a light and simple energy distribution system. Even if nuclear heat were distributed from thousands of relatively small ML-1 nuclear plants, the distribution of the heat by conventional heat distribution systems would be all but impossible under field conditions. Conversion to electrical energy would ease the distribution problem slightly at the expense of requiring a quadrupling of reactor capacity because of conversion inefficiencies. Consequently, application of mobile nuclear power plants to heating during the time frame of this study will be confined to high localized heat requirements.

(3) Conclusions: A requirement in the 1960-1970 time frame does not exist for mobile nuclear power plants to supply all the heating needs of the Army in the

Field because an energy distribution system which would make this practicable will not be available. It is of interest to note that an eventual shortage of fossil fuel, predicted for well past the 1960-1970 time frame of this study, may force development of some practical system for distribution of heat to troops in the field.

b. Hospitals:

(1) Basic Considerations: Large hospital units have the greatest requirements for heat of all units in the Army in the Field. These requirements consist of those for space heat, sterilization steam, hot water and cooking stoves. Medical units having the highest heating requirements are tabulated below:

TABLE V.

MEDICAL UNITS WITH HIGH HEAT REQUIREMENTS

TOE	Unit Designation	Capacity of Heat Devices (million BTU/hr)	Fuel Rqmts (gal/day)*
8-510	Field Hospital, 400 bed	7.5	1800
8-551	General Hospital, 1000 bed	18	4300
8-565	Station Hospital, 300 bed	7.5	1800
8-590	Convalescent Center	22	5300
8-581	Evacuation Hospital, Semi-mobile	10	2400

*Equipment operating at rated capacity.

[redacted]

TABLE VI

NUMBER OF 3000 KWE REACTORS REQUIRED FOR HEATING AND RESULTANT POL SAVINGS

TOE	Number of Units in Force of 500,000	Number of 3000 KWE Reactors Required: Direct Heating		Electrical Heating		Theater Fuel Savings 2/ (gal/day)
		Theoretical	Complete Units 1/	Theoretical	Complete Units 1/	
8-510	18	.15	18	.75	18	32,000
8-551	25	.37	25	1.85	50	185,000
8-565	12	.15	12	.75	12	22,000
8-590	3	.45	3	2.25	9	15,600
8-581	16	.21	16	1.05	16	38,000

1/ Assumes reactors are not shared between units.
2/ Equipment operating at rated capacity.

(2) Nuclear Application: The figures in Table VI show that a 3000 KWE mobile plant is overpowered for all hospital applications if a direct heating system is available, and well suited if electrical heating is used. To obtain, by either direct or electrical heating, the significant fuel savings shown in the table requires either an energy distribution system not presently available or a complete reequipping of hospitals with electrical heaters which would be inoperable unless the reactors listed or conventional power plants of comparable power output were available. Units listed may possibly be located in buildings with existing heating systems, and a mobile nuclear direct heating source could be tied in to these systems. However, a mobile reactor cannot be economically justified at this time for any one of these units on the basis that they might be able to use it. It is quite possible that a few mobile reactors might be made available to heat some of these hospitals in order to alleviate a local scarcity of POL when the occasion demands. Even then a compatible distribution system

[redacted]

must be available. Under these conditions, a reactor which would supply both electricity and heat would be the most practical. For such emergency use, a high capacity reactor (3000 KWE) is desirable, since it would be suitable for all types of installations even though it might exceed requirements in many cases.

(3) <u>Conclusions</u>: Mobile nuclear power plants should be made available to heat large field medical installations as soon as a feasible energy distribution system is available. These plants should then be authorized initially on an emergency basis until they become readily available, at which time they should become standard. No firm requirements for these plants by type and quantity can be made at this time.

c. <u>Base Development</u>:

(1) <u>Basic Considerations</u>: Heating requirements for base development vary with the type of installation and the standard of construction. Technical manuals in the Engineer Functional Components field will be published which will show the installed heating capacity for specific base development projects. It is the nature of base development construction standards to improve with time, that is, to improve from TOE tentage to floored buildings with complete sewage, heating and electrical facilities. Thus requirements for heat and heating fuel will also vary with time. The installation with the largest heating requirement is the 3000 man troop camp. Using the Theater Army temperate zone winter heating fuel consumption rate of 1.5 gallons per man per day, this installation uses 4500 gallons of POL daily. The average complete shop installation utilizing large tents or buildings requires 1000 gallons of heating fuel per day. Base development installations such as these are usually located where POL transportation and distribution facilities are readily accessible.

(2) <u>Nuclear Application</u>: With a heat distribution system, a 3000 man troop camp could be heated by a mobile nuclear power plant with a heat capacity equivalent to that of a 1500 KWE plant. With an electrical distribution system, 6000 KWE capacity would be necessary.

For the large shop installations, these figures are 330 KWE and 1300 KWE, respectively. Other installations could be considered but these are typical of installations with high heating requirements. Use of electrical distribution is reasonable for heating base development installations because of their permanent or semi-permanent nature. Mobility of the power source is not required for these applications.

(3) Conclusions: Base development offers several applications where mobile nuclear power plants could be conveniently used for heating troop camps and maintenance shops. However, because of their location, their permanent positioning, the relative priority of their heating requirement and the present lack of a feasible direct heat distribution system, there is no clear priority for mobile nuclear plants for this application at this time.

d. Command Posts:

(1) Basic Considerations: The following table shows the heating capacity and heating fuel requirement for the largest headquarters shown in TOE:

TABLE VII

HEADQUARTERS WITH HIGH HEATING REQUIREMENTS

TOE	Unit Designation	Capacity of Heat Devices (million BTU/hr)	Fuel Reqd (gal/day)*
51-1C	Headquarters, Army	5	1,200
51-2C	Headquarters, Corps	1.3	300

*Equipment operated at rated capacity.

The heating capacity indicated by Table VII is expended almost entirely in heating general purpose and command post tents of which there are 62 authorized in an Army headquarters. Since Army headquarters (and most other large headquarters down to Battle Group level) are usually sub-divided into two or more sections, such as main, rear, tactical and advance, which are physically separated by distances as much as 50 miles, no more than half these tents would normally be in one location. However, each headquarters has such a variety of ancilliary personnel, such as Engineer, Signal and security troops, liaison officers and observers, that each headquarters in the field has a main command post installation at least as large as the total authorized strength of the headquarters. Therefore, command post requirements based on authorized strengths and equipment should be reasonably accurate. Most of the personnel in headquarters require space heating to allow them to perform their relatively sedentary tasks efficiently for several hours at a time. A heat distribution system using air or water is completely unrealistic for this application, but because there is already an extensive electrical distribution system in these headquarters for lighting purposes, electric heaters might be feasible. Even then, the heating load in a single command post is so dispersed that filling the total heat requirement would necessitate an excessive distribution system. For example, a 1500 meter diameter for a Corps CP is not unusual.

(2) Nuclear Application: If applied to complete substitution of the present heating capacity of an Army headquarters, nuclear power can replace a POL expenditure of 1200 gallons per day. If an electrical distribution system is used, a reactor of 1500 KWE capacity is necessary. If a direct heating system is used, a heat only reactor of 400 KW equivalent capacity is adequate. Mobility of the heat source and the distribution system is a prime requisite, as well as comparative silence of operation. Start up and shut down times of less than a few hours are necessary. A serious drawback to this application of mobile nuclear heat sources is the possible necessity for an exclusion area around a reactor.

(3) Conclusion: A mobile Military Compact Reactor is adequate to meet Army and Corps headquarters heating requirements. Using an electrical distribution system, two of the 500-800 KWE MCR plants could serve the Army headquarters and one could serve the Corps headquarters. Parallel operation of two or more ML-1 type plants, especially in the period prior to the availability of the MCR in the field, could also be considered. To accommodate these applications, the present lighting equipment sets would have to be replaced with high capacity ground laid electrical distribution cables.

e. Saline Water Conversion:

(1) Basic Considerations: Saline water conversion units are authorized on an as need basis. In the kind of opposed tactical beachhead operations in which saline water conversion is necessary, the concentration of water purification facilities in a large single plant is undesirable because of the difficulty in transporting water along the length of the beach. As the beachhead expands, fresh water purified by standard equipment (Erdlators) or brought up from wells is more logistically feasible than converted salt water. At present, the conversion of salt water is accomplished by distillation units with capacities up to 300 gallons per hour. The largest existing unit weighs 8½ tons, is skid mounted and uses 4½ gallons of fuel per hour. Development of a family of lightweight distillation units is underway at USAERDL. The largest to be developed will have a capacity of 450 gallons per hour and be the size of the present 300 gallon per hour unit.

(2) Nuclear Application: A study accomplished within the Army Nuclear Power Program indicates that nuclear power can be readily adapted to the conversion of salt water. A 300 KWE reactor could produce 3500 gallons of potable water per hour from sea water. A mobile nuclear saline water conversion plant would be suited to field requirements if it had from 1/8 to 1/5 the capacity of the 300 KWE plant, with a corresponding reduction in size and weight. At this smaller capacity, the POL savings realized by use of the reactor are comparatively small. Mobility is not required for this application.

(3) Conclusion: There is no present requirement for mobile nuclear power plants for saline water conversion in the Army in the Field. However, an extensive campaign such as was waged in the South Pacific in World War II might generate requirements in the future. Since overall POL and concentrated power requirements for salt water distillation are small, use of a reactor for this purpose has a low priority.

f. Mess:

(1) Basic Considerations: It has been pointed out that heat for unit mess and sanitation purposes uses 0.1 gallon per man per day of fuel, which is more fuel than that used in the production of electricity. Because of the high temperatures required, heat from a central energy source for unit mess and hot water purposes would most likely have to be provided through electrical heating coils. This would require approximately 50 KWE of generating capacity. Supplying approximately 50 KWE of electric power to a company mess area and distributing the electricity to six or seven heating devices is not beyond reason, but the present disadvantages outweigh the advantages. These disadvantages are:

(a) The restrictions which such a system puts on the ability of a unit to disperse;

(b) The dependence of the unit on the single source of power; and

(c) The need for completely redesigned field ranges and immersion heaters throughout the Army. In addition to these present disadvantages which make nuclear power unattractive for mess purposes, the Quartermaster Corps, in the areas of field messing procedures and field rations, is conducting extensive research which probably will result in a smaller requirement for energy in the field for mess purposes. The MOMAR I concept envisions no unit messes.[1]

1/ US Continental Army Command, Modern Mobile Army, 1965-1970 (U), February 1960

(2) Nuclear Application: There are no proposed nuclear power plants of sufficiently small size to properly serve a unit mess. Using a reactor of a larger size than necessary might cause attendant problems in shielding within a company or battery area.

(3) Conclusion: There is no general requirement for use of mobile nuclear power plants for unit mess and sanitation at this time.

g. Synthetic POL:

(1) Basic Considerations: One method of alleviating part of the POL logistic burden is to acquire the POL products in the Theater of Operations. In areas of the world where petroleum sources are nonexistent or scarce, such as Western Europe, liquid POL could conceivably be produced synthetically from coal.

(2) Nuclear Application: The possibilities of the application of nuclear power to synthetic POL production in Western Europe were investigated by the Johns Hopkins University Operations Research Office, and the results were published in Technical Memorandum ORO-T-377, October 1953.

(3) Conclusion: The ORO study concluded that synthetic production of liquid POL from coal by fixed nuclear power plants was unfeasible. From this it follows that the use of mobile reactors, with their relatively higher cost and shorter core lives, is even less feasible.

8. (C) NUCLEAR SOURCES FOR BOTH ELECTRICITY AND HEAT: Of all the applications considered in paragraphs 6 and 7 above, only three had heavy requirements for both electrical power and non-electrical heating. These were command posts, hospitals and base development installations.

a. Command Posts: The tactical operation center is the heart of the command post. Accordingly, the TOC has first call on the services the command post provides, including power and heat. Discussion of the TOC in paragraph 7d indicated that the TOC requires a generating capacity of 400 KWE. The rest of an Army CP requires less than 50 KWE for uses other than heating. However, the rest of the CP would require nearly 400 KWE equivalent for direct heating and 1500 KWE for heating through an electrical system. Either heating system is difficult to use with a central source because of the dispersion inherent in CP's. Assuming either heating system is practicable, combining the energy source with that of the TOC is also practicable, as long as standby power is available from a separate source which is an inherent part of the TOC. However, CP heating, by other than electrical means requires development of a central heat distribution system. Consequently, combination of CP heating requirements and TOC electricity requirements will not affect the possible application of nuclear power to either requirement individually.

b. Hospitals: Heating in hospitals requires five times the fuel needed for electrical power generation. Nevertheless, successful application of nuclear power to heating hospitals depends on adaptation of a feasible energy distribution system, whereas application of nuclear power to the electrical needs of hospitals is possible today but not especially practicable. Combining the requirements of both heat and electrical power does little to advance the suitability of proposed mobile nuclear plants to fit requirements for either heat or electricity.

c. Base Development: Since, with the exception of hospitals, high electrical requirements and high heating requirements do not normally appear in the same base development installation, combining the two requirements makes no change in the requirements for mobile nuclear power plants for use in base development.

[redacted]

SECTION III. RECOMMENDATIONS

9. (C) **RECOMMENDED MOBILE NUCLEAR POWER PLANT APPLICATIONS:** The following requirements for mobile nuclear power plants, listed in order or importance, exist for the Army in the Field:

TABLE VIII

SUMMARY OF REQUIREMENTS

Application	Power Plant Type	Distribution	Date Reqd
1. FABMDS	MCR (500-3000 KWE)	As required to meet total power rqmts	Est 1968
2. TOC	MCR (500-800 KWE)	1 per Army, Corps & Div	1965
3. Improved NIKE-HERCULES	MCR (500-800 KWE)	1 per Btry Control Area	Now
4. Base Development[1]	MCR (300-500 KWE)	3 per entire US Army[2]	1963-1964
5. Base Development[1]	MCR (500-800 KWE)	10% of total US Army peacetime procurement[2]	1965-1970
6. Base Development	MH-1A (10,000-20,000 KWE)	To supplement conventional power barges[3]	As needed
7. Command Posts[4]	MCR (500-800 KWE)	2 per Army 1 per Corps	1965

1/ Includes hospitals.
2/ For general application in Com Z.
3/ The Corps of Engineers has three power barges.
4/ Applicable only if electrical heating is practicable.

[redacted]

SECTION IV. TRENDS

10. (C) FUTURE RESEARCH AND DEVELOPMENT AREAS: The preceding discussion indicates that controlled nuclear power can make a vital and strategically significant contribution to a Theater of Operations by providing a substitute for POL for vehicular propulsion and/or space heating and/or by providing gross electrical power to weapons systems which have yet to be designed. Throughout the discussion one gradually realizes that large scale use of nuclear power by the Army in the Field is not yet feasible because of present technical limitations in the production and distribution of nuclear energy. This paragraph is an outgrowth of the previous discussion and is concerned with technological advances and developments necessary to permit large scale use of mobile nuclear energy in certain areas by the Army in the Field.

a. Vehicular Propulsion: Though direct application of nuclear power to vehicular propulsion is beyond the scope of this study, it was found as work progressed that propulsion considerations became inextricably interrelated with examination of the overall POL problem. Indirect application of nuclear power to propulsion through use of stored energy appears to offer the greatest possibility of achieving positive savings in POL on a monumental scale. The great advantage of using mobile nuclear power sources for charging energy storage devices is that the sources can expect to run almost continuously, with a consequent high efficiency. On the other hand, any conversion of energy from one form to another is accompanied by a loss in efficiency which may be substantial. The two types of energy storage devices most likely to be applicable to vehicular propulsion are batteries and fuel cells.

(1) Batteries: The exigencies of war and the problems of supplying huge tonnages of POL to the Theater of Operations may make battery operated military vehicles sufficiently advantageous to justify resurrection of this concept at least for investigation. The biggest problem is to provide sufficient power to run a vehicle a reasonable length of time, e.g., a day or two,

without an exorbitant weight or volume of batteries. The individual batteries must be capable of being recharged quickly and the battery recharger must have a capacity sufficient to serve a large number of vehicles, such as all the tanks in a tank company. These rechargers must be in sufficient supply that the loss of one or two will not impair for long the ability of a unit to move. It is estimated that 24,000 KWE (provided by several mobile nuclear powered battery chargers) could adequately support a tank company on moves up to 200 miles a day, using one hour per day to charge the batteries of each tank. Possibilities of successful application of such a system have been enhanced by a renewed interest in battery technology in the past few years. Therefore, the system deserves close scrutiny by developers to see, first, if the motive system is feasible, and, second, whether a nuclear recharger system of sufficient size is feasible. It is felt that, unless there is a major breakthrough in battery technology, other systems, such as fuel cells, offer more promise for vehicular propulsion.

(2) <u>Fuel Cells</u>:[1/] Electrochemical energy storage devices called fuel cells are under intensive development. These cells have an energy per unit weight which is several times better than the best storage batteries, so the prospects of eventually applying them to an electric propulsion system are excellent. In a fuel cell system, energy must be expended to supply the fuel and charge the fuel tanks. In the most well known fuel cell system, using hydrogen and oxygen, the fuels could be obtained from the electrolysis of water, using nuclear power. One source estimates that a 500,000 man theater force could obtain a 20% reduction in POL requirements if 125 reactors of 5,000 KW each were used in production of hydrogen and oxygen from water and if these fuels were used for propulsion of vehicles through an electric drive.[2/] At present there are sufficient technical problems in application of fuel cells that practicable application to vehicular propulsion before 1970 is doubtful.

1/ Army Research Office, <u>Status Report on Fuel Cells</u>, June 1959

2/ ORO-T-377

b. Heating Personnel: To apply nuclear reactor energy to personnel heating in the field some reasonable distribution system for the heat must be found. Since the plumbing and ducts associated with conventional distribution systems make them appear completely impractical for field use and since electrical transmission lines have inherent disadvantages, other approaches must be considered. The Quartermaster Corps is attacking the problem of personnel heating by use of stored energy to heat uniforms and the people in them and by use of inflated shelters pressurized with heated air.

(1) Heat Energy Storage Devices: A distribution system involving the physical movement of heat storage devices may be feasible. This would be similar to heating a bed by inserting in it a rock which has been warmed in a fire. This principle seems poorly adapted to heating space as such, but might be used like the familiar pocket hand warmers to warm soldiers in their uniforms. If this could be done practicably throughout the Army, most space heating would be unnecessary. One possibility is a small isotope heating source activated by placing the source in a reactor temporarily. This would be used under insulated clothing. Another is a small rechargeable electrical source which heats wires woven in a uniform as in an electric blanket. Development of the heat source has to overcome the problem of providing sufficient heat without subjecting the user to dangerous radiation; the electrical source would have to store enough energy to last for several days. Tentative study is already underway to provide the soldier with a suit which will give protection from a myriad of natural and artificial hazards and discomforts.[1/] Whether nuclear energy can contribute to a better design of this suit should be carefully considered. Theoretically, the energy necessary to keep men warm in insulated clothing should be many times less than that required to keep the same men warm in a tent or van. This should more than overcome the loss of efficiency which occurs when nuclear energy is converted to heat, then to electricity and

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1/ The Quartermaster Board, Quartermaster Long Range Technical Forecast, January 1960 back to heat, as opposed to the simple chemical to heat energy transition which takes place in a gasoline heater. Thus, although a 500,000 man theater force would require 25,000 electric heaters and 400 reactors with an electrical output of 10,000 KWE each to provide a substitute for present temperate zone space heating, actually a far smaller number of reactors without any accompanying space heaters could fill the requirement if the energy were applied to suit heating instead of space heating. The exact number depends on the average weather conditions over a length of time. One slight drawback to this application of nuclear energy is the limited use it will receive in the summer months.

(2) Heated Air: The Quartermaster Long Range Technical Forecast indicates that future tents will be inflatable and that they will be heated by preheating the air which inflates them. This system will require energy both to keep up the air pressure and to heat the incoming air, possibly by passing it over electrical heating coils. Energy for pressurizing will be a completely new requirement. However, the energy requirement for heating will considerably overshadow the requirement for pressurizing, and should be no less than that for present space heating needs. This program should be watched by the Army Nuclear Power Program to see if mobile nuclear power plants will be the best method to supply these energy needs.

c. Beam Power Transmission: The Signal Corps is working on development of a wireless power distribution system. Such a system already exists in wireless communications, but the efficiencies are so low that the principles have not been successfully applied to transmission of large amounts of electrical power. Development of a practical beam power transmission system will go far toward eliminating the present power distribution problem.

d. Area Systems Communication: In an effort to supply increasingly rapid and responsive communications in the field, there is under development an area communications system using a network of high powered radio relay stations. The power requirements for such a system in a Theater of Operations are expected to be high enough to warrant consideration of nuclear energy sources, and these requirements will increase with the demand for more and more communications.

e. Automatic Data Processing Systems: The development of automatic data processing to the needs of the Army in the Field has not progressed to the point where ADPS applications are important users of electric power. The numerous ADPS studies being conducted under USCONARC auspices have not yet produced a single system which by itself warrants the introduction of equipment for a complete system. However, a six year contract has been let to produce an automatic data processing system which will handle all the Army information needs. It appears that there will be no significant addition of ADPS equipment to the Army in the Field prior to 1965 and that the power requirements for ADPS equipment cannot be forecast at this time. It is most probable that mobile nuclear power plants designed for other uses can be readily adapted to ADPS.

11. (U) LONG RANGE VIEWPOINT: The Combat Development Analysis Chart shows the schedule of major developments of new materiel which are in the top 25% of the priorities list of QMR. Most of the items on the chart are mechanical or electronic in nature; their adaption will raise POL requirements, with their attendant distribution and handling problems, and raise demands for concentrated electric power. In support of such items the advantages of nuclear power versus conventional power can be expected to increase with time. Therefore, mobile nuclear power plants should be considered among the possible energy sources for any powered equipment or heating devices being planned for development and eventual acceptance by the Army.

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ANNEX B

STUDY DIRECTIVE

DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON 25, D. C.

IN REPLY REFER TO
ENGOU

2 June 1959

SUBJECT: Combat Development Directive "Mobile Nuclear Power Plants" (U)

TO: Commandant
US Army Engineer School
Fort Belvoir, Virginia

1. (U) General: It is desired that a study be undertaken in furtherance of CDOG objectives 1110b and 1110f to develop requirements for Mobile Nuclear Power Plants within the Army in the field during the time frame 1960-1970.

2. (C) Objective and Scope: To determine within the Army in the field for the period 1960-1970 requirements for mobile nuclear power and heat sources exclusive of vehicular propulsion. Study will determine requirements for (1) electrical power and heat generation for command posts, present and proposed field guided missile systems, surveillance systems, ADPS and maintenance areas, and (2) mechanical power for compressing gases, generating missile fuels, possible drive for heavy construction and excavating equipment. Study will select optimum mobile nuclear power plants for initial development to fill the requirements most poorly met by existing power sources. Specific QMR will be recommended to supplement the existing general QMR for a family of nuclear power plants in paragraph 1139b(1), CDOG.

3. (U) References:

a. Department of the Army Research and Development Projects 8-86-00-000.

b. Pamphlet Army Nuclear Power Program (undated) prepared by the Special Assistant for Nuclear Power, Office of the Chief of Engineers.

c. ROCID, ROCAD and ROTAD TOE's and Training Texts.

d. Letter, ATSWD-P 322/3(Army)(S-RD)(9 Apr 58), Headquarters, US Continental Army Command, 29 October 1958, subject: "Transition Plan for Period 1958-1965, First Revision (U)".

e. CDOG Study Project CONARC(CD)59-5, 120ee, "Modern Mobile Army 1965-1970 (MOMAR) (U)".

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ENGOU
SUBJECT: Combat Development Directive "Mobile Nuclear Power Plants" (U)

f. CDOG Study Project CONARC(CD)57-5, 1620a, "Optimum Intra-Theater Logistic Support System for 1960-1970 (U)".

g. CDOG Study Project CECD 58-1, 620g, "Engineer Functions and Missions for Combat Support, 1960-1970 (U)".

h. Letter, ATSWD-R 063/2(S-RD)(10 Feb 59), Headquarters, US Continental Army Command, 10 February 1959, subject: "Combat Development Analysis Chart (U)".

4. (C) Assumptions that will apply to the study:

a. The organization to be supported will be those shown in reference 3c and 3d above for 1960-1965, and reference 3e above for 1965-1970.

b. Equipment will become operational as indicated in reference 3d and 3h above.

5. (C) Guidance: The following guidance for the preparation of the study is provided:

a. It is intended that this study will result in the development of more definite nuclear power QMR for the Army in the field than presently listed in CDOG (paragraph 1139b(1)).

b. The establishment of definite QMR will encourage concentration on development projects considered most important to the Army in the field.

c. The study should develop the extent to which nuclear power plants might be utilized based on optimum conditions of funding and personnel. Since it is recognized that such conditions are seldom attained, it is desired that the study include recommendations regarding priorities for the development and for the utilization of these power plants by categories of units or elements thereof under conditions less than optimum.

d. A survey to show by types, sizes (output) and mobility of nuclear power plants to meet the above requirements in tabular summation.

6. (U) Administration:

a. Coordination: The draft study will be coordinated with the Special Assistant for Nuclear Power, Troop Operations, Office Chief of Engineers (Rm 1338, Bldg T-7, Gravelly Point, Va.), and appropriate combat development agencies.

b. Suspense Date: 1 December 1960.

ENGOU
SUBJECT: Combat Development Directive "Mobile Nuclear Power Plants" (U)

c. Distribution:

(1) Chief of Engineers (10 copies).

(2) Chief of Research and Development (5 copies).

(3) Headquarters, US Continental Army Command (10 copies).

(4) US Army Command and General Staff College (5 copies).

(5) Other Schools (3 copies).

(6) Additional distribution as directed by CG, USCONARC and recommended for inclusion in paragraph 1122m, CDOG.

d. This project is assigned Project CECD 59-7 and will be recommended for inclusion in paragraph 1122, CDOG.

FOR THE CHIEF OF ENGINEERS:

H. F. CAMERON, JR.
Colonel, Corps of Engineers
Chief, Orgn & Tng Division

Copy furnished:
CG, USCONARC

ANNEX C

QUALITATIVE MATERIEL REQUIREMENT

1. (C) STATEMENT OF REQUIREMENT: Power Plant, nuclear, mobile, 500 KW (U).

(C) A mobile nuclear powered electrical generator to provide the electricity required at a Tactical Operations Center at Army, Corps and Division level. This power plant must be self contained, with its necessary electrical distribution cables, on a vehicle not larger than a standard 25 ton low bed trailer. It must have the mobility characteristics of the operating vans of a TOC. It must be capable of generating full power within 15 minutes after moving into position. It must operate at full capacity for 8000 hours on one fuel loading. It will replace four 100 KW generators presently planned for a TOC. (MR) Tentative CDOG paragraph number is 1139b(2).

2. (U) OPERATIONAL CONCEPT: This power plant will be used as the primary power source for all TOC's and for similar centers such as an AADCP which may have comparable power requirements. It may be employed in duplicate to have a 100% standby capacity or to allow continuous operation of the TOC during relocation. It may be used for any application requiring a large bloc of electrical power.

3. (U) ORGANIZATIONAL CONCEPT: This power plant will be assigned initially to Army, Corps, and Division Headquarters. Upon filling this requirement, this plant may be assigned to other TOE on an as needed basis. It will not normally be pooled but will be assigned to units having a heavy continuous electrical demand. It will be operated by personnel assigned to the appropriate headquarters company.

INCLOSURE 1 TO ANNEX C

BACKGROUND INFORMATION FOR
QUALITATIVE MATERIEL REQUIREMENTS

1. (U) Reference is made to:

a. CDOG, paragraph 1639b(1).

b. US Army Engineer School CD Study, CECD 59-7, Mobile Nuclear Power Plants, (Draft), March 1960.

2. (C) REASON FOR REQUIREMENT: The mobile Tactical Operations Center, planned for procurement in 1965, will have an electrical power demand of nearly 400 KW. This demand will be met, under present planning, by four trailer mounted generators of 100 KW capacity each, plus four similar generators for standby. The fuel consumption of four generators will be approximately 2000 gallons per day and the noise level will be detrimental to security and operational efficiency of the TOC. (The noise could be reduced in conventional plants with additional weight and fuel consumption.) The nuclear power plant will eliminate this fuel requirement and operate at a lower noise level than a single generator.

3. (U) EXISTING ITEMS TO BE REPLACED: Conventional trailer mounted 100 KW generators in certain applications.

4. (U) ADDITIONAL CAPABILITIES AND/OR CHARACTERISTICS DESIRED OF THE EQUIPMENT: This power plant must be capable of being employed in Phase III of an airborne operation even though this requires transporting the reactor-generator set separately from its trailer. The plant must be as silent as a 15 KW generator. It must have sufficient integral shielding so that when the reactor is operating at rated capacity in the open, a person may remain continuously within 20 meters of the reactor without receiving more than the maximum permissible dose of radiation. It should be roadable within 10 minutes after shutdown. Its control center should be mounted on a 3/4 ton truck. It should be capable of being refueled by the Engineer Heavy Maintenance Company in the Field

Army area. It should have a reliability equal to or greater than conventional power generators of comparable size.

5. (U) POSSIBLE DESIGNS OF THE MATERIEL TO MEET REQUIREMENTS: No specific design recommended.

6. (U) THE DEGREE OF URGENCY FROM AN OPERATIONAL POINT OF VIEW: The first production model should be in the hands of troops in 1965.

7. (U) PROBABLE MAINTENANCE AND SUPPLY IMPLICATIONS: Each 500 KWE reactor-generator plant for this application will replace four 100 KWE generators. There will be no significant changes in maintenance implications.

8. (U) PROBABLE MOS IMPLICATIONS: Use of this item will increase requirements for nuclear power plant operators, and reduce requirements for electricians. Total numbers of personnel involved in power generation will be essentially unchanged.

9. (U) PROBABLE TRAINING IMPLICATIONS TO INCLUDE REQUIREMENTS FOR TRAINING DEVICES: Personnel trained to operate and maintain this item will require extensive training for an estimated four months. Training can be conducted for the entire Army at one place. Expensive training devices will be necessary.

10. (U) OTHER ITEMS THAT MAY BE AFFECTED BY THIS MATERIEL OR ADDITIONAL REQUIREMENTS THAT MAY BE GENERATED: Some field equipment for removal and transport of highly radioactive expended fuel elements from the reactor must be made available.

11. (U) PROBABLE COVER AND DECEPTION IMPLICATIONS TO INCLUDE, WHEN APPROPRIATE, THE NEED FOR DECEPTION AND SIMULATION DEVICES: If possible, this power plant should resemble a standard van used for housing and operating electronic equipment.

12. (U) ADDITIONAL COMMENTS THAT APPEAR PERTINENT: None.

ANNEX D

QUALITATIVE MATERIEL REQUIREMENT

1. (U) STATEMENT OF REQUIREMENT: Propulsion system, vehicular, utilizing energy storage devices, (U).

(U) A new propulsion system for military vehicles which will utilize energy storage devices designed to be recharged from mobile nuclear power plants. The system, including energy storage devices and vehicular power train and excluding the power plant, should be of sufficiently small weight and volume that the operating capabilities of the vehicles in which it is installed will be at least equal to the capabilities of present gasoline or diesel fueled piston driven counterparts. (LR) Tentative CDOG paragraph number is ________.

2. (U) OPERATIONAL CONCEPT: The system will be used in all Army vehicles with priority of development and procurement given to use in combat vehicles. The energy storage devices will be of sufficient capacity to be able to operate a tank or a heavy cargo vehicle (truck or GOER) for 300-400 miles. The energy storage device or devices for one vehicle must be capable of being recharged in one hour. They must be capable of being recharged in place in the vehicle and/or of being easily replaced by a recharged energy storage device. A single energy storage device must be capable of being recharged and used repeatedly over a period of several months. The mobile nuclear energy sources for the system must be distributed in sufficient quantity that recharged energy storage devices are readily available to all vehicles.

3. (U) ORGANIZATIONAL CONCEPT: This system will eventually be used in all Army vehicles.

Army area. It should have a reliability equal to or greater than conventional power generators of comparable size.

5. (U) POSSIBLE DESIGNS OF THE MATERIEL TO MEET REQUIREMENTS: No specific design recommended.

6. (U) THE DEGREE OF URGENCY FROM AN OPERATIONAL POINT OF VIEW: The first production model should be in the hands of troops in 1965.

7. (U) PROBABLE MAINTENANCE AND SUPPLY IMPLICATIONS: Each 500 KWE reactor-generator plant for this application will replace four 100 KWE generators. There will be no significant changes in maintenance implications.

8. (U) PROBABLE MOS IMPLICATIONS: Use of this item will increase requirements for nuclear power plant operators, and reduce requirements for electricians. Total numbers of personnel involved in power generation will be essentially unchanged.

9. (U) PROBABLE TRAINING IMPLICATIONS TO INCLUDE REQUIREMENTS FOR TRAINING DEVICES: Personnel trained to operate and maintain this item will require extensive training for an estimated four months. Training can be conducted for the entire Army at one place. Expensive training devices will be necessary.

10. (U) OTHER ITEMS THAT MAY BE AFFECTED BY THIS MATERIEL OR ADDITIONAL REQUIREMENTS THAT MAY BE GENERATED: Some field equipment for removal and transport of highly radioactive expended fuel elements from the reactor must be made available.

11. (U) PROBABLE COVER AND DECEPTION IMPLICATIONS TO INCLUDE, WHEN APPROPRIATE, THE NEED FOR DECEPTION AND SIMULATION DEVICES: If possible, this power plant should resemble a standard van used for housing and operating electronic equipment.

12. (U) ADDITIONAL COMMENTS THAT APPEAR PERTINENT: None.

INCLOSURE 1 TO ANNEX D

BACKGROUND INFORMATION FOR QUALITATIVE MATERIEL REQUIREMENTS

1. (U) Reference is made to US Army Engineer School Study, CECD 59-7, Mobile Nuclear Power Plants, (Draft), March 1960.

2. (U) REASON FOR THE REQUIREMENT: Vehicular propulsion fuel requirements comprise 70% of the total Army in the Field liquid POL requirements, and 40% of the total logistics load. Replacement of conventional vehicular propulsion systems with a nuclear powered system can theoretically result in a million fold increase in energy production per unit weight of fuel. Direct application of nuclear reactor power to vehicular propulsion is not expected within the next six years at the earliest, and even then, would only be available for the heaviest vehicles. Adoption of a propulsion system using rechargeable energy storage devices with mobile nuclear energy sources to charge them will take advantage of the vast potential of nuclear energy, and at the same time offer a system which is more practical for light vehicles than direct application of a reactor in each vehicle.

3. (U) EXISTING ITEMS TO BE REPLACED: All gasoline and diesel fueled vehicular engines.

4. (U) ADDITIONAL CAPABILITIES AND/OR CHARACTERISTICS DESIRED OF EQUIPMENT: The proposed system should be as reliable and safe as conventional propulsion systems.

5. (U) POSSIBLE DESIGNS OF THE MATERIEL TO MEET THE REQUIREMENT: No specific design recommended. The system may employ fuel cells, batteries or some other suitable energy storage device. An electric drive appears to be indicated for the system.

6. (U) THE DEGREE OF URGENCY FROM AN OPERATIONAL POINT OF VIEW: Development of this system should progress at such a rate that procurement can be initiated in 1970.

7. (U) <u>PROBABLE MAINTENANCE AND SUPPLY IMPLICATIONS</u>: Adoption of this system will cause no great changes in the amount of maintenance required for vehicular propulsion systems. However, mobile nuclear power plants must be made available. Adoption of this system for all vehicles will reduce the overall Army logistics burden by nearly 40% and the overall POL requirements by 70%.

8. (U) <u>PROBABLE MOS IMPLICATIONS</u>: Nuclear power plant operators in large numbers are required.

9. (U) <u>PROBABLE TRAINING IMPLICATIONS TO INCLUDE REQUIREMENTS FOR TRAINING DEVICES</u>: Motor vehicle mechanics will have to be trained in maintenance of the proposed propulsion system. The magnitude of the training task should be no greater than that required for conventional vehicle mechanics; however, the changeover of training courses from one system to the other will require extensive effort.

10. (U) <u>OTHER ITEMS THAT MAY BE AFFECTED BY THIS MATERIEL OR ADDITIONAL REQUIREMENTS THAT MAY BE GENERATED</u>: Petroleum handling, distribution and storage facilities can be reduced by more than half.

11. (U) <u>PROBABLE COVER AND DECEPTION IMPLICATIONS TO INCLUDE, WHEN APPROPRIATE, THE NEED FOR DECEPTION AND SIMULATION DEVICES</u>: None.

12. (U) <u>ADDITIONAL COMMENTS THAT APPEAR PERTINENT</u>:

a. Development of a suitable nuclear power source for direct propulsion of vehicles may obviate the requirement for this propulsion system. However, the technological problems of shielding reactors in operation are such that practicable direct drive of vehicles with reactors appears unlikely for vehicles under 35 tons within the next 20 years.

b. Eventual shortage of fossil fuels will dictate use of some form of energy for vehicular propulsion other than combustion of POL. The materiel requirement stated herein, if practicable, can solve this problem while eliminating the major portion of POL requirements.

ANNEX E

QUALITATIVE MATERIEL REQUIREMENT

1. (U) STATEMENT OF REQUIREMENT: Heat distribution system based on use of nuclear energy, (U).

(U) A new system utilizing nuclear energy to provide heat to keep personnel warm. This system will replace most POL fired space heaters in the Army in the Field, be far more convenient to use than POL fired space heaters, and will make heat available to those personnel whose activities have usually prevented them from using conventional space heating in the past. The system is expected to consist of energy storage devices, heatable and/or insulated uniforms which convert the stored energy to a suitable heat form, and mobile nuclear power plants which recharge the energy storage devices. (LR) Tentative CDOG paragraph number is ________.

2. (U) OPERATIONAL CONCEPT: The system will be used under appropriate climatic conditions throughout the Field Army and among appropriate units in COM Z. It will free the users from reliance on heated enclosures for many types of sedentary work and will increase the efficiency of those who now must work in the cold.

3. (U) ORGANIZATIONAL CONCEPT: This system will be organic to Field Army units and appropriate units in COM Z. The mobile nuclear energy source will be organic to the unit in which it is habitually employed.

INCLOSURE 1 TO ANNEX E

BACKGROUND INFORMATION FOR
QUALITATIVE MATERIEL REQUIREMENTS

1. (U) Reference is made to:

a. Quartermaster Long Range Technical Forecast.

b. US Army Engineer School Study, CECD 59-7, Mobile Nuclear Power Plants, (Draft), March 1960.

2. (U) REASON FOR THE REQUIREMENT: POL requirements for space heating amount to 25% of the total yearly POL requirement and 12% of the total logistic tonnage. The Army in the Field has approximately one tent heater for every 20 men, and, when in use, these heaters required continuous attention. Only personnel with relatively sedentary tasks can take advantage of space heaters. Others rely mainly on physical activity or bulky clothing to keep warm. A system must be provided to drastically reduce POL requirements for space heating and to make heat conveniently available to all personnel. It is expected that the system described herein can accomplish this.

3. (U) EXISTING ITEMS TO BE REPLACED:

a. Tent stove oil burner.

b. Duct type heater (250,000 BTU/Hr).

c. Space heater (45,000 BTU/Hr).

d. POL: 1 gal/man/day

e. Present winter field uniforms.

4. (U) ADDITIONAL CAPABILITIES AND/OR CHARACTERISTICS DESIRED OF THE EQUIPMENT: The uniform plus energy storage device must be light enough to be worn comfortably. The energy storage devices must be in sufficient numbers that spent devices may be immediately exchangeable at unit level for recharged devices. A freshly charged device must

have an energy supply for three average days during the coldest winter month in temperate zones. The mobile reactors must be in sufficient numbers to maintain an adequate supply of charged energy storage devices. If practicable, the uniform should be capable of being "plugged in" to a conventional electrical distribution system.

5. (U) POSSIBLE DESIGNS OF MATERIEL TO MEET THE REQUIREMENT: The energy storage device may use any one of several methods to store energy and transmit it as heat to the user. For example, it may be similar to a storage battery and be recharged periodically from a mobile reactor-generator set and deliver its energy through high resistance wires woven into the uniform fabric. Or it may utilize artificially radioactive isotopes, activated in a mobile reactor, which also produce electricity for transmission through a high resistance wire. Or it may utilize an isotope source which delivers heat directly inside an insulated uniform designed to diffuse heat along its undersurface. The reactor capacity and uniform design depends on the design of the energy storage device.

6. (U) THE DEGREE OF URGENCY FROM AN OPERATIONAL POINT OF VIEW: The first production model of this system, including uniforms, energy storage devices and mobile reactor, should be in the hands of troops by 1970.

7. (U) PROBABLE MAINTENANCE AND SUPPLY IMPLICATIONS: This system will require more maintenance than present uniforms and heaters. It will reduce requirements for heavy bulky cold weather clothing, but will require new and probably more expensive clothing. It will reduce POL requirements by up to one gal/man/day for each man equipped with a heatable uniform. It will eliminate most requirements for space heaters.

8. (U) PROBABLE MOS IMPLICATIONS: Nuclear power plant operators will be required.

9. (U) PROBABLY TRAINING IMPLICATIONS TO INCLUDE REQUIREMENTS FOR TRAINING DEVICES: Personnel capable of

maintaining the energy storage devices must be trained, along with nuclear power plant operators.

10. (U) OTHER ITEMS THAT MAY BE AFFECTED BY THIS MATERIEL OR ADDITIONAL REQUIREMENTS THAT MAY BE GENERATED:

a. A suitable mobile nuclear energy source is required. This source must have sufficient capacity to charge the energy storage devices of the unit to which it belongs and still not be so large that it impairs the mobility of the unit. The number of units cannot be forecast until the capacity of suitable energy storage devices and heat retention properties of suitable uniforms are determined.

b. A suitable heatable uniform is required. It must be as rugged and allow as much freedom of action as present uniforms. It must offer no danger to the wearer in case of malfunction of the heating system.

11. (U) PROBABLE COVER AND DECEPTION IMPLICATIONS TO INCLUDE, WHEN APPROPRIATE, THE NEED FOR DECEPTION AND SIMULATION DEVICES: None.

12. (U) ADDITIONAL COMMENTS THAT APPEAR PERTINENT: The Quartermaster Corps is developing heatable winter uniforms. (See reference 1a). The system proposed here appears suitable to provide the heat for this uniform and at the same time provide a significant reduction in POL consumption.

ANNEX F

QUALITATIVE MATERIEL REQUIREMENT

1. (U) STATEMENT OF REQUIREMENT: Improved electrical distribution system, (U).

(U) An improved system of distributing electricity in the field from large mobile central power plants. This system will be more convenient to use than present ground laid or pole strung power lines and will be capable of transmitting power farther than present ground laid systems. This will allow the Army to take advantage of the POL savings inherent in the use of nuclear power, to make electricity more readily available in the field, and to better provide electricity to the electronic complexes being designed for field use. The system will be used throughout the Army in the Field and will replace present heavy electrical distribution cables. (LR) Tentative CDOG paragraph number is ________.

2. (U) OPERATIONAL CONCEPTS: The system will be used as needed in the Army in the Field to transmit electrical energy.

3. (U) ORGANIZATIONAL CONCEPT: This system will be designed principally for units which have a high power demand but which must disperse over several square kilometers for protection against nuclear weapons. The central mobile power source will be assigned to units as needed. Depending upon how the system evolves, the distribution equipment may be carried by the using unit or by the unit with the central power source, or by both.

INCLOSURE 1 TO ANNEX F

BACKGROUND INFORMATION FOR QUALITATIVE MATERIEL REQUIREMENTS

1. (U) Reference is made to US Army Engineer School Study, CECD 59-7, Mobile Nuclear Power Plants, (Draft), March 1960.

2. (U) REASON FOR THE REQUIREMENT: Military generator population has increased significantly since World War II until now there is one generator for every 60 men in the Field Army. The mobility, dispersibility and amount of electronic gear desired by military units will tend to increase generator population and problems of electricity distribution unless larger generators and a more convenient electrical distribution system are used. As overall power requirements rise, significantly large local POL requirements to supply the necessary generators also arise. Some of these power requirements will be met by mobile nuclear power plants, with a consequent reduction of POL. Development of a better field electrical distribution system will allow a greater application of nuclear energy. Because nuclear energy will make high level power sources available in the field, the new electrical distribution system may have higher power losses than conventional systems yet still be acceptable. The system will also help to make electricity more available in the field.

3. (U) EXISTING ITEMS TO BE REPLACED: Conventional electrical distribution lines and transformers.

4. (U) ADDITIONAL CAPABILITIES AND/OR CHARACTERISTICS OF EQUIPMENT: This system must be able to distribute significant amounts of electrical energy out to a distance of at least 10 kilometers from a central power source. Once the source becomes operable, electrical power should be made available to the user in no more time than it takes a vehicle to move from the source to the user. The system should be safe, reliable, inconspicuous, and easily maintained.

5. (U) POSSIBLE DESIGNS OF THE MATERIEL TO MEET THE REQUIREMENT: No specific design is recommended. Possibilities include:

a. Transmission of electrical energy by electromagnetic waves.

b. Development of means to transmit power reliably over lightweight transmission lines for longer distances than presently attainable without use of transformers.

c. Use of rechargeable high capacity energy storage devices which may be easily carried from central power source to using equipment.

6. (U) THE DEGREE OF URGENCY FROM AN OPERATIONAL POINT OF VIEW: The first production model of this system should be in the hands of troops in 1970.

7. (U) PROBABLE MAINTENANCE AND SUPPLY IMPLICATIONS: Cannot be forecast with any accuracy until the type of system is determined.

8. (U) PROBABLE MOS IMPLICATIONS. See paragraph 7.

9. (U) PROBABLY TRAINING IMPLICATIONS TO INCLUDE REQUIREMENTS FOR TRAINING DEVICES: See paragraph 7.

10. (U) OTHER ITEMS THAT MAY BE AFFECTED BY THIS MATERIEL OR ADDITIONAL REQUIREMENTS THAT MAY BE GENERATED:

a. The requirement for small generators may be greatly reduced.

b. Large mobile central power sources, preferably using nuclear energy, will be required.

11. (U) PROBABLE COVER AND DECEPTION IMPLICATIONS TO INCLUDE, WHEN APPROPRIATE, THE NEED FOR DECEPTION AND SIMULATION DEVICES: The system should be easily concealed.

12. (U) ADDITIONAL COMMENTS THAT APPEAR PERTINENT: None.

ANNEX G

COORDINATION

The following comments received from reviewers were not included in the revised study. Following each comment is a statement by the preparing agency indicating the reason for its non-acceptance.

1. (U) OFFICE, CHIEF OF ENGINEERS: Page 44 & 45, paragraph 5b(3) & (4). It is extremely unlikely that reprocessing spent nuclear fuel elements will occur in a theater of operations. Reprocessing is difficult and requires extremely expensive facilities. It is probable that facilities will have to be provided for the storage, shipping and disposition of spent cores in the field. Therefore, recommend deleting the fifth sentence in subparagraph.

Regarding subparagraph (4): Radioactivity, recommend adding, "This can be reduced by use of earth berms, etc", after the second sentence.

Disposal of radioactive wastes should also be considered at this point in the report. Recommend adding and developing subparagraph: "(5) Disposal of Radioactive Waste".

USAES Comment: Concur in the first and second paragraphs of the above comment; the text has been modified accordingly. USAES believes that the problem of radioactive waste disposal is important; however, with the normal operation of closed cycle nuclear power plants there is no "radioactive waste". If the comment is meant to consider the resulting radioactivity from an accident or incident then the discussion involved is far beyond the scope of this study. The requirement for study to determine staff responsibilities for monitoring and decontamination following accidents at nuclear power plants in the field is valid and should be undertaken by the appropriate agency in the near future. It is understood that some work is being conducted in this field at the present time.

2. (U) HQ, USCONARC: Page 3, paragraph 1. The statement of the problem excludes requirements for nuclear power sources for vehicular propulsion, but a large part of the study concerns propulsion of vehicles by means of energy storage devices. It is recommended that the statement of the problem be expanded to include consideration of these devices, but to exclude individual propulsion plants. It is further recommended that an examination be made of the use of these energy storage devices for the numerous low power requirements in the Field Army.

USAES Comment: USAES believes that it is neither necessary nor desirable to include in the statement of the problem consideration of energy storage devices. If such a statement is included then the entire tenor of the study would change from "requirements for mobile nuclear power plants" specifically excluding direct vehicular propulsion to "the requirements for nuclear power plants to provide vehicular propulsion". The latter subject is certainly valid for investigation; however, more as a feasibility study than a CD study. In the application of energy storage or direct energy conversion devices to meet the numerous low power requirements, again there seems to be no necessity to determine a requirement, but to investigate feasibility. Appropriate R&D agencies should be monitoring the development of these devices, closely alerted to possible breakthroughs which would make the application of fuel cells (etc.) to power requirements feasible and practical.

3. (S) US ARMY AIR DEFENSE SCHOOL: Page 1. The application of mobile nuclear power plants for 1960-1970 Army air defense weapon systems appears to be limited.

a. The Army in the Field:

(1) Improved NIKE-HERCULES: There is no apparent requirement for a mobile nuclear power plant having the limitations listed below in the improved NIKE-HERCULES missile system in either CONUS or the Army in the Field.

(a) The inherent disadvantages of the proposed nuclear generator are:

1. 12 hour "start up" time.

2. 24 hour "cool down" time.

3. Separation distances (150 meters).

4. High cost ($1,000,000 to $2,000,000).

5. Possibility of requiring another nuclear, or several conventional, backup generators with attendant reduction in mobility.

These advantages are not tactically or economically acceptable. Although POL requirements will be extensive (about 3,000 gallons per day) for battery logistics, the introduction of nuclear power generators will reduce Field Army POL requirements by less than three per cent. The POL requirements for an Improved HERCULES battery can be met by employment of GOER type fuel transporter (Truck, Tank, Logistical, High Mobility, 5,000 gal, 4 x 4, XM438).

<u>USAES Comment</u>: USAES concurs in that the mobile nuclear power plant with the limitations listed above will have little application in the Field Army; however, these limitations specifically apply to the ML-1 plant which is a prototype scheduled for operation in 1961. The QMR contained in Annex C is indicative of the characteristics of subsequent mobile nuclear power plants in the 500 KWE range. This plant is considered to have wide application in the field army. When approved, this QMR will accurately describe a plant to be developed under the Military Compact Reactor (MCR) Program.

4. (U) <u>OFFICE, CHIEF SIGNAL OFFICER</u>: Page 2. This study is concerned primarily with large (300-2500 KW) power plants. There is a dire need for light, durable power plants in the 5 to 45 KW sizes as a large percentage of present POL and maintenance requirements stem from supporting power plants of this size.

USAES Comment: USAES concurs that there is a need for light, durable power plants in the 5 to 45 KW sizes; however, within the technology in the 1960-1970 time frame the direct application of nuclear power to individual power requirements of less than 300 KWE is neither operationally nor economically feasible. A breakthrough in fuel cell technology may permit application of nuclear power to production of fuels for fuel cells to meet the 5 to 50 KWE power requirements.

5. (U) HQ, US ARMY ARMOR SCHOOL: USAARMS does not concur in the proposals for the use of mobile nuclear power plants for purposes of heating, lighting or vehicular propulsion, in support of subordinate tactical echelons of the field army for the following reasons:

a. The mobility of nuclear power plants discussed in the study appear to be severely limited due to size, weight, cool off time required, and type of carriers envisaged for their transportation so as to preclude their use tactically in support of combat operations.

b. The application of mobile nuclear power plants to vehicular power systems for tanks and wheeled vehicles appears to be technically and economically infeasible at this time.

c. The consideration of mobile nuclear power plants as a source for vehicular propulsion appears to exceed the scope of the problem as stated in paragraph 1 of the study.

USAES Comment:

a. The purpose of this study is to determine requirements for mobile nuclear power plants which can meet the stringent limitations imposed by operations with the Army in the Field in the 1960-70 period. Therefore, of prime importance are the QMR's developed through an examination of the operational requisites and probable technological progress. USAES does not know whether the above comments pertain to these QMR's or to the characteristics of the ML-1 plant soon to be in operation. If the Armor School takes exception to the materiel requirements proposed, then detailed comments are invited. If the comment concerns the ML-1 trailer mounted plant then USAES concurs; however, it must be remembered that the ML-1 is a prototype plant and is subject to considerable improvement in size, weight, safety radius and cool-off time.

b. Concur; however, feasibility in 1960 should not rule out continued investigation during the next ten years, particularly when the rewards are great.

c. The fact that a particular sub-subject exceeds the scope of the study is not considered adequate for non-concurrence in the proposals contained therein. To be precise, however, the study only considers, in some detail, the indirect application of nuclear power to vehicular propulsion. Of importance is the application of nuclear power to the possible production of fuels for fuel cells. The fuel cells would then be used for vehicular propulsion. It is realized that fuel cell technology has not progressed to the point where their application to vehicular propulsion on a large scale is practical; however, when that time arrives, nuclear power should be considered for fuel production.

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