COAL UTILIZATION

UNSOLVED PROBLEMS

- FEEDING WET COAL WITH FINES
  - RELIABILITY
  - COST
- SORBENT UTILIZATION & REGENERATION
  - REDUCE MATERIAL QUANTITIES
  - COST
- COAL–OIL MIXTURE STABILIZATION
  - RELIABILITY
  - COST
- CORROSION RESISTANT HIGH TEMPERATURE MATERIALS
  - Na_2SO_4 ATTACK AT 1650° F
  - COST EFFECTIVENESS
- LOW NO_x, HIGH η COMBUSTION OF AROMATIC FUEL
- CLEANUP OF HOT, HIGH PRESSURE GAS
  - 1600 F, 6–10 ATM.
  - PARTICULATES, Na_2SO_4
- TWO–PHASE, SOLIDS–GAS, FLUID MECHANICS IN COMPLEX EQUIPMENT

For sorbent utilization, limestone and dolomite are used to absorb the SO_2, forming a dry granular solid that sets up with the ash and the coal as low-grade cement. A contractor to the EPA, who was conducting sorbent leaching column work, experienced a problem with the columns setting up solid thereby blocking all water throughput. So, we believe that we have a once-through disposal technique that is both economical and environmentally acceptable. However, when you look at the enormous quantities of limestone and sulfated limestone that come out of a fluidized-bed combustor operation, it appears that the amount of limestone from quarries that will be required compared to the amount of disposal area required is undesirable.

So, we are concerned as to whether or not we can practically regenerate the limestone or sulfated limestone into lime again for reuse in the process.

We have to be very much concerned as to the fuel that we use for regeneration. People have made prototype regenerators that are natural gas fired, but that is premium fuel and we would prefer having to use direct coal combustion products. There is concern also during the limestone regeneration process that the SO_2 or H_2S given off (depending whether it is an oxidizing or reducing atmosphere) may have to be passed on to another plant. This regeneration plant has to be economical and dispose of the sulfur in an environmentally acceptable manner as we have seen in that first diagram where the solid waste product had to be acceptable.

The capital cost of equipment is of concern again (as in any utility operation) where coal-oil mixtures are concerned. Coal-oil mixtures are feasible, however the only question is: What is the cost of the preparation of the mixture, and the reliability of operation with a mixture because, whenever you have coal, you have ash. That is the way it comes from the ground. That's the reason for its low price. It hasn't been de-ashed yet and the fate of this ash in the boiler is of concern. Will it compromise boiler reliability? Require a boiler down-rating? And what are the prospects of the stabilization of the mixture?

You can take coal and oil, make a mixture, put various surfactants in to stabilize it so that it will not settle out and remain in a pumpable form, but the cost of surfactants adds to the cost of the product when we are concerned with making stable mixtures.

(Slide 5)

This slide is presented to review the roles of technology development and implementation.

There are different roles. Government has to have RD&D in industry, where the big equipment is built, so that resultant projects will proceed to low-cost reliable products which can be rapidly implemented. When we look at the energy picture and the urgency to switch over to coal, we really cannot afford an extra 10 years for industry to learn from the national laboratories and research communities.

COAL UTILIZATION

TECHNOLOGY UTILIZATION

- BY INDUSTRY
  - FABRICATION, OPERATION, SERVICE
- R, D&D IN INDUSTRY
  - TODAY'S ELEC POWER GENERATION
  - HIGHLY RELIABLE, LOW COST, SERVICE
- SUPPORT OF SCIENTIFIC COMMUNITY
  - BASIC RESEARCH
    MATERIALS & PROPERTIES
    EXPLORATORY PROCESS RESEARCH
  - APPLIED RESEARCH
    SCIENTIFIC BASIS OF PROCESSES
    SYSTEM OPTIMIZATION
  - CROSS FERTILIZATION OF DISCIPLINE
  - INSTRUMENTATION
    USEFUL OUTPUT OF BASIC RESEARCH

There is a support role in the scientific communities falling between basic and applied research which includes the dissemination of information and cross-fertilization of technologies. A case in point is that of the boiler manufacturer learning about fluidized-bed combustion from the cat cracker and incinerator industries.

(Slide 6)

I assume that someone else on the Program Agenda will discuss the Energy Research Centers that were previously part of the Bureau of Mines and of the Department of the Interior. They have expertise in coal handling and processing.

As I see them, the National Labs are places for big, high-powered science - like development of synchrontrons, cyclotrons and whatever else is being made these days under what I used to refer to as "atom smashers."

Instrumentation, selected scientific problems such as sorbent regeneration, chemistry of sorbent materials, in what phases they (sorbents) exist, when, and to which phases they may go, and the nature of their pore structure--these research problem areas, for example, are appropriate for the Laboratories.

The universities have their traditional basic knowledge, new ideas, and the training of the next generation of engineers and scientists. This is an important role because we have to have new

COAL UTILIZATION

RESEARCH RESOURCES

- ERC'S
  - COAL TECHNOLOGY
  - INDUSTRIAL IMPLEMENTATION
  - FEASIBILITY DEMONSTRATIONS
- NATIONAL LABS
  - USES OF BIG, HIGH POWERED, SCIENCE
  - SELECTED PROBLEMS OF DIRECT COAL INVOLVEMENT
  - INSTRUMENTATION
- UNIVERSITIES
  - BASIC KNOWLEDGE
  - NOVEL SYSTEMS & IDEAS
  - PERSONNEL DEVELOPMENT
  - DISSEMINATION OF INFORMATION
- INDUSTRY
  - DEVELOPMENT OF COMMERCIAL EQUIPMENT END PRODUCT OF R, D&D
  - COMPONENT DEVELOPMENT
  - SYSTEM DEMONSTRATION

people coming into development areas who can identify the real problems and can utilize real elements in providing solutions to these problems.

Industry plays an important role serving an implementor. Next.

(Slide 7)

Okay. Whenever I have a meeting of this nature and identify a list of research needs, I am usually inundated in about 6 weeks with research proposals. Please be reminded at this point that Dr. Mills's group is for exploratory research--where most of the novel new ideas usually are worked out first. When or after scientific feasibility has been proven, the pilot plant group gets the projects for determination of engineering practicality at this level. Following that level is the Demonstration Plant level for demonstration of a project in an actual commercial type environment.

So we are concerned about competition for the research budget, and those are some thoughts that I had about research expanding to fill the available budget.

I did a doctor's thesis once, and it was explained to me that every thesis has to uncover more problems than it solves.

I think I had one more slide for wrap-up.

(Slide 8)

Yes. In "Researcher Horizons," in the near-term, you can't do much in five years. All you can do is improve what you have

COAL UTILIZATION

PARKINSON'S LAW
4th CORROLARY

RESEARCH EXPANDS TO FILL
ACCESSIBLE BUDGET

PH.D. THESIS RULE

DISCOVER ν NEW PROBLEMS FOR
EVERY ONE SOLVED

ν = 2.47, EXPERIMENTALLY

COAL UTILIZATION

RESEARCH HORIZONS

- NEAR–TERM
  - IMPROVE PROCESSES
  - EVOLUTIONARY IMPROVEMENTS
- MID–TERM
  - NEW PROCESSES
  - APPLICATION OF RESEARCH
- LONG–TERM
  - BETTER WAYS TO UTILIZE COAL
  - REVOLUTIONARY IMPROVEMENTS

and make evolutionary improvements on existing technology. In the mid-term we can get some new processes going and apply what's already in the basic research inventory now. And then, the way I see it, in the long-term, which is after the year 2000 anyway, we have opportunities for revolutionary improvements and ideas that we haven't worked on yet.

Thank you.

DR. KANE: Are there questions? Yes, sir.

Dr. Baron.

DR. BARON: As a potential large-scale user of coal, what frightens us most is the problem of transportation; assured and reliable transportation. Where in the Government are studies being made in the technical and legal aspects of assured continuous supplies?

DR. FREEDMAN: Has anyone given the overall fossil-energy organization?

DR. KANE: No, Dr. White has not yet given it.

DR. FREEDMAN: Okay. In the Office of Fossil Energy there is an Office of Program Planning Analysis, which has an Office of Long-Range Plans -- if that's the correct name -- or Strategic Plans. I forget -- one name or the other, headed by Martin Adams. That is the group that does the overall total systems analysis.

I look at a utility plant as a system, not as a collection of components. He looks at the entire coal process, which includes mining, limitations on new equipment for mines, the five-year lead time for drag lines, how long it takes to open a deep mine, the transportation limitations and potential bottlenecks, as well as the economic advantages of newer competing modes.

You have rails, slurry pipelines, barges -- how do they compete with each other?

Then the utilization aspects, be it conversion to liquid or gas, or utilization directly, as coal; and then the interaction with the waste disposal.

So it's Martin Adams, in either strategic plans or long-range planning in the Office of Program Planning and Analysis, in Fossil Energy. I trust that answers the question.

DR. KANE: Could you come to the microphone and give your name, please.

MR. CROSS: I'm Jim Cross. I'm from ERDA also.

Would you care to say anything about possible utilization of coal in heating of private homes?

DR. FREEDMAN: Right now something like 1 percent; and whether it's .8 or 1.1, I don't know. But it's less than 1-1/2 percent. I've seen the numbers -- of coal used in domestic applications. CEQ had a study done on coal for residential/ commercial applications.

Their conclusion was that the difficulties associated with coal -- handling it, getting rid of ash -- as well as the environmental problems -- because when you burn, if you burn in a small residential combuster, you would not have a reasonably high stack for dispersion, and the sulfur emissions were serious problems and that for ordinary economic reasons they did not see the residential coal market expanding.

Now there are some people who in the last winter wanted coal because they couldn't get natural gas and they considered coal as readily available. That's more a people problem than a national energy problem; and we would be assisting those people in finding out what domestic coal furnaces are now available. The home stoker has gone up from about 25 units a year to about 300 units a year being sold.

But when you turn that in terms of quads, it's negligible. The British Solid Fuel Advisory Service have a collection of brochures showing the extremely attractive architect-designed home fireplaces that include both hot-water heating for baseboard heating and some of them also include stoves and combined heaters, to use coal.

We would make this information available to people in an information dissemination mode, but I do not see us doing anything in R&D.

DR. NEUWORTH: You should tell them about that smokeless fuel they're talking about, which doesn't have a counterpart in the U.S.

DR. FREEDMAN: We don't have the smokeless fuel here yet, and I think it might be ironic if we wound up importing coal.

(Laughter).

But using coal in a residential application is more difficult than using wood. People who used it 30 and 50 years ago put up with a lot of inconveniences and a lot of emissions that I do not think we'd put up with today.

MR. CROSS: Does that mean you don't have any programs for domestic fuel?

DR. FREEDMAN: We have no program on domestic use. We're trying to put together an information-dissemination program, so that we'll just provide information for those people who are interested.

DR. KANE: The chairman has a question.

DR. FREEDMAN: Go ahead.

DR. KANE: Dr. Neuworth pointed out that solvent-refined coal was shipped and pulverized and fed into at least large industrial boilers. Is there any luck at all in doing this in domestic-size?

DR. NEUWORTH: I don't think so.

DR. KANE: None. "None" was the answer.

DR. NEUWORTH: We'll be very happy if we can get some of the industry to use it, I think. That would be quite an accomplishment.

DR. KANE: Any further questions?

MR. BORIS: Boris, IGT.

Just to comment in this regard, getting coal into the home is a problem. You can accomplish it by shipping the coal directly, as a solid. You can also gasify the coal and burn it as a gas in the form that you're already equipped to use. I think that, in the long term, may be a more acceptable solution.

DR. FREEDMAN: I would stress: Direct combustion is used as a solid not gas from coal or a liquid from coal.

DR. KANE: Yes.

DR. REYNOLDS: Lou Reynolds, Stanford.

The programs you're working on now seem to me to be the long-term programs of an earlier era. And you are benefiting them from the basic research that was done some time ago.

With this in mind, can you tell us a little bit about how your people are guiding the basic research that's going on today? -- to be sure that it will be useful.

DR. FREEDMAN: That's a difficult question. Let's see.

The basic research really winds up being communicated to the pilot-plant and possibly the demonstration-plant people if it might affect components -- by the program managers who handle the contracts for the basic research -- and I'll call it the exploratory research -- where it may be of value to a particular program I'll have somebody from Dr. Mills's group or occasionally from Dr. Kane's group come and say, "Hey, Steve, this may be of interest to you."

It's this information broker, in the terms of the research manager within the Government, who plays a key role in making sure that the users of his product are aware of it.

And the formal reports as they get bound into overall documents are distributed. But it's usually a personal one-to-one basis of saying "Here's something that may be of interest to you -- I think it fits in -- that has a key role." I think it's always been that way.

DR. MILLS: I think you missed Dr. Reynold's question. A reservoir of basic research accomplishments, based on an earlier generation's efforts, has not been utilized.

Is there a mechanism within ERDA to guarantee a certain budget level, or whatever, to ensure the input to reflect what is being used?

DR. FREEDMAN: Well, between Dr. Mills, of Fossil Energy Research, and Dr. Kane, in Division of Physical Research, their budgets -- I really can't speak from the administrator's level as to how sacred their budgets are. But there is every indication that it's intended to continue, and the rate of growth is the only thing that's really something of concern.

We have these organizational areas, to support the research and nurture it through its infancy, so that it will be available in 10 or 15 years when we need it.

Bill, am I on the topic?

DR. REYNOLDS: What I'm curious about: for example, I think you said, "There's been 25 years of research in fluidized bubbles, and it's been on single bubbles; and it hasn't been very relevant to us." All right?

Now I'm asking you, what are you doing to tell the research community now, that you think will be relevant to you in 15 or 20 years?

What you've told us, I think, is you're listening to what's going on in research now. And if it's useful to you now, you're listening.

I'm asking you to look ahead a bit more. Looking down the road, what are you doing to tell the research people to do now that will give you some interesting results?

DR. FREEDMAN: Well, there are two kinds of areas. There's one area; it's called "new ideas," and I can't tell the research people what new ideas to come up with. Before Winkler came up with the fluidization or before the cat-cracker people decided to apply Winkler's fluidization, there was nobody around to tell them what the next thing, that we don't know about today, will be discovered in the future.

With the exception of Arthur Clarke and Herman Kahn and the futurologists who may get involved in that -- all that I can do, really, is describe the technology as I see it 15 years from now.

Then the researcher has to do his thing, because if I could really tell him what to do, I would be in that field, not in the pilot plant field.

(Laughter).

DR. KANE: There was a gentleman here that had a question. Where was it? Yes sir.

DR. HOLLOWAY: Holloway, from Exxon.

More specifically to this basic research question. What are you doing to fund basic research in universities. How does your level compare with that of other mission-oriented agencies and with the National Science Foundation?

DR. FREEDMAN: Do you want to answer that one?--because you have all the charts with the pies.

That will be gone over. And there's a whole bunch of budget breakdowns and pie charts as to how much goes where.

DR. KANE: I believe both Dr. Hill and Dr. Holloway's questions are excellent, and Alex will face them this afternoon, and I will face them tomorrow in my part of it.

VOICE: Roland.

DR. SMITH: Roland Smith, General Electric.

Let me pursue Bill Reynolds's question a little bit further, Steve, and not look to the future but today.

We have a bunch of unsolved problems here. All of the problems are divided in terms of the application you need.

Now who in ERDA, you or Kane, is responsible for saying what is the scientific research that should be undertaken to solve these problems? These things are not defined in terms of the science that underlie the problems, in the areas of research that should be supported.

Is there anyone in ERDA who has that responsibility?

DR. KANE: As far as the basic research, I have it; and as far as the more applied, Alex Mills has that. And we'll talk in our turn about how we do it and how we talk to each other about that problem. That's subsequent talks.

A good point, again. I think you're all asking different aspects of kind of the same question. We deserve to be asked those questions. So don't forget them when our time comes.

Yes?

Paul Scott.

MR. SCOTT: I just had one additional comment to help to answer Steve's question on the guidance that we get from the pilot-plant people in terms of doing research.

I think one of the most valuable things we get, both from the energy centers and from the people at headquarters, is review of the proposals that we receive from universities. And we look at how our pilot-plant people and how our field people view these proposals; and this helps us keep our course straight.

So this is another kind of guidance on an ad hoc particular-event basis.

VOICE: Jim.

DR. KANE: Go on.

Again I say this as I preface each of these talks. Dr. White has not yet arrived, so we'll go on to the final one of the three technology presentations for this morning.

Mike Raring is going to talk about the magnetohydrodynamics program.

MR. RARING: I hope you will understand I'm substituting for Bill Jackson who will return tomorrow from Moscow where he has spent the past week. He delivered a five Tesla superconducting magnet to the U-25 facility which will be used in the joint US-Soviet MHD cooperative program.

I will attempt to explain what we're doing in MHD: what the purpose is; the nature of the work that's required; how we're trying to accomplish that work logically, in accordance with priorities necessary to meet the goals we've set; and finally who's doing the work.

And I will try to include a little about what's being done, and why. Finally, I'll try to say something about where we stand.

If there is time, we have a film on the U-25 pilot plant in Moscow which I know Dr. Jackson and Mr. Licarrdi, the Deputy Director, would like you to see: it makes an excellent introduction to MHD. However, if we put that on now, there will be little or no time to outline the program. So, if anyone would like to see the film and we don't have time now, I would suggest that we may be able to show it during the lunch hour: it is interesting.

After that introduction, let me say that MHD is somewhat different from most of the programs in Fossil Energy. It has a specific power conversion mission. It's an advanced Electromagnetic turbine development project. And it has a clear purpose. As in all power systems work, development requires strict engineering and economic disciplines. We've got to identify engineering problems in the correct environment, that is, with realistic electromagnetic, fluid dynamic, electrochemical and thermal stresses. Then we've got to work to solve those problems through development of designs which get to the root of the difficulties. And we've got to avoid being sidetracked into non-productive research, no matter how well qualified the available resources or how alluring the path. Engineering goals cannot be met when efforts are fragmented in peripheral research.

The design concept we're following is different from the systems which have been considered for military applications. Our work is directed predominantly to the coal-fired, open cycle system

MHD Program Goal

Develop a Coal-Fired, Electric Power Commercial Demonstration Plant which will

- Achieve Thermal Efficiencies of at Least 50 Percent (Compared with 38 Percent for Present Day Steam Plants)
- Operate Competitively Under Central Power Station Conditions
- Meet Environmental Air Quality Standards

in which coal is burned in a combustor to produce a high temperature, potassium seeded plasma. The high conductivity fluid is passed through the channel where it interacts with a high strength magnetic field to generate electricity. The plasma is analogous to the rotor of a conventional electric generator.

The first slide (Fig. 1) summarizes the objectives of the MHD program. The essential objective is to achieve an overall efficiency of 50% or more in a combined cycle MHD-Steam commercial power plant. You are probably aware of the ECAS studies which were conducted by NASA under ERDA and National Science Foundation Sponsorship. The studies were made by both NASA and industrial analysts. Industrial developers and manufacturers of heavy electrical generating equipment were represented. These studies compared advanced power conversion systems, based upon coal firing, and found that open cycle MHD looked about the best from both efficiency and cost of electricity standpoints. Of course, coal-fired MHD plants will have to supply AC power to existing grids at competitive costs. They will need to meet applicable environmental standards. In this respect, MHD possesses an intrinsic advantage: sulfur is captured by the potassium which is used to "seed" the plasma. The potassium sulphate, which is formed, can be drained off at a downstream station in the gas path and the potassium can be converted back to carbonate for reuse. This advantage means that MHD could burn high sulphur coal with minimal capital cost penalty in stack gas scrubbing equipment.

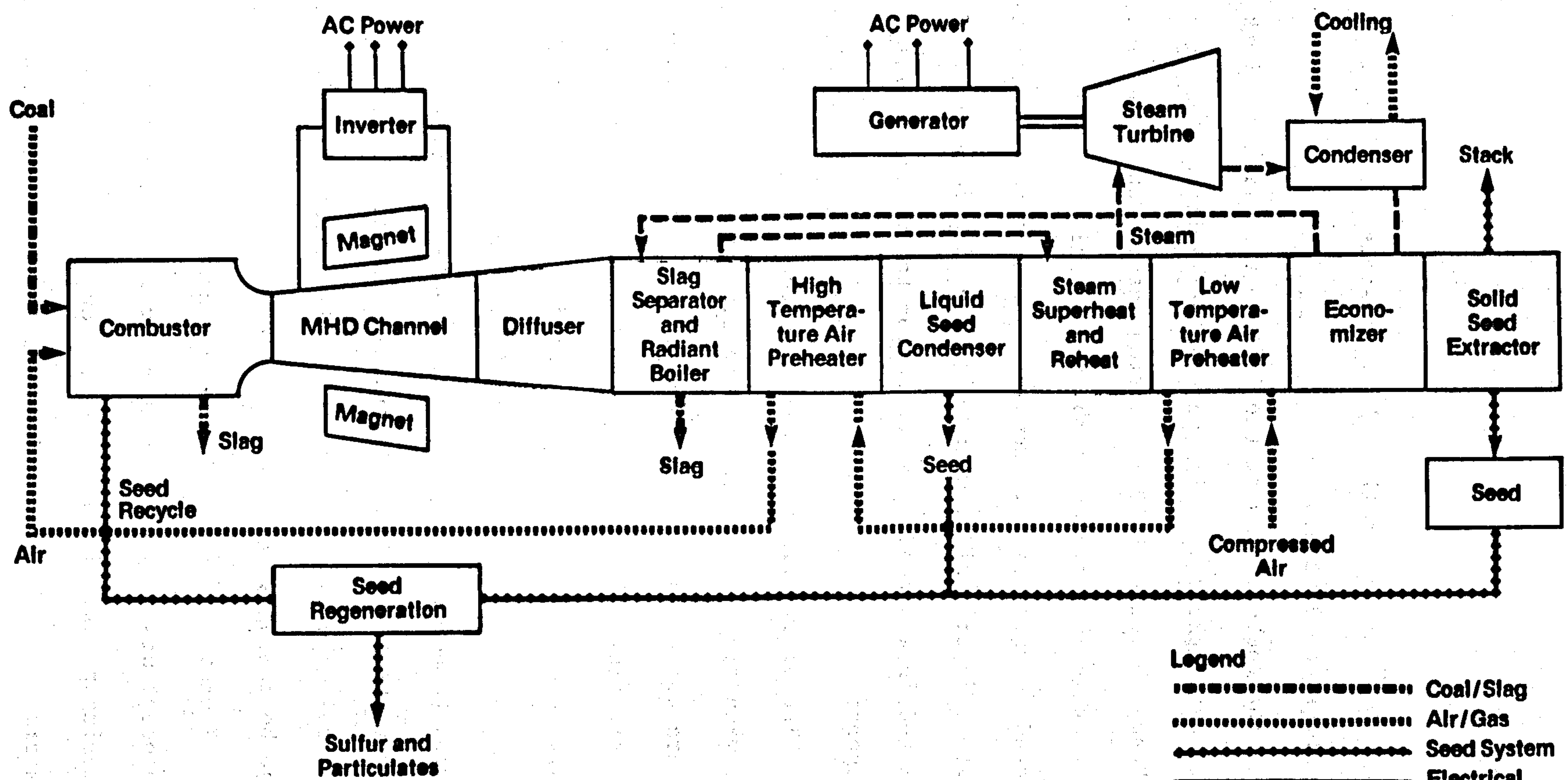
The next figure (Fig. 2) represents a schematic of a typical MHD-steam system.

The combustor is at the left in this figure. Work on combustor development is being pursued primarily at the Pittsburgh Energy Research Center (PERC). Current design envisages two stages. The first stage is a cyclone combustor in which 80 or 85% of the ash is rejected as molten slag. Combustion conditions are maintained on the substoichimetric side, which minimizes NO_x formation. Combustion is completed in a second stage combustor to produce a plasma at around 4800°F.

The plasma flows down through the channel where it interacts with the magnetic field to produce an electric field. Electric charges are collected by electrodes placed on the walls parallel to the magnetic field direction. This D.C. current is inverted to A.C. and conditioned to suit the utility grid. The hot gases then flow through the diffuser into a radiant boiler where thermal energy is transferred to boiler feed water. The cooler gases, still around 3000°F, move next into the regenerative air heater where seed and slag are drained off. Finally, the cooled gases, at around 2000°F, enter the bottoming steam plant.

I want to stress the unique character of the generator. This component has no precursor in power conversion machinery. There are no moving parts. The stresses are entirely different than the high temperature mechanical and corrosion conditions encountered in

MHD Schematic — Coal-Fired/Directly-Fired Air Preheater

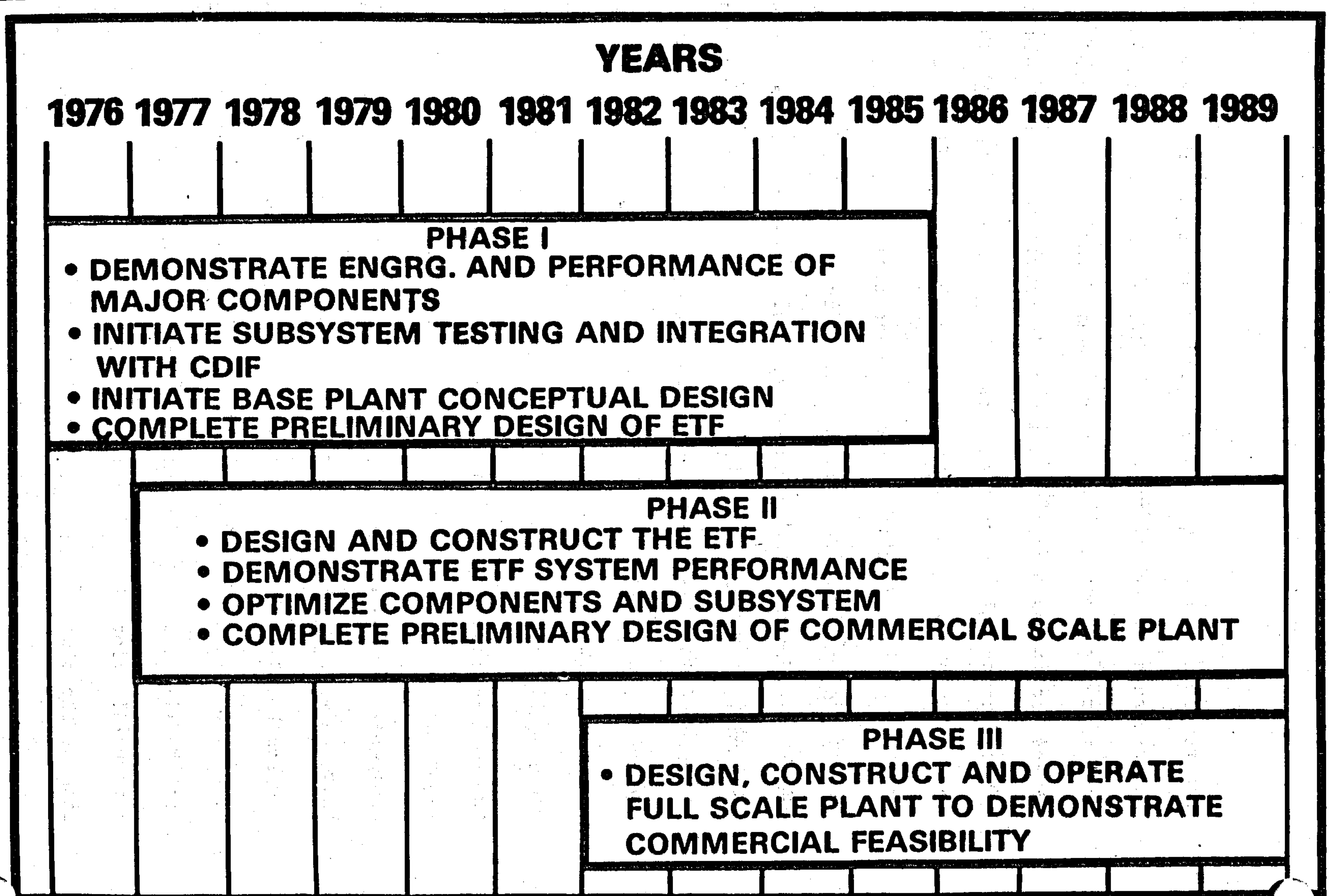


92

gas turbines or steam generators. The problems are electrochemical, electromagnetic, and thermal. Heat fluxes are high. Development work must take into account these combined environmental conditions. Stress conditions must be realistically simulated in the evaluation of design variables - whether material, geometric, thermal, or electrical.

In power equipment development like this, as the history of piston engine, steam turbine, and gas turbine development shows, work progresses through clearly marked stages. After rudimentary proof - of - principle is achieved, there is an engineering development phase to show that the concept works; then comes a commercial feasibility demonstration phase. The final phase is directed to full-fledged commercial demonstration. Our program is presently well into the first, or engineering feasibility demonstration phase as shown in this slide (Fig. 3). We are developing components for engineering feasibility testing at the 50 megawatt thermal level. A test facility, designated as the Component Development and Integration Facility, or CDIF, is being constructed in Butte, Montana. After we pass this program hurdle, we will advance to a commercial feasibility demonstration pilot plant. We have designated this project as the Engineering Test Facility, or ETF for short. This will, in effect, serve as a commercial pilot plant - about 250 megawatts thermal. Design selection of the power train will, of course, be derived from the CDIF experience.

ERDA MHD POWER DEVELOPMENT PROGRAM
MAJOR PROGRAM PHASES



The MHD program is organized in accordance with these realities. Work is classified in accordance with a Work Breakdown Structure designation to identify where it fits in the total effort. These identifications span all activities from basic design support research, analytical studies, engineering evaluations to resolve basis component design issues, then on to major engineering tests to validate the development work and finally into commercial demonstration. This slide (Fig. 4) identifies the basic development requirements and activities by Work Breakdown Structure designation. The next slide (Fig. 5) indicates the shift in program emphasis, by work breakdown structure, as work moves through the successive phases.

To illustrate the kind of Phase I support research and engineering work we are doing - it has been necessary to establish electrical, thermal, physical, and chemical properties of coal slags, electrode materials, insulators, and other materials of design interest, under conditions as closely representative of the MHD environment as possible. Seed recovery experimental work has been initiated - determination of the thermal and fluidynamic conditions under which seed and slag condensation occurs.

Stanford University has been investigating basic MHD phenomena to provide a basis for better analytical understanding of generator performance. MIT is studying combustion kinetics,

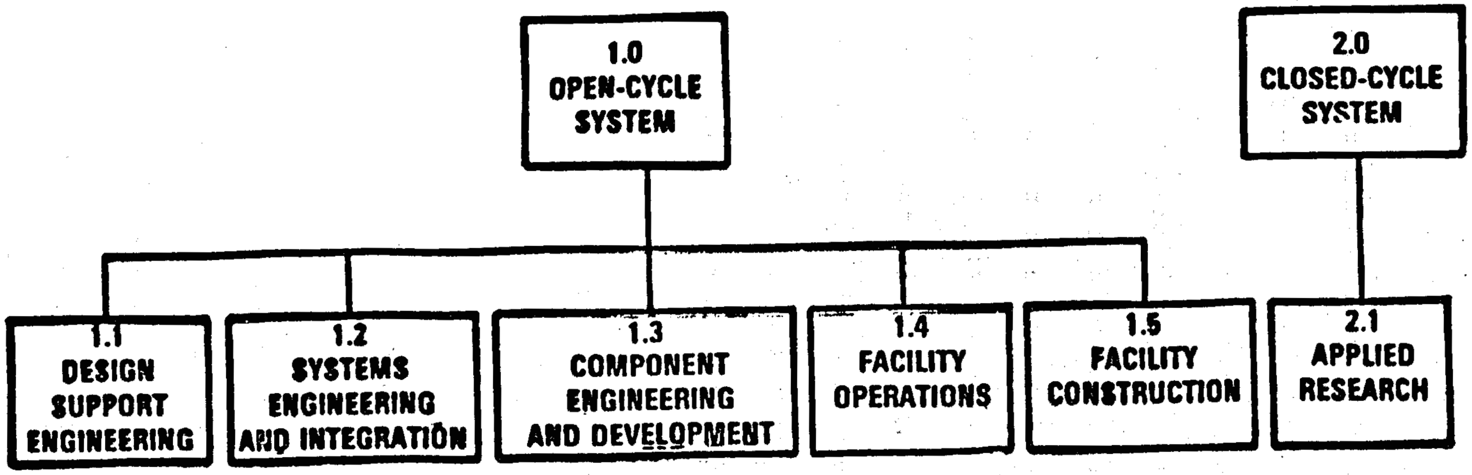

1.0 OPEN-CYCLE SYSTEM
2.0 CLOSED-CYCLE SYSTEM
1.1 DESIGN SUPPORT ENGINEERING
1.2 SYSTEMS ENGINEERING AND INTEGRATION
1.3 COMPONENT ENGINEERING AND DEVELOPMENT
1.4 FACILITY OPERATIONS
1.5 FACILITY CONSTRUCTION
2.1 APPLIED RESEARCH

FIGURE (Y)

OPEN CYCLE MHD PROGRAM
WORK BREAKDOWN STRUCTURE

FUNCTION	← RESEARCH AND DEVELOPMENT →				
		← ENGINEERING DEVELOPMENT AND TEXT →			
			← PLANT DEMONSTRATION →		
WBS ACTIVITY	1.1 DESIGN SUPPORT ENGINEERING 1.1.1 DESIGN PROPERTIES 1.1.2 COMPONENTS 1.1.3 ANALYTICAL 1.1.4 1 and C	1.2 SYSTEMS ENGINEERING AND INTEGRATION 1.2.1 SYSTEMS ANALYSES 1.2.2 SYSTEMS ENGINEERING 1.2.3 ENV. & SAFETY 1.2.4 SUP. STUDY AND ENGR.	1.3 COMPONENT ENGINEERING AND DEVELOPMENT 1.3.1 POWER TRAIN 1.3.2 MAGNET 1.3.3 AIR SUBSYSTEM 1.3.4 RAD. BOILER 1.3.5 STEAM SUB.	1.4 FACILITY OPERATIONS 1.4.1 – 1.4.2 CDIF[1] 1.4.3 ETF[2] 1.4.4 CDP[3]	1.5 FACILITY CONSTRUCTION 1.5.1 CDIF[1] ETF[2] CDP[3]

(1) COMPONENT DEVELOPMENT AND INTEGRATION FACILITY – DEMONSTRATE ENGINEERING FEASIBILITY (50MW_t)

(2) ENGINEERING TEST FACILITY – DEMONSTRATE COMMERCIAL FEASIBILITY ($\approx$ 250 MW_t)

(3) COMMERCIAL DEMONSTRATION PLANT – DEMONSTRATE COMMERCIAL OPERATIONS ($\wedge$ 1000 MW_t)

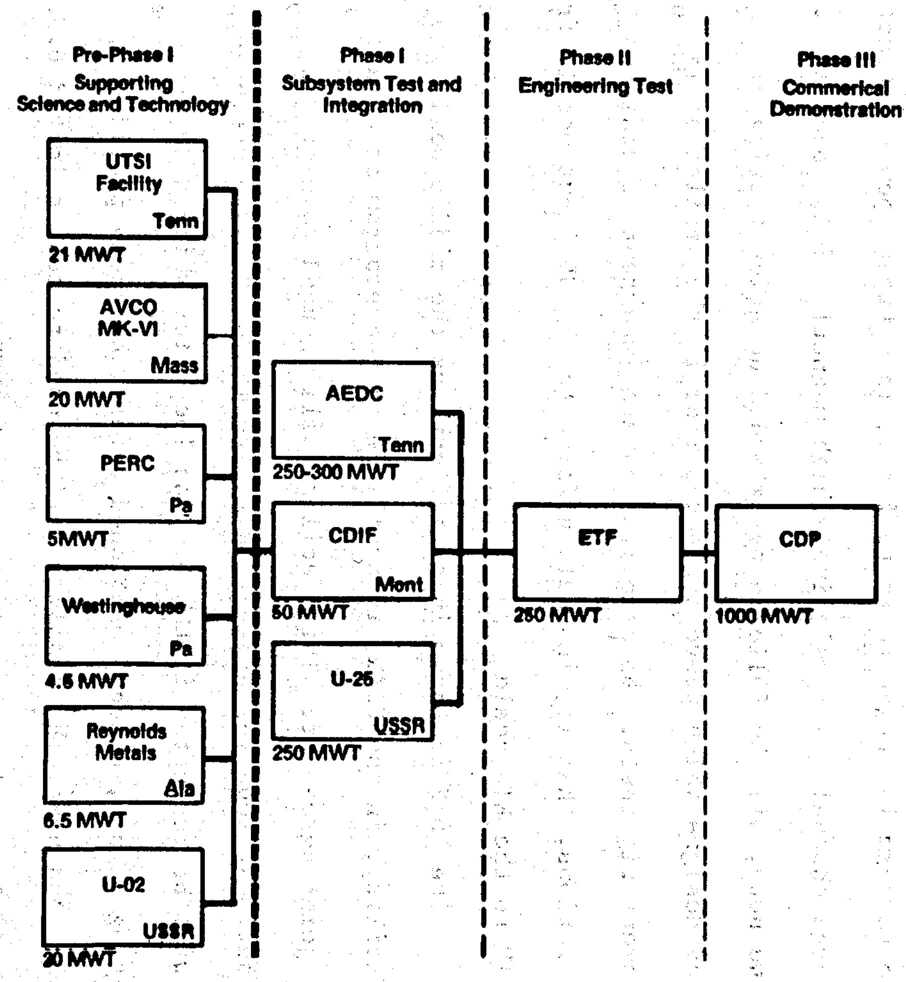
evaluating electrode and insulator materials under simulated channel design conditions, and so forth.

This slide (Fig. 6) shows the general course of component development. The left hand column of boxes represent the more significant component development efforts. The University of Tennessee Space Institute, at the top, is at present upgrading their facilities. Dr. Dicks, who directs the work for UTSI, has been active in MHD work for a number of years. The AVCO-Everett Research Laboratories, next in line in this Figure, are doing the bulk of the channel development work which will determine the design of the first CDIF test channels. PERC is responsible for development of the first coal combustor which will be tested, in tandem with an AVCO channel, in the CDIF. They are basing their development work on a five MW thermal experimental model of the projected CDIF design. Westinghouse is using bench test facilities to evaluate electrode designs. They are also upgrading a small channel facility which can provide test environments more nearly duplicating power generating duty conditions.

The Reynolds effort has been aimed toward advanced electrode engineering development and to the evaluation testing of more conventional designs. The USSR U-02 facility has provided valuable test experience on ceramic electrode designs under channel operating conditions.

The next column in Fig. 6 represents major test facilities, where designs developed by the first column activities, can be tested

MHD Development Sequence

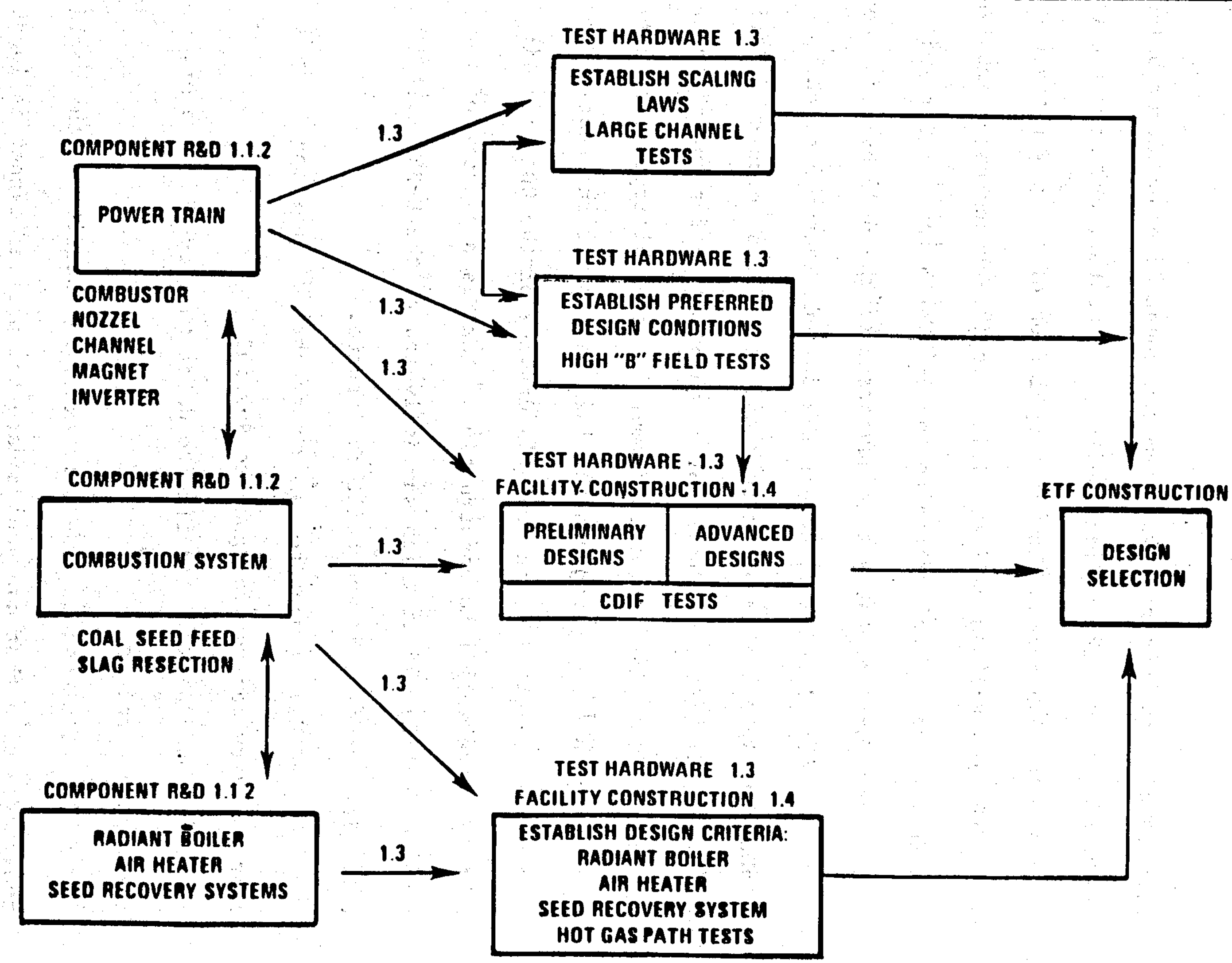


at a larger scale and under more stringent engineering conditions. The first box here is the Arnold Engineering and Development Center in Tallahoma, Tennessee. They have a 250MWt facility in which we plan to perform important tests to first, investigate power extraction in a large channel under relatively high magnetic field conditions. This, we hope, will be followed by extended duration testing of selected designs which prove to be superior in the smaller scale development rig tests. Both activities are important to scale-up considerations, that is, in scaling first to the CDIF but mostly from the CDIF to the ETF scale.

The CDIF is shown in this figure as the middle box. The U-25 facility, in the USSR, is available to the program as a part of the joint agreement. This facility will be used to meet two important test requirements. First, high magnetic field strength tests will be conducted in the by-pass loop, for which a superconducting magnet, which I mentioned before, has been provided by the U.S. And next, the facility will be used to test selected U.S. designs in large sizes - equivalent to the ETF size.

This next slide (Fig. 7) indicates the flow of activities. The top left hand box represents MHD power trains for CDIF testing. This includes the combustor, channel, inverter, and so forth. Related combustion activity, represented by the next box, is intended to look ahead to advanced coal combustor designs which would lay the ground work for an advanced CDIF test train. These activities are

MAJOR MHD PROGRAM LOGIC



(NUMBERS REFER TO WBS ELEMENTS)

intended also to support downstream component development or balance-of-plant systems - the radiant boiler, air heater, and seed recovery systems. The chart also shows extrapolation of the power train development into high B field regime. This involves extension of experimental work from a 2 to 3 Tesla range to the 5-6 Tesla range. Our initial efforts here will probably take advantage of the U-25 by-pass loop.

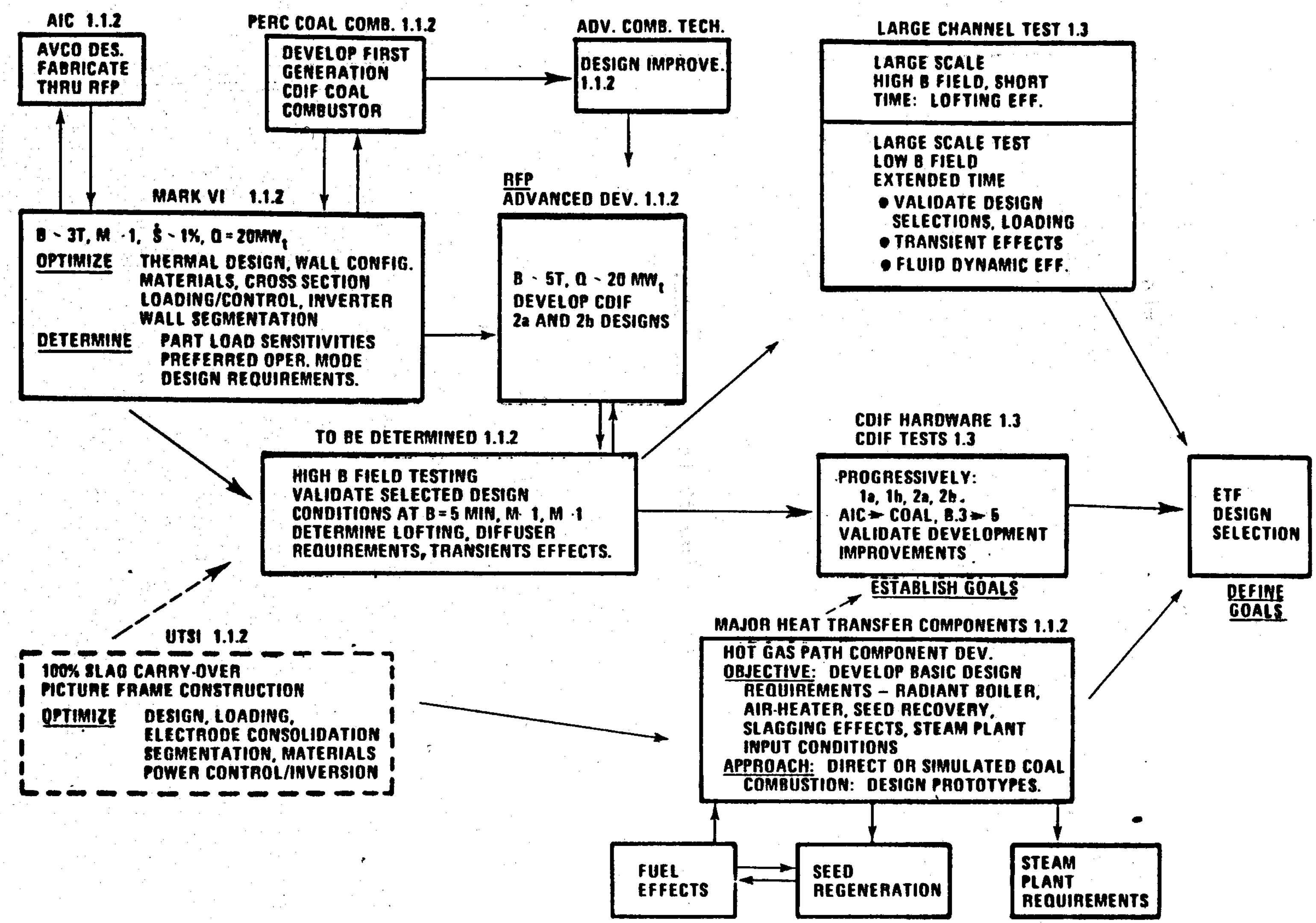
This, I believe, covers the salient features of our program. As you see, we are attempting to keep our efforts focused on a firm objective, namely, development of a sound design for the ETF combined MHD-steam pilot plant to prove commercial feasibility. The next slide (Fig. 8) simply repeats the last one except in greater detail. This figure (Fig. 9) is an artist's drawing of the CDIF facility in Butte - we're well into construction. Next is a picture of the superconducting magnet which was delivered to the U-25B site (Fig. 10). It was designed and built by Argonne.

VOICE: I want to ask a very obvious question. Why is it that our very best device goes to Russia?

MR. RARING: I'd like to defer that question to Mr. Liccardi, the Deputy Director.

MR. LICCARDI: The only existing facility in the world today of a size that can accommodate the present magnet is located in the Soviet Union. The quid pro quo that we have with the Soviets is that we will get all the data from the operation of the U-25B facility with the loan of this magnet. There is no magnet fabrication technology

MHD PROGRAM LOGIC



Slide #9 is unavailable.

Slide #10 is not available.

transfer, if that is your concern, because, as you all know, technology transfer comes primarily from the know-how in the fabrication of equipment, that is fabrication techniques. This is a scaled unit. We feel that we will not be in a position to get that data from a large scale MHD facility for about another two years. So this will help us immensely in designing our channels and future MHD power systems.

VOICE: Good answer.

DR. KANE: Dr. Green.

DR. GREEN: I have a question regarding the efficiency with which the thermal energy is converted into electrical energy in our MHD duct.

MR. RARING: The enthalpy extraction generally considered as necessary to commercial success is typically 15% minimum. Achieving this in a small channel with a high surface to volume ratio is very difficult. However, a recent test at AVCO on a disk generator under conditions which simulated combustion gas chemistry, did achieve 14% on two successive tests, shock tube tests. In the view of some plasma physicists, at least, the experiment is relatively independent of the configuration - it's a plasma experiment and the results are applicable to a large linear channel. So, there has not yet been any experimental evidence to show that 15% or more is impossible in a large linear channel.

MR. LICCARDI: We do have what we call a high-performance demonstration experiment that will be done at the Arnold Engineering

Development Center, and this will be a short duration 15 to 20 second run on a channel the size of the ETF, which is 250 megawatts thermal, and this will allow us to go to steady state conditions and validate the enthalpy extraction and turbine efficiency. That's about a year or more away.

MR. RARING: That's the purpose of that test, as I mentioned earlier. This is intended to validate enthalpy, extraction and turbine efficiency, in a large channel test.

DR. KANE: Are there other questions?

I think this meeting is a great example of the best-laid schemes. Let me tell you the nice logical order we laid it out in, so you can contrast this with what's happening here.

I was supposed to give you a focusing talk which told you the area we were specifically going to aim at for the rest of the meeting. And the remainder of the morning was to contain, first, a talk by Dr. White, in which he would give the goals, the strategy, the overall picture of the fossil energy program. Without that kind of talk, it's difficult to do what I asked you, to put the research portions in context.

After that, we were going to have, and we have had, some talks on the technologies. I told you specifically that these technologies per se were not the topic of this meeting, but nevertheless they were necessary if you were to make pertinent comments on the meeting.

Now, you still haven't had Dr. White's talk. I'm still desperately hoping that he'll make it, because I think he's an essential ingredient to this meeting.

We have one more talk that was supposed to give you the background on the meeting today, and I think it's equally essential to the technology, and that is the probable costs of synthetic fuels.

Now, you understand that the purpose of this meeting is how much research, what kind of research, ought we to have; and certainly one of the driving forces to do more or less research is the state of what you already have. So the next talk is by Dr. Chris Knudsen, and he will discuss the subject of estimates of synthetic fuel costs from fairly well-known processes. This is another talk which is supposed to put in context the question, "What research, how much, and what kind should we do?"

So, it's all backward today. I'm sorry, but we couldn't avoid it. Is Chris here, so he can go into this aspect of it. If he's not, we're in real trouble.

See, Chris too is up at the Hill today.

We do have a pinch-hitter for Dr. White, who could give his talk from the slides and so on.

Leroy Furlong. Leroy, I hate to do this to you at the last minute. I hear somewhere that you can -- if we've lost him, we're in real trouble.

Let me tell you what the topic of the Hill is today, because it really is a serious one. It has something directly to do with this meeting. Last week there was an enormous furor in the Senate over some estimates of availability of fossil energy as a function of price, existing sources--natural gas, predominantly. The subject is one in which practically everyone in fossil energy has been occupied more or less continuously, and that's the one that has, today, Dr. White, Mr. Fri, Chris Knudsen, and Harry Johnson up there. That's the reason they're not here.

I see no alternative, except to go to our first speaker of the afternoon. Alex, could we do that to you?

Let me back up just a minute and tell you the why and the reasons for this.

VOICE: Why don't you run the film?

DR. KANE: The MHD film? I would rather hold off. The subject of this meeting is really to give us advice on what we ought to do. The MHD film, we'll have it here, we'll show it during the noon hour. I haven't seen it, but I'm sure it's a good film. But the real purpose is the critique, and I think that's probably less valuable for the critique than some of the other things.

Now, the next speaker is Dr. Alex Mills.

He's director of the Division of Materials and Exploratory Research, which means that in fossil energy, he is the man in charge of the development of the intermediate, and in some cases long-range research.

Rather than describe what Alex does, I'll let him describe it. This is the talk that was to have been given this afternoon--we'll move it forward now.

Alex, sorry to do this to you on such short notice.

DR. MILLS: Thank you.

(Slide 1)

I'd like to begin with the first vugraph, which lists objectives of the division. I need to tell you, since you haven't seen the overall distribution of divisions, that we are one of the divisions, budgetarily one of the smaller divisions, but naturally we think one of the most important divisions in fossil energy. The Materials and Exploratory Research Division has these objectives. These bullets are not quite equally distributed, but the point is that we are to serve in concept as the central research management for all program areas of fossil energy.

And I hope, incidentally, Gerry, that while you stressed coal, I would believe that our discussions today should cover all fossil energy, so that oil shale is also a candidate. And a chief function that we have is to insure that we lay the foundation for innovative technology, which is an aspect we haven't heard in our discussions so much today.

To do that, we ought to develop a technology for processes we have listed; gasification, liquefaction, and also refining and chemicals. We want, on the other hand, also to improve the operational reliability and efficiency of synthetic fuel plants through materials

MATERIALS AND EXPLORATORY RESEARCH

OBJECTIVES

- SERVE AS THE CENTRAL RESEARCH MANAGEMENT ARM FOR ALL PROGRAM AREAS OF FOSSIL ENERGY
- ENSURE THE FOUNDATION FOR INNOVATIVE TECHNOLOGY THROUGH ITS PROGRAMS IN THE ERDA ENERGY RESEARCH CENTERS, NATIONAL LABORATORIES, AND OTHER GOVERNMENT AGENCIES, PRIVATE INDUSTRY, AND UNIVERSITIES.
- DEVELOP INNOVATIVE FOSSIL ENERGY TECHNOLOGY LEADING TO SIGNIFICANTLY CHEAPER SYNTHETIC FUEL PROCESSES
  - GASIFICATION
  - LIQUEFACTION
  - REFINING AND CHEMICALS
- IMPROVE THE OPERATIONAL RELIABILITY AND EFFICIENCY OF SYNTHETIC FUEL PLANTS THROUGH RESEARCH ON MORE CORROSION/EROSION RESISTANT MATERIALS AND COMPONENTS
- DEVELOP ADVANCED TECHNIQUES TO PERMIT INCREASED COMBUSTION OF COAL IN AN ENVIRONMENTALLY ACCEPTABLE MANNER

and components research. So this is a little different from the chemical kind of processing. And we want to develop advanced techniques for combustion and direct utilization.

(Slide 2)

The next slide lists some special concerns for university programs. These are listed as the objectives to locate and use the talents of university people, and I hope we use them in a constructive manner--give them the opportunity to come forward. One of the things that we've recognized of great significance is that we have a communications channel. We have had great difficulties, I think, communicating with the public at large, and also with special groups, and we think that the universities is one segment of our United States community that can communicate what the realities are.

And, of course, the last, and in some ways we would think the most important of these, is to assure an adequate manpower base. This was mentioned once before.

(Slide 3)

The next slide deals with the distribution of funds. And you see under "Advanced Research and Supporting Technology," in 1977 some 7.7 percent and 6.1 percent in the '78 budget. The Division of Materials and Exploratory Research is a major part of that, but not all. There is a planning function within that budget. So this gives a distribution of the various divisions that I mentioned earlier, and which will appear in Dr. White's talk.

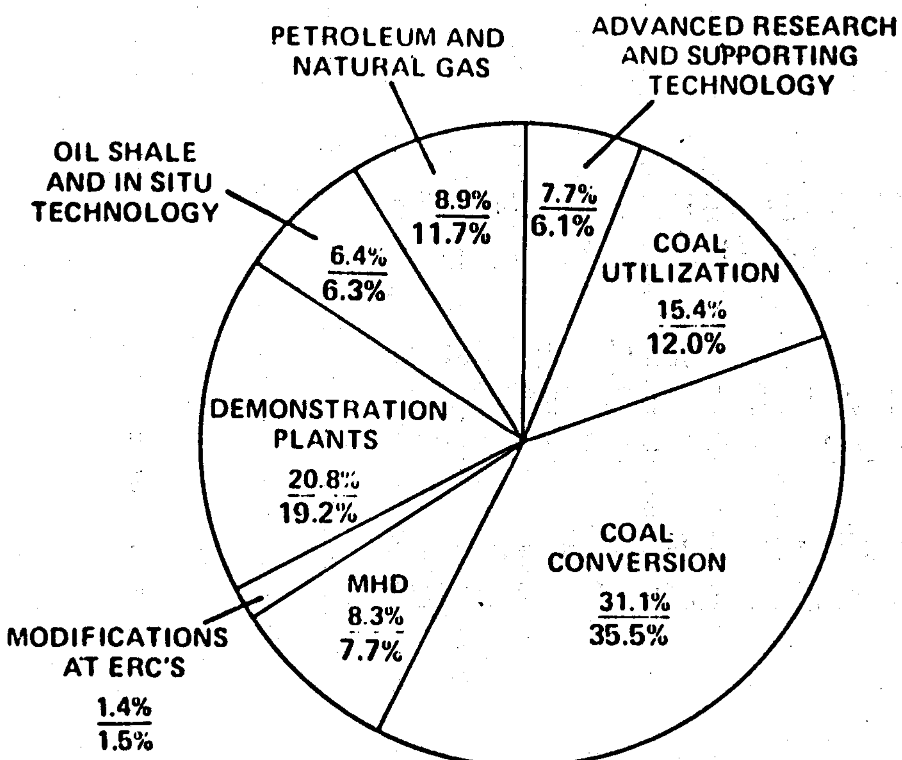
MATERIALS AND EXPLORATORY RESEARCH

UNIVERSITY PROGRAMS

OBJECTIVES

- LOCATE AND USE TALENTS OF UNIVERSITY PEOPLE TO CARRY OUT RESEARCH RELATED TO FOSSIL ENERGY
- PROVIDE COMMUNICATION CHANNEL BETWEEN ERDA–FE AND UNIVERSITIES ON RESEARCH NEEDS AND INFORMATION DISSEMINATION
- ASSURE ADEQUATE MANPOWER BASE IN SCIENCE AND TECHNOLOGY RELATED TO FOSSIL ENERGY

FOSSIL ENERGY BUDGET ESTIMATES
DISTRIBUTION OF FUNDS



PERCENTAGE DISTRIBUTION OF FOSSIL ENERGY BUDGET ESTIMATES IN FY 1977 AND FY 1978 SHOWN AS FOLLOWS:

FY 1977%
FY 1978%

BUDGET AUTHORITY (DOLLARS IN MILLIONS)

	FY 77	FY 78	INCREASE DECREASE
COAL CONVERSION	$150.3	$233.3	$ +83.0
COAL UTILIZATION	74.4	79.1	+ 4.7
ADVANCED RESEARCH AND SUPPORTING TECHNOLOGY	37.1	40.3	+3.2
DEMONSTRATION PLANTS	100.3	125.9	+ 25.6
MAGNETOHYDRODYNAMICS (MHD)	40.0	50.5	+10.5
PETROLEUM AND NATURAL GAS	43.2	76.7	+33.5
OIL SHALE AND IN SITU TECHNOLOGY	31.0	41.5	+10.5
MODIFICATIONS AT ERC'S	6.9	9.6	+2.7
TOTAL	$483.2	$656.9	$+173.7

77-2656M/1-4

(Slide 4)

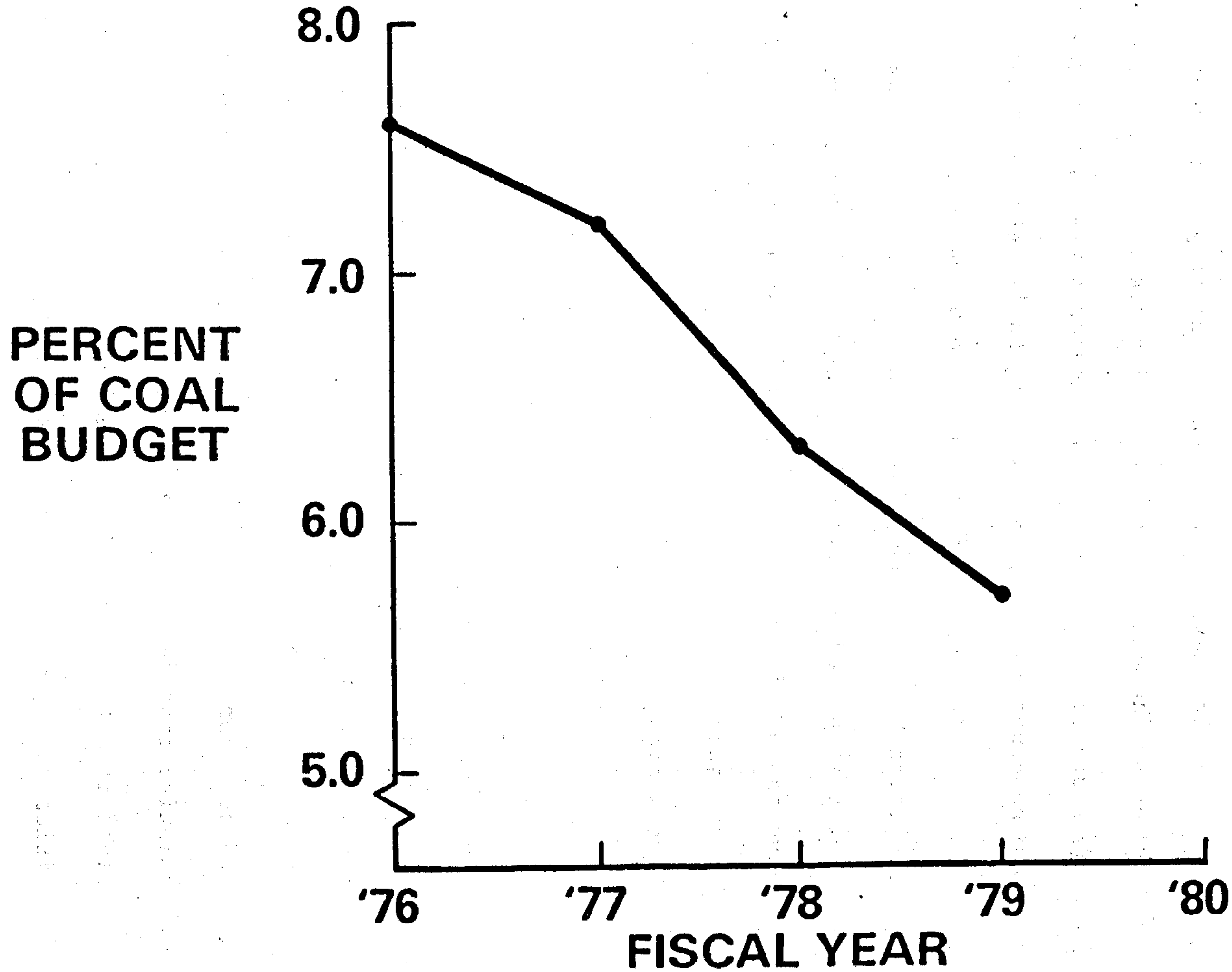
The next vugraph--and I want to go over some of these to get to the end few, which I think are more significant--related to the share of funds for this particular division in percentage, and I'm no doubt somewhat self-serving to illustrate it this way.

It shows a diminution. To bring it into focus, our budgeting has been essentially constant, constant plus 8 percent, over this period of time. The reason it has this form is that the development of power plants and large-scale activity has gone up, but at the same time I will make the point that the research activities have stayed essentially constant.

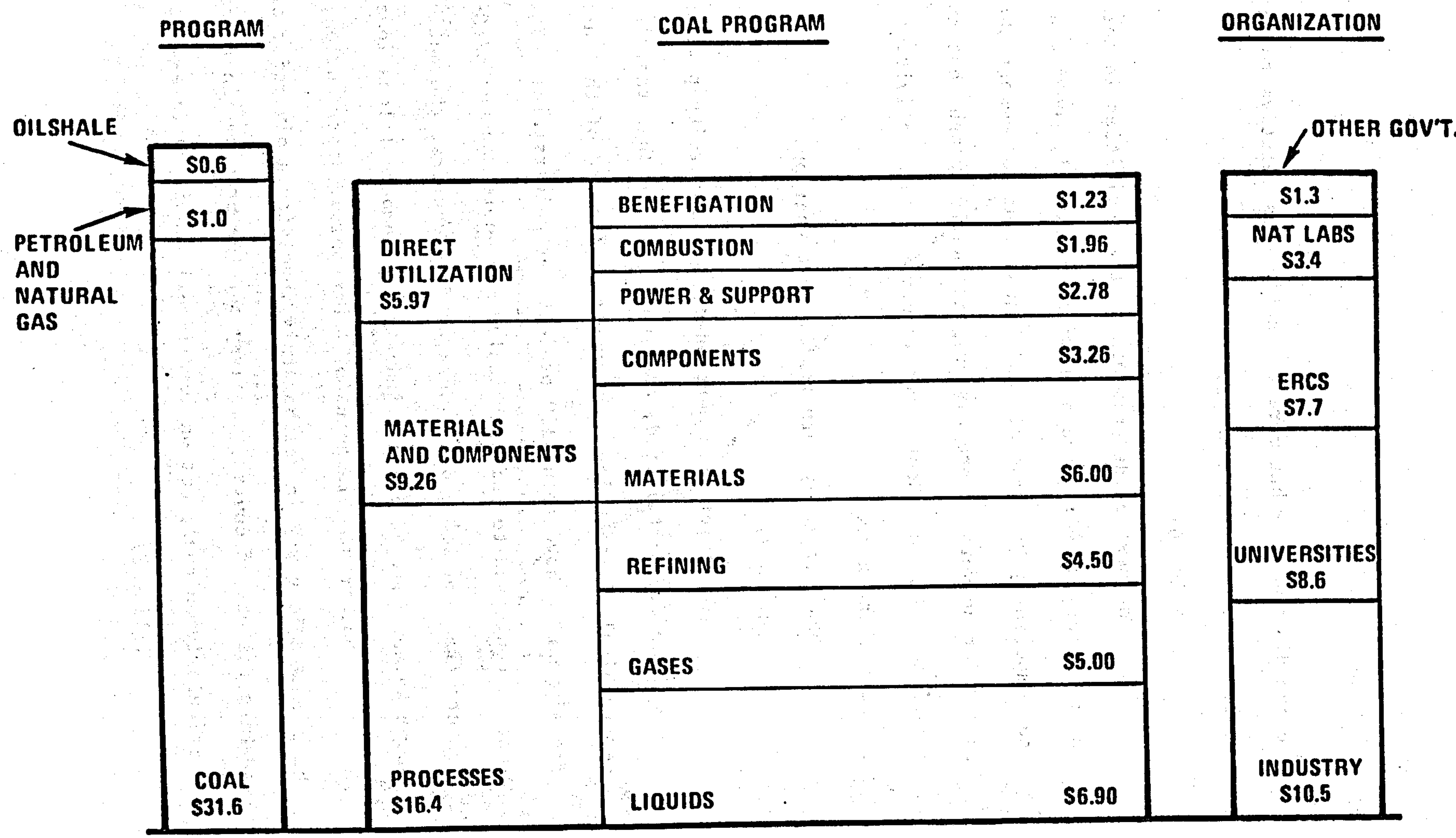
(Slide 5)

The next vugraph comments on two things, programwise and where we do work. You see that $31.6 million for this division is in the coal area. There is some additional research activities in oil shale and petroleum. The center bar depicts the fact that our activities are divided into three parts: direct utilization, materials and components, and processes. And this bar graph represents the relative funding. And they're broken down into subgroups. At the right illustrates what organization is used to carry out the activities, and you see industry, $10 million; universities, $8.6; energy research centers, $7.7, national labs, $3.4. So, at the left is the general things we're doing, and at the right where we're doing this.

MATERIALS AND EXPLORATORY RESEARCH
SHARE OF COAL BUDGET



MATERIALS AND EXPLORATORY RESEARCH
FY78 FUNDING DISTRIBUTION (MILLIONS)



We can discuss somewhat more our activities relative to the universities or relative to industry.

(Slide 6)

The next slide comments on the activities in terms of how we're organized: processes with Dr. Podall, power and materials and components, Dr. Frankel; and I just want to comment that we regard our university programs significantly enough that these are organized under Paul Scott, who is here. Their activities actually are across the board.

Now, if I may turn to the next vugraph.

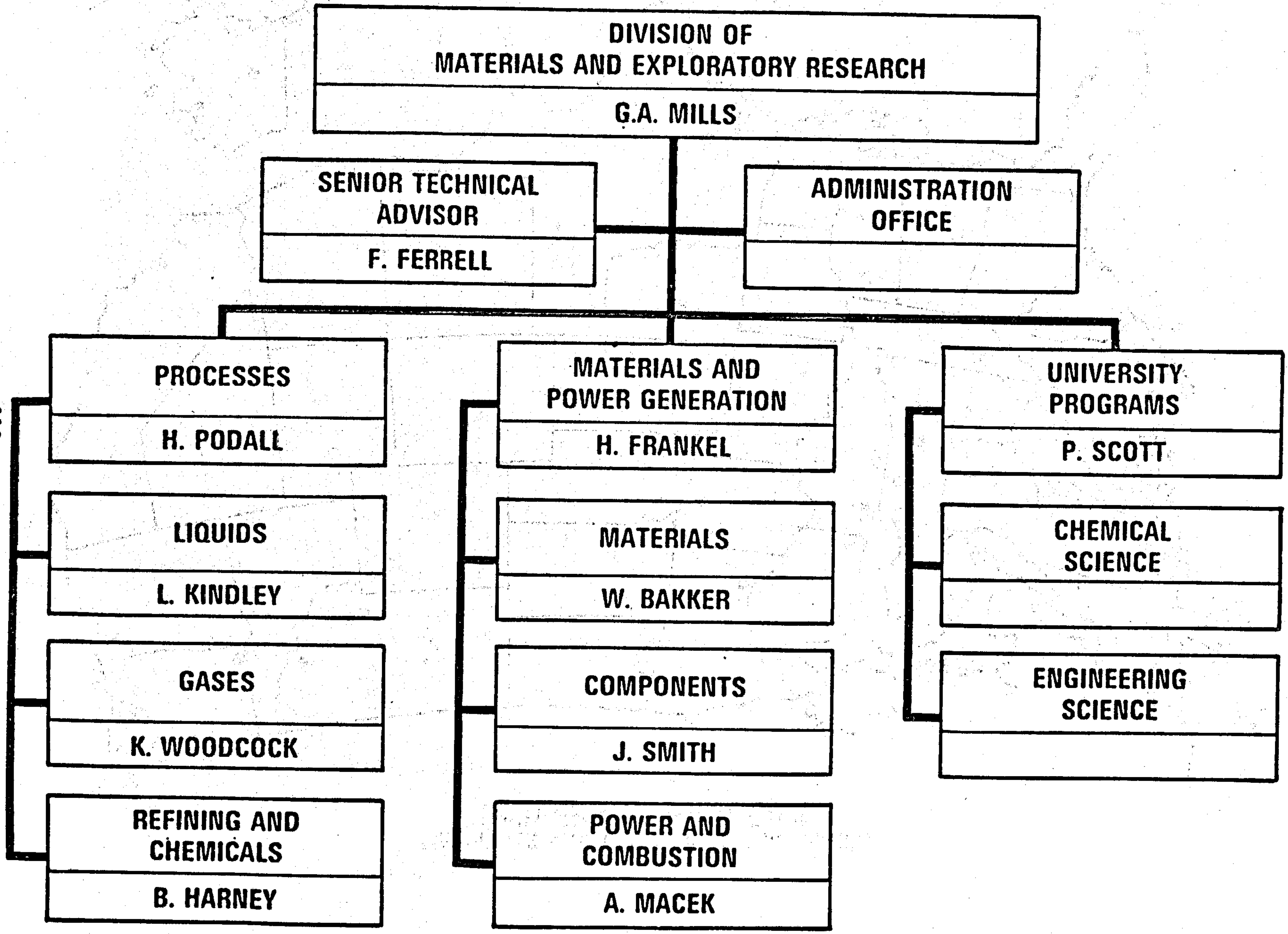
(Slide 7)

This depicts, as mentioned, the university programs where these are distributed, and you'll notice that there's wide geographical distribution. We expect at the end of the current fiscal year to have about 150 projects at universities. I thought that we could add to this particular map where the energy research centers are, and we're doing work at five centers, the national labs, about seven, and, of course, industry, a number of locations.

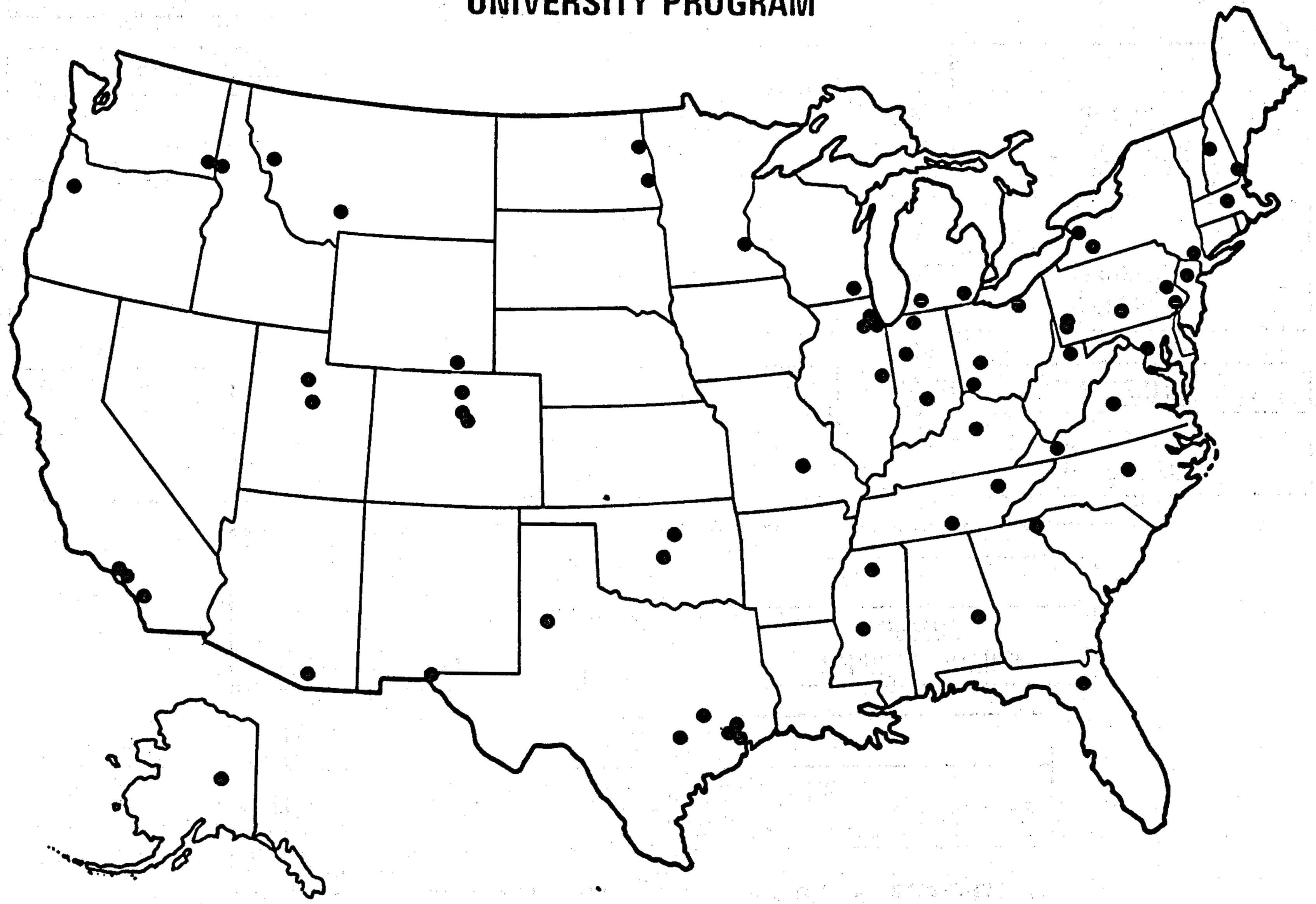
So, from a viewpoint of geographical distribution, we have come a long way in deliberately involving a diversity of groups, seeking talent, of course, to carry out the programs in research, particularly on coal, but on fossil--all fossil energies.

(Slide 8)

MATERIALS AND EXPLORATORY RESEARCH



MATERIALS AND EXPLORATORY RESEARCH
UNIVERSITY PROGRAM



MATERIALS AND EXPLORATORY RESEARCH

FY/76 PROPOSAL/CONTRACT SUMMARY

- **PROPOSALS**

NATIONAL LABORATORIES	123
ENERGY RESEARCH CENTERS	37
UNIVERSITIES	230
INDUSTRY AND OTHER	119
	509

- **CONTRACTS/PROJECTS**

	IND	UNIV	GOV'T	TOTAL
PROCESSES				
– GASES	15	24	11	50
– LIQUIDS	13	20	11	44
– REFINING & CHEMICALS	2	2	9	13
MATERIALS & COMPONENTS				
– MATERIALS	15	4	10	29
– COMPONENTS	3	2	2	7
DIRECT UTILIZATION				
– BENEFICATION	1	2	4	7
– COMBUSTION	2	12	4	18
– ENERGY TRANSFER	–	–	2	2
– SUPPORT STUDIES	3	7	2	12
	54	73	55	182

The next vugraph comments on how we get suggestions for research. And I must say we come to a sort of an issue as to whether we ought to be a reactive group in ERDA or one which does more positive planning. From a reactive point of view, which is described here, we took the trouble in '76, the last complete year, to list where we were getting proposals. These are unsolicited proposals from the national labs, et cetera. And, at the bottom, where the contracts or projects are. So we have, at the end of '76, some 54 with industry, 73 with universities, 55 with government labs--about 200 projects.

The plan of work which we do is then balanced in part by the projects which are proposed from various institutions--universities and others--but more importantly, I believe, our activities are fashioned on a consideration of what the needs are, and then by reacting to unsolicited proposals on the one hand, to issue either requests for proposals or so-called PERDAs, and we have three PERDAs out at the present time, one for novel, innovative research on refining, on coal gasification, on liquefaction.

So we go to the community with a discussion of needs and the PERDA has got more latitude in it than a request for proposal in the sense that it's not as well defined except as to objectives. So we have unsolicited proposals on the one hand, we have our concern for what is needed, and I'm going to come to that later. There was some discussion today, of course, on how the power plant or larger scale activities are describing their needs in terms of the problems which they have.

(Slide 9)

Next vugraph. I would say today that if you want to learn about what we're doing in the Divison of Materials and Exploratory Research, there are three sources. First is the gold book, copies of which have been available, which describes all fossil energy activities.

The second is an annual report which is available, and a new one is to come out in the middle of July.

And the third is to look at what we would call our fact sheet. We have a book that each project has a particular one-page description objective, funding, who does it, and so on, so I will give you that information to delve into. You can pick up the sheet, see what the project is, and then you can go and get progress reports and so on.

Obviously, since our projects are on the average, $200,000 per project, and we have seen that there were 182 last year, and we are going to pick up another 30 starter grants, it's impossible to discuss these individually.

So, what I'd like to do now is, in the next slide, to discuss a few particular projects with the idea of letting you see what these are like.

(Slide 10)

MATERIALS AND EXPLORATORY RESEARCH

MAJOR RESEARCH AREAS

RESEARCH AREA/MAJOR PROJECTS	CONTRACT VALUE (MILLIONS)	NUMBER OF CONTRACTORS
• MORE ECONOMICAL SYNFUEL PROCESSES	55.4	107
– METHANOL–TO–GASOLINE (MOBIL)		
– CATALYTIC GASIFICATION (EXXON)		
– FLASH HYDROPYROLYSIS (GULF, IGT, SUNOIL, BNL)		
– COAL STRUCTURE/REACTION MECHANISMS		
– REFINING OF COAL AND SHALE OILS		
– NEW CATALYSTS FOR COAL LIQUIFACTION		
• RELIABLE MATERIALS AND COMPONENTS		
– COAL GASIFICATION (MPC, ANL, ORNL, NBS) – FIRESIDE CORROSION (COMB. ENG., BATTELLE, G.E., EXXON, WESTINGHOUSE)	14.6	29
– VALVES FOR COAL GASIFICATION (CONSOL. CONTROLS, FAIRCHILD, MERC)	7.6	7
– FAILURE ANALYSIS		
– TECHNOLOGY TRANSFER – NEWSLETTER		
• IMPROVED DIRECT UTILIZATION OF COAL	5.8	39
– BENEFICIATION (SRC, PERC, AMES, PERC)		
– COMBUSTION PROCESSES (MRI, GFERC, MERC)		
• EXPLORATORY RESEARCH AT UNIVERSITIES	24.5 (INCLUDED ABOVE)	77 (INCLUDED ABOVE)

MATERIALS AND EXPLORATORY RESEARCH
MAJOR PROJECTS

- **COAL TO METHANOL, METHANOL TO GASOLINE**
  - METHANOL AS A FUEL
  - CRUDE METHANOL TO HIGH OCTANE GASOLINE AT LOWER COST AND REDUCED POLLUTION EFFECTS
- **CATALYTIC GASIFICATION**
  - CATALYTIC GASIFICATION OF COAL USING POTASSIUM CARBONATE AS CATALYST – ELIMINATES OXYGEN PLANT, SHIFT AND METHANATION
- **FLASH HYDROPYROLYSIS**
  - HYDROPYROLYSIS OF COAL IN SECONDS TO MORE AROMATIC LIQUIDS AND FUEL GAS WITH SIGNIFICANT POTENTIAL TO REDUCE INVESTMENT
- **BASIC APPLIED RESEARCH**
  - RELATIONSHIP OF COAL CHARACTERISTICS TO LIQUEFACTION BEHAVIOR;
  - KNOWLEDGE OF KEY STEPS AND INTERMEDIATE PRODUCTS
  - CRITICAL CATALYTIC EFFECTS OF COAL MINERALS; ESSENTIAL CHARACTERISTICS OF CO–MO CATALYSTS
- **REFINING OIL FROM SHALE & COAL**
  - APPLICATION OF PETROLEUM TECHNOLOGY AND SEARCH FOR IMPROVED CATALYSTS FOR COAL AND SHALE OILS

MATERIALS AND EXPLORATORY RESEARCH
MAJOR PROJECTS (CONT'D)

- **COAL BENEFICIATION**
  - BENCH SCALE OXYDESULFURIZATION HAS SHOWN RELATIVELY SIMPLE AND INEXPENSIVE PROCESS TO REMOVE ALL INORGANIC AND 40% OF ORGANIC SULFUR
- **MATERIALS**
  - COAL GASIFICATION – DATA BASE ESTABLISHED FOR ALLOYS AND CERAMICS ABLE TO WITHSTAND GASIFICATION CONDITIONS
  - FAILURE ANALYSIS SYSTEM ESTABLISHED, TECHNOLOGY TRANSFER INCLUDING NEWSLETTER
  - FIRESIDE CORROSION PROGRAM FOR MATERIALS FOR COMBUSTION OF SYNTHETIC FUELS, FLUID BED COMBUSTION, HIGH TEMPERATURE COAL COMBUSTION
  - INITIATED PROGRAM FOR IMPROVED CERAMICS AND ALLOYS
- **VALVES**
  - DEVELOPMENT OF IMPROVED VALVES FOR FEEDING COAL AND WITHDRAWING CHAR CAPABLE OF RELIABLE OPERATION, COLD OR HOT
- **UNIVERSITY**
  - IN ADDITION TO THEIR CONTRIBUTIONS TO THE ABOVE, ABOUT 1,000 STUDENTS AND FACULTY RECEIVE TRAINING IN FOSSIL FUEL SCIENCE AND ENGINEERING

Now, I'm somewhat in the dilemma of trying to tell you what a great job we are doing, on the one hand, and then later tell you all the things that need to be done. So on the great-job activity, we would like to point out that, especially in the last couple years, with the surge of funding and interest on the part of the technical communities at various locations, that we have uncovered what we think are some promising activities for projects which we'd like to think of as kind of third-generation activities.

And, to give you some sense of reality, I've listed here the first one; coal to methanol, and then to gasoline. The point being here is that we'd like to think, first of all, that methanol is a viable product from coal, and that we should not be locked into the concern that gasoline is our only transportation fuel.

Now, I see the people from the petroleum industry see the need to bring some added costs into this, because there are great problems in distribution, the question of whether methanol is mixed with gasoline or used alone. We would feel that methanol is an option that we need to have facts about. So we're doing work on the use of methanol in terms of power output and pollution control. So there are opportunities there.

The second part relates to the fact that working with the Mobil people, it has been discovered that crude methanol can be transformed into high-octane gasoline, 95-octane research, without lead, in almost quantitative fashion. And this gives another option, from coal to high-octane gasoline, which we think, first of all, is much superior to the SASOL process--the only process in the world being used, which is in South Africa.

I would like to comment that, interestingly enough, this is achieved by a novel concept of a catalyst which acts as a molecular sieve, which only lets gasoline molecules get out. And a key feature there is that you have a very select product of high quality.

Catalytic gasification, the second item in the slide, has already been mentioned by Martin Neuworth, and the fact that it eliminates the oxygen plant, shift and methanation steps. We think that inherently this is the right direction to go, how to do gasification at a lower temperature and, of course, more rapidly.

Flash hydropyrolysis, the third activity, refers to the fact that in a second or even less, if coal is pyrolyzed you get a significantly different product distribution, and in some instances relatively high aromatic products.

The third is basic applied research, I find myself trying to use some term, such as basic applied research which refers to an investigation of an applied research, but looking somewhat more into the scientific or chemistry and engineering of it. We need to know the relationship between coal characteristics and its behavior to liquefaction. And I might mention already some very interesting things are being found.

For example, it's been discovered that, when solvent-refined coal, which you heard about earlier, is examined, after it's been processed under hydrogen pressures for long periods of time, the darned stuff has less hydrogen in it than there is in coal. So that we have a few dilemmas that we're discovering. It's been discovered that solvent-refined coal goes most of the way to dissolved liquid in the first minute or two, and then you beat it to death for the rest of the time. So that there is a belief that by understanding some of the mechanisms of the chemistry that this will provide the basis for people to have ideas to make significant improvements.

The second part, which is mentioned here, is critical catalytic effects. It is being discovered that the minerals are highly active as far as catalysts are concerned, and therefore I sort of object when this is called a thermal reaction when in fact it's been discovered that the minerals are active. And surely, it's the case that the minerals as found in coal should not be in their best catalytic form, that it ought to be possible to improve this situation by studying this in some detail.

Refining of oil from shale. I have listed here the application of petroleum technology and the search for improved catalysts, so that we begin sort of as a base case and then go on from there.

The next and last group of these major projects, to illustrate some of the interesting things that I think are happening, coal benefication turns out to be a device which is sort of not synthetic fuel, but has great opportunities. And at the Pittsburgh Energy Research Center recently it's been discovered that by a relatively simple process of heating coal under pressure with air and water that all the pyrite can be converted to sulfuric acid, and as much as 40 percent of the organic sulfur also. It's this news about the organic sulfur that's interesting. And so this looks like it might be a way to bring into compliance a very high percentage of eastern coals and is certainly, I think, an exciting possibility.

As far as materials are concerned--

DR. BARON: What is the cost of this?

DR. MILLS: We have an engineering study. It's a good question and obviously must be attractive.

We have two numbers. One is very low, and one is very high. One is $7, and the other is $27 a ton.

Materials research we regard as a very serious part of activities. If the plants don't run because they have difficulties from materials of construction, both alloys and ceramics, obviously, no matter how good the process is, it's not worthwhile. So we have a very substantial program on materials research applicable to coal gasification which we can elaborate on. We have installed a failure-analysis system, so that when failures occur these are looked into systematically. And the question of technology transfer that came up earlier, the information is disseminated in a newsletter which has wide circulation.

We have fireside corrosion activities in three parts: synthetic fuels, fluidized bed combustion, and high-temperature coal. We have a valve program. And just to add one thing about the university community, in addition to the 1000 students and faculty that we now have in active programs, faculty members can go to the energy research centers or other locations during summer months. This is a program similar to the one that AEC in past years practiced, and we have, for example, about 10 faculty members at Pittsburgh, and about the same number at Morgantown and other locations. And I think this is being received on both parts with a good deal of enthusiasm.

I hope I haven't overdone this bit about the projects we have underway. (Slide 10).

Now, I have a couple more things to say. First, I would like to turn to the next vugraph, if I may.

(Slide 11)

Issues. And perhaps this, for some, may be the most important slide, the most important consideration.

As far as criteria are concerned, I think we need to define our objectives more accurately--the objectives, I am saying, of ERDA. What are the objectives? We need to define these much more accurately than we have in the past.

132

MATERIALS AND EXPLORATORY RESEARCH

RESEARCH MANAGMENT ISSUES

- DEFINE OBJECTIVES
- CRITERIA FOR SELECTION
- SIZE OF BUDGET
- ORGANIZE – CENTRAL/MISSION
- INTERACTION WITH OTHER DIVISIONS/AAS PLANNING/TECHNOLOGY TRANSFER
- IMPROVE QUALITY
- WHERE – ERC/NL/UNIV./IND.
- TRAINING FUNCTION
- FUNDING SECTOR – PRIVATE/GOV'T AGENCIES

The second item there, how do we set criteria for selection of projects. Now every company or research group has that kind of a problem. In general, of course, it ought to fall from the objectives. You make your selection on criteria based on objectives.

I think something surely has to do with the fact that an assessment has to be made of the part that fossil fuels will play in the next 50 years. So that's one basis for considering what the importance of fossil energy activities are, technology and research. So what part will fossil energy play in the next 50, 75 years.

The other is an assessment of what the needs are. Obviously, if the situation is well in hand, that's different from some other kind of activity which is very much undetermined. There needs to be some sort of a priority in balance relative to short, medium, and long range, and I might object, if I may, to one of the early speakers who had a triangle that said we all know that our research must be concentrated on the near term, and if I personally can take issue with that and say he had the triangle inverted, and where the need is in the long-term for fossil energy research, I think the long-term, the long-term being what are we going to do 20 years from now.

So anyway, that's a comment on that.

The question is also, in setting criteria, how much for support and how much for advance. Our division, I might mention, was previously named Advanced Research and Supporting Technology. In some ways I liked that, because it made you think there were two objectives. You must help get the plants, the power plants and the synthetic fuels plants that are being built operating, but then the other part, you must deliberately decide what you are going to do about advanced research. And, of course, there is another concern, as to the split between basic and applied research.

What is it, if it's long-term, or basic, what gets into one particular group? Or is it the fact that the organization should choose one or the other. Well, obviously it's a concern of having both.

Another feature that is of importance in this criteria is quality; the quality of research. Jim Kane mentioned earlier that this was a key issue. I just want to touch briefly on this, and I do have a couple more things.

If I may have that back, please, Gerry. I know you have a piranha pit here.

The size of the budget, whether it's organized all in central or mission-oriented, the interaction with other divisions, the quality I just mentioned, where research should be done, the balance; obviously it's not going to be one or the other. The training function, and the last item there--training of people at universities or other locations, to what degree should that enter into judgment about funding the selection of projects.

And, finally, the question is open. What should the government do, and what is it not proper for the government to do?

The next slide says something about future research, and the question I want to raise is the need for major improvements. Is there a need? And then, can research do it? And the last is, well, okay, if you decide that, what is the strategy?

And I have the next slide.

(Slide 12)

We haven't heard from Chris Knudsen, but I have here some economics that Frank Ferrell and others have listed, and the point is that with the 50,000-barrel-a-day plant, which costs a billion dollars, that using these capital charges plus coal and the operating cost, that the selling price for 10 percent return on investment after taxes, I say its $5 a million Btu or $31 a barrel. And, Dr. Baron, you asked about prices earlier. I'd say I think that you start by saying that if you've got a billion dollars of capital charge, and we heard earlier this puts a burden on some 65 percent of the selling price, now if I have your agreement that it's $31 a barrel for the process of billion-dollar plants, my conclusion is that when these plants are operated, and the public then, the corporations, are then presented with good processes that produce, refined oil, this oil will be priced at now three times what the Arabs are

COAL CONVERSION ECONOMICS

COST *	PLANT SIZE		
	50,000 BPD		100,000 BPD
	$/MILLION BTU	$/BBL	$/BBL
• CAPITAL CHARGES – 16%	1.47	8.8	4.4
• INTEREST (4.5%)			
• DEPRECIATION (5.0%)			
• MAINTENANCE (4.0%)			
• INS. AND TAXES (2.5%)			
• COAL AT $25/TON	1.67	10.0	10.0
• OPERATING COST	0.20	1.2	1.2
• MANUFACTURING COST	3.34	20.0	15.6
• PROFIT 10% ROI AT	1.83	11.0	5.5
SELLING PRICE	5.17	31.0	21.1

*Based on 2.5 BBL Oil/Ton Coal, Net Plant Cost of $1 Billion

TABLE 2.

charging. Everyone is then going to say, "Well, why aren't we doing something about major improvements?"

So, I have a concern that this puts emphasis on new processes.

(Slide 13)

Once we decide we need to do something, the thing is, is it theoretically possible, just like thermodynamics. Can you go to that? And the first equation here says that if coal was reacted with water, you should get methane and CO_2 quantitatively with no energy loss.

And so this is what the research scientists should strive to do. Therefore, it is possible to convert coal to methane, and you should do a trade, an equal trade, with no energy loss.

(Slide 14)

The next slide which we have here says for the liquefaction situation, if you take a coal molecule of bituminous coal and would have a chemical scissors, that ought to be able to cut this apart, and it's not necessary to use, as the Germans did, 10,000 pounds pressure, or we, doing it at several thousand pounds. So it should be possible to accomplish liquefaction selectively.

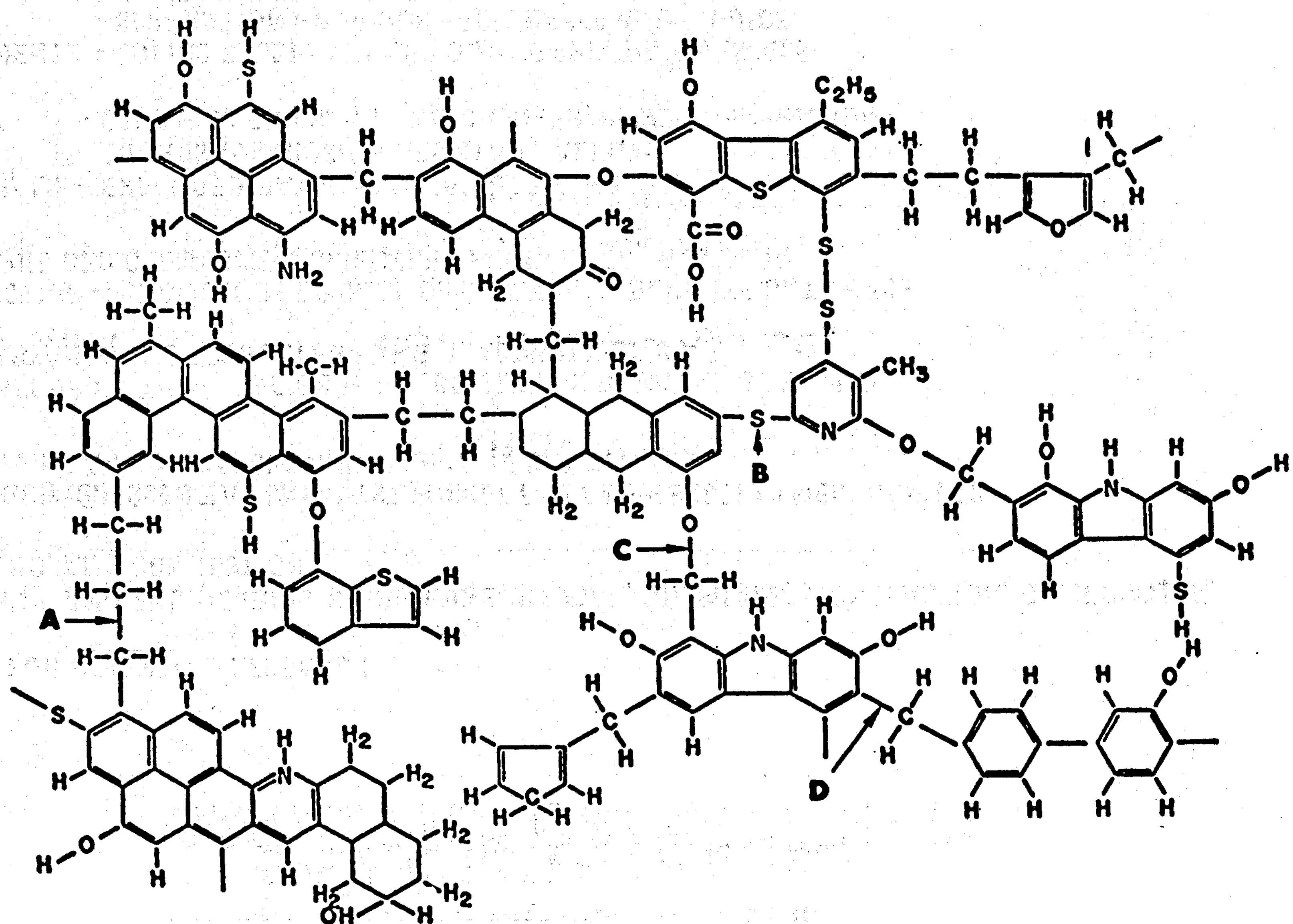
Now, the last slide which--

(Slide 15)

CATALYTIC GASIFICATION

• IDEAL:	$COAL + H_2O \longrightarrow CH_4 + CO_2$	(1)
• GASIFICATION:	$COAL + H_2O \longrightarrow CH_4 + CO_2 + H_2 + CO$ (HIGHLY ENDOTHERMIC)	(2)
• SHIFT:	$CO + H_2O \longrightarrow H_2 + CO_2$	(3)
• METHANATION:	$CO + 3H_2 \longrightarrow CH_4 + H_2O$ (HIGHLY EXOTHERMIC)	(4)

FIGURE 4


A
B
C
D

MATERIALS AND EXPLORATORY RESEARCH

SPECIFIC RESEARCH NEEDS

- IDEAS FOR INVENTIVE RESEARCH
- CHEMICAL AND ENGINEERING KNOWLEDGE OF COAL, OIL SHALE, LIQUEFACTION, GASIFICATION, REFINING, AND COMBUSTION
- RESEARCH ON ESSENTIAL CATALYST PROPERTIES AND REACTION MECHANISMS TO PROVIDE ACTIVE' STABLE AND SELECTIVE CATALYSTS
- COAL BENEFICIATION – CHEMICAL PROCESSES FOR REMOVAL OF S and N; UNDERSTANDING OF STRUCTURE AND REACTIVITY OF COAL
- COMBUSTION – KNOWLEDGE OF COAL COMBUSTION, ADEQUATE DATA BASE FOR FLUID BED COMBUSTION, SCIENTIFIC FACTS OF SO_2 REMOVAL
- MATERIALS – EXPANDED DATA BASE, FAILURE ANALYSIS
  - CORROSION/EROSION RESISTANT ALLOYS
  - CERAMICS FOR SLAGGING GASIFIER, POWER GENERATION
- COMPONENTS –SOLIDS FEEDING IN AND OUT OF PRESSURE VESSELS
  - SEPARATION OF SOLIDS FROM GASES AND LIQUIDS
  - INSTRUMENTATION OF CRITICAL PROCESS ELEMENTS
- POLLUTION CONTROL IN ALL OF ABOVE

--lists specific research needs. You can read them. I begin by emphasizing that the first need is for ideas for inventive research.

Welcome, Dr. White.

We need--and I'm repeating somewhat--chemical and engineering knowledge of coal. There's a great opportunity for better catalysts. Coal benefication we spoke of before. You've heard something from Steve Freedman about the opportunities in combustion, because after all people decide, you know, not a bad thing to do with coal is to burn it.

Materials, we need to expand our data base, to have improved materials for the known systems, components, and, of course, pollution control in all of the above.

Well, Jerry, I think I could elaborate more. As you realize, I heard the dinger go off a long time ago. So this is the last activity.

(Applause.)

DR. BROWN: Your slide went by too quickly on shale. Can you tell me what dollars those were? Are they '75 or '77 or future dollars?

DR. MILLS: Current dollars.

DR. BROWN: Current dollars.

DR. MILLS: Right.

Do you have a comment about those general prices? This is not a long economic evaluation we'll hear from Chris. I just give the simplistic viewpoint about these numbers.

DR. BARON: I'm a little astonished. Not critical. Just a little surprised. I would have thought more for coal liquefaction, $20-plus, say. And the 30 figure just shocks me a little bit. But I didn't see the breakdown, you know, what you assume for coal prices. It went too fast.

DR. MILLS: This is all equity.

DR. BARON: I certainly will agree with you that coal liquefaction is very much more costly at this point than the imported price of Arab oil or something like that.

DR. MILLS: That's the main point, I think.

Thank you.

DR. HOLLOWAY?

DR. HOLLOWAY: I wonder if you'd put that economic slide (12) back on. I'd like to ask a question or two about it.

The first question, I'll go ahead, you showed two costs, one at 50,000 barrels a day, and the other at 100,000 barrels. And the first one--

DR. MILLS: Can I comment on that? I'm sorry in a sense that I didn't cross off the 100,000 barrels or explain it. This was put on as what I would say a sensitivity analysis. It said if you would take the same plant and be able to put twice as much through it, how would this help you. And the answer is you would go from $31 down to $21 a barrel.

DR. HOLLOWAY: Well, that answers my first question, why capital charges are just half for a plant twice as big. What is this thing called "manufacturing cost" that is separate from operating cost?

DR. MILLS: That's merely a summation, and if you'd had an opportunity to examine the table you'd have realized that the first three are added up to $3.34 per million Btu or $20 per barrel.

DR. HOLLOWAY: I just had one other comment. You compared it with Arab prices. You shouldn't compare it with prices in the Persian Gulf. You should compare it with price delivered to the United States and converted into usable product, comparable to what you get from this.

DR. MILLS: Thank you.

DR. NELSON: Norton Nelson, Institute of Environmental Medicine, New York University Medical Center.

My question is a rather general one, and perhaps is as much to Dr. Kane as to you.

As the descriptions of technology and now just recently discussion of exploratory research proceeds, many issues arise which are obviously health menaces and will require control of various sorts in the plant and operational unit and source of extraction, and, finally, to consumers and to disposal problems. My question comes down to this: What mechanism is there now for following through the identification of decision points as to when health-related research or environmental research needs to be done to determine the acceptability of these various technologies?

Is that done by you? Is it done through Jim Liverman's group? And when finally the decision is made, who monitors it? Where do the funds come from?

DR. KANE: I think I will defer answering that question and let our environmental man, who is on the program later, speak to that one. Is that all right?

DR. NELSON: That's tomorrow.

DR. KANE: Yes. Because I might not be able to answer it well enough if I tried to answer it off the cuff.

DR. NELSON: I would be interested in hearing your point of view.

(Laughter.)

In other words, if you depend fully on them--

DR. KANE: I think that--I'm a proprietor of the basic research business, and my empire is exclusively defined as physical research only. So I am not concerned--the two people that would be concerned are Jim Liverman and the fossil energy people. And so let's have Alex try it first, and then--Jim Liverman is the person who can do it tomorrow.

DR. MILLS: Yes. It's a very pertinent question. First of all, Dr. White has one of the divisions specifically concerned with the environmental factor with Marvin Singer as head, so this focuses attention within fossil energy on the environmental situation. But much further than that, we have for each of the projects, to a greater or less degree, experimentation specifically designed from an environmental viewpoint.

This begins with identification of the products in detail, with special attention to those that are of environmental concern. So that each of the pilot plants, for example, has a portion of the budget and a portion of the activities specifically designed for providing information as to what products are of environmental concern. And, of course, from an overall viewpoint, each of the pilot plants has had to have an environmental impact statement and had to conform with federal laws and the state and local activities.

From a research viewpoint, we are also concerned with the ultimate importance of the environmental factor. For example, we have thought as to the relevance of high-temperature gasification, which doesn't make tars, to lower temperature, which does, as to the ultimate potential for high and low temperature processes.

But I think the main part is that we regard each of the projects as having an environmental component and examining that, and the additional part is that we have close coordination with Liverman's group as to identifying future environmental standards for gasification.

So, that's the view, at least as I see it.

DR. NELSON: What I'm really concerned about, I guess, maybe it will develop during the course of the day and tomorrow, what sort of participatory techniques one has to judge acceptability, at the same time you are judging feasibility. I think, of course, it's important that once a pilot plant is built that it comply with existing standards. But that's not my question. My question was: How do you identify, in effect, acceptability, which in some cases could be a major complement in feasibility.

DR. KANE: I understand your question perfectly, and I think any answer I would be apt to give would be dangerously wrong. I'd prefer to have the pro who is going to talk tomorrow on that precise subject answer the question.

Are there any further questions?

VOICE: From the meetings last week I heard some comments that seemed to imply that refining of shale oils and coal oils were not in the official ERDA mission, and yet this morning I've seen where you have described recently some basic research project in the area of refining.

Could you please clarify for me the official ERDA role in the area of refining of these fuels?

DR. MILLS: It is in the mission. We have projects on coal refining at Universal Oil Products, at Air Products, and Chevron. There is discussion of what we should do and what the petroleum industry should do, so that is a valid activity, and we would like to think that the things that we are supporting have to do with research aspects of unsolved problems.

VOICE: So then, would there be any applied research at the demonstration-plant level?

DR. MILLS: Ultimately, yes, but it's at the research and lab development stage at the present time, plus catalyst work which would have an implication, especially how to keep catalysts active.

DR. KANE: We'll take one more question, and Dr. White is finally here. We will put him on.

Let's take the gentleman there in the gray suit.

DR. KELLER: Bruce Keller of Oak Ridge.

In terms of research now going on, Dr. Mills, and in terms of developing new economic processes, can you look in your crystal ball and say which research areas look like they may improve the economics and give better processes for the future?

DR. MILLS: My salary doesn't provide that.

(Laughter.)

I think that we decide why do these processes cost so much from an investment viewpoint? They are too complex, too high a pressure, too low a throughput, too much hydrogen consumption. So each time we have a new activity, we look at it from the viewpoint, can it simplify the process? Can it have less hydrogen consumption,