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WAR DEPARTMENT

REPORT NO. 773

Final Report

METHANOL-WATER TYPE, LOW PRESSURE, HYDROGEN GENERATOR

5 October 1943

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Corps of Engineers, U. S. Army
Fort Belvoir, Virginia

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REPORT NO. 773

Final Report

METHANOL-WATER TYPE, LOW PRESSURE, HYDROGEN GENERATOR

Project No. BE 620 H

Low Pressure Hydrogen Generators

5 October 1943

Submitted to

THE ENGINEER BOARD

Fort Belvoir, Virginia

and/or

The Chief of Engineers

U. S. Army

Washington, D. C.

FOR OFFICIAL ACTION

by

Jack R. Caddell

1st Lieutenant, Corps of Engineers

Fort Belvoir, Virginia

[redacted]

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SYLLABUS

1. The development of equipment for the field generation of hydrogen and other lifting gases was transferred from the Army Air Forces when the Chief of Engineers became responsible for the development of barrage balloon equipment in April 1942.

2. In addition to correcting certain deficiencies of the existing ferrosilicon plants, the Engineer Board investigated other methods of hydrogen generation. Close liaison was maintained with the Navy Department which, in cooperation with duPont Company, developed a low pressure, methanol-water type, hydrogen generator. This type was selected in order to minimize mechanical difficulties and to provide another source of raw materials, as the ferrosilicon supply appeared to be inadequate.

3. In accordance with a request of the using arm, a low pressure, methanol-water type, hydrogen generator was obtained by the Office, Chief of Engineers, from the Navy Department. After engineering tests were completed, the generator was turned over to the Barrage Balloon Board for service test. As the subject generator proved more satisfactory than the ferrosilicon plants, the using arm initiated procedure to classify the methanol-water type as standard and to reclassify the ferrosilicon type as limited standard.

4. It is concluded that:

a. The mobile, low pressure generator, with compressor, satisfactorily meets the approved military characteristics for a mobile high pressure unit, except the characteristics for gas with a minimum hydrogen content of 99 percent.

b. The trailer mount for the equipment must be modified in order to conform to Army standards and good engineering practice. Most changes could readily be made; however, increasing front and rear tire sizes would necessitate redesign of the equipment in order to hold the overall height to the existing 12 feet, or to reduce it to 11 feet as required by AR 850-15.

c. Changing the front tire size from 7.50x15 to 7.50x16, and retaining the present rear tire size of 7.50x20, would make the tires standard and the equipment would be suitable for use by barrage balloon organizations even though the tires were overloaded.

5. It is recommended that:

a. The characteristic for gas with a minimum hydrogen content of 99 percent be changed by lowering the requirement

[redacted]

for hydrogen purity to 98 percent where the principal heavier gas is carbon dioxide.

b. For immediate procurement by the Army, the front tire size be changed to 7.50x16, and the overall height of 12 feet be accepted.

c. For future procurement by the Army, and in so far as practicable with present war procurement schedules, the trailing equipment be modified to conform to Army standards and good engineering practice.

METHANOL-WATER TYPE, LOW PRESSURE, HYDROGEN GENERATOR

I. SCOPE OF REPORT

1. This report covers the development and testing of a low pressure, hydrogen generator of the methanol-water type for use by barrage balloon field organizations located beyond a commercial source of hydrogen supply. The low pressure generator operates at a pressure of 0-10 pounds per square inch; a compressor being used to compress the hydrogen gas to 2,100 pounds per square inch for storage in cylinders.

II. AUTHORITY

2. The authority for this work is contained in the following official communications, copies of which are contained in Appendices A and B.

a. Letter, Headquarters, Antiaircraft Command, to the Commanding General, Army Ground Forces, subject: Development of Low Pressure Hydrogen Generator, dated 19 February 1943, file AAC 580.854/K-1-GNSBL; 2nd Indorsement, Headquarters, Services of Supply, to the Chief of Engineers, dated 8 March 1943, file SPRMD 412.42 (2-19-43); and 3rd Indorsement, Office, Chief of Engineers, to The Engineer Board, dated 27 March 1943, file SPESD.

b. Letter, The Engineer Board, to the Chief of Engineers, subject: Request for Development Projects, dated 27 April 1943, file 452.3 (BB-610-E); 2nd Indorsement, Headquarters Army Service Forces to the Chief of Engineers dated 30 April 1943, file SPRMD 452.3 (4-27-43); and 3rd Indorsement, Office, Chief of Engineers, to the Engineer Board, dated 1 May 1943, file SPESD.

III. PREVIOUS INVESTIGATION

3. The Chief of Engineers became responsible for the development of barrage balloon equipment in April 1942. The existing K-1, mobile, hydrogen generators for barrage balloon units, operating where a commercial source of hydrogen supply was not available, was the high pressure ferrosilicon type, which was based on a French process, improved and developed by the Air Corps. Sixty of these generator plants were constructed, or in process of construction.

4. Reports from Army troop organizations, possessing the ferrosilicon generators, which operated at 2,200 p.s.i., indicated that many operating difficulties could be traced to extensive procurement of the equipment before completion of development and

service testing. Moreover, prospective increased use for hydrogen for barrage balloons was said to be great enough to require a considerable expansion in the facilities for producing ferrosilicon -- already considered a strategic material -- or the substitution of other materials in its place. Thus, in addition to initiating procedures for the correction of certain deficiencies in the existing generator, an investigation was made of other methods for generating hydrogen.

5. The Navy Department, obtaining M-1 generators from the Army, was experiencing similar difficulties and was following similar policies of development. In cooperation with the duPont Company, the Navy Department developed a low pressure, methanol-water type, hydrogen generator, with a capacity of 4,000 cubic feet per hour. Although close liaison was maintained, the Corps of Engineers, adhering to military characteristics of the using service calling for high pressure equipment, continued with modifications and improvements to the 60 M-1 type generators then on order.

IV. PRESENT INVESTIGATION

6. In accordance with a request of the using arm, Appendix A, work was started under the present investigation. A mobile, low pressure, methanol-water type, hydrogen generator was obtained by the Office, Chief of Engineers, from the Navy Department and shipped to Barrage Balloon Training Center, Camp Tyson, Tennessee, for engineering and service tests.

7. The low pressure generator is a trailer mounted unit 8 feet wide, 20 feet long, and 12 feet high; the weight is 29,000 pounds. The associated equipment, obtained from the Navy also, included a Chicago Pneumatic, 4-stage, class PO-44, hydrogen compressor for compressing the gas to 2,100 pounds per square inch, as required for storage in cylinders. A detailed description of the generator and compressor, with photographs and outline of the process and flow sheets, is given in Appendix C.

8. Operating crews of the using arm were trained, with the cooperation of the Navy, during the engineering tests. After engineering tests, and the elimination of difficulties attributed to dirt and fouling due to shipment uncrated on an open flatcar, the plant was submitted to the Barrage Balloon Board at Camp Tyson for service test. Some further difficulties encountered during the service test, again attributed to prior use and poor shipment, were corrected and extended operation proceeded satisfactorily.

9. As a result of service tests, the Barrage Balloon Board, in its Report No. 137, dated 7 July 1943, recommended classification of the low pressure, methanol-water type, hydrogen generator as:

Required type
Adopted type
Standard Article.

The M-1 generator was recommended for reclassification as:

Required type
Adopted type
Limited Standard Article.

10. A list of tools and spare parts, as compiled by the Navy Department, was submitted to the service board and found satisfactory. Appendix F gives the list with comments and findings of the service board.

11. A medium pressure, methanol-water type, hydrogen generator, operating at 300 pounds per square inch, as compared to 5 pounds per square inch in the low pressure unit, also was developed by the Navy Department. This plant, obtained by the Office, Chief of Engineers, was tested by the service board and found to be unsatisfactory for use by barrage balloon organizations.

V. DISCUSSION

12. The low pressure, methanol-water type, hydrogen generators were developed by the Navy Department in cooperation with the duPont Company. The generators are mobile, trailer mounted units, designed to produce 4,000 cubic feet per hour of hydrogen containing less than 2 percent of heavier gases at a pressure of 0-10 pounds per square inch. In operation, a hydrogen-carbon dioxide mixture is formed by cracking methanol on a hot catalyst in the presence of steam, and then scrubbing the gas mixture with monoethanolamine solution to remove the carbon dioxide. Provision has been made for the regeneration and recycling of the scrubbing solution. All parts normally required are mounted on a single trailer. The only normally unavailable supplies required are specially refined methanol and monoethanolamine.

13. Tests of the generators were conducted by towing the generator and compressor to some convenient location, piping suitable connections, and then starting the production of gas. Crews of four men were trained and material records were maintained. A summary of service test results, with a comparison of the M-1 generator, has been extracted from Barrage Balloon Report No. 137, and is given in Appendix D. It has been noted that the original cost of the methanol type is somewhat higher than the ferrosilicon type, but that the following advantages outweigh this first cost:

a. Greatly increased reliability.

b. Minimized maintenance and breakdowns.

c. Fifty percent reduction in manpower requirements; from an 8-man to a 4-man crew.

d. Continuous process, instead of batch process.

e. Seventy-five percent reduction in raw material and fuel costs, which amounts to $7,200 per month per LA battalion or VLA battalion operating balloons in tandem.

f. Reduction of water requirements by more than 2,500 percent; from 900 to 35 gallons per hour of operation.

g. Twenty-three percent reduction in shipping space of raw materials, or a monthly saving of about 3,300 cubic feet per battalion.

14. At the time the low pressure, hydrogen generator project was initiated, no military characteristics had been approved. However, the plan of development, given in Appendix B, was written and tests of equipment were started under the desirable characteristics for a portable, low pressure generator, which were included with the request for development by the using service. (Appendix A.) Three other sets of military characteristics, including those for a mobile, high pressure unit, were subsequently approved, and are shown in Appendix E. No characteristics have been approved for a mobile, low pressure unit, which is the subject equipment. However, as reported in Barrage Balloon Board Report No. 137, the mobile low pressure, methanol-water type, hydrogen generator, with compressor, is desired by the using arm. This generator satisfactorily meets the approved characteristics for a mobile, high pressure, hydrogen generator, when the compressor in considered, except the characteristic for hydrogen purity of 99 percent. In addition, the mobile, low pressure generator, as an individual unit, and without a compressor, meets the military characteristics for a portable, low pressure generator, except the characteristics for breakdown into sub-assemblies for transportation and for hydrogen purity of 99 percent. As the characteristics for portable, low pressure generators require sub-assemblies for transportation in a 2-$\frac{1}{2}$-ton truck, consideration was given to designing plants, similar to that in test, for skid mounting in light weight sections. However, this proved impractical, due to the number of rigid gas connections and the careful high temperature control required for minimum fuel consumption and control of chemical reactions.

15. The generator tested was originally developed by the Navy Department and built according to Navy characteristics. All equipment necessary for operation was mounted on a single 4-wheel trailer. Although the unit satisfactorily meets the approved military characteristics, the trailing equipment is not in accordance with Army standards and the tires are overloaded. A detailed description of the 4-wheel trailer is given in Appendix C. In order to conform to the characteristics for Army trailing equipment, it would be necessary to make changes in the tire sizes, brakes, lights, and coupling

connectors for cable jumpers. A performance specification, adapting the Navy type generator and trailer to Army Standards, except height, is given in Appendix G. Changes to the brakes, lights, and couplings can readily be made. However, any increase in tire sizes, as required to meet good engineering practice, would necessitate redesign of the generating equipment in order to hold the overall height to the existing 12 feet, or to reduce it to 11 feet as required by AR 850-15.

16. The total weight of the generator, including the trailer, is 29,000 pounds, which is carried on 7.50x15 dual tires in front, and by 7.50x20 dual tires on the rear axle. The rear tire size, 7.50x20, is an Army standard; however, the front tire size, 7.50x15, is non-standard and should be changed to 7.50x16 to conform to Army standards. This change can be made by increasing the overall height in front approximately 1/2-inch. The use of 7.50x16 tires in front would decrease the wheel clearance under the goosenock only a negligible amount and redesign and layout of the equipment would not be necessary. However, with 7.50x16 and 7.50x20 tires, both the front and rear tires are overloaded according to good engineering practice for the design of trailing equipment. Nevertheless, for immediate procurement requirements, the tire overloading should be neglected and the present overall height of 12 feet should be accepted for the following reasons:

a. It is understood that recommendations have been forwarded by Headquarters Army Ground Forces to classify the existing M-1, mobile, high pressure, ferrosilicon type, hydrogen generator as obsolete, and to issue the low pressure, methanol-water type, with compressor, as soon as possible.

b. The total number of generators required to meet existing activation schedules for barrage balloon battalions is estimated to be 30 units.

c. The use of the trailer is limited to the subject equipment, and it will not be used for general trailing purposes.

d. The employment of the equipment is relatively static, and when moved, will usually move on roads and not across-country.

e. Changing the front tire size from 7.50x15 to 7.50 x16, and retaining the present rear tire size of 7.50x20, would make the equipment suitable for use by barrage balloon organizations even though the tires were overloaded.

f. Existing designs for the equipment can be utilized.

g. Quantity procurement would be delayed by the extensive development required to increase tire sizes, reduce the height, and alter the layout and trailer design.

17. The gas produced by the low pressure plant contains from 98 to 99.5 percent hydrogen, while the gas produced by the M-1 generator contains 99.4 percent hydrogen. The heavier gas from the low pressure plant is principally carbon dioxide, which is not objectionable, while the heavier gas from the M-1 generator is principally oxygen, which is highly objectionable.

VI. CONCLUSIONS

18. It is concluded that:

a. The low pressure, methanol-water, hydrogen generator, complete with compressor, portable manifold, and connections, is superior to the Generator, Mobile, Hydrogen, M-1, for use by barrage balloon organizations.

b. The mobile, low pressure generator, with compressor, satisfactorily meets the approved military characteristics for a mobile, high pressure unit, except the characteristic for gas with a minimum hydrogen content of 99 percent.

c. The mobile, low pressure generator, as an individual unit, and without a compressor, meets the approved military characteristics for a portable, low pressure generator, except the characteristics for breakdown into demountable sections for transportation and the production of hydrogen of 99-percent purity.

d. Hydrogen gas of 98-percent purity or higher, as produced by the test plant, is satisfactory.

e. It is impracticable to breakdown the low pressure, methanol-water type, hydrogen generator into a number of smaller skid mounted sub-assemblies.

f. The trailer mount for the equipment must be modified in order to conform to Army standards.

g. Increasing the tire sizes to conform to good engineering practice would necessitate redesign of the generating equipment in order to hold the overall height to the existing 12 feet, or to reduce it to 11 feet as required by AR 850-15, and should be neglected for immediate procurement requirements.

h. Changing the front tire size from 7.50x15 to 7.50x16, and retaining the present rear tire size of 7.50x20, would make the tires standard and the equipment would be suitable for use by barrage balloon organizations even though the tires were overloaded.

VII. RECOMMENDATIONS

19. It is recommended that:

a. Military characteristics be changed to lower the requirement for hydrogen purity from 99 percent to 98 percent, where the principal heavier gas is carbon dioxide.

b. For immediate procurement by the Army, the front tire size be changed to 7.50x16 and the overall height of 12 feet be accepted.

c. For future procurement by the Army, and insofar as practicable with present war procurement schedules, the trailing and generating equipment be modified to conform to Army standards and good engineering practice.

Submitted by:

Jack R. Caddell,
1st Lt., Corps of Engineers,
Chief, Barrage Balloon Branch.

Forwarded by:

Walker W. Milner,
Lt. Col., Corps of Engineers,
Director, Technical Division II.

LIST OF APPENDICES

Appendix A — Letter from Headquarters, Antiaircraft Command, to the Commanding General, Army Ground Forces, Subject: Development of Low Pressure Hydrogen Generators, dated 19 February 1943, with 3 Indorsements.

Appendix B — Letter from The Engineer Board to the Chief of Engineers, Subject: Request for Development Projects, dated 27 April 1943, with 3 Indorsements.

Appendix C

- Exhibit 1 — Description of generating unit and trailer. Extract from Barrage Balloon Board Report No. 137.
- Exhibit 2 — Description of Compressor. Extract from Barrage Balloon Board Report No. 137.
- Exhibit 3 — Outline of Process. Extract from duPont Company Operating Manual.
- Exhibit 4 — Flow Sheet for GRX unit.
- Exhibit 5 — Photographs of Generator and Compressor.

Appendix D — Comparison between Low Pressure, Methanol-Water, Hydrogen Generator and M-1 Generator. Extract from Barrage Balloon Board Report No. 137.

- Exhibit 1 — Descriptive Comparison.
- Exhibit 2 — Tabular Comparison.

Appendix E — Approved Desirable Military Characteristics.

Appendix F — Tools and Spare Parts. Extract from Barrage Balloon Board Report No. 137.

Appendix G — Corps of Engineers (Engineer Board) Tentative Specification, EBP No. 483, dated 28 September 1943, title: Generator, Hydrogen Gas, Low Pressure, Methanol-Water Type, Trailer Mounted, 4,000 Cubic Feet per Hour.

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APPENDIX "A"

HEADQUARTERS ANTIAIRCRAFT COMMAND
Richmond, Virginia

AAC 580.854/K-1 - GNSBL February 19, 1943.

Subject: Development of Low-Pressure Hydrogen Generator.

To: Commanding General, Army Ground Forces, Army War College, Washington, D. C.

1. The present standard hydrogen generator, M-1, mobile, has certain mechanical weaknesses which appear to be inherent in high-pressure generators. The most serious of these weaknesses are the caustic pump and fitting. It is understood that the Chief of Engineers has discontinued development of a low-pressure sodium hydride generator which was being considered by him. It is also understood that the Navy is using a methanol process for generating hydrogen which is very promising except that the equipment required for this process is also very cumbersome.

2. In view of the probability that a more mobile source of supply of hydrogen may be required with very low altitude barrage balloons, it is believed that a generating unit consisting of a low-pressure generator with a compressor and the necessary accessories should be developed.

3. It is recommended that:

a. The Chief of Engineers develop at the earliest practicable date a hydrogen generating unit which will meet the inclosed desirable military characteristics.

b. Development of the generator referred to in paragraph 3a, above, be given a high priority.

For the Commanding General:

/s/ C. V. R. Schuyler
/t/ C. V. R. SCHUYLER,
Colonel, G.S.C.,
Chief of Staff.

1 Incl. - Desirable Military Characteristics for a Hydrogen Generating Unit for Bar. Bln. Organizations.

APPENDIX "A" cont

SUBJECT: Development of Low-Pressure Hydrogen Generator.

412.5-GNRQT-9/32330
(2-19-43) 1st Indorsement

HQ., ARMY GROUND FORCES, Army War College, Washington, D. C., February 28, 1943.

TO: The Commanding General, Services of Supply, War Department, Washington, D. C. (Att: Development Branch Requirements Division).

1. The recommendations of the Antiaircraft Command appearing in Paragraph 3 of the basic letter are approved.

2. It is recommended that the development of hydrogen generators for Barrage Balloon Units be coordinated between the Chief of Engineers and the Chief Signal Officer since the latter is developing hydrogen generators for the inflation of meteorological balloons.

For the COMMANDING GENERAL:

/s/ C. H. Day
/t/ C. H. DAY,
Colonel, A.G.D.,
Asst. Ground Adj. Gen.

1 Incl.
(Dupl. w/d)

SPRMD 412.42 (2-19-43) 2nd Indorsement

Headquarters, Services of Supply, Washington, D. C., March 8, 1943.

To: The Chief of Engineers.
Attn: Development Branch, Supply Division.

1. It is desired that action be initiated to develop, at the earliest practicable date, a hydrogen generating unit which will meet the desirable military characteristics as listed in the inclosure.

SPRMD 412.42 (2-19-43) 2nd Indorsement cont.

2. This development is to be given high priority.

For the Commanding General:

W. A. WOOD, JR.,
Brigadier General, General Staff Corps,
Director, Requirements Division.

1 Incl.
n/c

/s/ R. R. Robins
/t/ R. R. ROBINS
Colonel, General Staff Corps,
Chief, Development Branch.

SPESD Subject: Low-Pressure Methanol-Type Hydrogen Generator.

3rd Ind.

Office, C. of E., Room 1415 Tempo "G", 23rd and C Streets, N. W., March 27, 1943.

To: The President, The Engineer Board, Fort Belvoir, Virginia.

1. A Navy methanol-type, low-pressure, hydrogen generator is being shipped to the Engineer Board for service test to determine whether or not this generator is suitable for Army purposes.

2. Desirable military characteristics for a hydrogen generating unit for barrage balloon organizations are inclosed. The Engineer Board is directed to investigate the adaptability of the Navy hydrogen generator to these characteristics.

3. It is requested that a report be submitted as soon as possible. This report should cover the modifications required to make the Navy hydrogen generator conform to the inclosed characteristics.

By order of the Chief of Engineers:

/s/ F. C. Kendall
/t/ F. C. Kendall,
Major, Corps of Engineers,
Executive Officer,
Engineering and Development Branch,
Supply Division

1 Incl: n/c

APPENDIX "A" cont

DESIRABLE MILITARY CHARACTERISTICS FOR A
HYDROGEN GENERATING UNIT FOR
BARRAGE BALLOON ORGANIZATIONS

1. To consist of a low-pressure generator, a compressor and all of the accessories required for the generation of hydrogen and its storage in standard gas cylinders at 2,000 pounds pressure, per square inch.

2. To be capable of generating and storing in gas cylinders an average of at least 2,500 cubic feet of free hydrogen per hour of operation.

3. To be capable of being usefully operated for 20 hours per day.

4. To produce hydrogen of higher than 99 percent purity.

5. To have the maximum practicable percentage yield for all materials used for the generation of hydrogen.

6. To have the minimum practicable requirements of cooling water and gas drying materials.

7. The Generator:

a. To be capable of being broken down readily into subassemblies, each of which may be transported in a standard 2½-ton truck.

b. Subassemblies to be mounted on skids or wheels in such a manner as to facilitate their being loaded onto and unloaded from a standard 2½-ton truck.

c. To be capable of being assembled from subassemblies and placed in operation in less than five hours, by the crew.

8. The Compressor:

a. To be capable of being broken down into subassemblies each of which may be transported in a standard 2½-ton truck, or to be mounted on wheels, as a trailer, capable of being towed at 25 MPH, on good roads.

b. To be capable of being assembled and integrated with the generating unit, ready for operation, in less than five hours, by the crew.

9. Each assembly and subassembly of the breakdown for transportation to have minimum size and weight, consistent with other requirements.

10. To involve a minimum hazard to operating personnel.

11. To require the minimum practicable number of operators.

Incl. 1.

APPENDIX "B"

WAR DEPARTMENT
THE ENGINEER BOARD
FORT BELVOIR, VIRGINIA

Refer to File No.
452.3 (BB 610 E)

April 27, 1943

Subject: Request for Development Projects.

To: Chief of Engineers, U. S. Army.

It is requested that approval be given for initiating work on the following development projects in accordance with the plans of development forwarded herewith:

a. BB 600 A(4) - Ballonet Type Very Low Altitude Balloon. The present M-1 very-low altitude balloon requires approximately 12 pounds of rubber for its dilation system and considerable maintenance. A ballonet operated very low altitude balloon will eliminate these difficulties and save a considerable quantity of critical material.

b. BB 610 G - Hand Operated Winch for Very Low Altitude Balloons. The using service has requested a winch that will combine the features of the British Mark VII hand winch and the British Admiralty winch.

c. BB 620 H - Low Pressure Hydrogen Generator. The present Generator, Hydrogen, Mobile, M-1, requires 900 gallons of cooling water per hour, overhauling after each move, continuous maintenance, weighs approximately 28,000 pounds, occupies approximately 2,000 cubic feet of space, and requires a comparatively large crew considering the hydrogen production.

The low pressure generator contemplated will be designed to eliminate the above difficulties and will be particularly suitable for overseas operations with very low altitude organizations.

For the Board:

/s/ W. J. Matteson
/t/ W. J. Matteson,
Colonel, Corps of Engineers,
Assistant Executive Officer.

6 Incls.
3 - Authority for Initiation of Project
3 - Plans for Development

APPENDIX "B" cont

SPESD SUBJECT: Request for Development Projects.

1st Ind.

Office, C. of E., Room 1428 Temp G Bldg., 23rd & C Sts., N. W.
Washington, D. C., April 28, 1943.

To: THE COMMANDING GENERAL, ARMY SERVICE FORCES.

1. Attention is invited to the attached request from the Engineer Board and to the six (6) inclosures therewith, regarding the following development projects:

a. BB 600 A(4) - Ballonet Type Very Low Altitude Balloon.
b. BB 610 G - Hand Operated Winch for Very Low Altitude Balloons.
c. BB 620 H - Low Pressure Hydrogen Generator.

2. Authority to initiate these projects in accordance with the attached Plans for Development is requested.

For the Chief of Engineers:

/s/ F. S. Besson, Jr.
/t/ F. S. Besson, Jr.,
Lt. Col., Corps of Engineers,
Chief, Engineering and Development Branch,
Supply Division

Incls.
n/c

SPRMD 452.3 (4-27-43) 2nd Indorsement

Headquarters, Army Service Forces, Washington, D. C., April 30, 1943.

To: Chief of Engineers (Attn: Engineering & Development Branch, Supply Division).

Request contained in the 1st Indorsement is approved.

For the Commanding General:

Incls. n/c

for
R. R. Robins
Colonel, General Staff Corps
Chief, Development Branch

W. A. WOOD, JR.,
Brigadier General, General Staff Corps,
Director, Requirements Division
/s/ Francis J. Dailis, Jr. Lt. Col. Sig. C.

APPENDIX "B" cont

SUBJECT: Request for Development Projects.

SPESD 3rd Indorsement

Office, C. of E., Room 1424, Tempo. Bldg. G, 23rd & C Sts., N. W., May 1, 1943.

To: The President, The Engineer Board, Fort Belvoir, Virginia.

The following development projects as outlined in basic letter and in accordance with the inclosed military characteristics and plan of development are approved and assigned to the Engineer Board:

a. BB 600 A(4) - Ballonet Type Very Low Altitude Balloon.
b. BB 610 G - Hand Operated Winch for Very Low Altitude Balloons.
c. BB 620 H - Low Pressure Hydrogen Generator.

By Order of the Chief of Engineers:

/s/ F. C. Kendall.
/t/ F. C. Kendall,
Major, Corps of Engineers,
Exec. Officer, Engineering & Development Branch
Supply Division.

Incls: n/c

Project No. BB 620-H Low Pressure Hydrogen Generator

Authority for Initiation of Project:

Letter Headquarters, Antiaircraft Command, Richmond, Virginia to the Commanding General, Army Ground Forces, Washington, D. C., subject: Development of Low Pressure Hydrogen Generator, dated February 19, 1943, file AAC 580.854/K-1 - GNSBL; 2nd indorsement, Headquarters, Services of Supply to the Chief of Engineers, dated March 8, 1943, file SYRMD 412.42(2-19-43) and to 3rd indorsement Office, Chief of Engineers to the Engineer Board, dated March 27, 1943.

Purpose of Project:

To develop a suitable methanol-water hydrogen generator for use with barrage balloon organizations.

Military Characteristics:

1. To consist of a low-pressure generator, a compressor and all of the accessories required for the generation of hydrogen and its storage in standard gas cylinders at 2,000 pounds pressure, per square inch.

2. To be capable of generating and storing in gas cylinders an average of at least 2,500 cubic feet of free hydrogen per hour of operation.

3. To be capable of being usefully operated for 20 hours per day.

4. To produce hydrogen of higher than 99 percent purity.

5. To have the maximum practicable percentage yield for all materials used for the generation of hydrogen.

6. To have the minimum practicable requirements of cooling water and gas drying materials.

7. The Generator:

a. To be capable of being broken down readily into subassemblies, each of which may be transported in a standard $2\frac{1}{2}$-ton truck.

b. Subassemblies to be mounted on skids of wheels in such a manner as to facilitate their being loaded onto and unloaded from a standard $2\frac{1}{2}$-ton truck.

c. To be capable of being assembled from subassemblies and placed in operation in less than five hours, by the crew.

8. The Compressor:

a. To be capable of being broken down into subassemblies each of which may be transported in a standard $2\frac{1}{2}$-ton truck, or to be mounted on wheels, as a trailer, capable of being towed at 25 MPH, on good roads.

b. To be capable of being assembled and integrated with the generating unit, ready for operation, in less than five hours, by the crew.

9. Each assembly and subassembly of the breakdown for transportation to have minimum size and weight, consistent with other requirements.

10. To involve a minimum hazard to operating personnel.

11. To require the minimum practicable number of operators.

APPENDIX "B" cont

Project BB 620-E — Low Pressure Hydrogen Generator

Plan for Development
April 26, 1943

1. To test the low and medium pressure methanol-water hydrogen generator developed by the U. S. Navy and loaned to the Engineer Board in accordance with arrangements made by the Chief of Engineers.

2. To contact manufacturers and secure proposals for the construction of pilot models with necessary modifications for barrage balloon use based upon the results of the test outlined above.

3. No military characteristics have been approved, but the design will be based upon the following considerations:

a. To be capable of generating at least 2,500 cubic feet of hydrogen per hour of operation.

b. To be capable of being usefully operated for 20 hours per day.

c. To produce gas with a minimum hydrogen content of 98% exclusive of water vapor content.

d. To require a minimum of materials required for the generation by:

(1) Proper choice of reaction to be used.

(2) Maximum chemical efficiency during reaction, consistent with other requirements.

(3) Minimum requirements of cooling water.

e. To require a minimum of personnel for operation.

f. To have minimum size and weight consistent with other characteristics.

g. To permit the use of a compressor for raising the pressure of the resulting gases to 2000 pounds per square inch pressure.

4. After constructing pilot models, several engineering tests will be conducted and the units will be sent to the Barrage Balloon Board of the Coast Artillery Corps for service test and comment.

APPENDIX "B" cont

5. After receiving the results of the service tests, desirable changes will be incorporated in the design, specifications will be prepared, and standardization procedure initiated based upon recommendations of the using service. General plans and specifications will also be prepared for a 1000 cu.ft. generator for use of other than balloon organizations.

Approval by Board _____
Date

APPENDIX "C", EXHIBIT I cont

E X T R A C T

REPORT, BARRAGE BALLOON BOARD PROJECT NO. 137. Subject No. 57-8 dated 7 July 1943.

* * * * *

Description of Low-Pressure, Methanol-Water Hydrogen Generator.

1. General. The low-pressure, methanol-water hydrogen generator is a trailer-mounted unit 8 feet wide, 20 feet long, and 12 feet high. The weight is 29,000 pounds. The gas production system consists of a 140-gallon feed tank, a feed pump, a vaporizer, a preheater, a catalytic converter, an air-cooled cooler, a water separator, and a gas scrubbing column. The scrubbing cycle consists of the gas scrubber, a centrifugal scrubber pump, a regenerating column, a boiler, a centrifugal boiler pump, a heat exchanger, and an air cooler. Distilled water for the feed is provided by a water still. Heat is furnished by means of oil burners supplied with combustion air by a blower. Air for all cooling is supplied by a second blower. Power for the operation of the plant is provided by an Allis-Chalmers, 32-horsepower, 4-cylinder gasoline engine connected directly to the main drive shaft through a disk type clutch. Power is transmitted to the various equipment pieces through V-belt drives.

2. Trailer. The trailer is a four-wheel Kentucky model. The rear wheels have 9.00 x 20 dual tires; the front wheels have 7.50 x 15 dual tires. The trailer is equipped with vacuum brake system on two rear wheels, but has no parking brake. There is a standard tail light at the rear but there are no rear and side marker lights, reflectors or blackout lights. A standard Army jumper cable will not fit the single electrical connection on the front.

APPENDIX "C", EXHIBIT I cont

SPECIFICATIONS

Model L-B 400 - 4 wheel trailer drawing #TW 317-A

FRAME

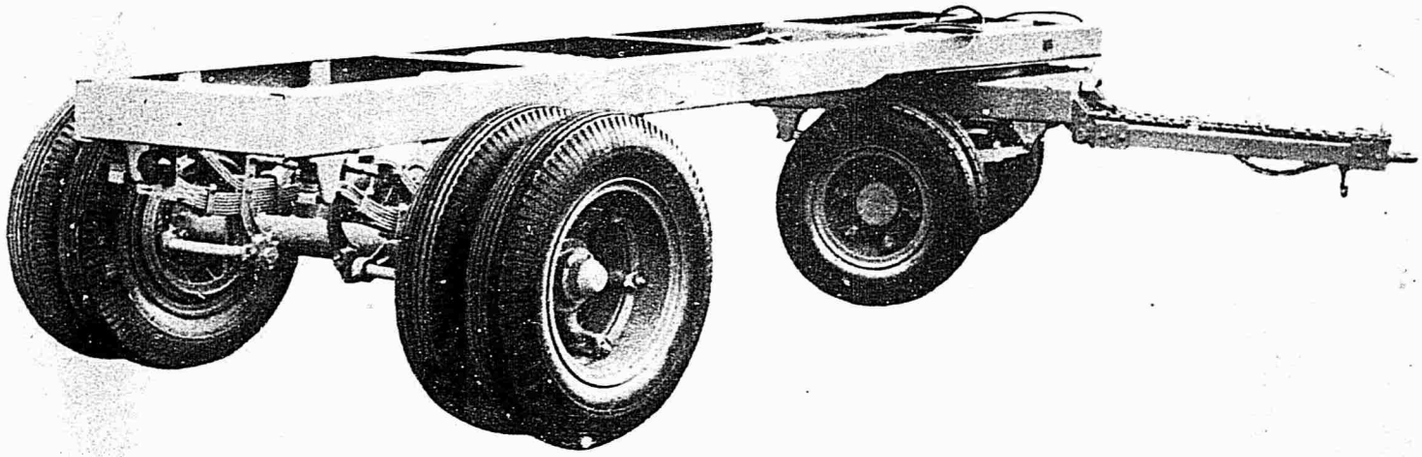
1/4 x 5½" at front neck with reinforcing insert. 1/4 x 7" from neck to rear end over all length - 15 ft. - both ends square.

FRONT DOLLY

4 ft. hinged draw bar - with 2 safety chains
4-1/2" Timken tubular axle - no brakes - dayton cast steel wheels
18 inch - 15 x 7 rims for low bed type 7.50 x 15 dual tires.
Special springs shackled at each end.
Dolly frame members 1/4" steel.
Gear lock at front end for backing.
5th wheel is 30 inch flat ring type.

REAR AXLE

Springs special type same as front.
Timken tubular axle with Timken.
P. series brakes 16½ x 5 with 3/4" molded lining. Vacuum brake actuation.
Dayton steel wheels and brake drums.
7.50 x 20 dual tires mounted on 20 x 7 rims.
Standard stop tail light.
Paint Navy Gray.



APPENDIX "C", EXHIBIT 1
LOW PRESSURE GENERATOR - TRAILER

APPENDIX "C", EXHIBIT 2

E X T R A C T

REPORT, BARRAGE BALLOON BOARD PROJECT NO. 137. Subject No. 57-8, dated 7 July 1945.

* * * * *

Description of the Portable Chicago Pneumatic Tool Company

Air Compressor

1. General. The compressor is of the air-cooled, Chicago Pneumatic Tool Company, P-type design, having four cylinders and four compression stages.

2. Pistons. The pistons are actuated through rods and crossheads in addition to the conventional automotive-type connecting rod linkage, but the pistons, nevertheless, are single-acting. The crossheads are built like complete pistons with piston rings for oil control and to form an effective gas seal between the crank case and the space above the crosshead. Gas leaking past the compressor pistons is trapped in the space between the piston and the crosshead and is piped back to the compressor inlet for recompression.

3. Intercoolers. Air-cooled, finned-tube-type intercoolers are provided between each of the successive compression stages. An after-cooler of the same type is optional equipment, but was not provided on the compressor tested. The fin and tube structure of the coolers is made up almost entirely of copper. Fans are arranged to draw cool air over the tubes.

4. Safety Valves. Each intercooler is provided with a safety valve to prevent excessive pressures in the intercooler or in the compression cylinder discharging into it. The final-discharge flange also has a safety valve. The safety valve settings are as follows:

First stage	65 lbs.
Second stage	210 lbs.
Third stage	850 lbs.
Fourth stage (final discharge)	2,400 lbs.

5. Safety Shut-off Control. When the compressor is to be used to compress hydrogen gas with an intake pressure above atmospheric, the compressor is provided with a shut-off control arranged to stop the machine if the intake pressure falls below two pounds gauge. This prevents the possibility of drawing in atmospheric air through any leaks

EXHIBIT "B"

in the piping, and also stops the machine if the source of gas fails. The control equipment consists of a diaphragm shut-off valve and a throttle controller with suitable pipe and fittings.

6 Lubrication. The compressor crankshaft bearings, connecting rod bearings, and crosshead pin bushings are lubricated by a full pressure system. The crosshead walls are lubricated by spray from the crankshaft. The compressor cylinders are lubricated by a forced feed lubricator, driven by belt from the intercooler fan drive pulley.

7. Engine. The compressor is driven by a six-cylinder, Caterpillar Diesel engine, model D-4600, through a spring-loaded, multiple-disk clutch. The speed of the engine is governed at 900 rpm.

8. Trailer. The complete unit is mounted on a four-wheel trailer, capable of being towed 30 miles per hour.

9. General Data.

a.	Number of stages	4
b.	Number of Compressor Cylinders	4
c.	Diameter of Cylinder Bores, Inches	6-1/2, 3-1/4, 1-15/16 and 1-1/4
d.	Stroke, Inches	5-1/2
e.	Capacity Compressor Crankcase Oil, Gallons	4
f.	Capacity Compressor Force Feed Cylinder Lubricator, Pints	7
g.	Inlet Pressure, Lb. per Sq. In., Gauge	0 to 5
h.	Discharge Pressure, Lb. per Sq. In. Gauge	2,200
i.	Pipe Size, Compressor (Inlet, Inches	3
	(Discharge	1
j.	Compressor Speed, rpm	900
k.	Compressor Displacement, cfm	95
l.	Compressor Delivery, cfm	71
m.	Engine, Caterpillar Tractor Company, Model D-4600	

APPENDIX "C", EXHIBIT 2 cont

n.	Number of Engine Cylinders		6
o.	Engine Bore and Stroke, Inches		4-1/4 x 5-1/2
p.	Capacity Fuel Tank, Gallons		39
q.	Capacity Engine Lubricating Oil, Gallons		5.5
r.	Capacity Engine Cooling System, Gallons		15
s.	Weight on Standard Steel Wheels, Lbs.		7,900
t.	Weight Without Running Gear, Lbs.		7,285
u.	Overall Dimensions on Standard Steel Wheel Mounting	(Length	14 ft., 3 in.
		(Width	5 ft., 9 in.
		(Height	6 ft., 5 in.
v.	Overall Dimensions Without Running Gear	(Length	14 ft., 3 in.
		(Width	4 ft., 1 in.
		(Height	6 ft., 0 in.
w.	Size Pneumatic Tires		7.50-16,8 ply

APPENDIX "C" EXHIBIT 3

EXTRACT FROM DUPONT OPERATING MANUAL GRX UNIT (REVISED)

OUTLINE OF PROGRESS AND EQUIPMENT.

All equipment essential to the operation of the GRX unit is mounted on an 8 foot by 20 foot trailer and is arranged so as to require a minimum road clearance of 12 feet. The motive power for all moving parts is provided by a speed governed Allis-Chalmers 32 H. P. -4 cylinder gasoline engine connected to a main drive shaft from which belt drives transmit power to the various equipment pieces. The following descriptions may be more easily followed by reference to Piping Diagram, Figure 1, and Flow Sheet, Figure 2.

The methanol-water feed mixture is contained in a 140 gallon feed storage tank (Eq.Pc. No. 1) suspended under the trailer frame. This feed is supplied to the unit by means of a reciprocating feed pump (Eq.Pc. No. 2) which has a maximum capacity of about 1.3 G.P.M. (610 lbs./hr.) and which may be adjusted from zero to full flow by changing the length of the plunger stroke. The output of this pump is fed to a coil type vaporizer (Eq.Pc. No. 5) where the feed is vaporized before being fed to the converter. All heat required for the various operations is supplied by means of oil burners fed with oil from the fuel oil storage tank (Eq.Pc. No. 3) by means of a gear pump (Eq.Pc. No. 4). Combustion air is supplied by the combustion air blower (Eq.Pc. No. 11). An interlocking control is provided so that anyone of three factors, low feed pressure, low oil pressure or low combustion air pressure, will result in the closing of an air-operated shut-off valve in the fuel line to the burners. (Note: On all units except the first the factors causing closing of the air-operated oil valve will also cause closing of a valve in the feed line).

The vaporized feed at a temperature in excess of 212° F. is fed to a coil preheater (Eq.Pc. No. 6) where the temperature is raised to about 570° F. and then fed to a 77-tube single pass converter (Eq.Pc. No. 7) where the reaction occurs. Each tube of this unit is filled with DuPont CN catalyst. Both Eq.Pc. No. 6 and Eq.Pc. No. 7 are heated by a hot gas stream circulated by the hot gas blower (Eq. Pc. No. 9). Heat is supplied to this gas stream by direct mixing of the circulating gases with the products of combustion of an oil burner in the air heater (Eq. Pc. No. 10). Detailed head loads and flows are shown on Flow Sheet, Figure 2.

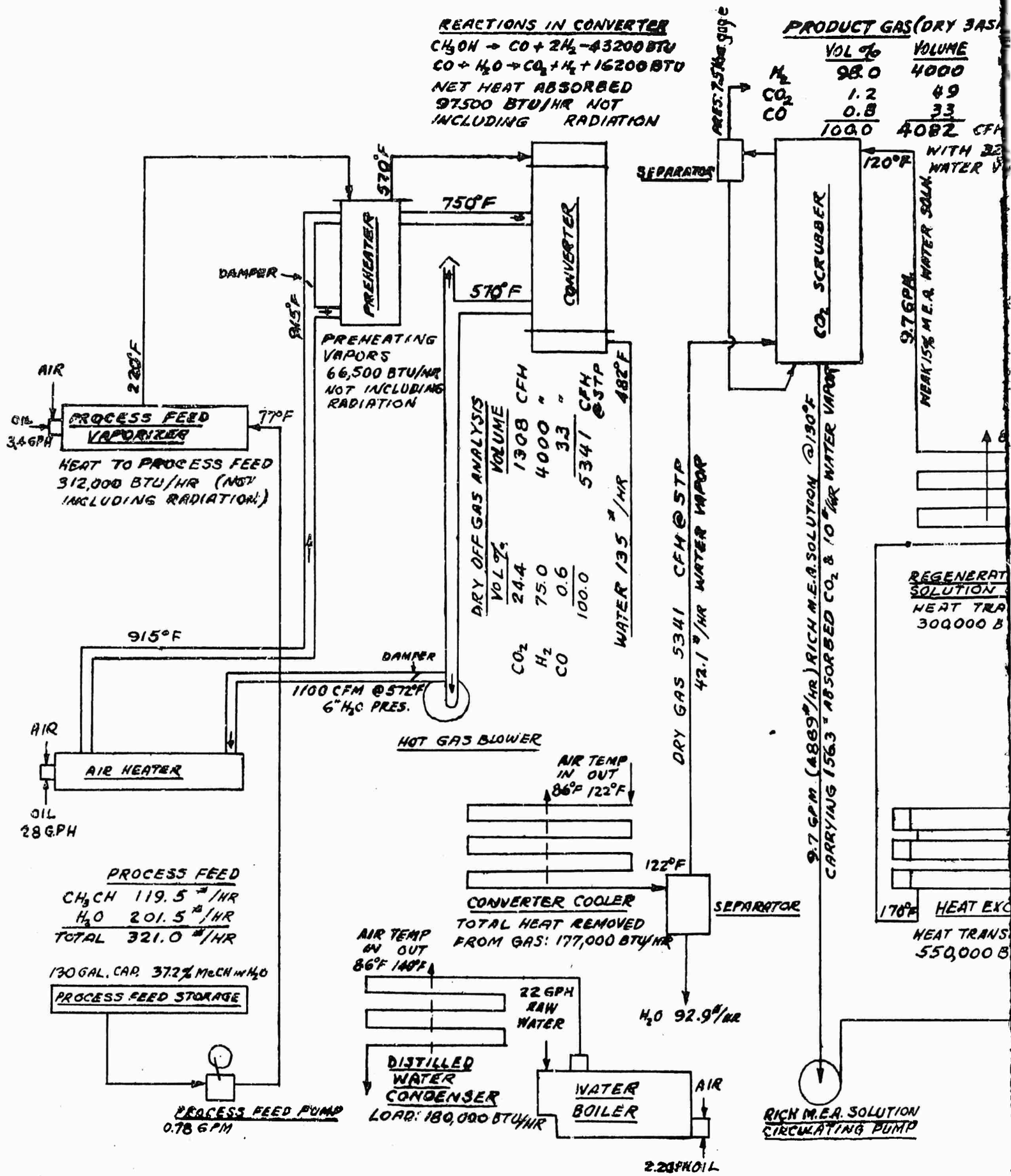
Since the net heat of reaction is endothermic, a temperature drop is taken in the converter and the exit mixture, consisting mainly of carbon dioxide, hydrogen and steam, leaves the converter at about 480° F. and enters the converter cooler (Eq. Pc. No. 8) where most of the steam is condensed. Eq. Pc. No. 8 is air-cooled and consists of ten passes of four parallel finned tubes. The cooling air is supplied

by the cold air blower (Eq. Pc. No. 15). The water condensed in Eq. Pc. No. 8 is removed from the gas stream in the separator (Eq. Pc. No. 16) and then drummed for recycling, provided that extended operation of the unit proves this procedure to be satisfactory.

To prevent contamination of the feed mixture to the converters the unit must be supplied with distilled water. Since the water recovered is only a portion of that fed, a water still (Eq. Pc. No. 13) has been provided. The boiler is a fire-tube type heated by an oil burner (Eq. Pc. No. 12) with two passes on the flue gas. Steam from the boiler is condensed in Eq. Pc. No. 14 which is a 7-pass, 4-parallel finned tube air-cooled exchanger supplied with air from Eq. Pc. No. 15. Water from the condenser is drummed for use as needed. On standing this water may show traces of rust which will not be harmful to the operation. The water should be filtered through several layers of cloth to remove large particles.

The cooled hydrogen-carbon dioxide mixture from Eq. Pc. No. 16 flows to the CO_2 scrubber (Eq. Pc. No. 17) where it is scrubbed with a 30% monoethanolamine (MEA) solution to remove the carbon dioxide. This scrubber is 2 feet in diameter and is packed with 1/2 inch steel rings. The gas passes up through the packing which is wetted by a continuous stream of MEA solution added through a seven-point distributor at the top of the column. The gas leaving Eq. Pc. No. 17 passes through a separator (Eq. Pc. No. 28) to remove any spray carried over from the scrubber. At this point the hydrogen should contain less than 2% of heavier gases and is ready for use. The CO_2 rich MEA solution from the bottom of Eq. Pc. No. 17 is picked up by the rich solution pump (Eq. Pc. No. 18) and pumped through heat exchanger (Eq. Pc. No. 19) where it picks up heat from hot regenerated MEA solution. The rich solution flows through the tube side of each of the five exchanger bundles and then to the regeneration column (Eq. Pc. No. 20). This column is similar to the scrubber in construction and is also packed with one-half inch rings, but operates at 35 pounds pressure. The solution collecting in the bottom of the regeneration column is pumped by circulating pump (Eq. Pc. No. 21) through the MEA boiler (Eq. Pc. No. 22) where it is partially vaporized. Eq. Pc. No. 22 is oil-fired and the liquid flows through two parallel coils while being heated. The mixture of vapor and liquid is returned to the base of the regeneration column to supply heat for the regeneration of the MEA solution. Since more heat is added to the column than is required for chemical reaction, a condenser (Eq. Pc. No. 24) is provided to remove the excess heat and to condense the water vapor present in the carbon dioxide released from the spent MEA solution. This unit is a finned tube cooler of 10 passes and 8 parallel tubes, cooled by air from the cold air blower. Condensed liquid is collected in the separator (Eq. Pc. No. 25) and returned to the base of the regeneration column. The released carbon dioxide is vented to the atmosphere through an automatic back pressure valve which maintains a constant pressure on the regeneration system.

Liquid from the base of the regeneration column is let down through the shell side of the heat exchanger Eq. Pc. No. 19 where it is partially cooled by exchange with the rich liquor. It is then passed through a finned tube cooler of 45-2 pipe passes (Eq. Pc. No. 26) where it is cooled sufficiently for reuse in the scrubber. The cycle on the solution is then repeated.


REACTIONS IN CONVERTER
$CH_3OH \rightarrow CO + 2H_2 - 43200$ BTU
$CO + H_2O \rightarrow CO_2 + H_2 + 16200$ BTU
NET HEAT ABSORBED 97500 BTU/HR NOT INCLUDING RADIATION
PRODUCT GAS (DRY GAS)
VOL % VOLUME
H_2 98.0 4000
CO_2 1.2 49
CO 0.8 33
100.0 4082 CFH
WITH 32
WATER V
PRES: 7.5 lbs gage
SEPARATOR
120°F
CO_2 SCRUBBER
9.7 GPM
WEAK 15% M.E.A. WATER SOLN.
570°F
750°F
PREHEATER
CONVERTER
DAMPER
570°F
915°F
PREHEATING VAPORS 66,500 BTU/HR NOT INCLUDING RADIATION
AIR
OIL 3.4 GPH
PROCESS FEED VAPORIZER
77°F
HEAT TO PROCESS FEED 312,000 BTU/HR (NOT INCLUDING RADIATION)
DRY OFF GAS ANALYSIS
VOL % VOLUME
CO_2 24.4 1308 CFH
H_2 75.0 4000 "
CO 0.6 33 "
100.0 5341 CFH @ STP
482°F
WATER 135 #/HR
DRY GAS 5341 CFH @ STP
42.1 #/HR WATER VAPOR
9.7 GPM (4889 #/HR) RICH M.E.A. SOLUTION @ 130°F
CARRYING 156.3 # ABSORBED CO_2 & 10 #/HR WATER VAPOR
REGENERAT
SOLUTION
HEAT TRA
300,000 B
915°F
DAMPER
1100 CFM @ 572°F
6" H_2O PRES.
HOT GAS BLOWER
AIR
AIR HEATER
OIL 28 GPH
AIR TEMP IN OUT 86°F 122°F
122°F
CONVERTER COOLER
TOTAL HEAT REMOVED FROM GAS: 177,000 BTU/HR
SEPARATOR
170°F
HEAT EXC
HEAT TRANS
550,000 B
PROCESS FEED
CH_3CH 119.5 #/HR
H_2O 201.5 #/HR
TOTAL 321.0 #/HR
130 GAL. CAP. 37.2% MeCH in H_2O
PROCESS FEED STORAGE
AIR TEMP IN OUT 86°F 140°F
22 GPH RAW WATER
H_2O 92.9 #/HR
DISTILLED WATER CONDENSER
LOAD: 180,000 BTU/HR
WATER BOILER
AIR
2.2 GPH OIL
PROCESS FEED PUMP 0.78 GPM
RICH M.E.A. SOLUTION CIRCULATING PUMP

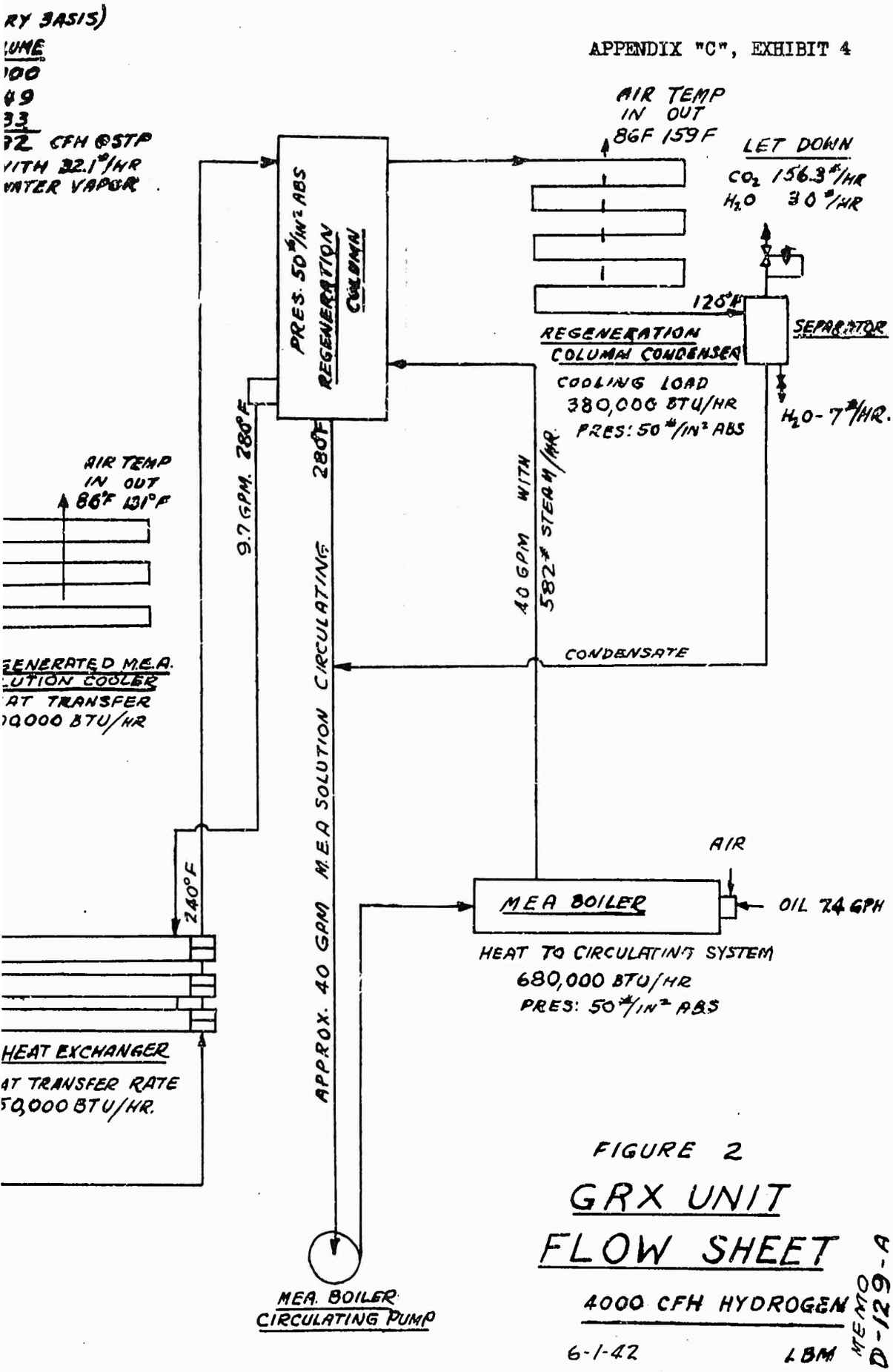


FIGURE 2

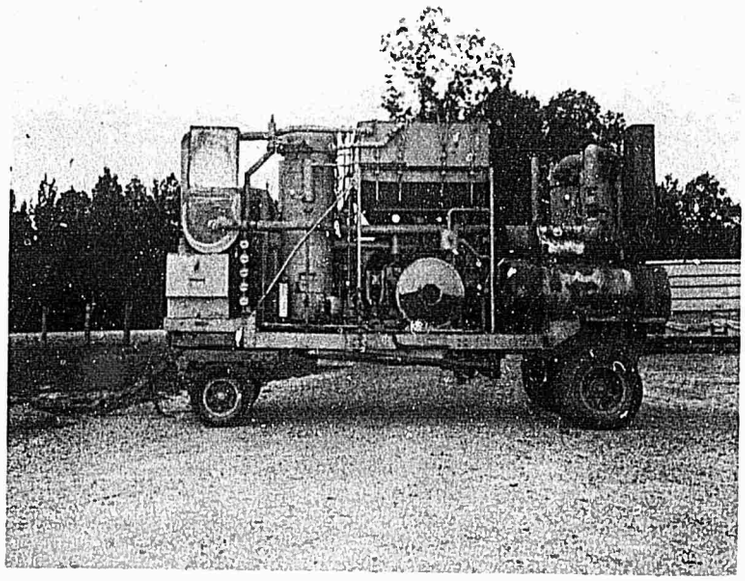
GRX UNIT

FLOW SHEET

4000 CFH HYDROGEN

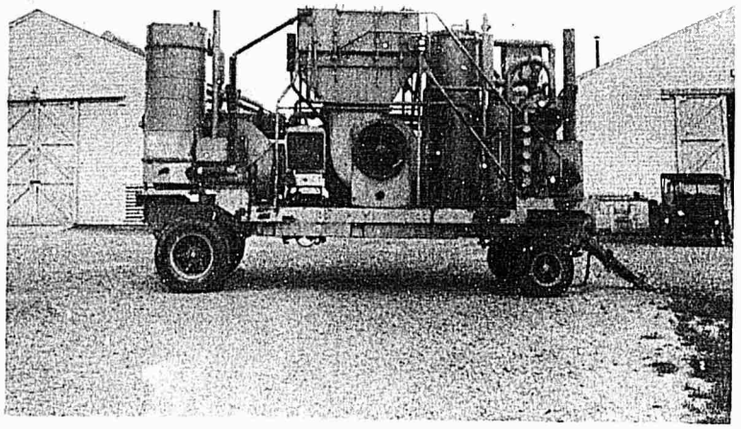
6-1-42 LBM

MEMO D-129-A



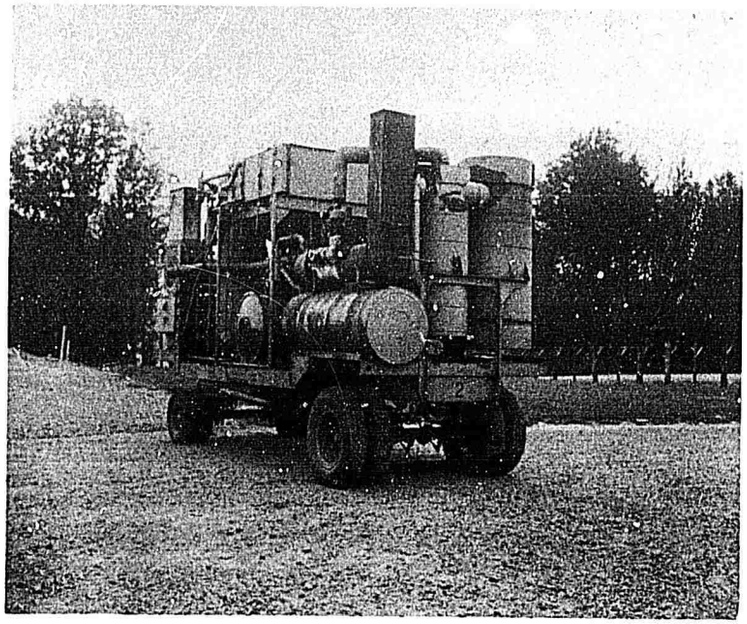
Low Pressure Methanol-Water Hydrogen Generator, 4000 Cu.Ft. per hour

Portable, 4 Stage, Diesel Engine Driven, Hydrogen Compressor for use with Low Pressure Methanol-Water Hydrogen Generator.



Low Pressure Methanol-Water Hydrogen Generator.
Side View Showing Power Unit, Cooler Fan, and Gas Scrubbing System.

Low Pressure Methanol-Water Hydrogen Generator.
Front View Showing Distilled Water and MEA Boiler.



Low Pressure Methanol-Water Hydrogen Generator.
Rear View Showing Feed Vaporizer, Preheater, Converter, and Air Heater.

Portable, Four Stage, Diesel Engine Driven Compressor
For Use With Low Pressure Generator.

APPENDIX "D", EXHIBIT 1

E X T R A C T

REPORT, BARRAGE BALLOON BOARD PROJECT No. 137. Subject No. 57-8, dated 7 July 1943.

* * * * *

IV. DISCUSSION:

* * * * *

8. Comparison Between Low-Pressure, Methanol-Water Hydrogen Generator and M-1 Generator.--a. Maintenance. The low-pressure unit requires very little maintenance other than that which can be accomplished during operation. Few replacements of parts are necessary. The M-1 generator requires constant maintenance and replacement of parts resulting in the plant being shut down 42 per cent of the time for this work. The spare gaskets, valves, and sludge lines required are excessive. It is estimated that the cost of spare parts alone for one year would be $15,000.00 for an M-1 generator as compared to not more than $3,000.00 for the low-pressure unit.

b. Raw Materials. The cubage of raw materials and fuel for the low-pressure unit is approximately two-fifths of that required for the M-1 generator. The difference amounts to 2.76 cubic feet of shipping space for materials for each thousand cubic feet of gas or a total difference of 3,312 cubic feet per month for an LA battalion or for a VLA battalion operating balloons in tandem and using approximately 1,200,000 cubic feet of gas per month.

c. Water. The low-pressure unit requires 35 gallons of water per hour, while 900 gallons per hour are required for the M-1 generator.

d. Cost of Gas. The cost of gas per 1,000 cubic feet, based on raw materials and fuel, is $1.50 to $2.00 with the low-pressure units as compared to $7.50 to $8.00 with the M-1 generator. The difference of $6.00 per thousand cubic feet would amount to a total of $7,200.00 per month for a battalion.

e. Crew. The minimum crew requirements are four men for the low-pressure unit and eight men for the M-1 generator.

f. Operation. The operation of the low pressure unit is continuous. After the plant has reached operating condition, it will produce at a constant determined rate for as long as desired. The M-1 generator uses a batch operation process which requires frequent shutdowns to recharge the generator with materials. The time lost in recharging the M-1 generator each time is equivalent to that required to start the low-pressure plant initially. While the M-1 plant will produce more gas per operating hour, its overall production is less than that of the low-pressure plant.

g. Protective Clothing. No protective clothing is required for operators on the low-pressure unit as none of the raw materials or waste products is injurious to flesh or clothing. Rubber gloves, goggles, rubber overshoes, and cotton outer clothing are required for operators on the M-1 generator due to the nature of caustic soda, one of the raw materials which must be handled, and due to the danger of rupture of high-pressure lines containing hot caustic solutions.

h. Mobility. The low-pressure plant, including the compressor, can be towed at 30 mph over good roads and at lower speeds over poor roads or rough terrain. The M-1 generator can be towed at only 15 mph over good roads and not at all over poor roads or rough terrain.

i. Installation. No special installation is required for the low-pressure plant. For the M-1 generator provision must be made for drains and disposal of the caustic sludge.

j. Purity of Gas. The gas produced by the low-pressure plant contains from 98 per cent to 99.5 per cent hydrogen, while the gas produced by the M-1 generator contains 99.4 per cent hydrogen. The impurity with the low-pressure plant is principally carbon dioxide which is not objectionable, while the impurity with the M-1 generator is principally oxygen which is highly objectionable.

k. Weight. Each generator weighs 29,000 pounds, but the low-pressure plant requires a separate compressor weighing an additional 7,900 pounds.

l. Cost. The initial cost of the low-pressure generator is $22,000.00 and of the compressor $5,800.00. The initial cost of the M-1 generator is $19,000.00

m. Tabular Comparison. Exhibit "E" is a tabular comparison of the hydrogen generators.

APPENDIX "D", EXHIBIT 2

TABULAR COMPARISON OF HYDROGEN GENERATORS

	Hydrogen Generator M-1		Methanol-Water Hydrogen Generator	
	Ferrosilicon-Caustic Soda Process	Aluminum-Caustic Soda Process	Low-Pressure	Medium-Pressur
1.Weight (uncrated)	29,000 lbs.	29,000 lbs.	29,000 lbs.	16,200 lbs.
2.Weight (crated)	31,565 lbs.	31,565 lbs.	33,800 lbs.	19,000 lbs.
3.Dimensions (uncrated)	8 ft. x 18 ft. 6 in. x 11 ft. 7 in.	8 ft. x 18 ft. 6 in. x 11 ft. 7 in.	8 ft. x 20 ft. x 12 ft.	8 ft.x16 ft. x 12 ft.
4.Weight of compressor	None	None	7,900 lbs.	2,150 lbs.
5.Generator cubage (crated)	2,466 cu.ft.	2,466 cu.ft.	2,630 cu.ft.	2,140 cu.ft.
6.Compressor cubage (uncrated)	None	None	520 cu.ft.	280 cu.ft.
7.Mobility (good roads)	15 mph	15 mph	30 mph	30 mph
8.Overall production rate	3,470 cu.ft./hr.	3,810 cu.ft./hr.	4,000 cu.ft./hr.	Unknown
9.Maximum rate obtained	7,000 cu.ft./hr.	8,000 cu.ft./hr.	4,500 cu.ft./hr.	1,800 cu.ft./hr.
0.Raw materials per 1,000 cu.ft. of gas:				
Ferrosilicon	65 lbs.			
Aluminum		55 lbs.		
Caustic Soda	88.4 lbs.	109 lbs.		
Gasoline	.3 gal.	.3 gal.	.6 gal.	.6 gal.
Methanol			5.6 gals.	5.6 gals.
Fuel Oil				

EXHIBIT "E"

APPENDIX "D", EXHIBIT 2 cont

TABULAR COMPARISON OF HYDROGEN GENERATORS (Continued)

	Hydrogen Generator M-1		Methanol-Water Hydrogen Generator	
	Ferrosilicon-Caustic Soda Process	Aluminum-Caustic Soda Process	Low-Pressure	Med.-Pressure
. Raw Materials cubage/1,000 cu.ft. gas:				
Ferrosilicon	1.42 cu.ft.			
Aluminum		0.65 cu.ft.		
Caustic Soda	3.21 cu.ft.	3.96 cu.ft.		
Gasoline	0.028 cu.ft.	0.028 cu.ft.	0.056 cu.ft.	0.056 cu.ft.
Methanol			1.09 cu.ft.	1.09 cu.ft.
Fuel Oil			0.75 cu.ft.	0.53 cu.ft.
Total	4.66 cu.ft.	4.64 cu.ft.	1.90 cu.ft.	1.68 cu.ft.
. Water requirements per hour.	900 gals.	3,500 gals.	35 gals.	39.4 gals.
3. Raw Material: Cost per 1,000 cu.ft. gas.	$7.52	$10.42	$1.50-2.00	$1.50-$2.00
4. Cost of generator	$19,000.00	$19,000.00	$22,000.00	$16,000.00
5. Cost of compressor	None	None	$5,800.00	$2,200.00
6. Crew	8 men	8 men	4 men	4 men
7. Special clothing required	Rubber gloves Goggles Rubber overshoes Cotton outer clothing	Rubber gloves Goggles Rubber overshoes Cotton outer clothing	None	None
. Type operation	Batch	Batch	Continuous	Continuous
. Ease of operation	Fair	Fair	Good	Good
0. Maintenance and replacement	Excessive	Excessive	Little	Little
. Waste products	Semi-solid sodium silicate sludge and caustic soda	Sodium-aluminate and caustic soda	Carbon dioxide gas	Carbon dioxide gas

APPENDIX "E"

APPROVED DESIRABLE MILITARY CHARACTERISTICS FOR A PORTABLE HIGH-PRESSURE HYDROGEN GENERATOR FOR LOW ALTITUDE BARRAGE BALLOON UNITS.

1. To be capable of generating at least 4,000 cubic feet of hydrogen per hour of operation.

2. To be capable of generating gas continuously while unit is in operation.

3. To be capable of being usefully operated for 20 hours per day.

4. To produce gas with a minimum hydrogen content of 99 per cent calculated on the dry basis.

5. To produce hydrogen at a pressure corresponding to that used in the cylinders in use.

6. To require a minimum of materials for the generation of hydrogen by:

a. Proper choice of reaction to be used.

b. Maximum chemical efficiency during that reaction, consistent with other requirements.

c. Minimum requirements of cooling water, and gas drying or purifying materials.

7. To require a minimum of personnel to operate it.

8. To require a minimum of accessory equipment, spare parts, or special and unusual tools.

9. To be mounted on skids so that the generator as a unit can be moved short distances.

10. To be capable of being dismounted into units of such size and weigh to permit transportation on a 2-1/2-ton truck.

11. To have a minimum size and weight, consistent with other requirements.

12. To provide a minimum hazard to operating personnel.

EXHIBIT "F"

APPENDIX "E" cont

APPROVED DESIRABLE MILITARY CHARACTERISTICS
FOR A MOBILE HIGH-PRESSURE HYDROGEN GENERATOR FOR
LOW ALTITUDE BARRAGE BALLOONS.

To be similar in all performance characteristics to the portable high-pressure generator, except that it shall be mounted on one or more trailers or semi-trailers capable of being towed at lease ten miles per hour over hard-surfaced roads and at least five miles per hour over ordinaly dirt roads, and be capable of maneuvering into position on normal terrain sites either forwards or backwards.

APPROVED DESIRABLE MILITARY CHARACTERISTICS FOR
A PORTABLE LOW-PRESSURE HYDROGEN GENERATOR FOR BARRAGE BALLOON USE.

1. To be capable of generating 4,000 cubic feet of hydrogen per hour of operation.

2. To be capable of generating gas continuously while unit is in operation.

3. To be capable of being usefully operated for 20 hours per day.

4. To produce hydrogen of 99 per cent purity exclusive of water vapor content, and water vapor content to be reduced so that it shall not exceed atmospheric saturation.

5. To have provision which will prevent travel of gases in the reverse direction (i. e. into the generator) due to any momentary excess in pressure in the manifold or inflation sleeve; to be provided with a safety valve which will operate with sufficient factor of safety to eliminate personnel hazard.

6. To require a minimum of materials for the generation of hydrogen by:

a. Proper choice of reaction to be used.

b. Maximum chemical efficiency during that reaction, consistent with other requirements.

c. Minimum requirements of cooling water, and gas drying or purifying materials.

7. To require a minimum of personnel to operate it.

8. To require a minimum of accessory equipment, spare parts, or special and unusual tools.

9. To be capable of rigid attachment as a unit, or in easily detached and reassembled sections, to the standard truck chassis, or of being loaded into the standard 2-1/2-ton army truck.

10. To be provided with skids which permit its removal from the chassis or truck. Skids to be such that the generator can be moved short distances over normal terrain after removal from the transporting vehicle.

11. The generator as a whole, or, alternatively, but not preferably, each demountable section thereof, not to weigh more than 5,00 pounds.

12. To have a minium size and weight, consistent with other characteristics.

13. To be usable directly in the vicinity of the barrage balloon, for topping-up purposes.

14. To permit the use of a compressor for raising the pressure of the resulting gases to that required for storage in compressed gas cylinders.

APPENDIX "F"

E X T R A C T

REPORT, BARRAGE BALLOON BOARD PROJECT No. 137. Subject No. 57-8 dated 7 July 1943.

TOOLS, SPARE PARTS AND SUPPLIES FOR LOW-PRESSURE GENERATOR

AS ISSUED BY THE NAVY DEPARTMENT

The following items, or their available equivalents, are to be included.

* * * * *

IV. DISCUSSION:

6e. Tools, Spare Parts and Supplies. The list of tools, spare parts, and supplies (Exhibit "D") issued by the Navy Department with each low-pressure generator is believed to be adequate although it would be desirable to have a gas analyzer of less fragile type.

1. TOOLS

Quantity Required	
2 doz.	Blades, hacksaw, 12 inches long, 24 teeth per inch.
1	Can, gasoline, safety, Protecto seal, 5-gallon.
1	Chisel, cold, 3/8-inch.
1	Chisel, cold, 3/4-inch.
1	Cutter, gauge glass, for 3/4-inch diameter tubing.
	Cutter wheels and pins, gauge glass for 3/4-inch diameter tubing.
1 set	EZy-outs, sizes Nos. 3, 4, and 5.
5	Faucets, 3/4-inch, Protecto seal, automatic, with provision for locking.
3	Funnels, 15-inch diameter, with 40-mesh screen.
1	File, flat, bastard cut, 12 inches long.
1	File, taper, double cut, 10 inches long.

Quantity Required	
1	Frame, hacksaw, adjustable, for 12-inch blades.
1	Gun, grease, push type, for Alemite hydraulic fittings.
1	Hammer, ball pein, 1-3/4 lbs.
1	Knife, putty.
1	Lock, pad, Yale No. 724, with two keys.
1	Oiler, bench, 1-pint capacity.
2	Pails, 14-quart capacity.
1	Pliers, combination, 8-inch.
1	Pliers, electricians, 8-inch.
1	Punch, drive pin, 3/32-inch diameter point.
1	Screw driver, 5/8-inch wide blade, 16 inches long.
1	Screw driver, 5/16-inch wide blade, 6 inches long.
1	Tool, flaring, for 1/4-inch to 3/4-inch copper tubing.
1 set	Tools, packing, Hound No. 4-P.
1	Torch, gasoline, single needle, 1-pint capacity.
2	Wrench, barrel, for 55-gallon capacity drums.
1	Wrench, box, 12-point, 15° offset, 11/16-inch and 1/2-inch openings.
2	Wrench, construction, 7/8-inch opening.
1	Wrench, Crescent, 6-inch.
1	Wrench, Crescent, 10-inch.
1	Wrench, pipe, rigid straight pattern, 10-inch.
1	Wrench, pipe, rigid straight pattern, 18-inch.

Quantity Required	
1	Wrench, pipe, rigid straight pattern, 24-inch.
1	Wrench, tire, for 5/8-inch lug nuts.
2 sets	Wrench, set screw, including hexagon sizes 5/64-inch, 3/32-inch, 1/8-inch, 5/32-inch, 3/16-inch, 7/32-inch, 1/4-inch (1 long and 1 short wrench of each size)
1	Wrench, spark plug.

2. EQUIPMENT SPARE PARTS

Equipment Piece No. 2-Process Feed Pump-Hills McCanna MXB-14 Single Unit Pump

Quantity	Part No.	Description	Material
1	M-5216	Bushing	Oilite
1	M-5226	Rocket Pin	Steel
1	M-5244	Bushing	Oilite
1	M-5229	Bushing	Oilite
1	M-5229½	Bushing	Oilite
1	M-5231	Pivot Pin	Steel
1	M-5233	Pivot Bolt	Steel
1	M-5250½	Bushing	Oilite
1	M-5257	Pin	Steel
1	M-5253	Bushing	Oilite
1	M-5264	Pin	Steel
5 lb.		Pump packing 3/8-inch square	Garlock 5203 or equal
1	8025	3/4-inch horizontal compositicone type check valve.	

Equipment Piece No. 4 - Fuel Oil Pump - Viking Rotary Oil Pump Model BFH

1	Pump complete
4 sets	Pump packing.

Equipment Piece No. 5 - Vaporizer.

1	No. 781 Hauck Manufacturing Company refractory tile combustion chamber.
1	Cuno Filter, type DS, bronze cartridge, length 1-5/8 inches, spacing 0.005 inch.
1	Regulator valve, Cash, class D, 3/8-inch, range 0 to 25 pounds, 200-pound body.

Equipment Piece No. 9 - Hot Air Blower.

2	Pillow blocks, single, Rafnir type SAO, for 1-7/16-inch shaft diameter.

Equipment Piece No. 10 - Hot Air Heater.

1	No. 780 Hauck Manufacturing Company refractory tile combustion chamber with 19-inch OD x 10-inch ID x 9-inch long extension.

Equipment Piece No. 11 - Combustion Air Blower - No. 1507-H Belt Driven Spencer Multi-Stage Turbo Blower.

1 set	Felt washer and rope packing.
1 set	Ball bearing (2).
1 set	Impellers, complete.

Equipment Piece No. 12 - Water Boiler Burner.

1	No. 779 Hauck Manufacturing Company refractory tile combustion chamber.

Equipment Piece No. 15 - Cold Air Blower.

2	Pillow blocks, single, Rafnir type SAO, for 1-15/16-inch diameter shaft.

Equipment Piece No. 18 - American-Marsh Centrifugal Pump No. 1A, Type RD, All-iron.

1	Key, impeller, No. 24A.
1	Shaft, steel, No. 41C.
2	Ball bearings, No. 81M (1 No. 6205Z and 1 No. 62052NR, SKF ball bearings).
5 lb.	Pump packing, 1/4-inch square, Garlock 5203 or equal.

Equipment Piece No. 21 - Allis Chalmers All-iron Centrifugal Pump, SSCBB, 3 x 1-1/2-inch.

2	Mechanical Seal ball bearing assembly, Fafnir type 1107-L, for 1-7/16-inch diameter shaft.
1	Sleeve, shaft, all-iron.
5 lb.	Pump packing, 3/8-inch square, Garlock 5203 or equal.

Equipment Piece No. 22 - MEA Boiler.

1	No. 782 Hauck Manufacturing Company refractory tile combustion chamber.

Equipment Piece No. 27 - Gasoline Engine, Allis-Chalmers, Model W-25, Outboard Bearing, 4-cylinder.

Quantity	Part No.	Description
2	U-3158	Bushing, main bearing, front.
4	U-3023	Bushing, main bearing, rear and center.
2	12060	Filter element, oil.
2	U-3132	Screw, valve adjusting.
4	U-3164	Insert, exhaust valve.
4	U-2142	Guide, valve stem.
2	U-3166	Valve, inlet.

APPENDIX "F" cont

Quantity	Part No.	Description
4	U-3167	Valve, exhaust.
2	U-2833	Spring, valve.
4	U-3131	Taper, valve spring.
2	U-3077	Gasket, water manifold.
1	U-3198	Gasket, cylinder head.
1	U-3006	Cover, cylinder head.
2	204801	Snap rings, valve stem.
1	U-3054	Gasket, gear cover.
1	U-3040	Gasket, cork, gear cover.
1	U-3184	Pump, water, complete.
1	U-3061	Gasket, water pump.
1	D7760	Valve and seat, fuel, size 44.
1 set	U-2890	Spark plugs.
1	1207K	Ball bearings, SKF.
6	U-3162	Gasket, manifold, inlet and exhaust.
1 set	208356	Gasket, manifold.
1	U-3205	Gasket, combination.
2	U-3181	Gasket, oil pan.
1	8505	Bearing, clutch, pilot by HD.
1	U-3090	Hose, radiator, lower.
1	205800	Hose, radiator, upper.
1	U-257	Filter Assembly, fuel.
2	U-3030	Gasket, push rod cover.
2	U-3034	Gasket, push rod cover.

Equipment Piece No. 27 (continued)

8	U-3989	Bearings, connecting rod.
2	U-3072	Belts, fan.
4		Clamps, hose, No. 10.
1	212081	Diagram, wiring.
1 set		Ignition cables, magnets.
1	U-3182	Screen, oil pump.

Spare Valves and Instruments.

1	Gauge, pressure, 2-1/2 inch American, type 1850, range 0-30 pounds, bronze element, bronze case, with threaded bronze ring.
1	Gauge, pressure, 2-1/2 inch Marsh, range 0-75 pounds, steel tube.
1	Gauge, pressure, 4-1/2 inch American, type 1079-B, range 0-60 pounds.
1	Gauge, pressure, 3-1/2 inch U. S. Gauge Company No. AD7937; range 0-60 pounds.
2	"Saran" U-tubes for 20-inch Miriam flowmeter.
2	Thermometers, Weston, Model 221D, 3-inch, range 50-400°F.
2	Thermometers, Weston, Model 221D, 3-inch, range 200-1000°F.
2	Thermometers, Weston, Model 221D, 3-inch, range 0-200°F.
1	Tubing, metal, flexible, 1-inch, 2 feet long, with 1-inch standard pipe female pipe thread fitting at both ends, for 75 psi air pressure.
1	Tubing, metal, flexible, 2-inch, 2 feet long with 2-inch standard pipe female pipe thread fitting at both ends, for 75 psi air pressure.
2	Valves, 1/2-inch all-iron globe, 150 standard.

Miscellaneous.

480 lbs.	Dupont GCN catalyst.

3. SUPPLIES

GENERAL SUPPLIES

Quantity Required	
1 set	V-Belts, No. 75 A, Matched set of 2
1 set	V-Belts, No. 75 A, Matched set of [illegible]
1 set	V-Belts, No. 85A, Matched set of 2
1 set	V-Belts, No. 105B, Matched set of 2
1 set	V-Belts, No. 105B, Matched set of 4
1 can	Cement, Smooth-on, No. 2, 1 pound
15 sht.	Cloth, Emery No. 00, 9 inches x 10 inches.
1 can	Compound, grinding, Grade B, 4 ounces.
1 can	Dope, oil, pipe, 1 pint.
2	Extinguisher, Fire, Lux CO_2, Model 10.
3	Fitting, No. 48F Imperial Brass, 1/4-inch O. D. tube x 1/4-inch I. P. S. coupling.
6	Fitting, No. 48F Imperial Brass, 1/4-inch O. D. tube x 1/8-inch I. P. S. coupling.
9	Fitting, No. 41F, Imperial Brass, 1/4-inch O. D. nut.
2 sht.	Gasket, sheet material, No. 60 J.M. Asbestos, 1 square yard.
4	Glass, gauge, 3/4-inch diameter x 24 inches long for 200 pounds pressure (glass tubes only).
6 cans	Gredag, small cans.
8 tubes	Lubricant, Masters' Lubriko M-6, 8-ounce tubes.
2	Nipples, brass, 3/8 I.P.S., 3 inches long.

General Supplies (continued)

4	Nuts, 1/4-inch, hexagonal.
3	Nuts, 3/8-inch, wing.
40	Nuts, standard hexagonal, 1/2-inch diameter, 13 threads/inch, 3-1/4-inches long, A.S.T.M. Specification A-193-39T, Grade B-7 or B-12.
6 yds.	Packing material, 3/8-inch twisted asbestos, Garlock 1700.
1 doz.	Packing, gauge glass, cone shaped for 3/4-inch Lunkenheimer Liquid gauge, No. 1024.
1 set	Parts for back-pressure valve (3/4-inch Mason Neilan No. 42 valve) to include: 1 diaphragm 1 orifice 1 upper guide plate stud 1 valve plug
4	Screws, cap, Allen head, steel, 1/4-inch x 1-1/4 inches.
4	Screws, cap, Allen head, steel, 1/4 inch x 3/4 inch.
4	Screws, cap, Allen head, steel, 1/4 inch x 2-1/2 inches.
4	Screws, cap, hexagonal head, steel, 1/4 inch x 5/8 inch.
4	Screws, cap, hexagonal head, steel, 1/4 inch x 1/2 inch.
7	Screws, cap, hexagonal head, steel, 5/16 inch x 5/8 inch.
4	Screws, cap, hexagonal head, steel, 1/4 inch x 1-1/2 inches
24	Screw, set, hollow head, steel, 5/16 inch x 3/8 inch.
24	Screw, set, hollow head, steel, 3/8 inch x 1/2 inch.
2	Screw, set, hollow head, steel, 1/4 inch x 1/4 inch.
2	Screw, machine, steel, No. 8 (0.164-inch diameter) 32 threads/inch, 1/4 inch long, oval filister head.
4	Screw, machine, steel, No. 10 (0.190-inch diameter). 24 threads/inch, 3/8 inch long, oval filister head.

General Supplies (continued)

2	Screw, 1/4-inch (0.250-inch) machine, steel, 20 threads/inch, 1/4 inch long, oval filister head.
4	Screw, thumb, 5/16-inch diameter x 1 inch long.
2	Screw, thumb, 1/4-inch diameter x 3/4 inch long.
3	Screw, machine, steel, No. 12 (0.216-inch diameter). 24 threads/inch, 1/2 inch long, oval filister head.
20	Studs, 1/2-inch diameter, 13 threads/inch, 3-1/4 inches long, ...S.T.M. Specification A-193-39T, Grade B-7 or B-12.
2 rolls	Tape, friction, 3/4 inch wide, 1/2-pound roll.
8 ft.	Tubing, copper, 1/2-inch O.D.
3	Washers, Brass, 1-inch O.D. x 3/8-inch I.D. x .081 inch thick.
20	Washers, lock, helical spring type, 1/4-inch.

ANALYTICAL EQUIPMENT AND SUPPLIES

Quantity Required	
5 vials	Acid, sulfuric, fixation N/1.0, standardized.
6	Bottle, capacity 4 ounces, No. 803.
1	Bottle, dropping, capacity 125 cc., Fisher No. 3000.
1	Bottle, reagent, capacity 32 ounces, Bottle No. 502, Catalogue No. 841.
1	Funnel, Diameter 75 mm, No. 6180.
1	Gas analysis apparatus, Burrell, consisting of: 1 Bag, gas sampling, size 6 inches. 1 Manifold No. A-39-870. 3 Francis Auto-Bubbler Pipettes No. A-40-100. 1 Gas Measuring Burrette No. A-39-980. 1 Leveling Bulb, capacity 250 cc. No. A-50-280. 1 Stand and case.

APPENDIX "F" cont

Analytical Equipment and Supplies (continued)

Quantity Required	
2	Hydrometer, with 0-50° C. thermometer enclosed. Range 0.895 to 0.955, No. 54298 Special.
2	Hydrometer, with 0-50° C. thermometer enclosed. Range 0.945 to 1.005, No. 54300 Special.
1	Hydrometer jar, diameter 38 mm., height 300 mm., Kimble No. 20060.
2 tube	Lubri-seal.
1	Methyl orange, 4 ounces, in tin-lined screw-cap bottle.
1 box	Paper, filter, Whatman No. 4, Diameter 11 cm.
2	Pipettes, measuring, capacity 5 cc. Kimble No. 37020.
2	Pipettes, measuring, capacity 10 cc. Kimble No. 37020.
2	Potash, caustic, 1-liter bottle, Fisher No. 10-595.

CORPS OF ENGINEERS
(ENGINEER BOARD)
TENTATIVE SPECIFICATION

EBP No. 483
28 September 1943

GENERATOR, HYDROGEN GAS, LOW PRESSURE METHANOL-WATER TYPE, TRAILER MOUNTED, 4000 CUBIC FEET PER HOUR

A. APPLICABLE SPECIFICATIONS AND DRAWINGS.

A-1. Specifications. - The specifications enumerated below of the issue in effect on the date of the invitation to bid are made a part of this specification; except that in case of their conflict with this specification the provisions of this specification shall govern:

A-1a. Federal Specification, No.:

ZZ-T-721 - Tubes; Automobile and Motorcycle, Inner.

A-1b. U. S. Army Specifications, Nos.:

T-1184 - Corps of Engineers Tentative General Specification for Finishing, Treating and Painting.

T-1483 - Corps of Engineers Tentative Specification for Maintenance Manuals and Spare Parts Catalogs for Engineer Equipment.

T-1739 - Corps of Engineers Tentative Specification for Standard Requirements for Marking Corps of Engineers Shipments.

USA-LP-91-400 - Ordnance Department Specification for Tires, Military, Pneumatic: Truck, Trailer, Automobile and Motorcycle.

A-1c. Nongovernmental Specifications:

Society of Automotive Engineers Standards.

American Welding Society Standard Qualification Procedure.

A-2. Drawings. - The following U. S. Army drawings of the issue in effect on the date of the invitation to bid are made a part of this specification:

A-2a. Corps of Engineers Drawings, Nos.:

A 4180-1 - Nameplate
A 4180-2 - Transportation Data Plate
B 2311-1 - Transportation Units, Wiring Diagram for Trailers.
D 2363-1 - Transportation Equipment, Trailer Units, Lunette Coupler, Details.

A-2b. Ordnance Department Drawings, Nos.:

B 161059 - Reflex Reflector.
07950-W(X) - Coupling Socket and Hinged Cover Assembly.
07955-W - Cable Assembly.
08242-X - Lamp, Service Tail and Stop and Blackout Tail.
08243-X - Lamp, Blackout Tail and Blackout Stop.
08671-W - Blackout Light Switch - Trailer.
08789-Y - Lamp Assemblies, Service and Blackout Clearance.
08405-Z - Studs and Cap Nuts (Wheel Mounting).
08408-Y - Disc and Rim Assembly, 20 x 8 Size.
087596-W - Tool Sets (Complete with Tools) Pioneer Equipment (Motor Vehicle) Set No. 1.
C-57093-X - Pintle Assembly (Revised).

B. TYPE.

B-1. This specification covers one type of trailer mounted low pressure hydrogen generator using distilled water and specially distilled methanol for the generation of hydrogen gas.

C. MATERIAL AND WORKMANSHIP.

C-1. Materials. - The materials used for each part of the hydrogen generator shall be as specified herein and on the applicable drawings. When a definite material is not specified, the material used shall be of the best quality normally used for the purpose in good commercial practice. All materials used shall be free from defects and blemishes (imperfections) that may affect the serviceability and appearance of the finished hydrogen generator and all materials used shall be such as to produce finished products meeting the requirements of this specification.

C-2. Workmanship. - Workmanship throughout shall be of the highest grade and in accordance with the best standard practice.

C-2a. Fabrication. - Before laying out or working in any way, material shall be thoroughly straightened by methods that will not result in injury, except that sharp kinks or bends will be cause for rejection. Shearing shall be neatly and accurately done and all portions of the work neatly finished. Re-entrant cuts shall be made in the best possible manner; where they cannot be made by shearing, a rectangular punch may be used. Corners shall be square and true. Flame cutting may be used for cutting instead of shears or saws, but if flame cutting is used, burned surfaces shall be ground sufficiently to remove ash and cooling checks and to provide a smooth surface for fabrication. All bends except for minor details shall be made by the use of metal dies or fixtures in order to insure uniformity of size and shape. Where heating is required, precautions shall be taken to avoid overheating the metal, and it shall be allowed to cool slowly. All bolts, nuts, and screws shall be tight. All rivet and bolt holes shall be accurately machined. Rivets shall be driven hot with pressure tools. When driven, rivets shall completely fill the holes, be neat and finished, and the heads shall be in full contact with the surface of the member. All holes shall be drilled to steel templets. All burrs, rough edges and edges of holes shall be ground smooth to avoid injury to hands.

C-2b. Welding and Welders.

C-2b(1). Welding. - The surfaces of all parts to be welded shall be free from rust, scale, paint, grease and other foreign matter. In all cases where embrittlement of the parent metal is likely to result, preheating or annealing shall be employed. Flux coated metallic electrodes shall be used. The electrodes shall be of a type that will produce a weld having chemical and physical properties similar to the parent metal. The weld shall develop full strength of the parts connected. All welding, unless otherwise specified, shall be in accordance with the applicable current rules of the American Welding Society.

C-2b(2). Welders. - Welders who have not been certified under a code satisfactory to the Contracting Officer within two years of date of signing the contract will be required to pass successfully the test as prescribed by the "Standard Qualification Procedure" of the American Welding Society before being assigned to production work. The contractor shall bear the expense of conducting these tests and shall certify by name, to the Contracting Officer, welders who have successfully passed the prescribed tests. The contractor shall require any welder to repeat these tests when in the opinion of the Contracting Officer, the work of the welder indicates a reasonable doubt of his proficiency. In such cases the welder shall be recertified as above if he successfully passes the retest; otherwise he shall be disqualified until he has successfully passed a retest.

D. GENERAL REQUIREMENTS.

See Section E.

E. DETAIL REQUIREMENTS.

E-1. Description. - The hydrogen generating plant shall produce hydrogen essentially by cracking methanol on a catalyst in the presence of steam to form a hydrogen-carbon dioxide mixture and scrubbing the mixture with a monoethanolamine solution to remove the carbon dioxide. Provisions shall be made for regeneration and recycling of the scrubbing solution. The plant shall have a continuous output capacity when referred to 29.92 inches of mercury and 32 degrees F. of not less than 4000 cubic feet per hour of actual free hydrogen containing less than 2 percent by volume of heavier gases. This capacity shall be obtainable while recycling the scrubbing solution and with ambient temperatures of 90 degrees F. and a relative humidity of 80 percent. The rated capacity shall be obtained while using not more than 23 gallons of methanol and 15 gallons of burner fuel oil per hour. The generator shall normally operate at a pressure of 0 to 5 pounds per square inch. The complete hydrogen generating equipment shall be mounted on an 8 foot by 20 foot trailer and arranged so that the maximum height will not exceed 12 feet. The complete trailer mounted plant shall weigh not more than 29,000 pounds.

E-2. Trailer. - The generating plant shall be mounted on a drop frame trailer so constructed that it may be physically adaptable for towing by a standard Corps of Engineers truck. The load of the trailer shall be distributed so that not more than 70 percent nor less than 55 percent of the gross weight will be on the rear wheels. The trailer frame or chassis shall consist of either formed or rolled structural steel shapes. All frame members shall

be of the proper size and shape, properly gusseted and braced such that there shall be a minimum of sagging or distortion of the frame under full load when towed at average speeds of 30 miles per hour.

E-2a. Drawbar. - The chassis shall be provided with a drawbar equipped with a lunette ring conforming to Corps of Engineers, U. S. Army Drawing No. D 2363-1. The towing height of the drawbar shall be suitable for use with pintle hooks mounted at heights of from 30 to 36 inches.

E-2b. Wheels and Wheel Bearings.

E-2b(1). Wheels. - All wheels for the trailer and dolly shall conform to Ordnance Department Drawing No. 08408-Y and shall be fitted with studs and cap nuts conforming to Ordnance Department Drawing No. 08405-Z.

E-2b(2). Wheel Bearings. - All wheels on the trailer and dolly shall be mounted on tapered roller anti-friction bearings of sufficient capacity to carry the loadings at a speed of 35 miles per hour. A positive means of making small adjustment shall be provided. The bearing shall be a design approved by the current S.A.E. specifications for similar applications.

E-2c. Tires. - The trailer and dolly shall be fully equipped with heavy duty, truck-bus balloon type tires with at least 10 plies and shall conform to Ordnance Department Tentative Specification USA-LP-91-400, Class "3", and shall be fitted with inner tubes conforming to Federal Specification ZZ-T-721.

E-2d. Brakes.

E-2d(1). Service Brakes. - The air chambers shall be located above the center line of the axle to prevent their being damaged and to provide trailer clearance in off-road operation. The brakes shall be of the 2-shoe, heavy duty, rigid anchor, cam type. Controls shall be provided with standard emergency breakaway features. The breakaway arrangement shall meet with the requirements of the Interstate Commerce Commission. The controls shall be sealed in a manner that will insure satisfactory operation in any kind of weather. Properly located drains shall be provided for draining the condensate from the chambers, diaphragms, cylinders, etc. All air hose fittings shall be the replaceable type with spring protectors. Air line filters in both emergency and service lines are required. Relay emergency exhaust check valves and heavy duty clamping studs shall be furnished. The brakes shall be provided with suitable, fully enclosed worm and gear type slack adjusters. All parts of the air brake control system shall be similar, equal and interchangeable with the equipment manufactured by the Bendix-Westinghouse Automotive Air Brake Company, Pittsburgh, Pennsylvania. Brake anchors and cams shall have lubrication fittings designed to prevent excessive greasing. Brake linings shall be not less than one square inch of friction surface for each 40 pounds of gross axle weight. There shall be provided with each trailer the following air hose connections and couplers:

(1) Two detachable 8 foot air hose lines equipped with standard air hose couplings shall be supplied with each trailer for connecting the brake system to the prime mover. When detached, these hose connections, with the electrical connecting cable, shall be carried in the trailer.

(2) Two standard air brake couplings shall be provided on each chassis for connecting the brake lines to the prime mover.

(3) A dummy coupling shall be attached with a chain to each of the two chassis hose couplings.

E-2e. Axle. - The axle provided shall be of good quality and sectional shape. The axle shall be designed with a factor of safety which conforms to that used in commercial practice. The spindles shall be of heat treated alloy steel, forged from the full size bar and ground to size.

E-2f. Service Brake Performance Requirements. - When used with a prime mover having comparable brakes, the entire brake system shall be capable of consistently bringing the fully loaded vehicle to a complete stop at a rate of deceleration equivalent to a stop within 30 feet from a speed of 20 miles per hour, when operating on an approximately level, dry, concrete pavement.

E-2g. Parking Brake. - In addition to the air brakes specified the wheels of the rear axle of each trailer shall be equipped with a hand operated mechanical brake control. The brake shall be capable of sliding the rear wheels with a full load on an approximately level, dry, concrete pavement. The setting mechanism shall be of the ratchet and pawl type or equivalent. The parking brake handle or wheel shall be placed in a suitable position on the off-road (right hand) side of the vehicle. No part of the brake mechanism shall be a factor limiting the travel clearances.

E-2h. Wiring and Safety Markers. - All trailer lamps shall be wired in accordance with the schematic diagram shown on the drawings. The wiring shall be of the rubber (synthetic or 100 percent reclaimed) insulated type or rubber (synthetic or 100 percent reclaimed) and fabric insulated type encased in an approved loom or flexible conduit. If flexible metal conduit is used, splices shall be made in junction boxes. All terminals shall be soldered to the wire ends. Any junction blocks used in the system shall have the bases made of Micarta, Bakelite, or other equally suitable material and be equipped with suitable studs, washers and nuts for the attachment of the wire and terminals. The circuits shall be color traced. The lights and reflectors shall be located on the trailer frame as shown on Corps of Engineers Drawing No. B 2311-1. A cable of the correct length for connecting the trailer to the prime mover shall be furnished with each trailer. The cable shall conform to U. S. Army, Ordnance Department Drawing No. 07955-W. A compartment shall be provided on the trailer for carrying the cable when not in use. A coupling socket conforming to Ordnance Department Drawing No. 07950-W(X) shall be mounted one on the front and one on the rear of the trailer. The tail and stop lamps on the trailer shall be recessed in the frame. The lenses shall be set back approximately 1/2 inch from the surface of the frame members. All lamps shall be readily accessible for the changing of bulbs, lenses, and for making other repairs.

E-2i. Bushings and Lubrication.

E-2i(1). Bushings. - Where anti-friction bearings have not been specified, all rotating shafts, trunnion pins, etc., shall have bushings made of steel backed bronze or other equally suitable material with ample bearing surface.

E-2i(2). Lubrication. - All moving parts shall be provided with suitable means of lubrication. The spring shackles, hubs, radius rods, trunnion pins, and any other part subjected to considerable wear shall be fitted with a pressure lubricating system. All pressure fittings shall be located in an accessible, protected position, and shall be of the hydraulic type serviceable by a pressure gun manufactured by the Alemite Division of the Stewart-Warner Corporation, Chicago, Illinois.

E-2j. Pintle Hook. - A pintle hook conforming to Ordnance Department Drawing C-57093-X shall be provided.

E-2k. Pioneer Tool Set. - One Pioneer Tool Equipment Set, complete with rack shall be furnished with each trailer and mounted in a protected, accessible location so as to avoid interference with the operation of the plant. The tool set shall conform to Ordnance Department Drawing No. 07596-W.

E-2l. Trailer Manufacturer's Nameplate. - A standard manufacturer's nameplate shall be permanently attached to the trailer. The nameplate shall give model number, date of manufacture, size or capacity, and any other information usually supplied on nameplates.

E-3. Framework. - The steel framing for support of equipment shall consist either of formed or rolled structural steel shapes. The body plan shall be adapted to fasten to the chassis.

E-4. Controls and Piping. - All piping, fittings, valves, meters, indicators, and other items required for ready dismantlement, replacement, adjustment, or for the successful operation of the generator shall be provided and installed so that they are readily accessible.

E-5. Nameplate and Transportation Data Plate. - An etched zinc nameplate as shown on Corps of Engineers Drawing No. A 4180-1 and transportation data plate as shown on Corps of Engineers Drawing No. A 4180-2 shall be mounted in suitable locations on the generator. The proper designations for insertion in the nameplate will be furnished by the Contracting Officer.

E-6. Finish and Painting. - The complete trailer and the equipment of the plant normally painted in good commercial practice shall be finished and painted in accordance with Corps of Engineers Tentative Specification T-1184, Class "A", Type "1" for steel. A U. S. Army registration number to be supplied by the Contracting Officer shall be stenciled on each unit.

E-6a. Stencilling. - In accordance with paragraph D-5b of the above specification the unit shall have the gross weight stencilled in white paint on each side in such a position that it will be readily discernible to interested dock or military personnel. The position of the marking shall be subject to the approval of the Contracting Officer. Such letters and figures shall be of a block type, two inches high, with a stroke of 3/8 inch.

E-7. Working Drawings.

E-7a. Responsibility for final design shall rest with the contractor, and detailed drawings necessary for manufacturing the equipment shall be prepared by him,

E-7b. As soon as practicable after approval of the contract the contractor shall submit to the Contracting Officer for approval, working drawings and manufacturer's plans and specifications in duplicate for the complete hydrogen plant. Approval of such drawings, plans and specifications will not relieve the contractor of the responsibility for satisfactory operation of the plant.

E-7c. Before final payment is made, the contractor shall furnish for use in future procurement by the Government, to the Contracting Officer, complete drawings and specifications with latest revisions included thereon of the equipment as furnished by the Government. All record prints furnished shall be reproducible.

E-8. Maintenance Manuals and Spare Parts Catalogs. - The contractor shall furnish maintenance manuals and spare parts catalogs covering the description, operation, adjustment, maintenance, lubrication and spare parts lists for all equipment furnished. The contents of these manuals shall be as set forth under "detailed specifications" outlined in paragraph 6 of Specification T-1483. The cover of each manual shall state the machine name and model, manufacturer's name, date of approval of the manual, title of the manual and machine serial numbers to which the spare parts catalog applies. (The machine name shall be as furnished by the Contracting Officer, in accordance with standard nomenclature). A preliminary dummy manuscript made up of typewritten sheets, clippings, photographs, sketches and other suitable material, will be forwarded to the Contracting Officer for approval. After preliminary approval, proof sample copies, in duplicate, of the Maintenance Manual and Parts Catalog, will be forwarded to the Contracting Officer, for final approval. After final approval two copies of the Maintenance Manuals and Parts Catalogs will be furnished with each machine, and two additional copies per machine plus manuals to the total required by the contract or invitation to bid, which will be determined by the spare parts lists for the machine, will be shipped to the Engineer Supply Officer, Columbus Quartermaster Depot, marked; "Attention: Spare Parts Branch". When specifically called for in the invitation to bid or the contract, these manuals shall conform to Corps of Engineers Tentative Specification T-1483.

E-9. Spare Parts and Tools. - One set of first echelon spare parts and tools listed in Appendix "A" hereof shall be furnished and shipped integrally and simultaneously with the prime equipment covered by this specification. When a manufacturer's model number or part number is shown in Appendix "A", it shall be construed as being for identification purposes only. If it is anticipated that any delay would occur in the shipment of the prime equipment covered by this specification for reason of the above requirement, the Contracting Officer shall be notified promptly. No shipment of prime equipment shall be made unless the first echelon spare parts are shipped with it or unless written approval for shipment without such parts has been received from the Contracting Officer.

F. INSPECTION AND TESTS.

F-1. Inspection. - The plant in which this equipment is being constructed shall be open at all times during working hours to the Contracting Officer and his representatives or inspectors, who shall have the right to follow the material through all the processes of manufacture. Every facility including

suitable office space, equipment and supplies shall be given the inspectors for the proper execution of their work. The contractor shall make, at his own expense, and previous to tests by the Contracting Officer, or his representatives, sufficient tests to insure that the equipment conforms in all respects to the specifications. Each unit will be inspected to see that it is constructed, finished, and packed in accordance with the requirements set forth in this specification.

F-2. Tests. - The equipment shall be given tests as may be necessary to assure compliance with this specification. When tests are made at the factory, the contractor shall furnish all facilities and supplies necessary to determine whether or not the equipment conforms and operates in accordance with this specification. The manufacturer shall be held responsible for any defects in material or workmanship which are of such a nature that they cannot be detected by careful inspection and tests.

G. PACKING AND MARKING FOR SHIPMENT.

G-1. Packing. - Packing shall be in accordance with the instructions furnished by the Contracting Officer.

G-2. Marking. - Marking for shipment shall be in accordance with Corps of Engineers Tentative Specification T-1739.

H. NOTES.

H-1. Copies of this specification and Corps of Engineers drawings may be obtained from the Engineer Board, Fort Belvoir, Virginia. Other specifications and publications listed herein may be obtained from the following applicable addresses:

Federal Specifications - Superintendent of Documents, Washington, D. C.

U. S. Army Specifications - Office, Chief of Engineers, Washington, D. C.

American Welding Society Publications - American Welding Society, 33 West 39th Street, New York, New York.

Society of Automotive Engineers Specifications - Society of Automotive Engineers, 29 West 39th Street, New York, New York.

H-2. Engineer Board Tentative Specifications are ad interim specifications which may be converted to Corps of Engineers Tentative Specifications. They are used for the procurement of engineer equipment during development, and for the purpose of making recommendations to the Office, Chief of Engineers. They should not be accepted as indorsed by the Corps of Engineers or the Engineer Board for quantity procurement, unless accompanied by specific instructions as to their use.

H-3. The following paragraph should be made a part of the contract: Guarantee. - Any defect clearly due to faulty design or to faulty material or workmanship, which may develop within one year after completion of the contract, unless otherwise specified, shall be made good by and at the expense of the

contractor. Corrections or replacements required because of faulty design, material, or workmanship, shall be made within the continental limits of the United States by the contractor at his expense, and at the convenience of the Government either at the plant of the manufacturer or at the point where the equipment is at the time located if so directed by the Contracting Officer. Corrections or replacements for units outside the continental limits of the United States shall be made at the expense of the contractor, it being understood that the Government will deliver the units to the contractor at the Columbus Quartermaster Depot, Columbus, Ohio, or that the Government will accept delivery f.o.b. Columbus Quartermaster Depot, Columbus, Ohio, packed for export shipment, of such replacement parts as may be readily installed in the field. The Contracting Officer shall decide which method is to be pursued. Corrections or replacements required because of faulty design shall be of redesign approved by the Contracting Officer. The Contracting Officer shall decide whether corrections or replacements are due to faulty design, material, or workmanship.

NOTICE. - When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

APPENDIX A 28 September 1943

To: Corps of Engineers
(Engineer Board)
Tentative Specification
EBP No. 483
28 September 1943

GENERATOR, HYDROGEN GAS, LOW PRESSURE METHANOL-WATER TYPE,
TRAILER MOUNTED, 4000 CUBIC FEET PER HOUR

First Echelon Spare Parts and Tools

The following spare parts and tools are considered an integral part of each generator and shall be provided, suitably packed, with each unit shipped.

a. Tools. - There shall be furnished with each hydrogen generating plant all the wrenches and special tools required for operating, making adjustments or field repairs. (Special tools shall mean those which are not standard commercial tools). The tools and manner of their storage shall be subject to the approval of the Contracting Officer.

b. Spare Parts. - The contractor shall furnish as integral equipment with each hydrogen generating unit a "field set" consisting of adequate spare parts to insure maintenance and continued operation of the equipment on an average of 500 operating hours per month for a six months period. A list of the proposed spare parts shall be submitted to the Contracting Officer for approval.

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U.S. ARMY CORPS OF ENGINEERS, ENGINEER RESEARCH AND DEVELOPMENT LABS., FORT BELVOIR, VA. (REPORT NO. 773)

METHANOL-WATER TYPE, LOW PRESSURE, HYDROGEN GENERATOR - AND APPENDIXES A-G

JACK R. CADDELL 5 OCT 43 60PP. PHOTOS, TABLES, DIAGRS

FUELS AND LUBRICANTS (12) PRODUCTION AND REFINING (9)

HYDROGEN - FIELD GENERATION, GENERATORS, GAS BALLOONS, BARRAGE

RESTRICTED