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REA 8079

MULTI-PURPOSE COLLECTIVE PROTECTION UNIT - FEASIBILITY

FINAL REPORT

CONVAIR SAN DIEGO CONVAIR DIVISION GENERAL DYNAMICS CORPORATION

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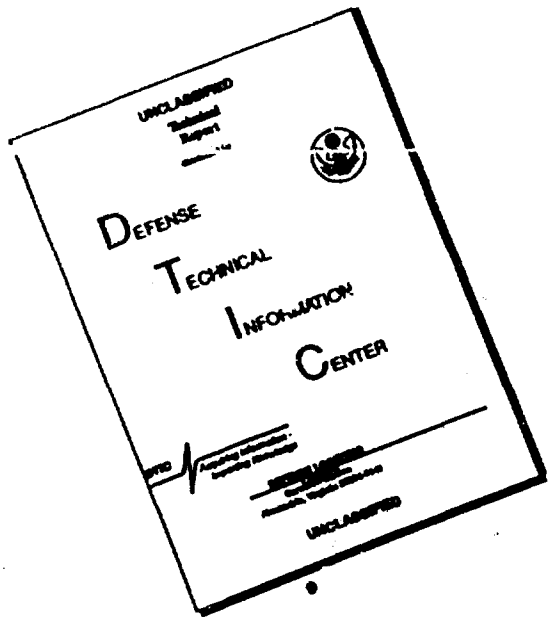

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REPORT ERR-SD-165

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MODEL

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MULTI-PURPOSE COLLECTIVE PROTECTION UNIT - FEASIBILITY

FINAL REPORT

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ABSTRACT

This report is the second monthly progress report on the Multi-purpose collective protector feasibility study authorized by REA 8079a. Multi-purpose collective protector design requirements are presented and the 1962 work effort is proposed. The feasibility and need for collective CBR protection has been emphasized in ERR-SD-156. In 1962 it is proposed that:

1. A family of multi-purpose collective protection units be theoretically designed for shelters in the 50 to 2500 occupant size range.

2. One demonstration unit be designed and fabricated.

3. Experimental work leading to the development of a catalytic pyrolyzer be initiated.

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I. INTRODUCTION

This is the second and final monthly report on the Multi-Purpose Collective Protector Feasibility study authorized by REA 8079a. The first monthly progress report, CV Report ERR-SD-156, generally established the feasibility of developing a dry heat collective protector unit. This report outlines and defines the work that should be accomplished in the next year to develop the dry heat unit, and covers the work accomplished from 11-20-61 through 12-31-61.

During this report period the literature survey was continued. Shelter and collective protector requirements were defined in more detail, and the chemical engineering background of Mr. A. Gensemer was utilized in determining the facilities and test equipment necessary to develop a CB pyrolyzer.

II. LITERATURE SURVEY

To date, more than 80 references pertaining to the subjects of chemical, biological, and radiological warfare and collective protection have been reviewed. It has been found that the Convair Division Library has one of the best, if not the best, collection of BW and CW information in the San Diego area. Even so, there is not adequate information on the specific subjects of collective protection and air purification. Pertinent references not available have been requested. From the documents reviewed it is concluded that practically no work is in process in the area of multi-purpose collective protection. However, some of the documents indicate that considerable work has been accomplished on new methods of air purification. Thus the results of the literature survey to date indicate that the survey must be continued in specific areas.

Subject headings where pertinent information can be found are listed as follows:

1. Chemical and Biological Warfare and Agents
2. Collective Protection
3. Shelters or Protective Shelters.
4. Air Purification
5. Atmosphere Purification & Control on Nuclear-Powered Submarines
6. Environmental Control Systems for Manned Space Vehicles
7. Catalytic Pyrolysis of Air Contaminants
8. Ventilation and Air Conditioning of Hardened Missile Bases

Background and up to date information is needed in the specific subject areas of:

1. Current and candidate BW and CW agent physical characteristics.
2. Methods and techniques of air purification.
3. Catalytic pyrolysis of air contaminants.

In these areas the library information must be kept up to date through constant review of ASTIA abstracts and procurement of pertinent documents.

When the Literature survey has progressed to where background information is up to date, personnel at government agencies and companies working in the specific areas of interest must be consulted. Personnel and/or government agencies that should be contacted are listed as follows:

1. U.S. Army Chemical Warfare Laboratories, Chemical Warfare Center, Maryland.
2. U.S. Army Biological Warfare Laboratories, Ft. Detrick, Maryland
3. Chemistry Division, U.S. Naval Research Laboratory, Washington, D. C.
   a. Mr. J. G. Christian or Mr. J. E. Johnson for catalytic pyrolysis information.
4. Naval Biological Laboratory, School of Public Health, University of California.
5. Dr. Benoit, Electric Boat Division of General Dynamics, Groton, Conn.

It will be mandatory that these contacts be established as soon as possible in the coming year to gain maximum benefit from prior work in specific areas.

III. DESIGN REQUIREMENTS

A. CBR-Protective Shelter

One problem of defining the design requirements governing the internal environment of protective shelters is the degree of comfort that can be economically provided. The degree of discomfort that shelter occupants can tolerate for the 14 day time period must be known. In other words what are the minimum

ventilation and space requirements per occupant. Reference 1, reports the results of studies of the effects of body and tobacco smoke odors on man and presents the ventilation requirements for the removal of these odors from enclosed structures. For a simple ventilation system, the minimum air space and outdoor air supply required per person were obtained by extrapolating the results of laboratory experiments and shelter occupancy tests; they are as follows:

1. In hot weather, 20 cfm of fresh air (Refrigeration may be required) and 100 cubic feet of space per person.
2. In temperate weather, 10 cfm of fresh air and 70 cubic feet of space per person.
3. In cold weather, 7 cfm of fresh air and 50 cubic feet of space per person.

In addition Reference 1 recommended:

1. That a system for recirculating indoor air through an activated charcoal filter to remove odorous vapors be installed inside all closed shelters.
2. That a small smoking room for a limited number of occupants be installed inside large shelters. This is probably a luxury which will not be provided.

This information is in general agreement with the conclusion reached in the first monthly progress report that 15 cfm per person should be the minimum design ventilation requirement. However, with adequate recirculation through an air conditioner (Ventilation system no longer simple) the outside fresh air can be reduced to 20% of the minimum requirement.

Consideration must be given to the possible variation in the number of occupants of a particular shelter in defining design requirements. For example, the environmental control system for a 100 occupant shelter should be able to provide, with a reduction in the degree of comfort, adequate ventilation for possibly 150 occupants. With this consideration in mind the design requirements for environmental control of a protective shelter can be defined as shown in Table I. These requirements are used to size air conditioning systems for shelters. With a

75° F effective temperature approximately 50% of the shelter occupants will be comfortable when local hot day design conditions (from Reference 2) exist outside the shelter and the number of occupants is equal to the shelter design number. With an occupancy 50% greater than the design number the effective temperature will not exceed 80° F. Considering that local hot day design conditions are achieved or exceeded only 2-1/2% of the total time during June through September of a normal year, the majority of the shelter occupants will be comfortable most of the time even with a 50% occupancy overload. Table I is based on standard design practices from Reference 2 considering Reference 1 recommendations, and is subject to modification by the results of future shelter habitability studies.

As recommended by Reference 1, all recirculated air should be passed through an activated charcoal filter to remove odors. One pound of activated coconut shell charcoal will purify for one year 100 cubic feet in a air raid shelter. Based on Table I this is one pound per year per person. Air is generally odor-free after passing through a 1/2 inch thick activated charcoal filter. It has a pressure drop of 0.2 inches of water at an airflow of 40 fpm, and is approximately 95% efficient. A 1 inch thick filter has a pressure drop of 0.30 to 0.35 inches of water at an airflow of 40 fpm. These requirements are for odor removal and not for collective CBR protection. However, the charcoal can be impregnated to remove any trace of toxic or irritant gases that may pass through the collective protector.

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TABLE I

PROTECTIVE SHELTER ENVIRONMENTAL CONTROL DESIGN RECOMMENDATIONS

Minimum Ventilation (Outside Air + Recriculation) Per Person	15 cfm
Outside Air Per Person (20% of Min. Ventilation)	3 cfm
Shelter Design Conditions	
Effective Temperature	75°F
Dry Bulb Temperature - t_s	80°F
Wet Bulb Temperature	69.6°F
Relative Humidity	60%
Air Velocity	15 - 25 fpm
Space Per Person	100 ft^3
Shelter Ventilation (Outside Air + Recriculation)	
Based on 30°F temperature difference between shelter design dry bulb, t_s, and air inlet dry bulb, t_1, or 15 cfm per person depending upon which ventilation rate is larger.	
Shelter Pressurization Above Outside Ambient	0.5 in. H_2O

B. Multi-Purpose Collective Protector

The collective protector must purify air contaminated with chemical, biological, and radioactive particles and toxic gases. Chemical and biological warfare particles will probably have diameters in the 0.1 to 1.6 μ range, the range of maximum lung retention. The atomic bomb air burst debris particle diameter is expected to be in the 0.03 to 0.3 micron range (Reference 3). Naturally occuring and industrial dust particle diameters range from less than 0.1 μ up to the size of lint, leaves, and insects. (Reference 2) There is a strong indication that the number of viable organisms (bacteria, virus, etc.) normally present in the atmosphere are agglomerated into particles larger than 5 μ (Reference 4). From this information it can be concluded that all outside air entering a protective shelter must pass through a filter capable of removing particles with diameters as small as 0.1 μ and possibly as small as .03 μ, to remove radio-active particles. Two filters in series, one to remove the larger size (also probably higher concentration) dust particle and one to remove the small size radioactive particle, will be required. Automatic moving-curtain viscous-impingement filters of the roll type are commercially available for the first filter. Either an automatic dry type air filter or an electronic air cleaner should be considered for the second filter. Each filter should be designed for a nominal face velocity between 300 and 400 fpm and a maximum resistance of 0.5 inches of water.

The air filters will not remove toxic gases or all biological warfare particles (some types of virus are 100 times smaller than bacteria), so additional air purification is necessary. Moist heat, dry heat, and ultraviolet radiation were considered in the first monthly progress report and dry heat appeared best for sterilization and gas pyrolysis. New concepts in air purification were considered as part of the research work reported in Reference 5. The concepts considered were too heavy for portability by one man, but may be applicable to collective protectors where weight and portability is not a problem. The new air purification concepts considered in Reference 5 are:

1. Diffuse oxygen through membranes that would be selective for oxygen.

2. Produce oxygen electrochemically from water, with the hydrogen reburned with contaminated air to reform water. Energy liberated from hydrogen combustion could be removed as electrical energy (H_2-O_2 fuel cell) to reduce the quantity of supplementary power necessary to perform the electrolysis.

3. Pyrolysis of toxic gases. Many toxic gases are decomposed at temperatures less than 200°C (392°F). Several decompose only at elevated temperatures: CG (800°C), SA (280°C), and tear and vomit gases.

4. Catalytically oxidize gases. Same as 3 above but with a catalyst added. Hopcalite is an active oxidation catalyst.

5. Absorb oxygen on an organic material such as salcomine. Evolve oxygen from salcomine bed.

6. Use refrigeration system to condense toxic gases.

7. Take advantage of paramagnetic properties of oxygen to channel only oxygen in desired direction.

The catalytic pyrolysis feasibility indicated in Reference 5 adds confidence to the conclusion that this approach should be experimentally developed. Also, new concept 6, using refrigeration to condense toxic gases, is feasible for collective protection, and should be studied. The heat removed by the refrigeration system in condensing toxic gases can be recovered by adding it to the purified air stream. From the concepts considered in Reference 5, it can be concluded that a portion of the future collective protection effort should be devoted to keeping up with the "State of the Art" of air purification techniques.

A schematic of a feasible multi-purpose collective protection system is shown in Figure 1. All components except the Catalytic Pyrolizer are relatively short term development items. Detail design requirements depend upon the shelter loads and the pyrolizer requirements. Design studies should be initiated to size multipurpose collective protection units for 50, 100, 250, 500 occupant shelters. These studies should include the determination of the type and size of motor generator unit

required as well as the most effective means of utilizing waste heat for pyrolysis. The component arrangement shown in Figure 1 is a tenative practical arrangement but not necessarily the most efficient or optimum. The combination of components into a compact portable unit must also be considered. Tenative pyrolyzer sizes can be determined assuming 600°F pyrolysis.

The primary future experimental effort should be directed towards development of the catalytic pyrolizer. The first step in this development is the determination of the catalytic pyrolysis time-temperature relationships necessary to neutralize CW and kill BW agents. Active catalysts must also be determined and evaluated. Reference 4 reports the use of a pyrolyzer instrument built by the Canadian Government for the detection of BW agents. A heater or pyrolyzer decomposes protein in the air and detects the HCN (a lethal CW agent) formed by the decomposition. Reference 6 reports the use of Hopcalite as a catalyst in a catalytic combustion unit for aerosols in nuclear submarines. Hopcalite was found to be a good catalyst for the combustion of hydrocarbons of several structural types as well as for the combustion of a number of oxygenated organic compounds. With the exception of methane, all the compounds studied were converted essentially quantitatively to carbon dioxide and water at 300°(572°F) to 400°C(752°F). A more detailed investigation of the work reported in these two references appears to be the starting point in the development of a catalytic pyrolyzer.

IV. TEST REQUIREMENTS

A. Procedure

It appears feasible to design and fabricate a small experimental catalytic pyrolyzer where the catalyst can be changed and the pyrolysis temperature controlled from approximately 400 to 1000°F. The time-temperature relationship for catalytic pyrolysis of air contaminants can be determined with this unit by passing known quantities of contaminated air through the unit maintained at a fixed temperature, and analyzing samples of the inlet and outlet air. The time of exposure at a fixed temperature can be varied by varying the quantity of contaminated air passed through the unit. Figure 2 shows a schematic diagram of the tentative test arrangement. An aerosol generator will be required to contaminate the air. Incapacitating CW agents such as tear gas and BW agent simulants can be used initially. Inlet and outlet air

samples can be collected and analyzed in a separate laboratory or instrumentation can be procured for continuous analysis during test. The cost of the laboratory instrumentation for separate sample analysis is less than that for continuous analysis but the manhour expenditure is greater for separate analysis.

B. Test Requirements

The laboratory facilities required to determine BW and CW agent catalytic pyrolysis time temperature relationships are listed as follows:

1. A supply of temperature and humidity controllable air in the flow range of 0 to 15 lb/min.

2. An aerosol generator. Reference 6 describes a simple portable unit.

3. BW agent simulants and incapacitating CW agents such as tear gas, plus facilities for the storing and handling of these agents.

4. Miscellaneous piping, ducting and valves.

The Thermodynamics Laboratory has the required airflow facilities. U.S. Army Chemical and Biological Laboratories should be contacted for recommendations on handling and other facilities. Figure 2 shows a tenative test schematic. Control valves will be required to adjust the aerosol concentration.

C. Instrumentation

Temperature, pressure, flow, gas analysis, and aerosol instrumentation will be required to develop the catalytic pyroloyzer. Standard temperature, pressure, and flow instrumentation available at the Thermodynamics Laboratory can be used. The gas analysis, and aerosol instrumentation is more complex and must be thoroughly investigated to determine the most simple and economical instrumentation necessary. The gas or aerosol concentration at the inlet and outlet of the pyrolyzer must be determined. In the case of aerosols this is done by counting the particles in a known quantity of air. The mass median diameter and the number diameter of the aerosol must also be determined. Available particle count must be made before and after pyrolysis when BW aerosols are used. Types of instrumentation for gas and aerosol analysis are listed as follows:

1. Aerosol Concentration

   a. Gravimetric analysis by passing a known volume of stream through

a glassfiber filter and weighing material collected.

b. Light scattering method. Particles down to 0.1 μ detected and measured.

2. Mass Median and Number Diameter of Aerosol

a. Light-scattering method (Reference 6) particles down to 0.1 μ

b. Air dilution method (Reference 4)

c. Electron microscopic examination of samples of the aerosol collected with impingers. (Reference 5) Particles smaller than 0.1 μ

d. Pass aerosols through a column filled with 1.5-mm load shot and measure % penetration as a function of particle size.

3. BW Aerosol Viability Count

a. Bio-assays - standard biological laboratory method of determining the number of live organism as compared to the total number in a sample.

4. Gas Analysis

a. Determine completeness of combustion by measurement of the CO_2 produced by means of a continuously recording infrared analyzer.

b. Gas chromatography - for trace contaminants

c. Oersat analysis

V. PROPOSED 1962 EFFORT

A. Objective

Chemical and biological warfare attacks are anticipated in conjunction with atomic attack. Chemical and biological warfare agents with lethal doses in the range of 1 to 50 particles (0.1 to 1.6 μ diameter) per liter of air have been developed. Early warning detection is not satisfactory, so the type of attack will not be known when a protective shelter is occupied. For protection from radioactive fallout, a shelter occupancy period of at least two weeks is recommended. At least 3 cfm of outside air will be required per shelter occupant. This outside air can be contaminated with biological warfare particles, chemical warfare particles and gases, and radioactive fallout particles from either separate or combined attacks. Lethal concentrations of all three hazards are highly probable during the two week occupancy period. Therefore, a shelter does not provide complete protection unless the required outside air is purified.

The recent government interest in both military and civilian protective shelters has been concentrated in the areas of shelter location, size and construction. Approximately $400,000,000.00 is allotted for civilian defense shelters in the next fiscal year. Most of this money will be used in surveys to locate and preliminarily design shelters.

Since the emphasis has been on the shelter and not the required air purification (collective protection), it will be necessary to sell the government agencies concerned on the need for collective protection. Also, the literature survey revealed very little information on military collective protectors and none on multi-purpose collective protectors, indicating that companies are either not aware of the necessity for collective protection or are keeping their work secret. Considering this information, it is proposed that a demonstration multi-purpose collective protection unit be developed as soon as possible.

Complete (99.9%) CBR protection for at least 14 days is required. A relatively long term development effort is necessary to achieve this degree of protection from current chemical and biological warfare agents. Catalytic pyrolysis appears to be the air purification technique to develop since waste heat from a shelters motor generator unit can be utilized. Also, the characteristics of chemical and biological agents under development indicate that the continuous development of more effective air purification techniques will be necessary to maintain 99.9% protection. Agents under development will have smaller particles (Diameters less than .1μ) and a lethal dose less than 10 particles per liter of air.

The study effort, to date, has established the feasibility of developing multi-purpose collective protection units. Auxiliary power, air conditioning, and collective protection can be combined into one efficient multi-purpose unit. Although a fair degree of protection can be provided with automatic dust and gas-particulate filters, another air purification technique must be developed to provide 99.9% protection for two week periods. Catalytic pyrolysis appears to be the technique to develop. Based on the preceding information 1962 objectives are proposed as follows:

1. Design, fabricate, and develop one demonstration multi-purpose collective protection unit.

2. Initiate the experimental work necessary to develop a catalytic pyrolyzer.

B. Task Definition

The study, design, development and experimental tasks necessary to accomplish 1962 objectives are defined as follows:

1. Study Effort

   a. To avoid duplication of effort, determine what has been done and is being done in the areas of collective CBR protection, air purification, and protective shelters by

      Continued Literature search.

      Contacting experts in above areas.

b. Investigate air purification methods and determine those most applicable to multi-purpose collective protection.

c. Through continued literature search, determine physical characteristics of current and candidate chemical and biological warfare agents and nuclear warfare hazards.

d. Determine equipment and instrumentation required to initiate development of a catalytic pyrolyzer.

2. Design and Development Effort

a. Theoretically design a family of multi-purpose collective protectors for the shelter size range of 50 to 100 occupants assuming a catalytic pyrolyzer can be developed to operate at 600°F. Determine size, availability, and cost of components.

b. Design and fabricate one demonstration multi-purpose collective protection unit without catalytic pyrolyzer, for a 50 occupant shelter.

c. Design and fabricate one experimental test rig to evaluate various types of catalytic pyrolyzers.

3. Experimental Effort

a. Initiate experimental testing to determine time-temperature relationships for catalytic pyrolysis of BW and CW agents.

b. Test demonstration unit as necessary to establish normal operation.

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REFERENCES

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2. ASHRAE Guide and Data Book, 1961, Fundamentals and Equipment for Heating, Refrigerating, Ventilating, and Air Conditioning.

3. Fallout Control; by C. E. Lapple; US AEC SRIA-3; August 1, 1958.

4. Supplement to Final Report Phase I, BW/RWS, Model DA-88; Douglas Aircraft Co., Report SM-38595; April 30, 1961.

5. AD 323858; "Respiratory Protection Research"; Mine Safety Appliance Co. 1st Bimonthly Progress Report; 12 June 1961.

6. Unclassified; AD 260235; The Present Status of Chemical Research in Atmospheric Purification and Control on Nuclear-Powered Submarines; Annual Progress Report; NRL Report 5630; July 14, 1961.

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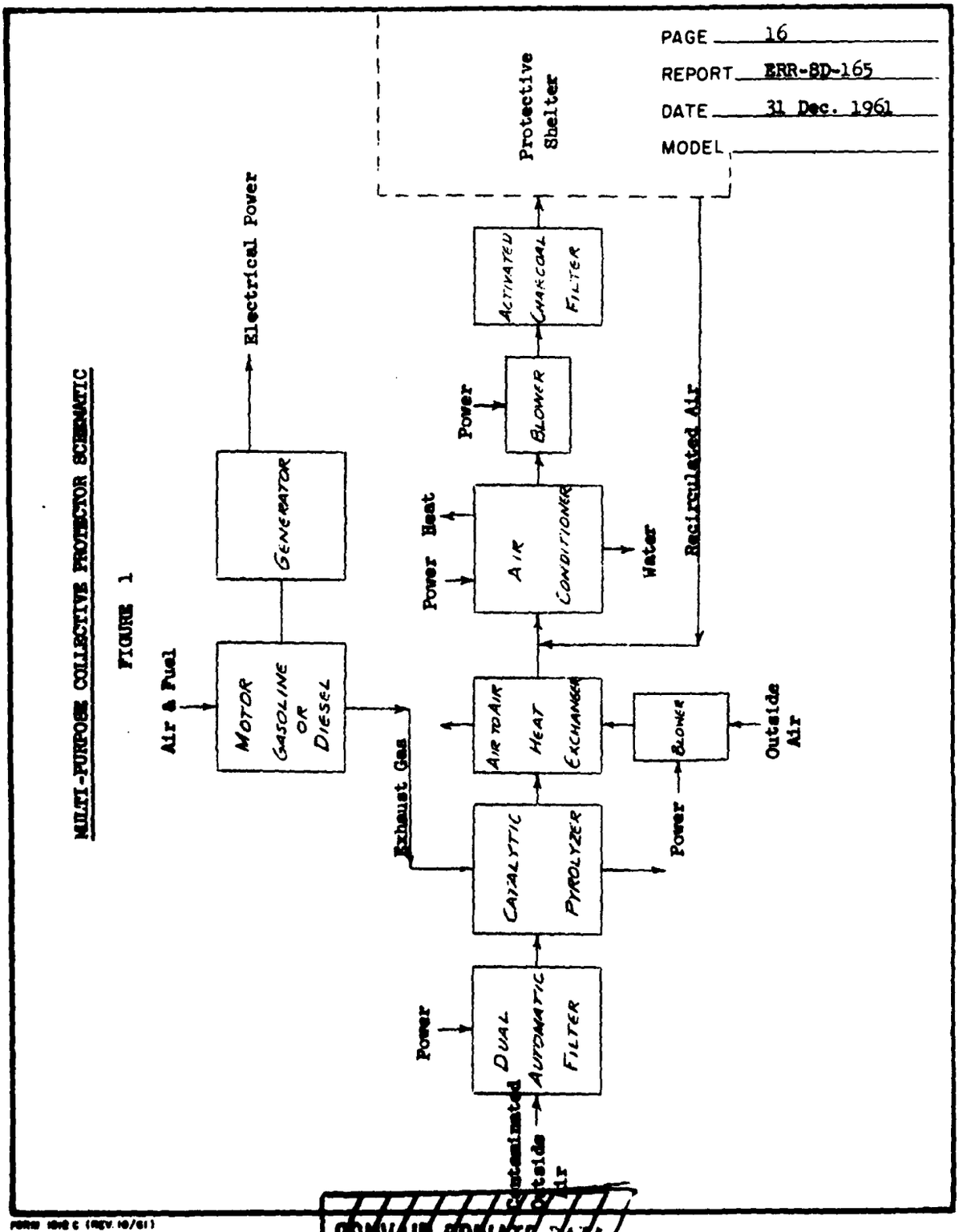
MULTI-PURPOSE COLLECTIVE PROTECTOR SCHEMATIC

FIGURE 1



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CATALYTIC PYROLYZER DEVELOPMENT TEST

SCHEMATIC DIAGRAM

FIGURE 2