The original documents are located in Box 56, folder "1976/02/02 - George Mechlin" of the James M. Cannon Files at the Gerald R. Ford Presidential Library.

GEORGE MECHLIN, Westinghouse
Monday, February 2, 1976
10:00 a.m.

Stove Solar

Dept Ag — work w/ TVA at Muscle Shoals

Energy
Pond(Fertilizer + Sun + BTU's + water

THE WHITE HOUSE

WASHINGTON

January 27, 1976

MEMORANDUM FOR: JIM CANNON

FROM: GLENN R. SCHLEEDE

SUBJECT: PROPOSED MEETING WITH DR. MECHLIN OF WESTINGHOUSE

I have looked over the correspondence from Dr. George Mechlin of Westinghouse concerning the problem of fertilizer energy-feedstocks. I agree that it would be a good idea to meet with Mechlin.

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Please let me know if you want us to make any of the arrangements.

cc: Jim Cavanaugh

Glenn – ok. Jim

THE WHITE HOUSE
WASHINGTON

January 22, 1976

Mr. Schleede

Mr. Cannon thinks we should be open to new ideas and thinks this one looks interesting.

He says that if you think it would be worthwhile, he would like to meet with Dr. Mechlin.

Please let us know your recommendation.

jennifer

the originals should come to you through the computer.

Mr. Cannon:

Dr. Mechlin would like to arrange a follow-up meeting to this letter with you to discuss increased fertilizer production and "how ERDA could mobilize to meet the energy challenges . . . of meeting future world needs."

I WILL SEE DR. MECHLIN ✓

with Schleede ✓ Humphreys_______ Leach_______

HAVE HIM SEE INSTEAD:

Schleede_______ Humphreys_______ Leach_______

j

Joe McMahon

833 5060

Try to set up for 2/2/76

Westinghouse Electric Corporation

George F Mechlin
Vice President
Research

Research & Development Center
Beulah Road
Pittsburgh Pennsylvania 15235

January 19, 1976

original to Computer for staffing jm

Mr. James M. Cannon
Assistant for Domestic Affairs
The Executive Office of the President
The White House Office
1600 Pennsylvania Avenue, N.W.
Washington, D.C. 20500

Dear Mr. Cannon:

We would like to bring to your attention a problem which could have a major impact on the future course of both national and international events, whose significance has not yet fully surfaced on the national consciousness.

The prospect that large segments of the human population face malnutrition and potential starvation within the foreseeable future due to lack of food surely constitutes one of the grimmest, most monumental challenges facing mankind in the latter quarter of the twentieth century. The current decline in world food production per capita, along with a projected increase in world population to six billion or more by the year 2000 from the current level of 3.8 billion, attests to the urgency required in dealing with this massive and potentially tragic problem. The United States, as the world's major food exporter, has a special responsibility to mobilize its resources, along with those of other world powers, in the battle against world famine. Should this battle be lost, the catastrophic consequences in those developing countries with the most severe food supply problems would reverberate throughout the world. The social and political implications are truly significant.

An essential weapon in the battle against world famine is fertilizer. Without fertilizer, U.S. food production would be reduced by a third. Eight to ten tons of grain are typically produced by a ton of fertilizer. In India, one of the nations most critically short of food, fertilizer usage per acre is about one-fiftieth that of Great Britain, a country

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Key ingredients in the production of fertilizer are the availability of energy and raw material feedstocks. These ingredients are necessary in the production of ammonia, the principal component of nitrogen-based fertilizer. At the present time, about 95 percent of ammonia production in the United States utilizes natural gas as the source of both hydrogen and process energy. Natural gas curtailments are expected to reduce ammonia production for the April 1975 - April 1976 period by about 670,000 tons, which represents almost four percent of current United States annual production capacity of 18.6 million tons. Various projections indicate that our domestic natural gas resources may be depleted within the next 20 to 30 years.

Organizations such as the Fertilizer Unit of the World Bank, the Fertilizer Institute, and the National and International Fertilizer Centers at Muscle Shoals, Alabama, with a deep interest in the world food problem and a recognition of the vital role which fertilizer can play in the battle against world famine, have expressed great concern over the increasing need for new fertilizer plants on the one hand (estimated to be 500 to 600 new plants by the year 2000) and the increasing shortage of natural gas (CH_4) needed to supply the hydrogen required for feedstock and the process heat needs of these plants. These organizations recognize the need for the rapid development of new technology for the production of ammonia with minimal use of fossil energy and fossil feedstock sources. Such technology, currently in the initial stages of development, utilizes water, rather than gas, as the raw material feedstock, and is adaptable to a variety of process heat energy sources such as nuclear, solar, fusion, or even fossil. As a matter of fact, the earliest techniques for ammonia-based fertilizer production utilized coal both as a feedstock and energy source. However, such an approach today may not be practical because of the already burdened state of our coal mining industry.

This new approach is based upon treating water both electrolytically and thermochemically to produce hydrogen, which is then available to react with nitrogen in the air to form ammonia. One such process, called the Sulfur Cycle Water Decomposition System, has been shown by Westinghouse to be technically feasible, with good prospects for economical production before the era of widespread natural gas usage has ended.

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There are currently a few low level activities having some relation to the problem which are getting some attention in the Fossil, Conservation, and Nuclear Divisions of ERDA. However, there is no single focal point within ERDA with both cognizance of the urgent need to solve the fertilizer energy-feedstock problem and the responsibility to take effective steps to do so.

It is for this reason that the Fertilizer Institute, in its October 1, 1975 Statement to ERDA on its National Plan for Energy Research, Development and Demonstration: Creating Energy Choices for the Future said "... in view of national values placed on food needs through the long-term, it is essential that ERDA's R&D Plan contain a major effort in developing alternative energy sources for natural gas as a chemical feedstock, and sources of electrical power generation less dependent on oil." They further recommended that "For the long-term, where emphasis is on nonexhaustible energy resources, technology must be developed for electrolytic or thermochemical hydrogen to serve as a fuel as well as a feedstock for substances like ammonia."

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Among the several future problems which Mr. Drucker discussed, there is one which may have the broadest impact and most far reaching consequences. Mr. Drucker stated this quite simply: "there is no shortage of any basic commodity with one exception and that is food." This is a problem which has a solution, and technology can provide that solution.

At the present time, with a world population of about four billion, approximately 400 to 500 million people lack sufficient food. The population is expected to soar to more than six billion by the end of the century, just twenty-five years from now. Most of this increase is expected in the poor, developing nations, which can least afford to provide for the sustenance of perhaps another two billion people.

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Haber process by the direct reaction of nitrogen with hydrogen. It has been estimated that the present world ammonia production capacity, about 70 million tons per year, will have to be increased to approximately 150 million tons per year in order to meet the minimal food needs of the world by the year 2000. The word "minimal" must be emphasized, since the quantities of fertilizer required for desired nutritional targets would be much larger.

Should the world's minimal need for fertilizer not be met or exceeded by the year 2000 and in the years beyond, major famines in the developing countries can be expected. These catastrophic events can only act as destabilizing forces on world political and economic systems, with major repercussions in the developed as well as the developing countries.

How, then, is mankind to cope with this situation? The only two alternatives appear to be (a) control of the rapid rise in the world population, currently estimated to be increasing by two percent per year, and (b) increased food production through increased fertilizer production at a rate sufficient to compensate for population increases. While population control may appear to be an obvious solution, the effectiveness of this approach may be limited by complex-socio-economic considerations, particularly in the developing countries. In any event, population control measures would probably not have any real impact in reducing population growth over the next few decades. Alternative (b), increased food production to compensate for population growth, would appear to be a more readily grasped goal, with recognizable means for its attainment.

It must be stressed that increased fertilizer usage is by no means the only route to greater food production, but it is one of the most effective routes toward that end. Food production can also be increased by bringing more land under cultivation. This approach seems to be favored in some parts of Africa. However, seven to nine acres of new land would have to be brought under cultivation to produce the same yield as a ton of fertilizer nutrients at present usage rates in the United States. As shown in Figure 1, additional routes to increased grain production include increased irrigation, extensive use of improved seed varieties, and additional and improved pesticides. Nevertheless, the use of more and better fertilizer appears to be the dominant factor in achieving increased grain production.

If the premise is accepted that a major increase in world fertilizer production capability will be required to keep pace with the demand engendered by continuing world population growth, the question then arises of the adequacy of current fertilizer technology to meet the challenges ahead. This question is particularly pertinent for nitrogen fertilizers, which use natural gas, oil, or coal as the feedstock from which the hydrogen required for ammonia synthesis is derived.

When available, natural gas is the preferred feedstock. The role of natural gas in the production of nitrogen-based fertilizers is illustrated in Figure 2. In the United States, about 95 percent of current ammonia production capacity utilizes natural gas for both a feedstock and process heat. Light and heavy oil fractions are generally selected as the feedstock when natural gas is not available. Because of the complexity and high cost of ammonia plants employing coal as a feedstock, relatively few modern ammonia plants which use coal have been built.

In the light of fast diminishing supplies of natural gas and oil, it is problematical how long existing ammonia plants can continue to use these fossil-based feedstocks, while reliance on gas and oil for the greatly expanded ammonia production capacity projected for the future can no longer be considered as a viable option. In the United States, natural gas shortages are already cutting into ammonia production. For the period April 1975 to April 1976, natural gas curtailments are expected to reduce ammonia production by about 670,000 tons, which represents almost four percent of current United States ammonia production capacity. While coal is an acceptable technical option for the mid-term, there are serious questions about the capability of the coal industry to expand at a rate sufficient to meet the greatly increased demand for its product. Coal-based ammonia plants are also at least twice as expensive as plants utilizing natural gas as the feedstock, making the justification for coal-based plants difficult except in locations where coal is cheap, abundant, and available.

Where, then, can one find a technology for ammonia production which avoids the limitations of fossil-based feedstocks? One can go back to the early 1900s when chemical processes for converting atmospheric nitrogen to a form suitable for fertilizer use were in their infancy. At that time, two processes were predominant - the cyanamide process and the electric arc process. The cyanamide process used carbon and lime to form calcium carbide, which then reacted with atmospheric nitrogen to form calcium cyanamide. The cyanamide in turn reacted with water to yield ammonia. The cyanamide process, in addition to requiring a fossil source of carbon, required more than four times the energy consumption of a modern ammonia plant. The electric arc process involved the direct passage of air through a high temperature electric arc, resulting in the reaction of nitrogen and oxygen to form nitric oxide. While not requiring a fossil fuel feedstock, this process required seventeen times as much energy as a modern ammonia plant.

Looking toward the distant future, some scientists are considering the possibility that atmospheric nitrogen can be combined with ground water to form ammonia by means of catalytic agents found in certain bacteria, with no need for large energy expenditures to produce free hydrogen for later combination with nitrogen. Some preliminary experimental studies have indicated that such bacteria, usually found near the roots of legumes such as clover and soybeans, may also be active in the vicinity of cereal grains. However, many unknowns are associated with the process of biological fixation of nitrogen, not the least of which is the low rate of fixation. It has been estimated, for example, that an area about one-tenth the size of the United Kingdom would have to be planted with clover to fix as much nitrogen as the annual nitrogen production (one to two million tons) of one of Britian's leading ammonia producers.

Lastly, one can consider producing the needed hydrogen directly from water. Water can be decomposed into hydrogen and oxygen electrolytically, by passing an electric current through it, or thermally, by heating water to a sufficiently high temperature. The thermal decomposition temperature can be lowered appreciably by employing a thermochemical process, in which two or more intermediate chemical reactions are employed in a closed cycle with water.

Hydrogen production by water electrolysis is an established technology, but one which is much more expensive and energy consumptive than hydrogen production from fossil feedstocks. Not only is the electricity consumption per unit of hydrogen production large, but less than 40 percent of the energy content of the power plant fuel is converted to electricity. As a result, less than 25 percent of the electrical plant fuel energy appears in the hydrogen product. Research is currently under way to increase both the efficiency of water electrolysis and the efficiency of electricity generation. If successful, this research could lead to overall efficiencies approaching 50 percent for the electrolytic production of hydrogen. If the electricity generating plant were nuclear-fueled, the fossil fuel bottleneck in the fertilizer production cycle would no longer exist.

In thermochemical hydrogen production, heat, not electricity, is involved in the water decomposition process. Thus, the inherent inefficiency in electricity generation is by-passed, with the potential for hydrogen production efficiencies well in excess of those encountered with current water electrolysis systems. Again, the use of a nuclear-fueled heat source avoids the problems of availability and supply associated with fossil fuels. While thermochemical hydrogen production has been a subject of intense research activity over the past few years, no pure thermochemical process has yet emerged with the requisites of moderate process temperature, high efficiency for hydrogen production, competitive costs, and practical process characteristics, which are of commercial importance.

On the other hand, studies and research to date have established that a hybrid water decomposition process, incorporating both electrolytic and thermochemical process steps, does have the desired characteristics of high efficiency (approaching 50 percent), moderate process temperature (1400° to 1600°F), competitive cost (comparable to hydrogen production from coal at $25 per ton), and practical process characteristics (use of common recyclable sulfur compounds, plus a high purity hydrogen product). This hybrid process is called the Sulfur Cycle Water Decomposition System, and was developed by Westinghouse. It is being regarded with considerable interest by organizations charged with the responsibility for fertilizer development and meeting future world fertilizer needs, such as the National Fertilizer Development Center, the Fertilizer Institute, and the World Bank. In addition, support for continued development of the process has been provided or is under consideration by such federal agencies as the National Aeronautics and Space Administration and the Energy Research and Development Administration.

The Sulfur Cycle Water Decomposition System consists of two basic steps. In the first step, sulfur dioxide reacts with water in an electrolysis cell to form hydrogen (the desired product) and sulfuric acid, according to the equation:

$$SO_2 + 2H_2O \longrightarrow H_2 + H_2SO_4$$

In the second step, the sulfuric acid is formed is thermally decomposed to water, sulfur dioxide, and oxygen, according to the equation:

$$H_2SO_4 \longrightarrow H_2O + SO_2 + 1/2O_2$$

The sulfur dioxide produced in the thermal decomposition step is recycled back to the electrolysis step. The oxygen produced is available for conversion of ammonia to nitrate form. Since the electrolysis step requires only about one-third the electricity of conventional water electrolysis, major energy usage economies result which lead to hydrogen production efficiencies on the order of 50 percent. A schematic of the major elements in the total process for producing ammonium nitrate fertilizer via the water decomposition is shown in Figure 3. A Very High Temperature Reactor concept capable of meeting the process heat and power requirements of the Sulfur Cycle is shown in Figure 4.

It is apparent that technological options do exist for meeting the increased food production needs of a rapidly growing world population through the increased application of fertilizers. These options do not require competition for fossil feedstocks, which are likely to become less and less available in the future. The lives of millions in the foreseeable future may well hinge on whether these options can be pursued to a successful conclusion.

REFERENCES

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2. Ewell, R., "Future Production and Use of Fertilizers", Paper presented at International Meeting on Scientific Research and Agricultural Problems, Association of Spanish Scientists of the Superior Council of Scientific Investigation, Madrid, Spain, November 10-14, 1975.

3. "Statement of the Fertilizer Institute", Submitted to the Energy Research and Development Administration on its National Plan for Energy Research, Development and Demonstration: Creating Energy Choices for the Future, October 1, 1975.

4. "Famine Respite Possible for Decade", Technology Forecasts, October 1975, p.9.

5. "Nitrogen Fixing Action of Micro-Organisms Initiated in ARC Research Project", Nitrogen, Vol. 94, March/April 1975.

6. Safrany, D. R., "Nitrogen Fixation", Scientific American, Vol. 231, No. 4, 1974, pp. 64-80.

FIGURES

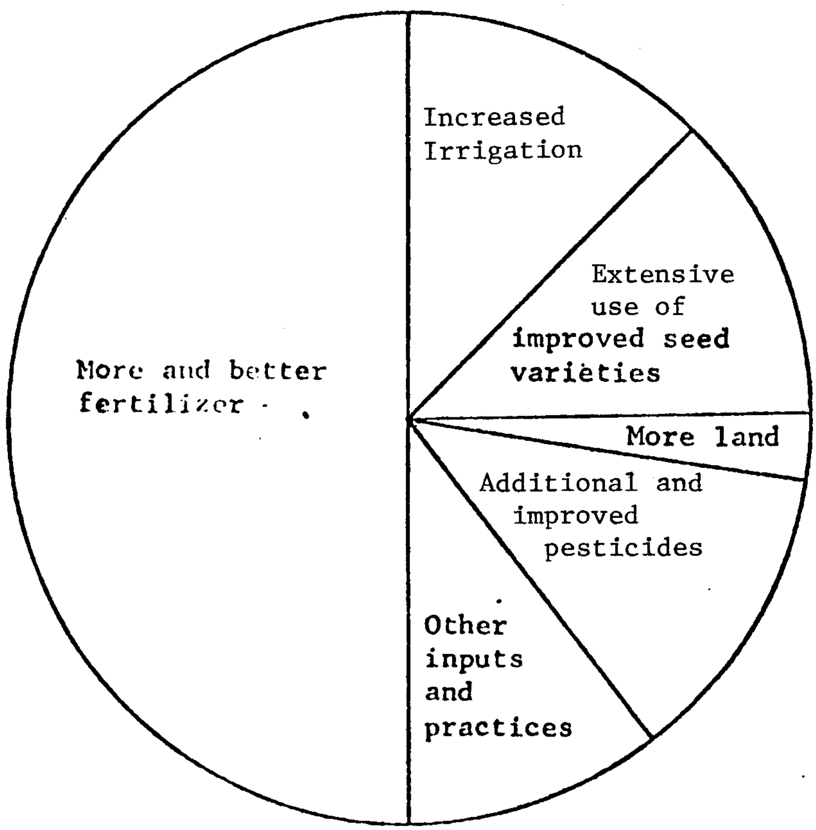


Figure 1. Factors Contributing to Increased Grain Production (Ref. 3)

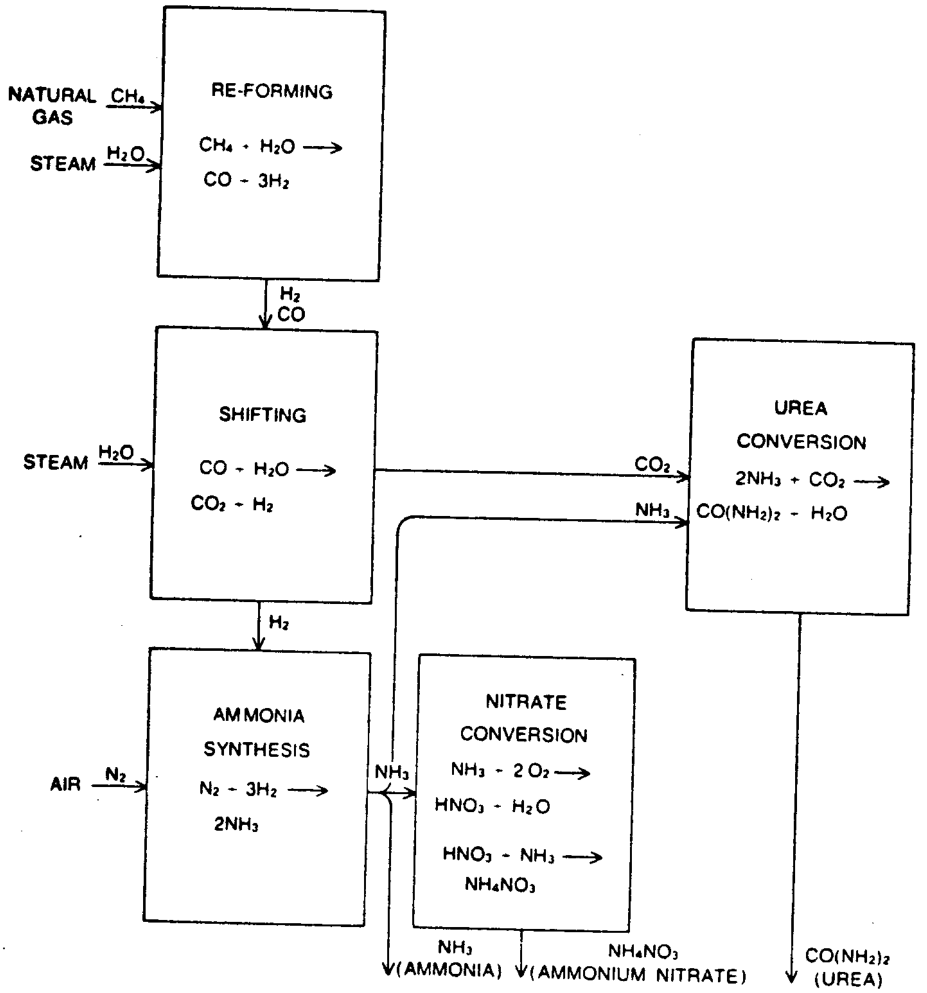


Figure 2. Process Steps in the Production of Nitrogen-Based Fertilizer from Natural Gas (Ref. 6)

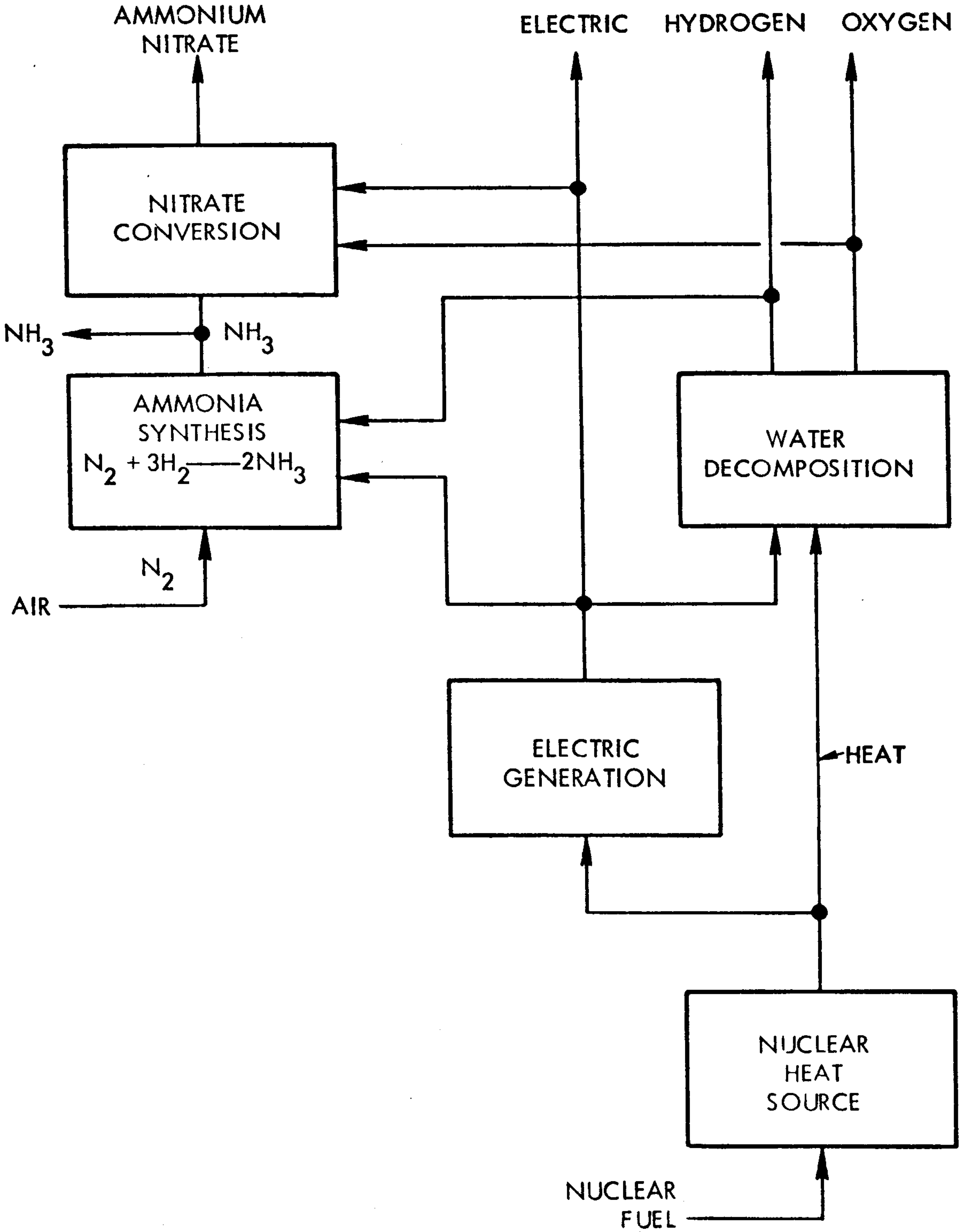


Figure 3. Process Steps in the Production of Amonium Nitrate Fertilizer from the Westinghouse Sulfur Cycle Water Decomposition Process

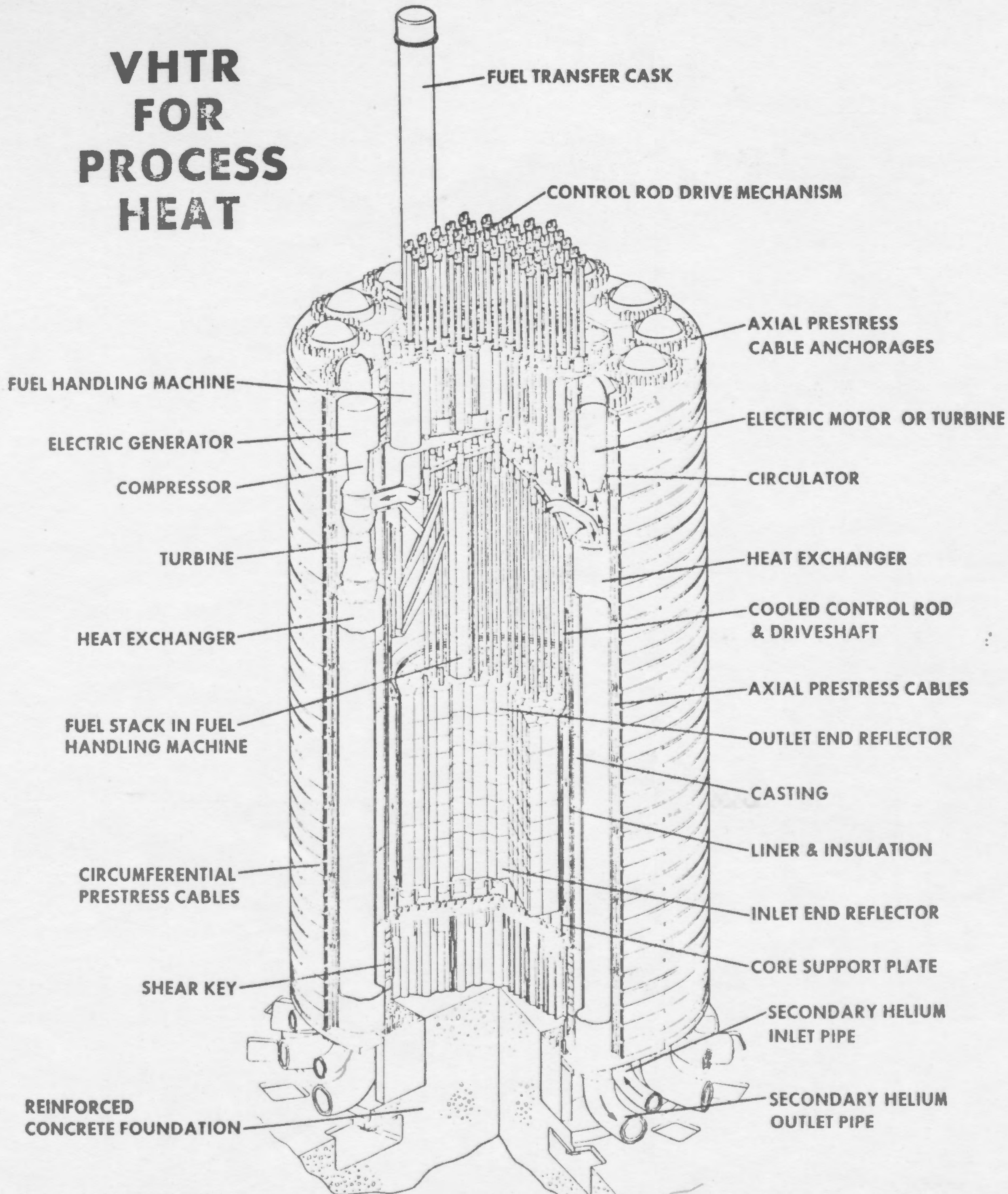


Figure 4. Westinghouse Very High Temperature Reactor (VHTR) Concept for Providing Process Heat and Power to Sulfur Cycle Water Decomposition Process

Mon
2/2
10 am

Mr. Cannon:

Dr. Mechlin would like to arrange a follow-up meeting to this letter with you to discuss increased fertilizer production and "how ERDA could mobilize to meet the energy challenges . . . of meeting future world needs."

I WILL SEE DR. MECHLIN ✓

with Schleede ✓ Humphreys______ Leach______

HAVE HIM SEE INSTEAD:

Schleede______ Humphreys______ Leach______

j

Joe McMahon

833 5060

copy to Schleede what do you think?

MacAvoy Fri

Schleede making arrangements

Westinghouse Electric Corporation

George F Mechlin
Vice President
Research

Research & Development Center
Beulah Road
Pittsburgh Pennsylvania 15235

one of oldest
2,000 + people

January 19, 1976

Mr. James M. Cannon
Assistant for Domestic Affairs
The Executive Office of the President
The White House Office
1600 Pennsylvania Avenue, N.W.
Washington, D.C. 20500

original to computer for staffing

Dear Mr. Cannon:

We would like to bring to your attention a problem which could have a major impact on the future course of both national and international events, whose significance has not yet fully surfaced on the national consciousness.

The prospect that large segments of the human population face malnutrition and potential starvation within the foreseeable future due to lack of food surely constitutes one of the grimmest, most monumental challenges facing mankind in the latter quarter of the twentieth century. The current decline in world food production per capita, along with a projected increase in world population to six billion or more by the year 2000 from the current level of 3.8 billion, attests to the urgency required in dealing with this massive and potentially tragic problem. The United States, as the world's major food exporter, has a special responsibility to mobilize its resources, along with those of other world powers, in the battle against world famine. Should this battle be lost, the catastrophic consequences in those developing countries with the most severe food supply problems would reverberate throughout the world. The social and political implications are truly significant.

An essential weapon in the battle against world famine is fertilizer. Without fertilizer, U.S. food production would be reduced by a third. Eight to ten tons of grain are typically produced by a ton of fertilizer. In India, one of the nations most critically short of food, fertilizer usage per acre is about one-fiftieth that of Great Britain, a country

with adequate food production. Increased fertilizer usage in countries such as India could have a dramatic influence on the magnitude and severity of world food problems.

Key ingredients in the production of fertilizer are the availability of energy and raw material feedstocks. These ingredients are necessary in the production of ammonia, the principal component of nitrogen-based fertilizer. At the present time, about 95 percent of ammonia production in the United States utilizes natural gas as the source of both hydrogen and process energy. Natural gas curtailments are expected to reduce ammonia production for the April 1975 - April 1976 period by about 670,000 tons, which represents almost four percent of current United States annual production capacity of 18.6 million tons. Various projections indicate that our domestic natural gas resources may be depleted within the next 20 to 30 years.

Organizations such as the Fertilizer Unit of the World Bank, the Fertilizer Institute, and the National and International Fertilizer Centers at Muscle Shoals, Alabama, with a deep interest in the world food problem and a recognition of the vital role which fertilizer can play in the battle against world famine, have expressed great concern over the increasing need for new fertilizer plants on the one hand (estimated to be 500 to 600 new plants by the year 2000) and the increasing shortage of natural gas (CH_4) needed to supply the hydrogen required for feedstock and the process heat needs of these plants. These organizations recognize the need for the rapid development of new technology for the production of ammonia with minimal use of fossil energy and fossil feedstock sources. Such technology, currently in the initial stages of development, utilizes water, rather than gas, as the raw material feedstock, and is adaptable to a variety of process heat energy sources such as nuclear, solar, fusion, or even fossil. As a matter of fact, the earliest techniques for ammonia-based fertilizer production utilized coal both as a feedstock and energy source. However, such an approach today may not be practical because of the already burdened state of our coal mining industry.

This new approach is based upon treating water both electrolytically and thermochemically to produce hydrogen, which is then available to react with nitrogen in the air to form ammonia. One such process, called the Sulfur Cycle Water Decomposition System, has been shown by Westinghouse to be technically feasible, with good prospects for economical production before the era of widespread natural gas usage has ended.

The implications of an accelerating energy and feedstock shortage for fertilizer production on our capability to deal with impending world food shortages are obvious. Yet, there is little evidence of which we are aware that ERDA, the federal energy research and development agency, has addressed these critical problems with a priority in accordance with the enormity and significance of the world food situation.

There are currently a few low level activities having some relation to the problem which are getting some attention in the Fossil, Conservation, and Nuclear Divisions of ERDA. However, there is no single focal point within ERDA with both cognizance of the urgent need to solve the fertilizer energy-feedstock problem and the responsibility to take effective steps to do so.

It is for this reason that the Fertilizer Institute, in its October 1, 1975 Statement to ERDA on its National Plan for Energy Research, Development and Demonstration: Creating Energy Choices for the Future said "... in view of national values placed on food needs through the long-term, it is essential that ERDA's R&D Plan contain a major effort in developing alternative energy sources for natural gas as a chemical feedstock, and sources of electrical power generation less dependent on oil." They further recommended that "For the long-term, where emphasis is on nonexhaustible energy resources, technology must be developed for electrolytic or thermochemical hydrogen to serve as a fuel as well as a feedstock for substances like ammonia."

We, at Westinghouse, strongly concur with the recommendations of the Fertilizer Institute. However, we feel that additional effort will be needed if ERDA is to recognize and take the necessary steps to implement an energy program which may well pay the incalculable dividend of life to millions of human beings, and improve the probability of worldwide social and political stability.

We would very much appreciate the opportunity to meet with you to present our thoughts on how ERDA could mobilize to meet the energy challenges which are inextricably woven into the fabric of the greater challenge of meeting future world food needs. Attached for your information are supplementary notes on technological options for increased fertilizer production.

Sincerely,

George Mechlin

SUPPLEMENTARY NOTES ON TECHNOLOGICAL OPTIONS FOR INCREASED FERTILIZER PRODUCTION

Mr. Peter Drucker, nationally known management consultant and economist, recently made a presentation to Westinghouse executives on what he believes will be the major problems of the future on both a domestic and worldwide basis.

Among the several future problems which Mr. Drucker discussed, there is one which may have the broadest impact and most far reaching consequences. Mr. Drucker stated this quite simply: "there is no shortage of any basic commodity with one exception and that is food." This is a problem which has a solution, and technology can provide that solution.

At the present time, with a world population of about four billion, approximately 400 to 500 million people lack sufficient food. The population is expected to soar to more than six billion by the end of the century, just twenty-five years from now. Most of this increase is expected in the poor, developing nations, which can least afford to provide for the sustenance of perhaps another two billion people.

The only feasible way to feed these additional billions is to increase food yields through increased application of fertilizers as Mr. Drucker pointed out, "the increase in food productivity in the developing world has been almost exactly an increase in application of fertilizer". Typically, an added ton of fertilizer may be expected to increase the yield of grain by eight to ten tons. Of the three essential fertilizer ingredients - nitrogen, phosphorou and potash - nitrogen is the most energy intensive. It must be removed from th atmosphere and "fixed" in a chemical form suitable for application to crops. The chemical form is usually a compound of ammonia, which is formed in the

more

Attendees for:
Monday, 10:00 a.m. - Mr. Cannon's Office

George Mechlin

Edward Ney

Leo Wright

Joseph McMahon

Paul MacAvoy

Robert Fri

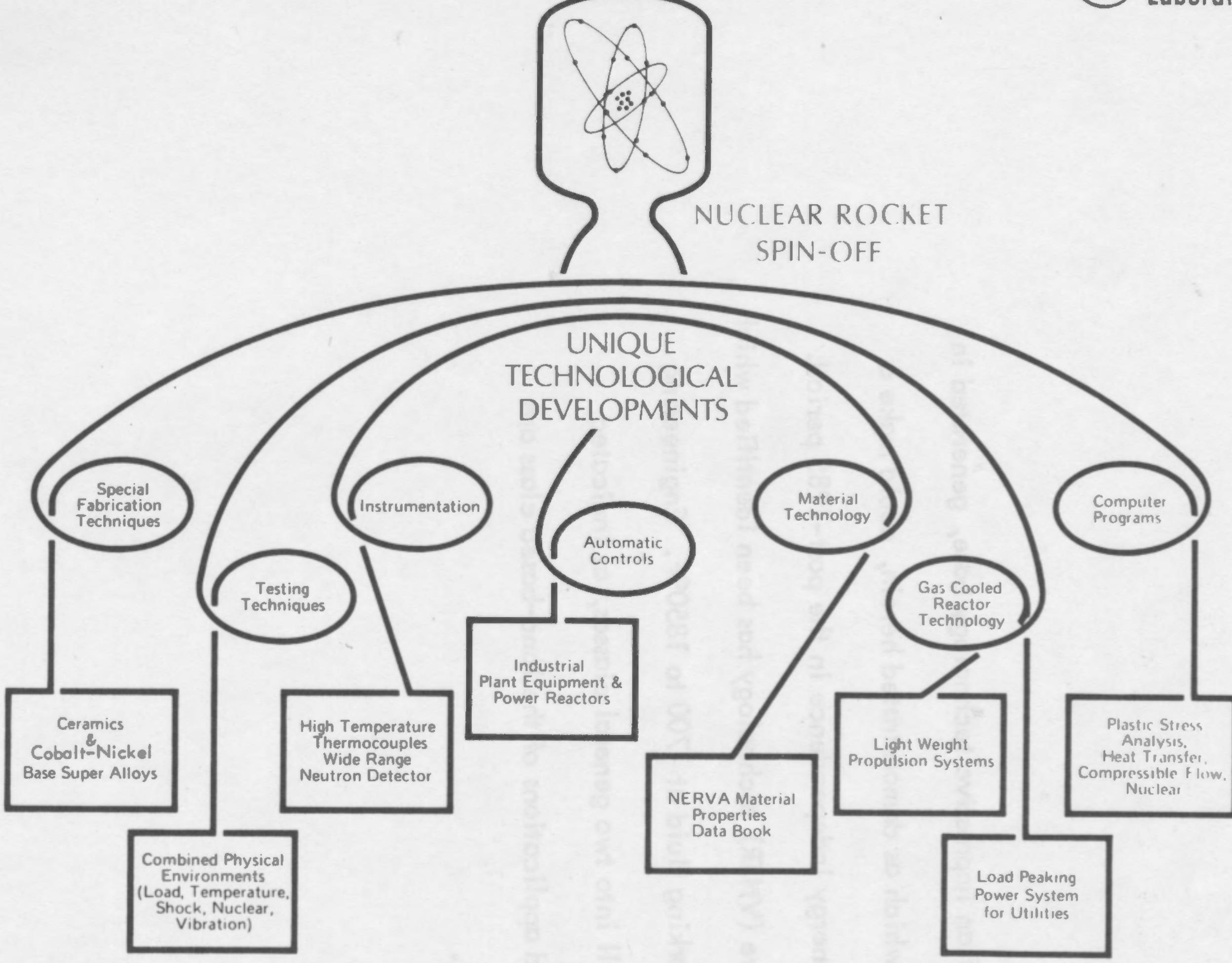
JANUARY 26, 1976

Westinghouse Astronuclear Laboratory

STATUS OF
THE VERY HIGH TEMPERATURE REACTOR
(VHTR)
FOR PROCESS HEAT

Attachment

Astronuclear Laboratory



UTILIZATION OF TECHNOLOGY FROM NERVA IN THE SOLUTION OF CONTINUING NATIONAL PROBLEMS

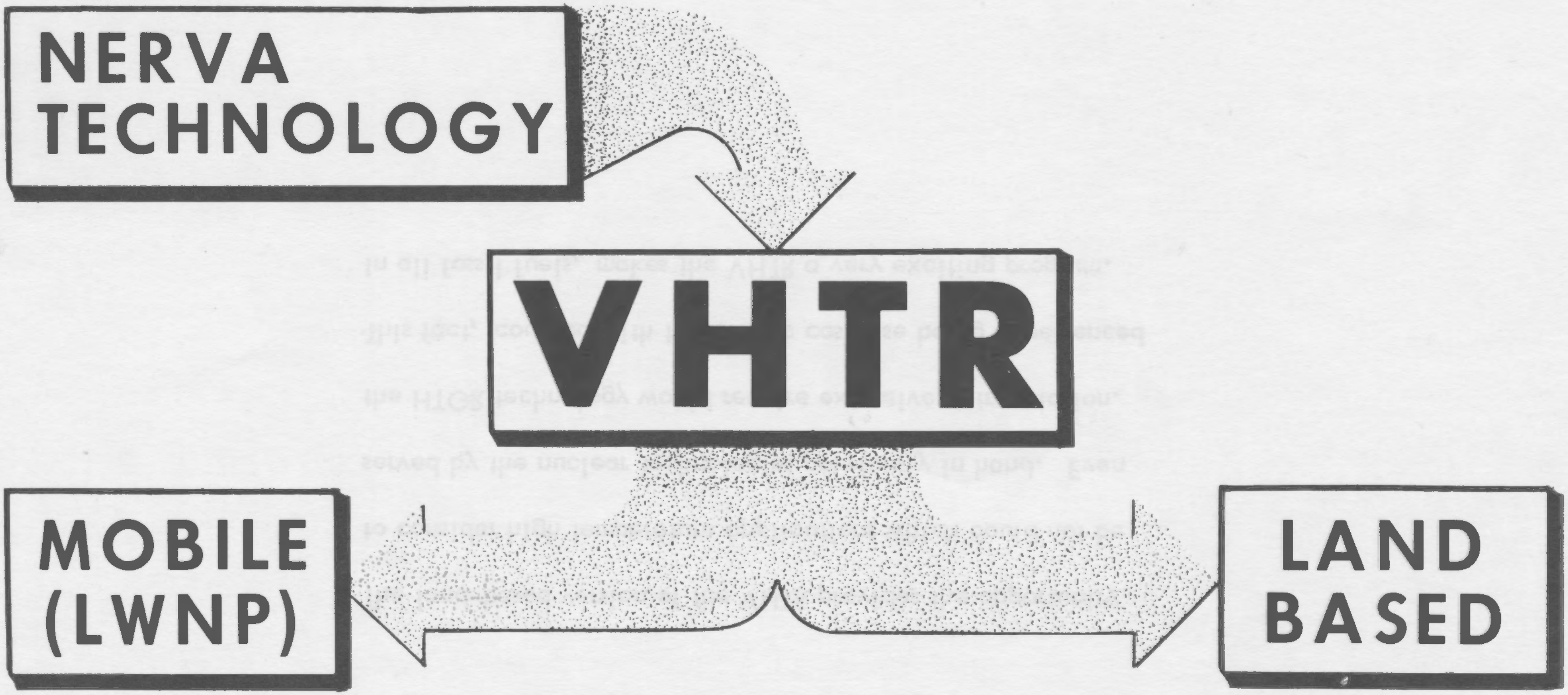
By

A. R. Jones
Manager, Special Projects

Westinghouse Electric Corporation
Astronuclear Laboratory
P. O. Box 10864
Pittsburgh, Pennsylvania 15236

The Nation is in possession of an impressive technology base, generated in the nuclear rocket program, which as demonstrated herein, could make a magnificent contribution to energy independence in the post-1985 period. A single very high temperature (VHTR) technology has been identified which can produce helium as the working fluid at 1700 to $1850^{\circ}F$. Engineering variants of this technology fall into two general classes, as indicated above. Typical examples and applications of the land-based class are shown on the following pages.

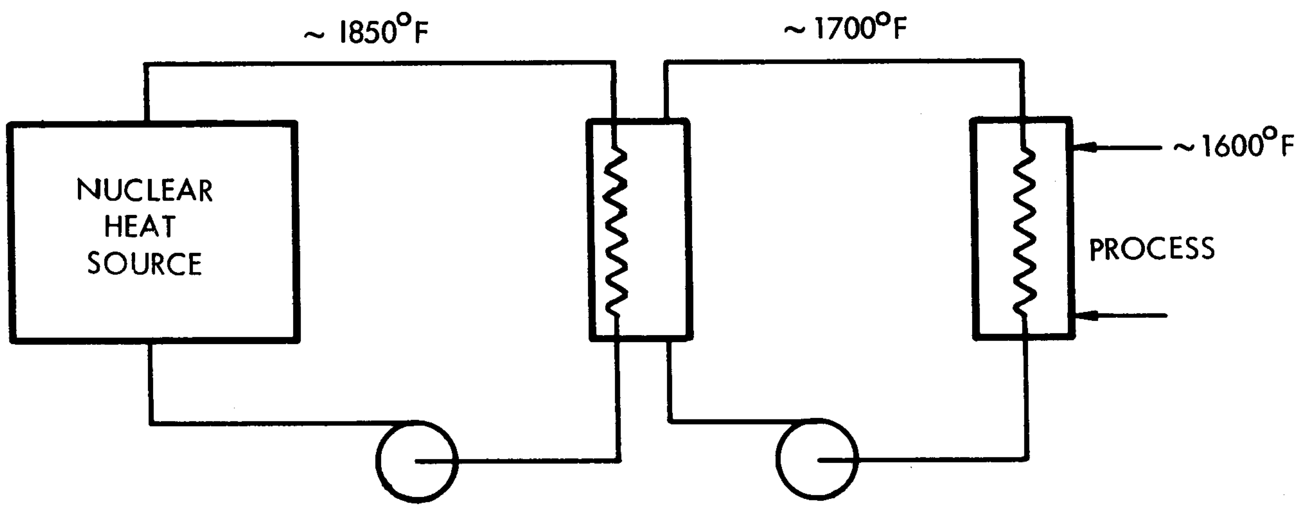
*U = Uranium, Th = Thorium



- U FUEL *
- COMPACT
- LIGHT WEIGHT

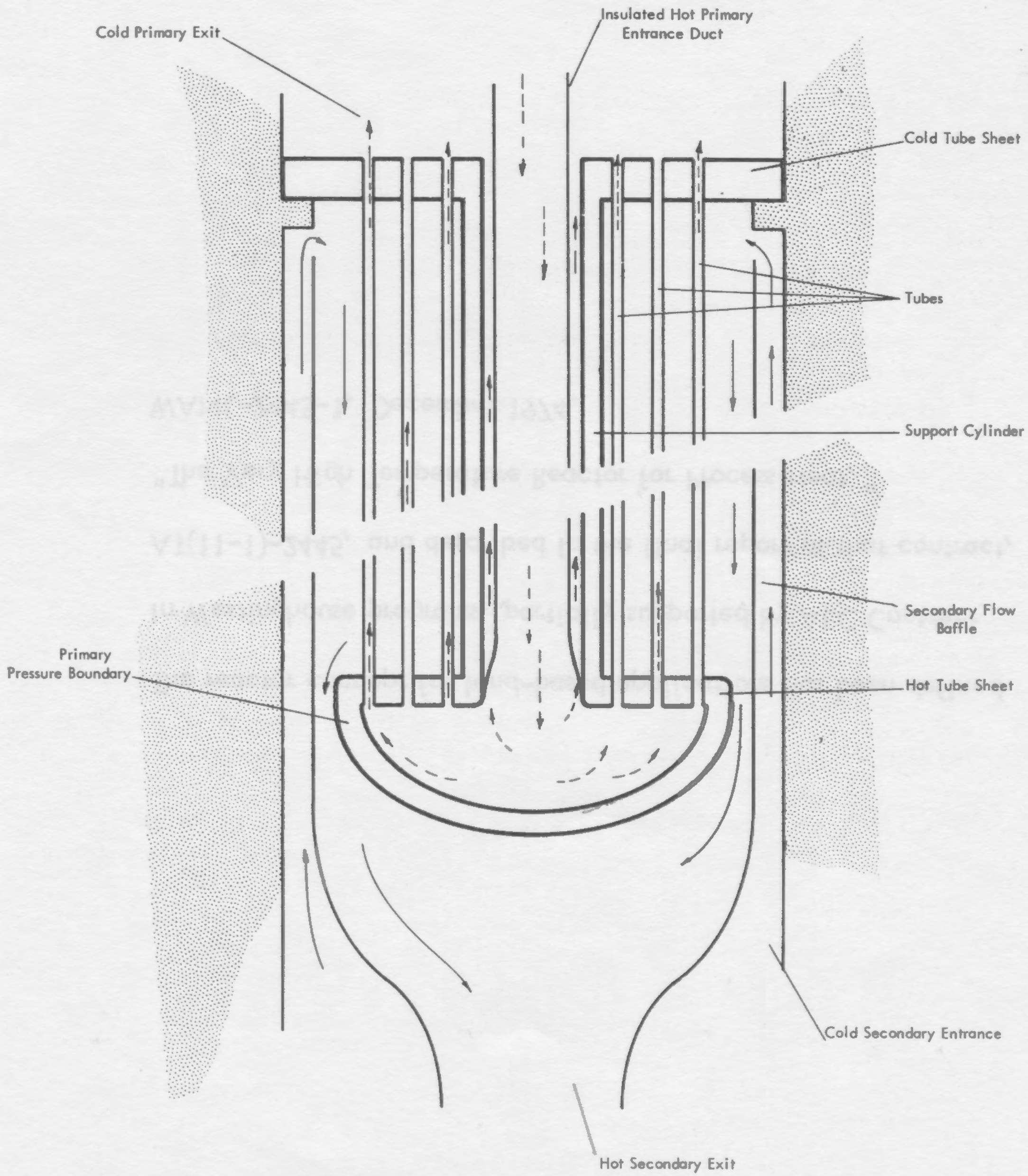
- U-Th FUEL *
- LOW FUEL COST
- HIGH TEMPERATURE

The land-based version of the VHTR provides the opportunity to consider high temperature applications which could not be served by the nuclear technologies previously in hand. Even the HTGR technology would require extensive extrapolation. This fact, coupled with the drastic cost rise being experienced in all fossil fuels, makes the VHTR a very exciting program.


~ 1850°F
~ 1700°F
~ 1600°F
NUCLEAR
HEAT
SOURCE
PROCESS

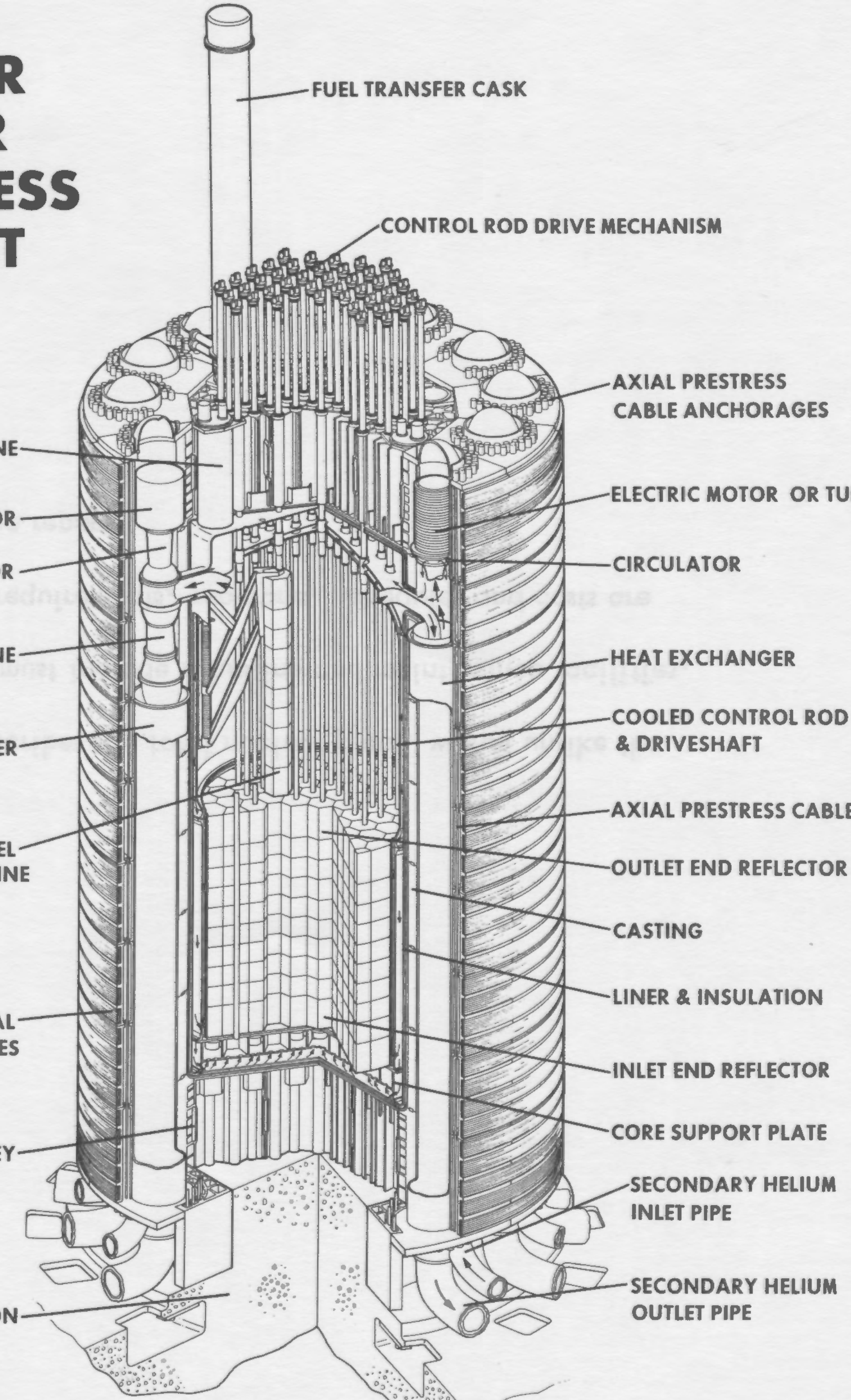
A major development area in the VHTR program is the materials required to withstand the pressure stress and temperature levels in the helium environment. The intermediate heat exchanger (IHX) is a most obvious example of a component requiring further R&D. Concepts and materials that appear to be both adequate and economic have been identified. Programs to confirm these materials and generate the engineering design data and satisfy code considerations have been described. An early start on R&D in this critical area is vital to timely definition of detailed engineering and costs.

REFERENCE IHX CONCEPT SCHEMATIC

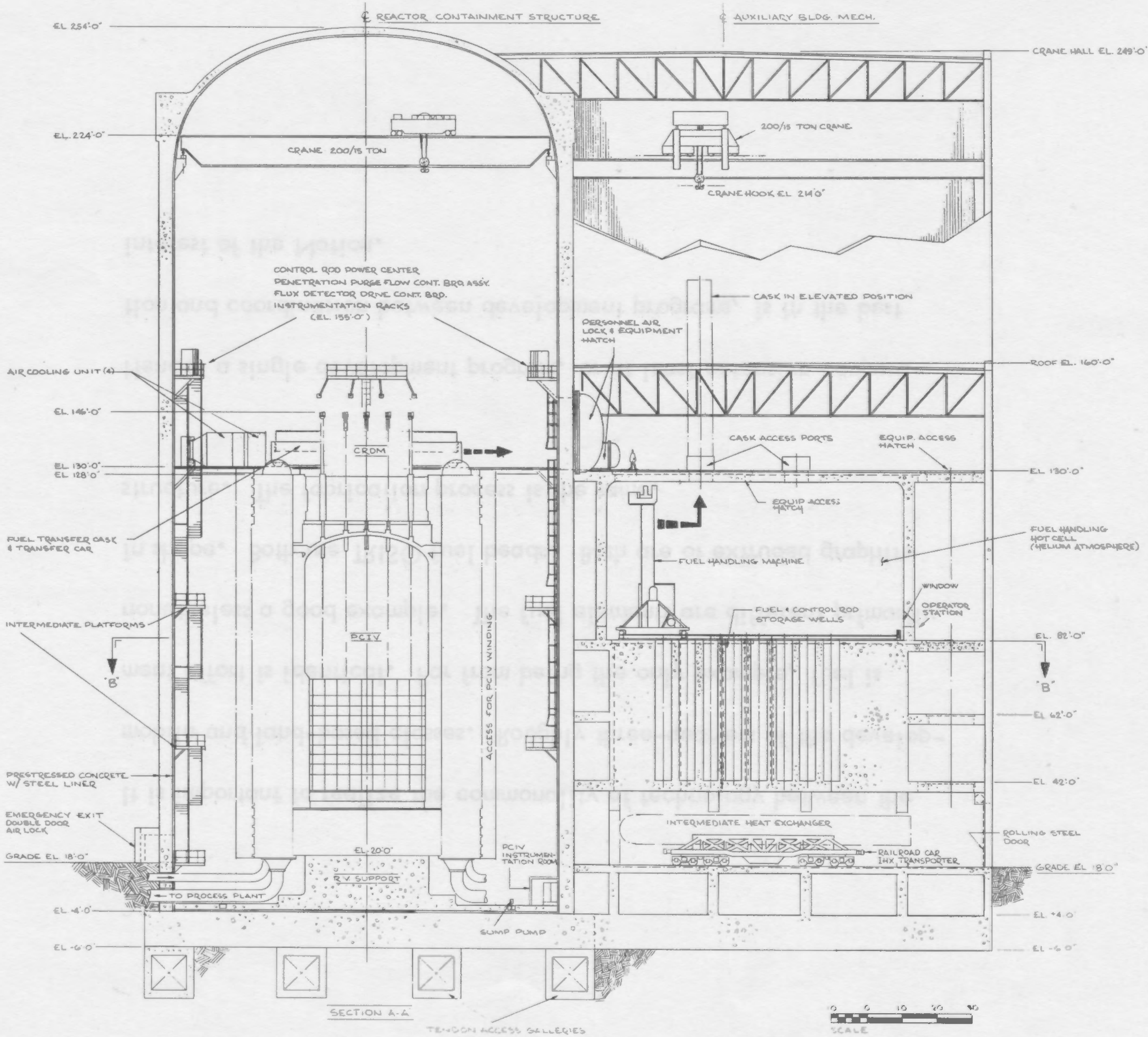


The reactor concept for land-based applications has been defined in Westinghouse programs, partially supported by AEC Contract AT(11-1)-2445, and described in the final report of that contract, "The Very High Temperature Reactor for Process Heat," WANL-2445-1, December 1974.

VHTR FOR PROCESS HEAT



This report describes the total nuclear plant, which unlike the mobile class, must include refueling and maintenance facilities. Development requirements, programs, schedules and costs are discussed in the report.

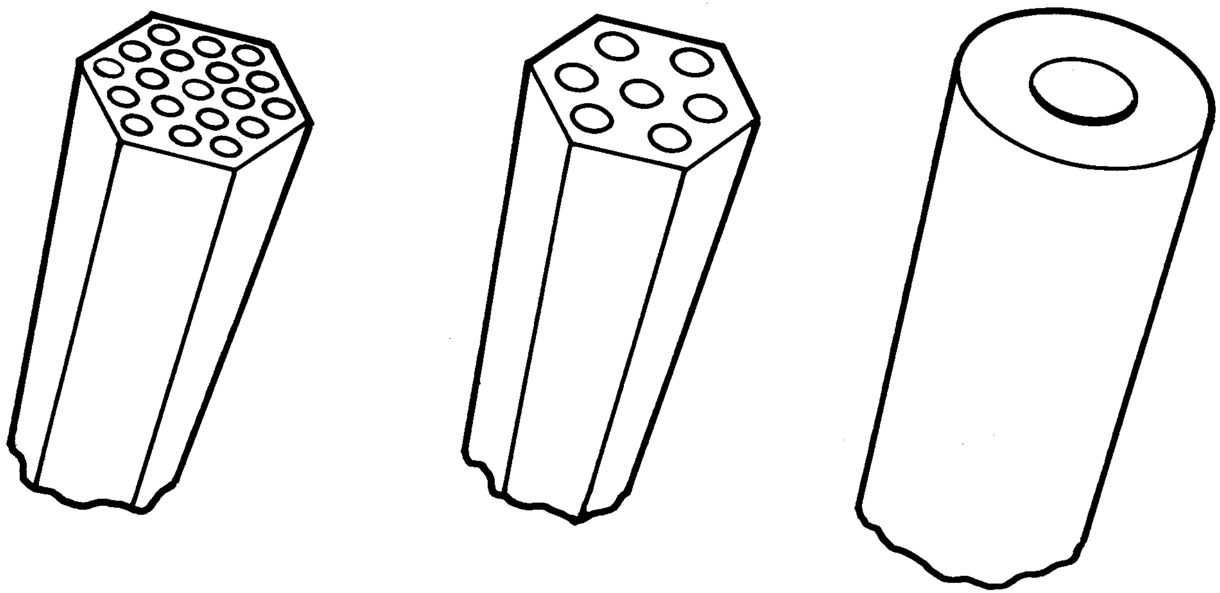


Reactor Containment and Auxiliary Building - Elevation

It is important to realize the commonality of technology between the mobile and land-based classes. Roughly three-quarters of the development effort is identical. Far from being the only example, fuel is nonetheless a good example. The fuel elements are different primarily in shape. Both use TRISO fuel beads. Both are of extruded graphite structure. The fabrication process is the same.

Hence, a single development program, or at least extensive cooperation and coordination between development programs, is in the best interest of the Nation.

POWER DENSITY EFFECTS

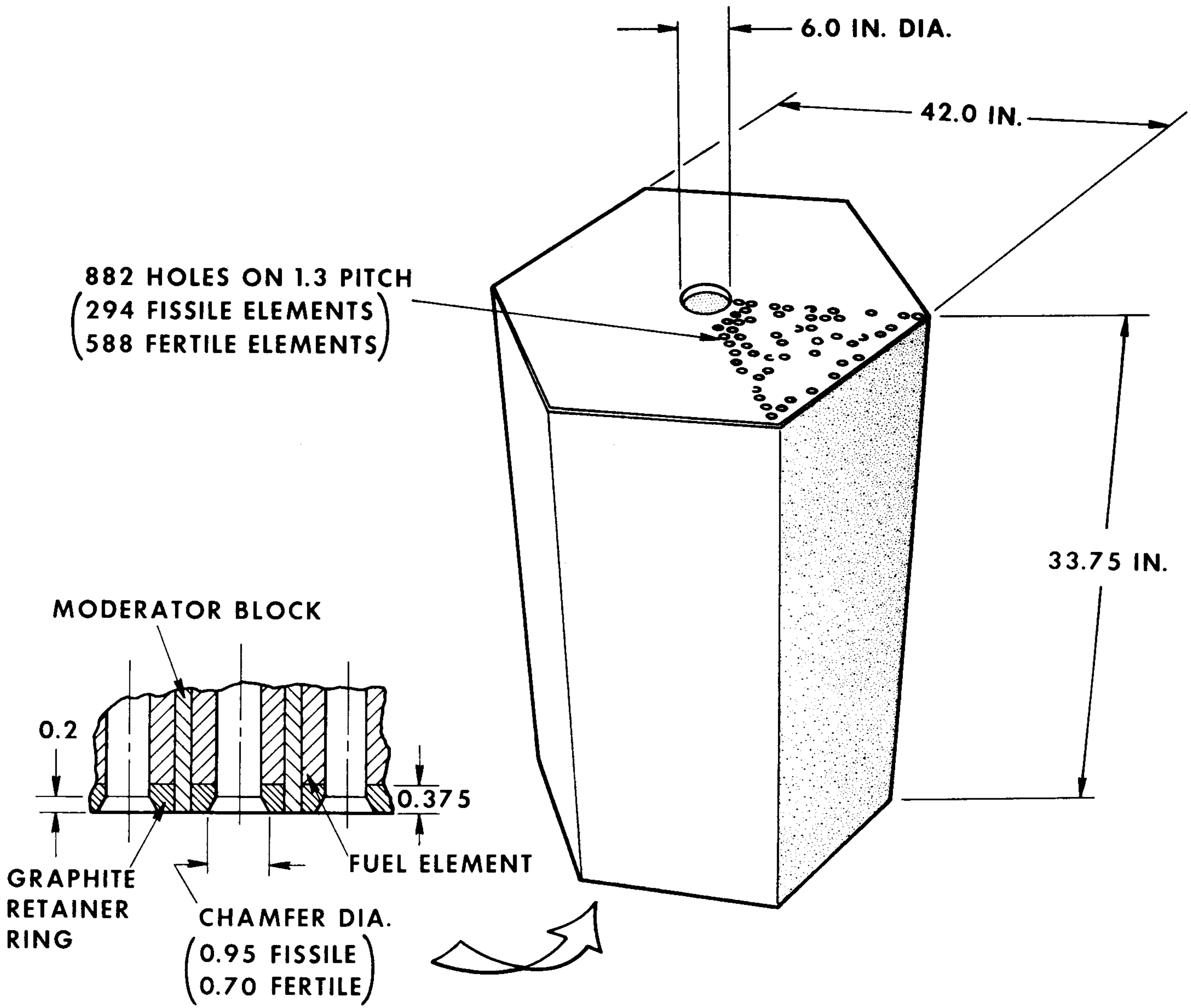


NERVA	LSWP	NUCO
1500-2500 MW/M^3	300 MW/M^3	10 MW/M^3

The demonstration programs are recognized to be different in character and separate demo units must be considered for each of the two clauses.

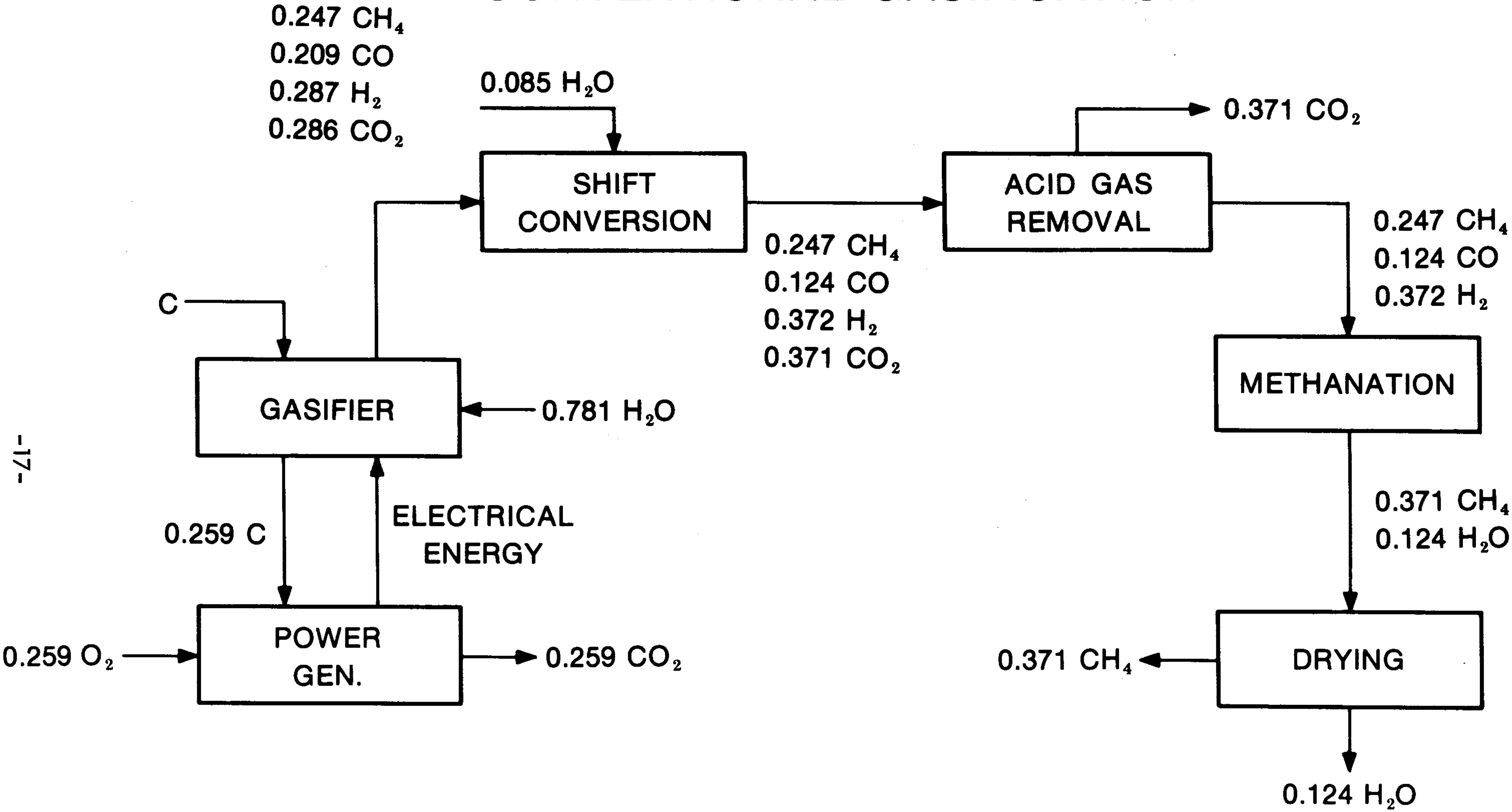
Again the fuel or core is a good component example. The mobile unit has no moderator except that provided by the graphite in the fuel element. The land-based unit has graphite moderator blocks, as shown above, into which the cylindrical fuel elements are inserted.

MODERATOR BLOCK



The most promising application may well be in the conversion of coal into synthetic hydrocarbons — oil, gas, methanol, etc. Clearly these materials are vitally needed and this need will increase. As illustrated above, up to 63 percent of the carbon in the coal, when used on conventional coal conversion concepts, is required to provide energy and reduce water to provide the hydrogen. Nuclear process heat offers the opportunity to increase, up to two or three times, the useful product from a given amount of coal.

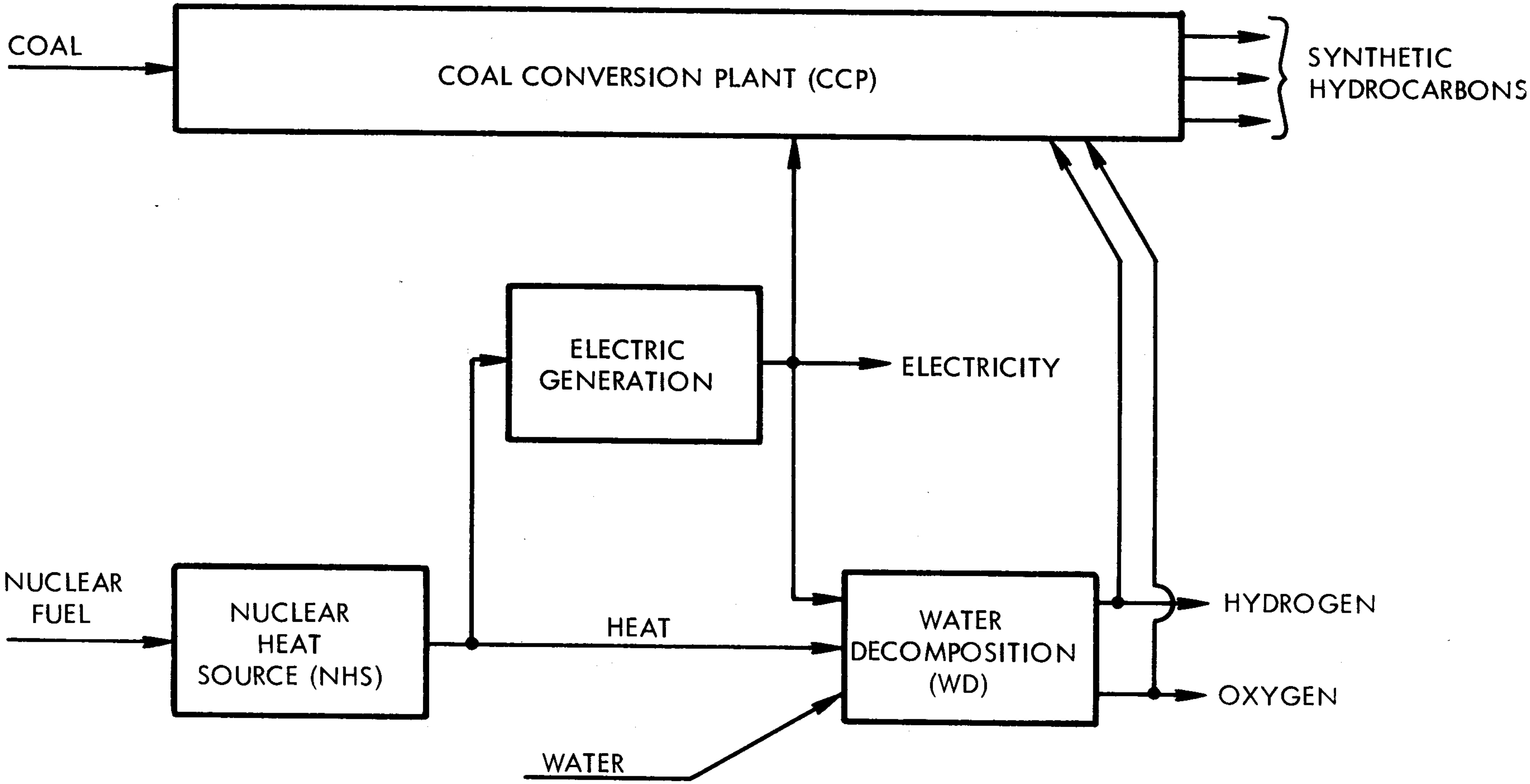
CONVENTIONAL GASIFICATION



TOTAL REACTION: $C + 0.259\ O_2 + 0.742\ H_2O \rightarrow 0.371\ CH_4 + 0.630\ CO_2$

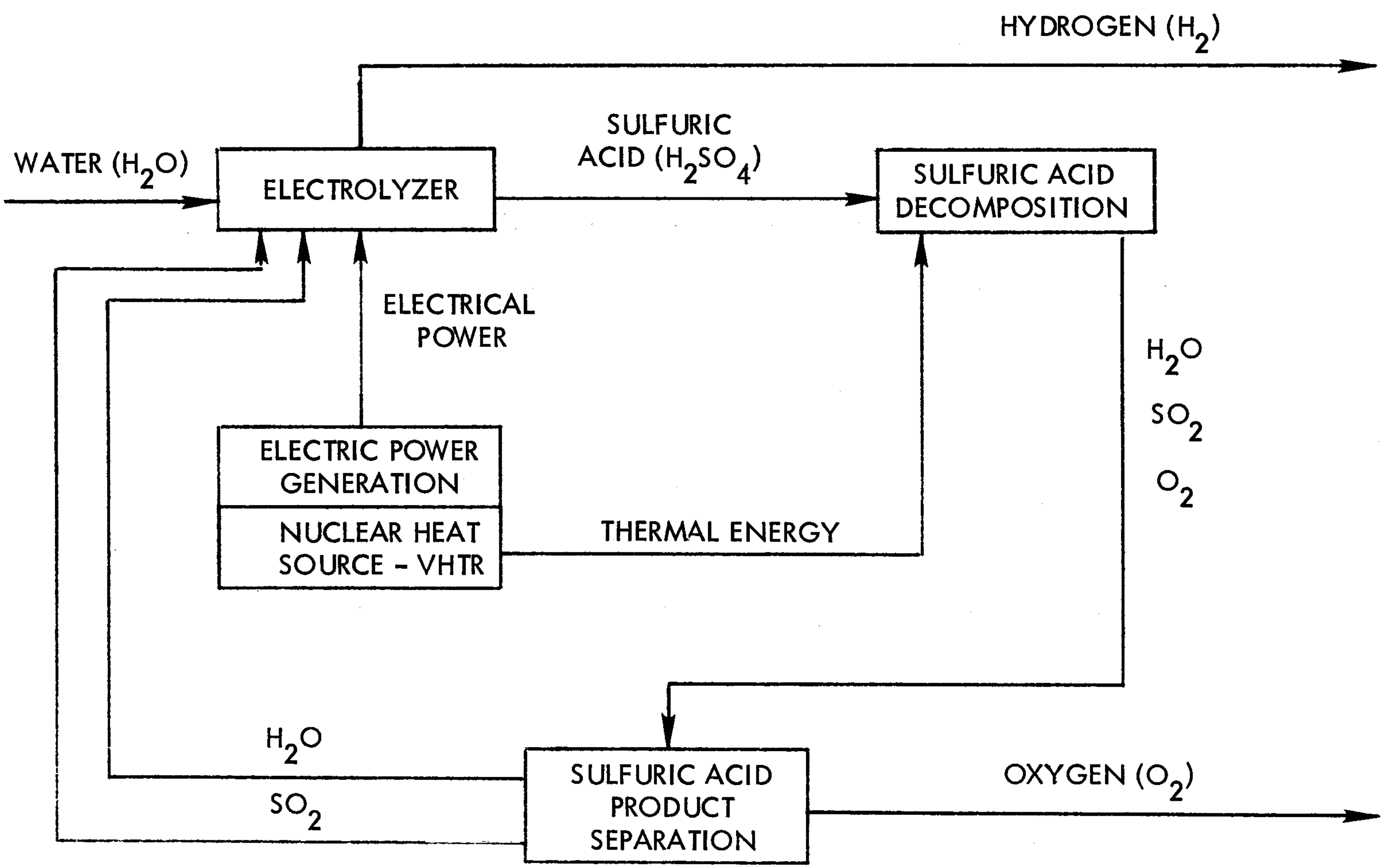
The nuclear coal conversion (NUCO) concept offers a method to accomplish this increase in product per unit of coal input. Relatively inexpensive nuclear fuel thus can be used in the production of synthetic fuels and thus its benefits can be expanded to many more users, not just the electric power segment.

The objective is not to displace coal. It is to use both coal and uranium in the best possible combination, with the least ecological disturbance and in the most economic fashion.


COAL
COAL CONVERSION PLANT (CCP)
SYNTHETIC HYDROCARBONS
ELECTRIC GENERATION
ELECTRICITY
NUCLEAR FUEL
NUCLEAR HEAT SOURCE (NHS)
HEAT
WATER DECOMPOSITION (WD)
HYDROGEN
OXYGEN
WATER

The key to the NUCO concept, as well as other process heat applications, is an efficient and economical system to produce hydrogen. A combination electrolysis — thermochemical system, based on a sulfur cycle, has been devised with the potential of greater than 60 percent overall efficiency.

This system is being developed with Westinghouse funds. A contract was initiated by NASA-LeRC, NAS 3-18934, to evaluate this, as well as competing conventional hydrogen generation systems. This effort produced a conceptual design and cost estimate comparable to that provided for the nuclear heat source under the AEC contract. The results indicate the concept to be very competitive with all known alternative systems.


HYDROGEN (H_2)
WATER (H_2O)
ELECTROLYZER
SULFURIC ACID (H_2SO_4)
SULFURIC ACID DECOMPOSITION
ELECTRICAL POWER
H_2O
SO_2
O_2
ELECTRIC POWER GENERATION
NUCLEAR HEAT SOURCE - VHTR
THERMAL ENERGY
H_2O
SO_2
SULFURIC ACID PRODUCT SEPARATION
OXYGEN (O_2)

The NUCO modification was analyzed in the Hydrocarbon Research Institute (HRI) refinery concept. The coal input was kept constant and the motor fuel and furnace oil output were retained.

The modification changed the system from a consumer of 47.7 million standard cubic feet per day of natural gas to a system producing over 97 million cubic feet of methane (equivalent to natural gas).

MATERIALS COMPARISON MODIFIED AND UNMODIFIED HRI REFINERY

	UNMODIFIED HRI REFINERY	NUCO MODIFIED HRI REFINERY
INPUT:		
DRY COAL	8616 TSD	8616 TSD
NATURAL GAS	47.7×10^6 SCF/D	-
ELECTRICITY	1695 MWHR/D	-
STEAM	3431×10^6 LB/D	-
NUCLEAR HEAT	-	3263 MW (t)
OUTPUT:		
MOTOR FUEL	19,830 BSD	19,830 BSD
FURNACE OIL	10,000 BSD	10,000 BSD
COAL RESIDUE	1474 TSD	-
BUNKER C OIL	-	668 BSD
METHANE	-	97.272×10^6 SCF/D
LPG	_	337.956 TSD
OXYGEN	_	6095 TSD

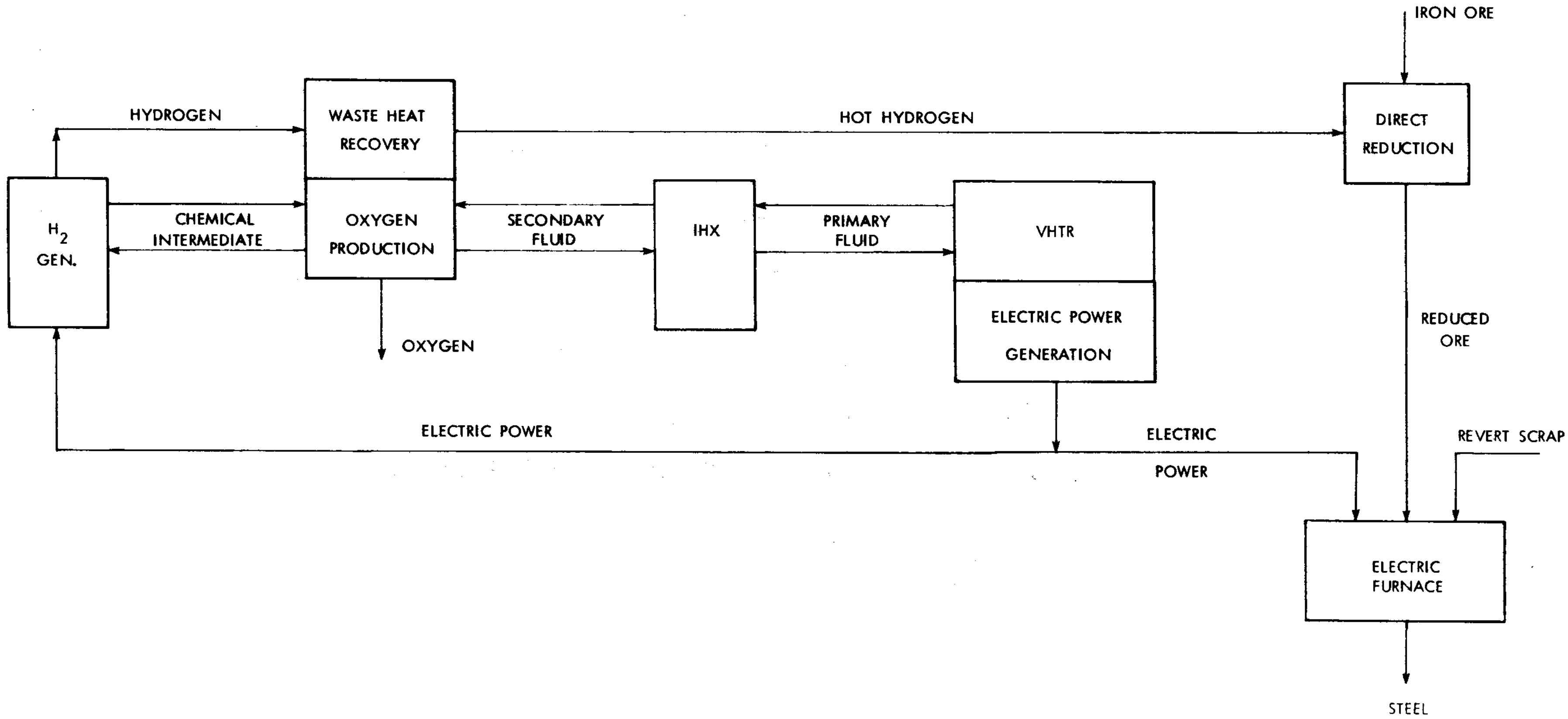
A system to produce low cost hydrogen will find many applications. The production of ammonia, which is an important ingredient of inorganic fertilizer, is an exciting possibility. The simultaneous production of oxygen opens many avenues for processess which use both elements. Nuclear iron ore reduction, under consideration by the American Iron and Steel Institute in this country and by the Germans and Japanese, is also possible.

PRODUCT	CHEMICAL FORMULA
SYNTHETIC GAS	$C + 2H_2 \longrightarrow CH_4$
SYNTHETIC OIL	$C + H_2 \longrightarrow CH_2$
METHANOL	$CO + 2H_2 \longrightarrow CH_3OH$
AMMONIA	$N_2 + 3H_2 \longrightarrow 2NH_3$
IRON ORE REDUCTION	$Fe_2O_3 + 3H_2 \longrightarrow 2\,Fe + 3H_2O$

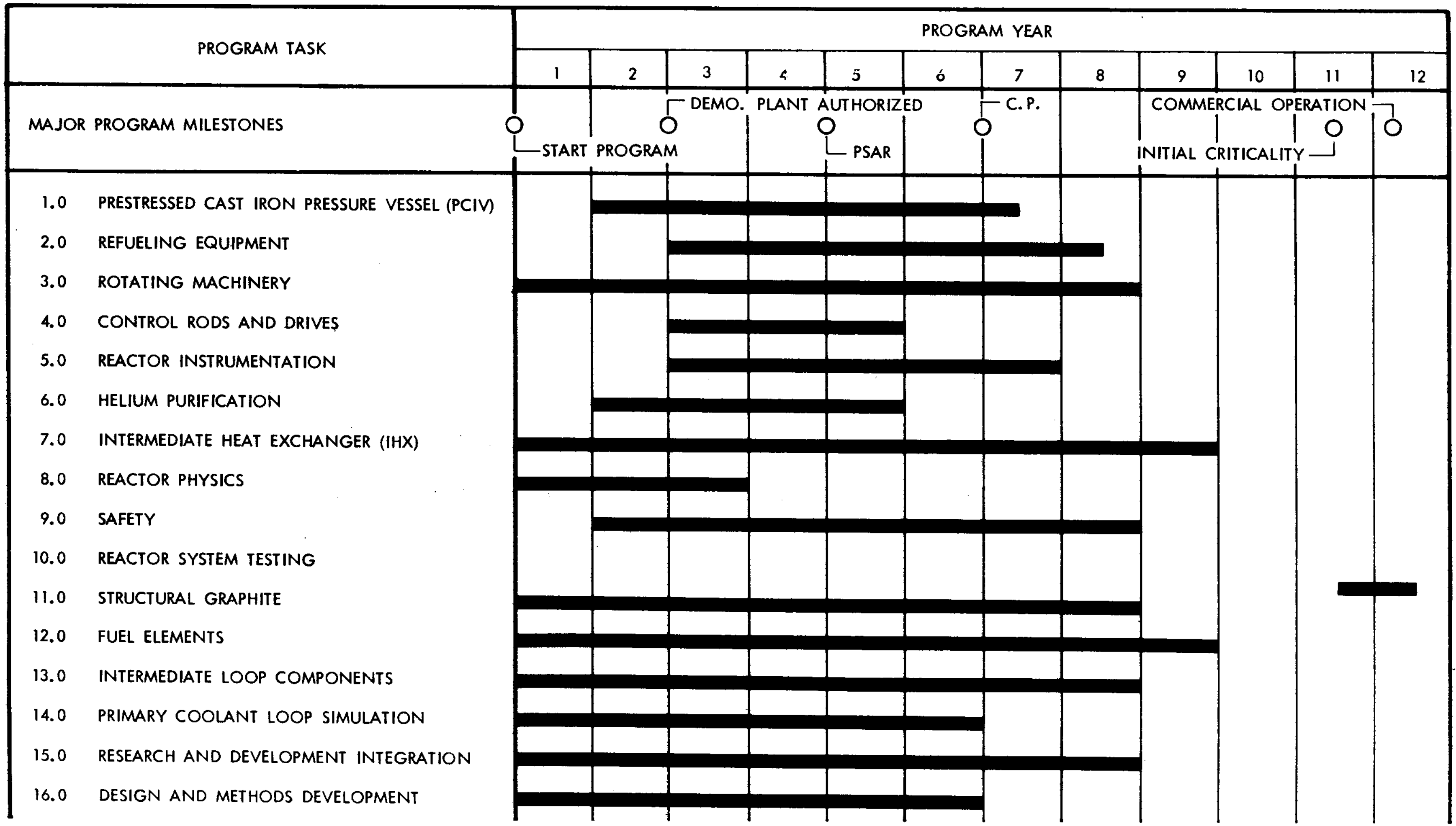
The VHTR, with the Westinghouse water splitting system, appears to be suited to providing hydrogen to a direct iron ore reduction system such as the H-iron process.

VHTR - HYDROGEN FOR DIRECT REDUCTION USING

WESTINGHOUSE HYDROGEN GENERATION PROCESS



The R&D program, specific to the land-based class of VHTR and based on the assumption that this is the only VHTR program, was defined under the AEC contract. This program is also planned on the basis of a two year effort prior to a final decision on the demonstration plant program. There are several areas where R&D tasks are on the critical path and deserve early initiation.


PROGRAM TASK
PROGRAM YEAR
1 2 3 4 5 6 7 8 9 10 11 12
MAJOR PROGRAM MILESTONES
START PROGRAM
DEMO. PLANT AUTHORIZED
PSAR
C.P.
INITIAL CRITICALITY
COMMERCIAL OPERATION
1.0 PRESTRESSED CAST IRON PRESSURE VESSEL (PCIV)
2.0 REFUELING EQUIPMENT
3.0 ROTATING MACHINERY
4.0 CONTROL RODS AND DRIVES
5.0 REACTOR INSTRUMENTATION
6.0 HELIUM PURIFICATION
7.0 INTERMEDIATE HEAT EXCHANGER (IHX)
8.0 REACTOR PHYSICS
9.0 SAFETY
10.0 REACTOR SYSTEM TESTING
11.0 STRUCTURAL GRAPHITE
12.0 FUEL ELEMENTS
13.0 INTERMEDIATE LOOP COMPONENTS
14.0 PRIMARY COOLANT LOOP SIMULATION
15.0 RESEARCH AND DEVELOPMENT INTEGRATION
16.0 DESIGN AND METHODS DEVELOPMENT

In summary, the VHTR, based on the NERVA technology, is an opportunity to realize many national benefits. The number of applications and their relevance in today's environment lend urgency to the program.

VHTR APPLICATIONS

MOBILE (LWNP)

- NAVY
  - SES
  - Hydrofoil
  - Surface Ships
  - Submarine
- COAST GUARD
- AIR FORCE
- COMMERCIAL
  - Ships
  - Oil Recovery
  - Mobile Power

LAND BASED

- PROCESS HEAT
  - Coal Conversion
  - Iron Ore Reduction
  - Ammonia Production
- ELECTRIC UTILITY
  - Direct Cycle
  - MHD