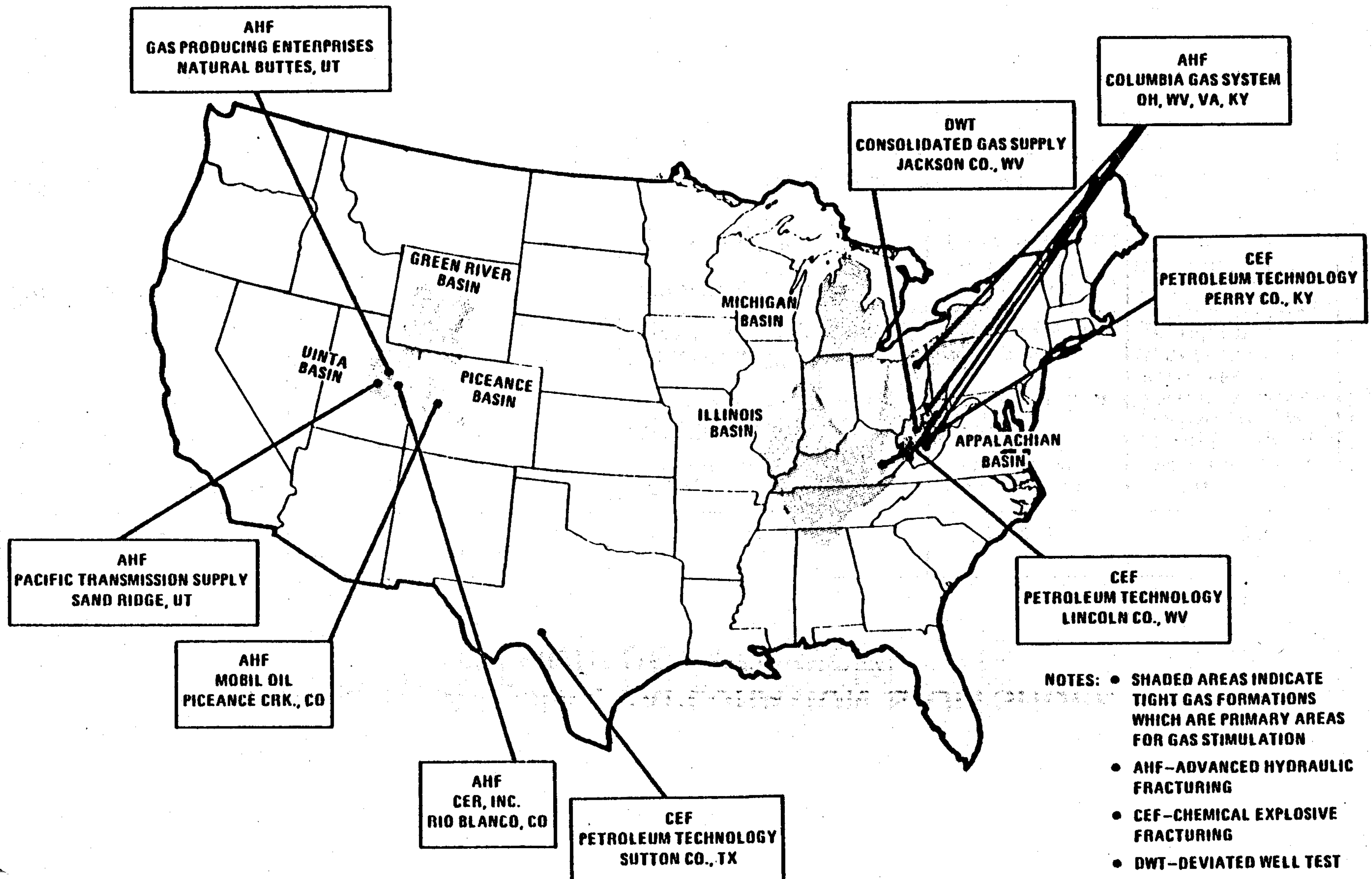
CURRENT MAJOR EGR CONTRACTS

PROGRAM	TOTAL FUNDING (MILLIONS)	GOVERNMENT CONTRIBUTION	PERFORMER	LOCATION	STATUS
MASSIVE HYDRAULIC FRACTURING	3.6	2.0	CER, INC.	RIO BLANCO CO., CO	FINAL TEST NOV 76
	4.3	2.1	COLUMBIA GAS SYSTEM, INC.	LINCOLN CO., WV	3 WELLS DRILLED; 3 OF 9 STIMULATIONS COMPLETE
	4.8	2.5	COLUMBIA GAS SYSTEM, INC.	OH, WV, VA, KY	DRILLING SELECTION
	7.0	2.2	GAS PRODUCING ENTERPRISE, INC.	NATURAL BUTTES, UT	2 WELLS STIMULATED; 10 REMAINING
	6.6	2.6	MOBIL OIL CORP.	UINTAH BASIN, UT.	DRILLING SPRING 77
	2.4	1.1	PACIFIC TRANSMISSION SUPPLY CO.	SAND RIDGE, UT	DRILLING OCT 76
CHEMICAL EXPLOSIVE FRACTURING	4.7	2.4	PETROLEUM TECHNOLOGY CORP.	1. PERRY, LESLIE, LETCHER COS., KY	STIMULATION NOV 76
			PETROLEUM TECHNOLOGY CORP.	2. SUTTON CO., TX	
			PETROLEUM TECHNOLOGY CORP.	3. LINCOLN CO., WV	
DEVIATED WELL TESTS	.8	.6	CONSOLIDATED GAS SUPPLY CORP.	JACKSON CO., WV	DRILL SITE SELECTION

POTENTIAL AREAS FOR GAS STIMULATION AND LOCATIONS OF ERDA CONTRACTS



CURRENT DRILLING, EXPLORATION & OFFSHORE TECHNOLOGY PROJECTS

PROGRAM	TOTAL FUNDING (MILLIONS)	GOVERNMENT CONTRIBUTION	PERFORMER	LOCATION	STATUS
DRILLING & EXPLORATION	4.00	2.00	TELECO, INC.	MIDDLETOWN, CT	INSTRUMENT DESIGN IN FIELD TESTS
	2.07	.99	GENERAL ELECTRIC	HOUSTON, TX	RESEARCH CONDUCTED
	.45	.45	SANDIA LAB	ALBUQUERQUE, NM	RESEARCH CONDUCTED
	.27	.27	TERRATEK, INC.	SALT LAKE CITY, UT	BIT AND ROCK SIZE DETERMINED
OFFSHORE TECHNOLOGY	.075	.075	GURC	HOUSTON, TX	FINAL REPORT PENDING
	.35	.35	SANDIA LAB	ALBUQUERQUE, NM	FINAL TRANSMITTER TESTING

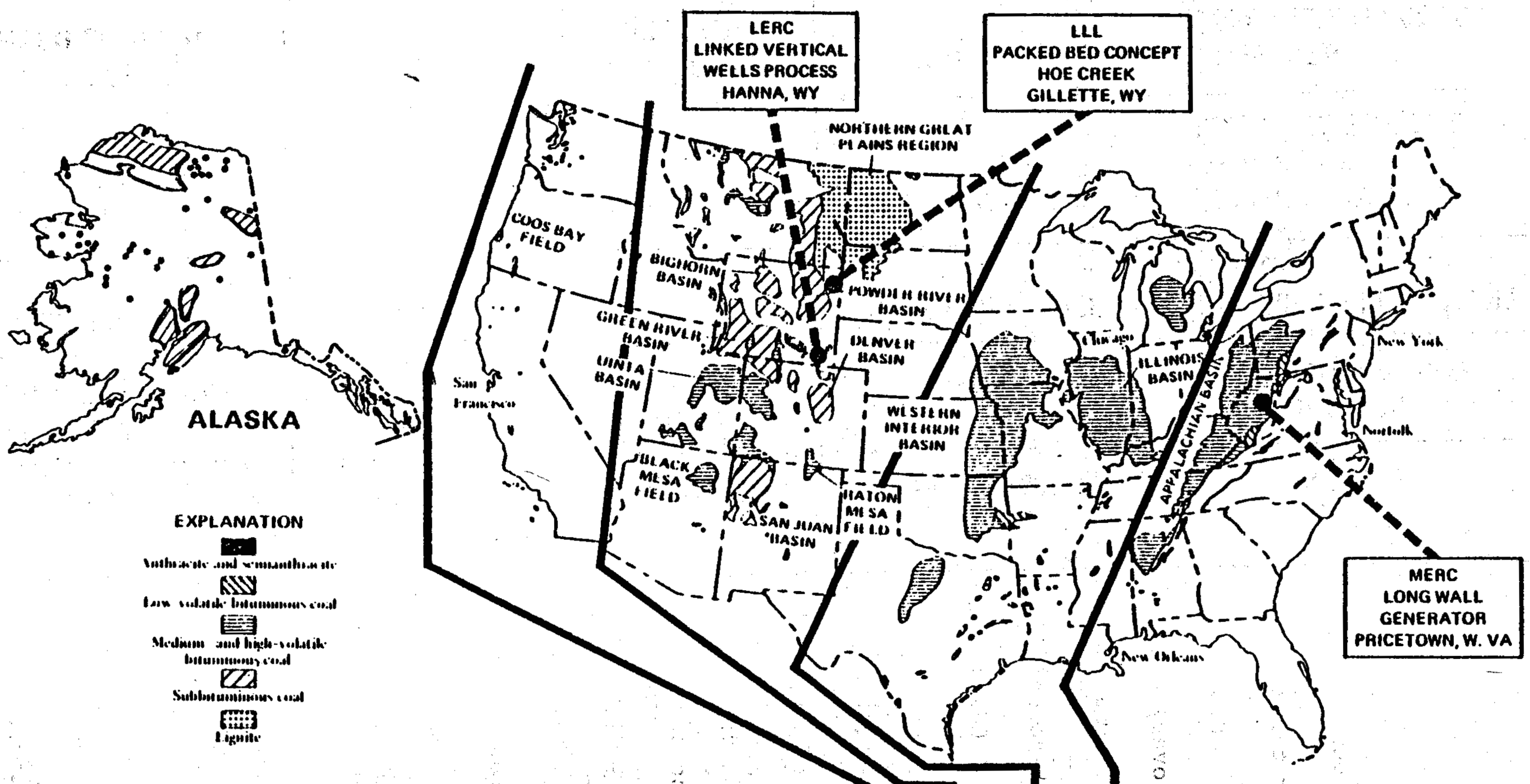
CURRENT MAJOR OIL SHALE PROJECTS WITH INDUSTRY

MAJOR PROJECTS	PERFORMER	LOCATION	STATUS
ANTRIM SHALE	DOW	MIDLAND, MI	4 YEAR CONTRACT AWARDED
TRUE IN SITU	TALLEY-FRAC	ROCK SPRINGS, WY	CONTRACT UNDER NEGOTIATION
SOLUTION MINING	EQUITY	RIO BLANCO COUNTY, CO	4 YEAR CONTRACT AWARDED
VERTICAL MODIFIED IN SITU	OCCIDENTAL	DEBEQUE, CO	CONTRACT UNDER NEGOTIATION
HORIZONTAL MODIFIED IN SITU WITH NOTICE-ABLE OVERBURDEN DISTURBANCE	GEOKINETICS	UINTAH COUNTY, UT	CONTRACT UNDER NEGOTIATION

CURRENT UNDERGROUND COAL GASIFICATION PROJECTS

PROJECT	FY77 FUNDING (MILLIONS)	PERFORMER	LOCATION	STATUS
LINKED VERTICAL WELLS (INTERMEDIATE, THICK)	3.3	LERC, SLA	HANNA, WYO.	TEST 3 ONGOING TEST 4 BEGINS SEPT.
PACKED BED (THICK)	2.7	LLL	HOE CREEK, WYO.	FRACTURE EXPERIMENT PLANNED
DEVIATED WELLS, LONGWALL (THIN)	1.0	MERC	PRICETON, W. VA.	PRELIMINARY TEST DESIGNED—WILL BE FIELDED IN THE FALL
DIPPING & DRY BEDS & ADVANCED CONCEPTS	1.2	ANL, ORNL, LASL, UNIV INDUSTRY	VARIOUS	RFD ISSUED RESPONSE EXPECTED 7/1

COAL FIELDS OF THE CONTERMINOUS UNITED STATES (8), (9), (10)



TOTAL COAL TO 6000 FEET (BILLIONS OF TONS):	2,029	103	3,263	620	352 - 6,367 TOTAL
ESTIMATED UCG RESOURCE (BILLIONS OF TONS):	640	15	920	140	80 - 1,795 TOTAL

*DIVIDE THESE NUMBERS BY 1.1 TO OBTAIN TONNES.

all of our technologies involve some kind of permeability enhancement, usually through fracturing.

Surface chemistry, very basic, particularly to our enhanced oil-recovery program.

Thermodynamic properties of fluids applies primarily to EOR, but secondarily to enhanced gas recovery.

Reaction kinetics is important in underground coal gasification.

Oil shale in situ retorting and gasification and thermal methods of enhanced oil recovery.

And, of course, environmental quality and reactions, the reactions part of which includes the environmental R&D, as distinguished from environment-compliance activities.

That's a rather rapid rackup, ladies and gentlemen. I think I've stayed within my time, to allow time for any questions.

DR. PHILLIPS: Thank you.

This talk is open for comments and discussion. Yes. Give your name, please.

MR. HILL: George R. Hill.

Do you have any work going on in safety in production, offshore drilling, preventing oil spills?

Is that in your bailiwick at all?

MR. WATKINS: Preventing oil spills is not; the prevention of and cleanup of contamination of oil spills is considered to be a province of the Coast Guard. We are doing work on oil identification from which you might be able to identify the source of an oil spill upon water from knowing the --

MR. HILL: -- depending upon a technique development to prevent it?

MR. WATKINS: Right. In safety, our work is only peripheral and it's very largely done in cooperation with our division of ESP, environmental and socioeconomic programs and in Dr. Liverman's shop. But we are becoming more interested in safety in our production and stimulation operations, yes.

DR. PHILLIPS: Dr. Holloway.

DR. HOLLOWAY: Holloway, from Exxon. What limits the amount of basic research you do in universities? And a related question, is it possible it's too small by an order of magnitude?

MR. WATKINS: In answer to your question, the only thing that limits it is the amount of supporting research that we feel we need to be viable with our applied research programs. Perhaps we do need more. I wouldn't say by an order of magnitude. My own opinion is that in the properties of mycellar and polymer chemicals, for example, we probably have all going on that is necessary to support our program.

Conversely, in the area of carbon dioxide and some of the other things, perhaps we don't have enough. So, there is nothing to prevent our program being higher. If fact, it has been increasing year by year and very possibly it should be quite a bit higher than it is at present.

DR. PHILLIPS: If I might take the Chairman's prerogative --

MR. WATKINS: Surely.

DR. PHILLIPS: I note there is nothing here on this list, sir, about instrumentation.

It would seem to me that in the in situ world that your group lives in, instrumentation for knowing what is going on down there must be very important.

MR. WATKINS: Oh, it is. It is, indeed.

DR. PHILLIPS: Can you say something about that?

MR. WATKINS: Yes. We have a very appreciable instrumentation effort being conducted primarily at Sandia Laboratories. This is instrumentation to determine what is happening in our in situ oil-shale retorting tests and in our underground coal gasification, as well as being applicable to enhanced gas recovery, where we are doing massive hydraulic fracturing and/or chemical-explosive fracturing. This is an appreciable effort. I don't know how much of it was racked up into the basic-research category that I came up with or the total figures, but part of it is instrument development and part of it, of course, is instrumentation for support of the project. But we are very cognizant of this.

DR. PHILLIPS: Miss Fox?

MS. FOX: Phyllis Fox. You stated that your activities were confined strictly to in situ. Are there any activities at all in the area of surface retorting of oil shale?

MR. WATKINS: At present, no Phyllis, except where our supporting, basic research and environmental research might be applicable to above-ground, as well as under-ground processing. There is, certainly, some overlap there. Now, we don't know what is going to happen in FY '79. We are trying to get an initiative into the budget for research on advanced above-ground retorting processes, but from here to OMB to the Congress is a long hard road, you know.

DR. PHILLIPS: If there are no other questions, we thank you, Mr. Watkins, and proceed with the meeting.

I will call next for Fred Holzer and his talk on In Situ Research.

MR. HOLZER: My purpose here is to describe to you very briefly the kind of in situ research being done at the national laboratories, to the best of my ability. But I really can't do that without also talking at some length about the work being done at the energy research centers.

Much of the work that I will describe is interdisciplinary in nature, with lab and field work - both theoretical and computational - and much of it has also been done by industry.

Most of the work that I will describe is being done at the Los Alamos Scientific Laboratory, the Lawrence Livermore Laboratory, Sandia Laboratory at Albuquerque, the Laramie Energy Research Center, and the Morgantown Energy Research Center. And if I am slighting those or others, please forgive me.

Let me start with my own definition of in situ research --

(Vugraph #1)

-- the study of underground processes leading to a conversion of a solid into either a gas or a liquid. I've restricted myself to coal gasification and shale oil from oil shale, although I would like to point out that in situ methods can have much wider application than that. For instance, a very active industrial process is now being carried out in uranium leaching in situ and recovery of oil from tar sands and heavy oil; some tar sand work has started at Laramie.

The motivation for this work is shown on the next vugraph.

(Vugraph #2)

Aside from the tempting targets of very large resources are the potential advantages of being cheaper and quicker with less environmental impact, and last, but perhaps not least, the potential for recovering those kind of resources which seem very difficult, if not impossible, to attack by conventional techniques at this time. I am primarily referring to the deep, low-grade resouces.

I would like to concentrate on two examples.

(Vugraph #3)

IN SITU RESEARCH IN COAL AND OIL SHALE

DEFINITION

THE STUDY OF UNDERGROUND PROCESSING METHODS IN WHICH CHEMICAL REACTIONS ARE INITIATED AND SUSTAINED IN A PREPARED VOLUME OF COAL OR SHALE, LEADING TO THE PRODUCTION OF A GAS (OF USEFUL ENERGY CONTENT) OR LIQUID PETROLEUM FROM THE ORIGINAL SOLIDS.

MOTIVATION

1. POTENTIALLY AN ALTERNATIVE TO MINES AND SURFACE PLANTS.

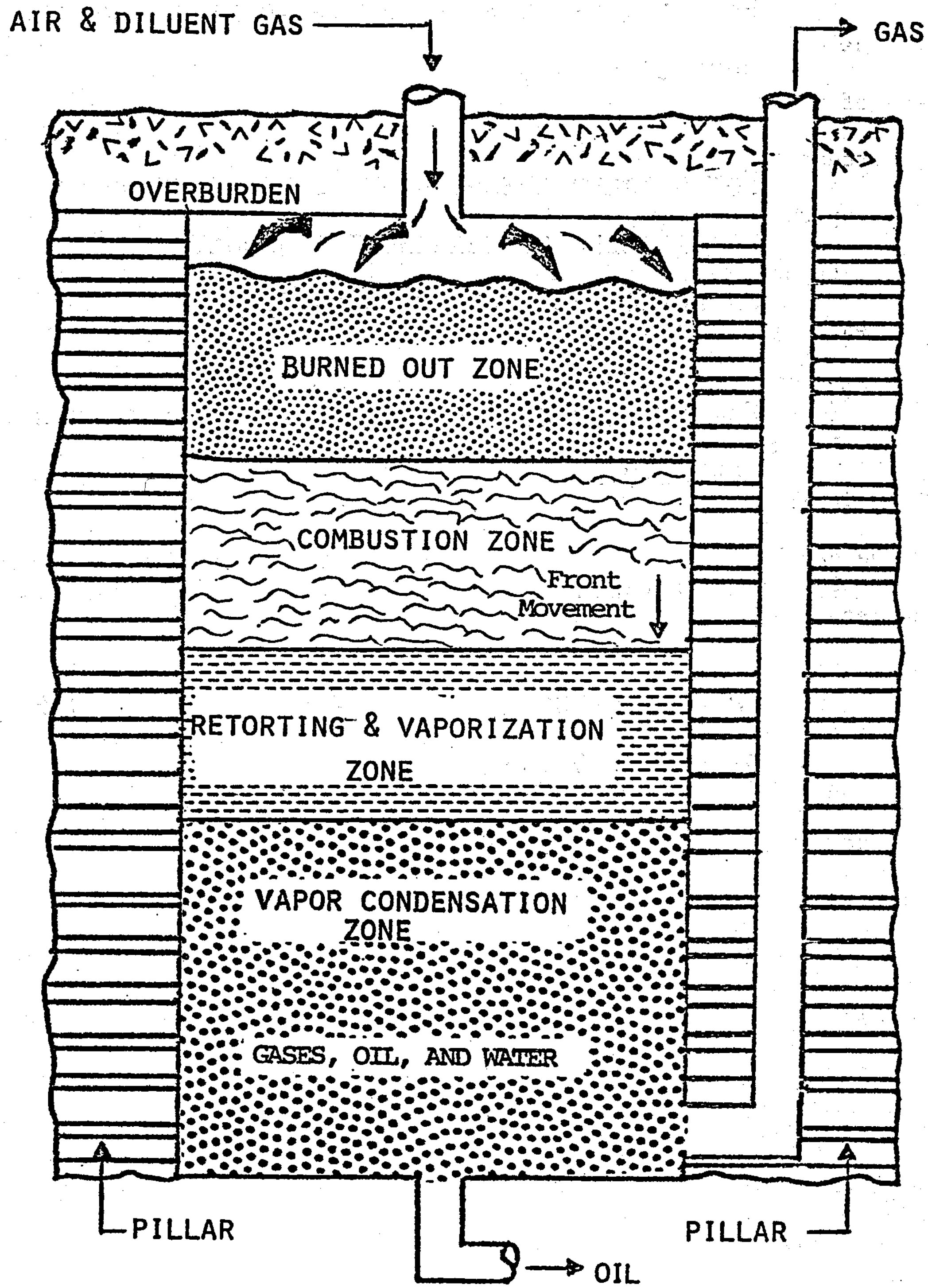
2. POTENTIALLY CHEAPER, BY ELIMINATING OR DRASTICALLY DECREASING THE AMOUNT OF MATERIAL THAT MUST BE HANDLED.

3. POTENTIALLY QUICKER, SINCE NO LARGE PLANTS ARE REQUIRED.

4. POTENTIALLY LESS ENVIRONMENTAL CONSEQUENCE.

5. POTENTIAL FOR MAKING DEEPER DEPOSITS, LOWER GRADES RECOVERABLE.

IN SITU OIL SHALE RETORTING



This first one is the so-called modified in situ retorting of oil shale. It requires the physical removal of about 10 to 20 percent of the volume to be retorted and the redistribution of this 10-20 percent an interstitial void between the particles after breaking up the remaining 80-90 percent of the rock.

Beyond that, the concept envisions a vertical retort similar to what might be carried out on the surface, with air injection at the top and gas and oil recovery from the bottom.

I might just point out that the amount of low Btu gas involved in in situ retorting of shale is a very large amount; if its Btu value can be kept steady and high enough, the gas can be utilized to generate electricity at the mine.

The second example --

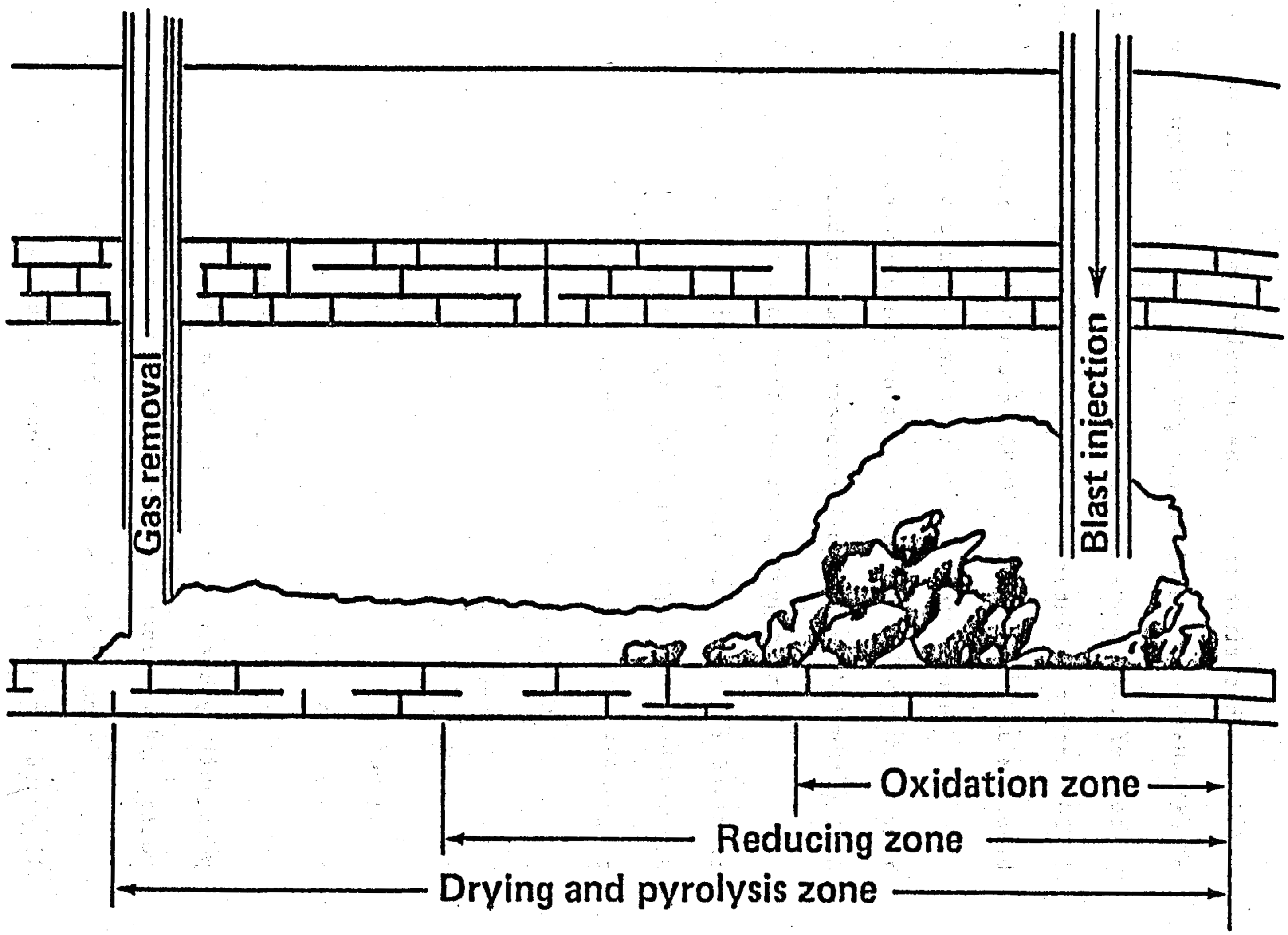
(Vugraph #4)

-- is the in situ gasification of coal, primarily of flat-lying beds. Here again there are a number of versions; some for instance, deal with steeply dipping beds.

I'm going to primarily talk about the method in which a low permeability channel is created by one means or another between two wells, and the coal between them is then gasified.

The in situ work on oil shale probably began between 10 to 15 years ago with its prime proponents being the Lawrence Livermore Laboratory and the Laramie Engineering Research Center. Coal gasification is a very much older subject, first suggested in the last

REVERSE COMBUSTION OF FLAT LYING COAL BEDS



century, and in 1931 it was started on a research basis in the Soviet Union. The Soviet Union has, in fact, put this technology on a commercial basis, starting in the late '50s or early '60s and is still operating three fairly sizable projects in in situ underground coal gasification.

In this country, while there has been sporadic effort following World War II, probably only in the last six or seven years has any sizable effort taken place.

(Vugraph #5)

The barriers to this type of work, of course, are many. The primary one, perhaps, is that up to now, with our resource and reserve availability, there has been no overriding need for it.

And it is difficult. It is difficult to adjust knobs and read meters, when you're dealing with processes underground.

Of course, all of these things, as you may have guessed and I am sure know, add up to higher costs.

I would like to guide you through a few of the items here to show you the status of these selected technologies and indicate the need for future work.

(Vugraph #6)

This vugraph shows the major research topics we believe need to be addressed. A good number of them are being addressed in developing these technologies.

BARRIERS

1. UP TO NOW LITTLE NEED IN THE U.S., AND VERY LITTLE EXPERIENCE WITH UNDERGROUND CHEMICAL ENGINEERING.

2. METHODS FOR DEPOSIT PREPARATION ARE STILL IN EARLY STAGES OF DEVELOPMENT, AND MUST BE INVESTIGATED ON A LARGE SCALE IN THE FIELD.

3. REMOTE MEASUREMENT AND CONTROL OF THE REACTION PROCESS IS NEEDED.

4. MANY OF THE RELEVANT PROPERTIES OF COAL AND OIL SHALE ARE ONLY NOW BEING DETERMINED.

MAJOR RESEARCH AREAS & TOPICS

LABORATORY EXPERIMENTAL RESEARCH

- REACTIONS, KINETICS, ANALYSIS
- LAB-SCALE RETORTING

LABORATORY CALCULATIONAL RESEARCH

- BED/DEPOSIT PREPARATION
- PROCESS MODEL

FIELD EXPERIMENTATION

- DEPOSIT CHARACTERIZATION
- DEPOSIT PREPARATION
- INSTRUMENTATION
- PROCESS EVALUATION

I'd like to add one word to those brought out by some discussion, particularly the environmental aspects. I personally quite firmly believe that research in the environmental aspects has to go hand in glove with, and at the same time as, research in the basic technology. I think doing one without the other is not very productive.

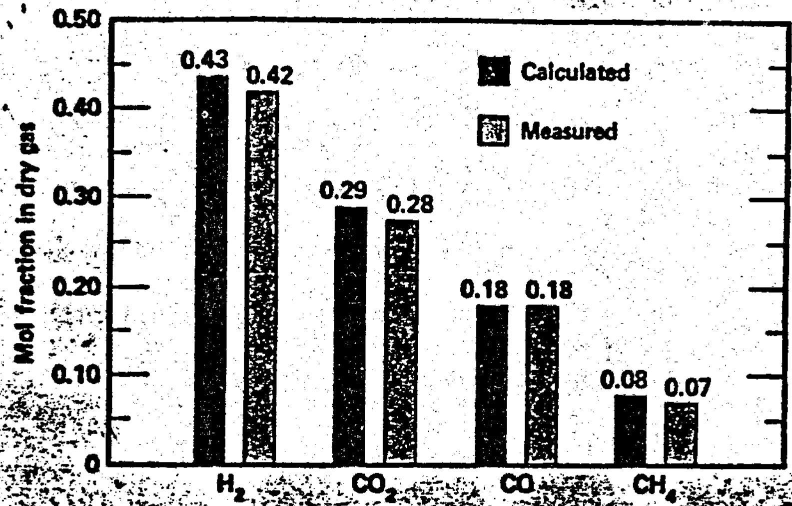
(Vugraph #7)

This vugraph, then, shows some of the coal reactions, both coal and char, with air, oxygen, steam, in the various temperature regimes of gasification, pyrolysis and drying, that go on when a temperature wave, which now is fairly broad, moves through a coal deposit.

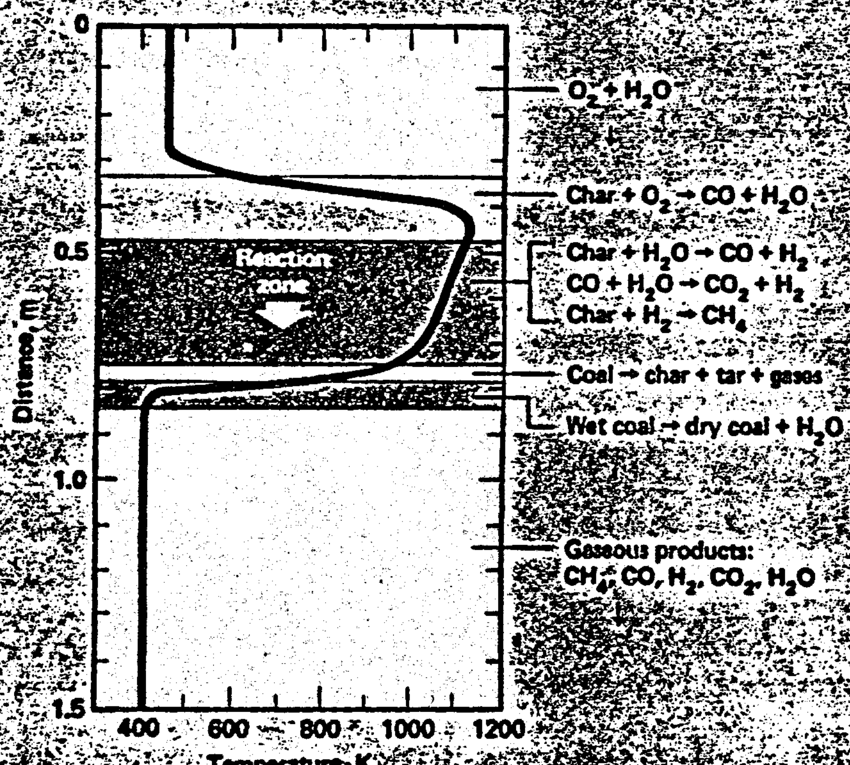
A very similar graph shown on the next vugraph holds true for oil shale.

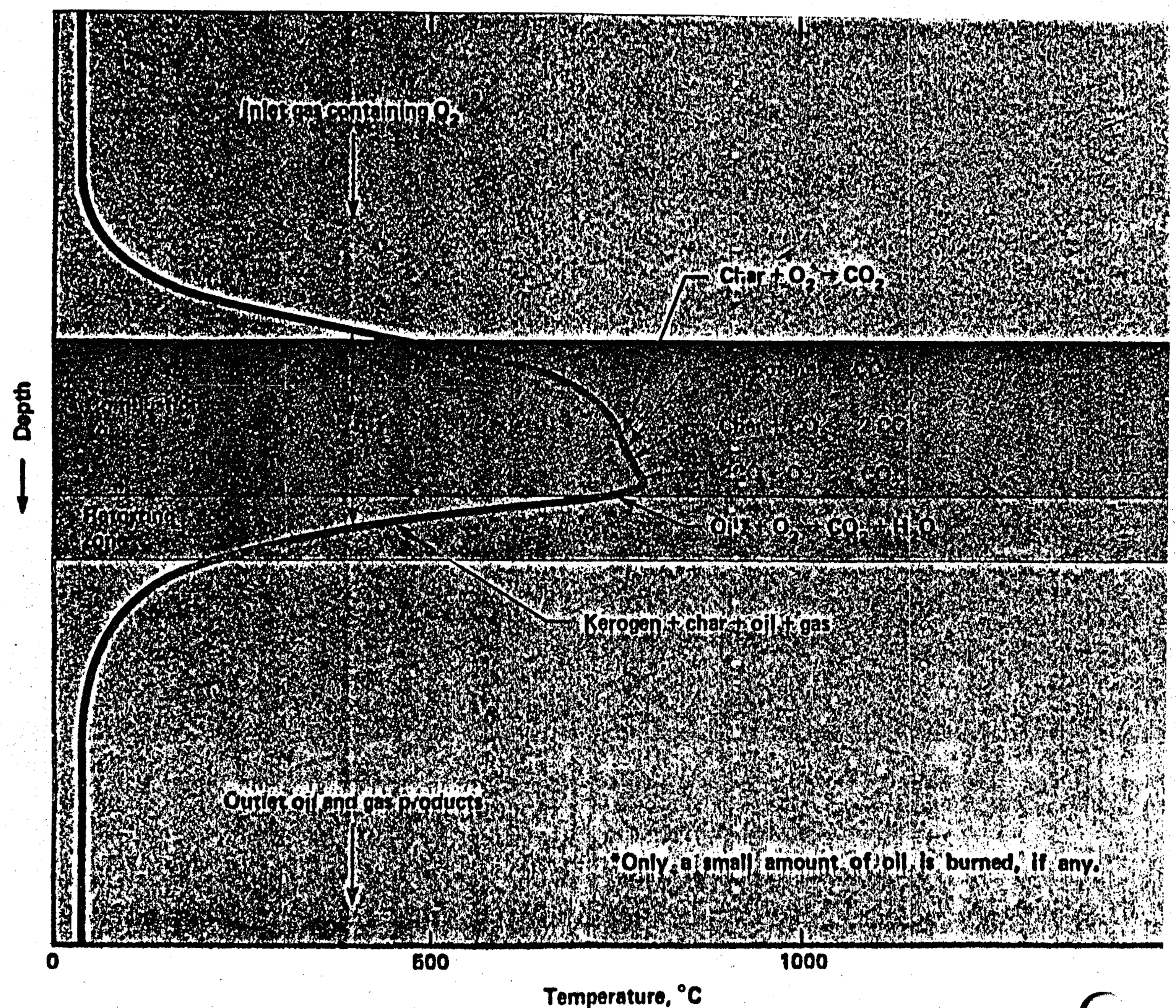
(Vugraph #8)

Again, pointing out the very close relation between these two subjects, I might point out that the reactions in shale are considerably more complex than the ones that we're dealing with in coal. Not only do you have to deal with the decomposition of kerogen in oil shale, but subsequently, you have to deal with the reactions of the carbonate material left behind in the rock which makes up most of the shale. The reactions of carbonates with water vapor, carbon dioxide, and carbon monoxide, particularly in the presence of very finely divided silica, is something that is not at all well-undersood.



Calculated and experimental gas quality





Inlet gas containing O2
Char + O2 → CO2
Oil* + O2 → CO2 + H2O
Retorting zone
Kerogen → char + oil + gas
Outlet oil and gas products
*Only a small amount of oil is burned, if any.
Depth
0
500
1000
Temperature, °C

There is a very strong suggestion now from the work that has been done that these reactions are really much more important than people have perhaps realized.

A good part of experimentation, aside from purely analytical, kinetic, and reaction chemistry is something that I might like to call macroscopic experiments, and is done in controlled and instrumented retorts.

Big pressure vessels can be instrumented and controlled rather closely. These vessels span the spectrum of sizes.

(Vugraph #9)

This shows two very large ones in operation at the Laramie Energy Research Center for oil shale; the larger one of the two is able to handle 150 tons of shale.

(Vugraph - photo not available)

The next vugraph shows a much more modest one that Lawrence Livermore Laboratory uses to study reactions in coal; here the instrument cables are disconnected and the thing rides on trunnions for easier loading.

Data from both the material properties and the retorts are integrated into a computational framework, a model if you will, which serves to determine the sensitive variables, to plan retort experiments, to establish design criteria, and to optimize and control in situ retorting designs.

The 10-Ton and 150-Ton Oil Shale Retorts

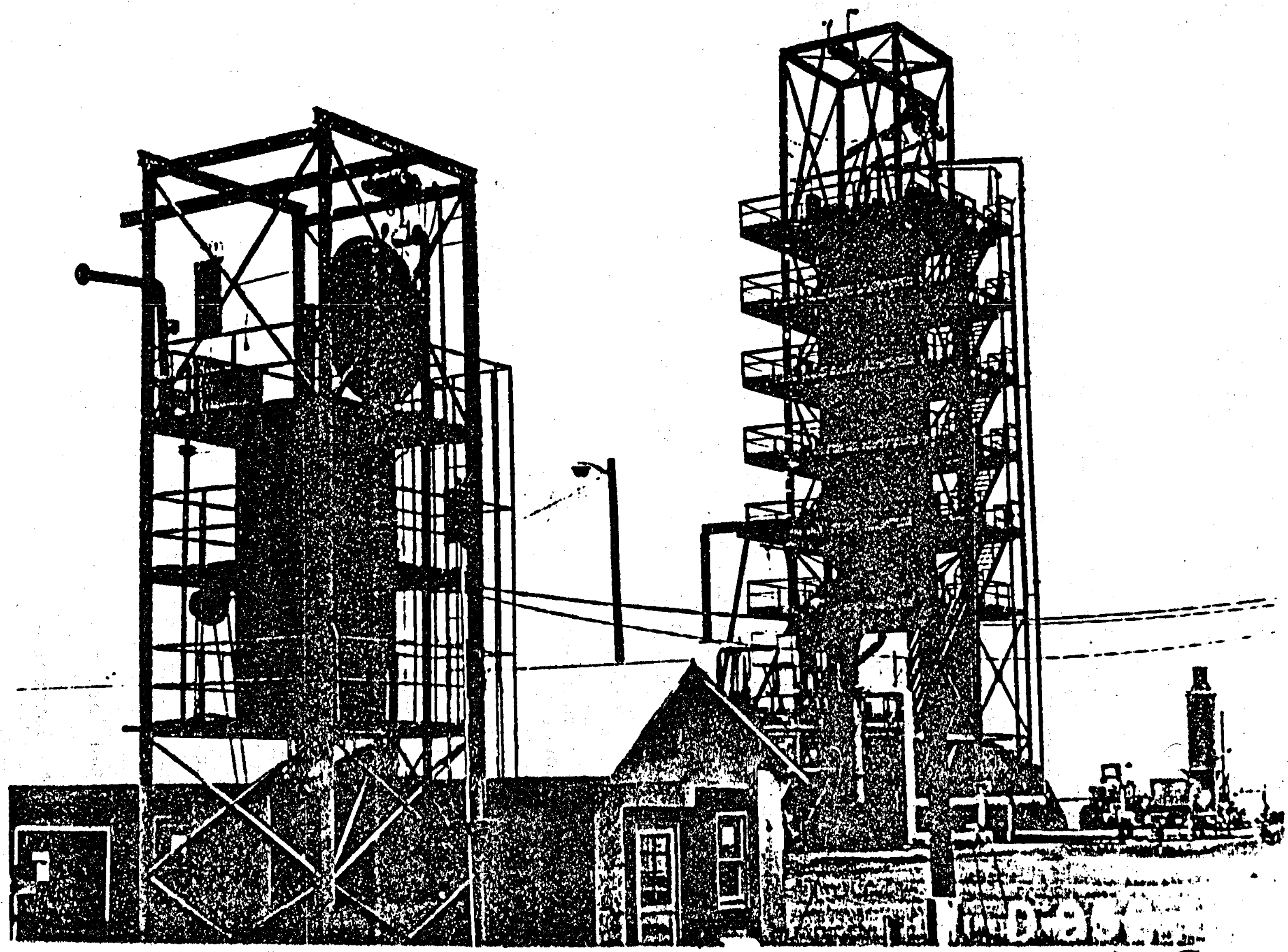


Photo provided by the Bureau of Mines

(Vugraph #11)

This vugraph shows a conceptual schematic of a central role that I believe, we will see these rather complex computer-based models take on in the near future.

Just to give you some idea of what is in some of these models that are in operation, the next vugraph lists the contents of an oil shale retort in operation at the Lawrence Livermore Laboratory at this time.

(Vugraph #12)

It includes hot gas and combustion retorting and takes into account particle size distribution, temperature compositions, flow rates, end yields as an output, and not only oil yield and rate of recovery, but the details of temperature, pressure, and composition within a retort during the retorting cycle.

This particular model is still in the process of being added to and developed, and the next vugraph--

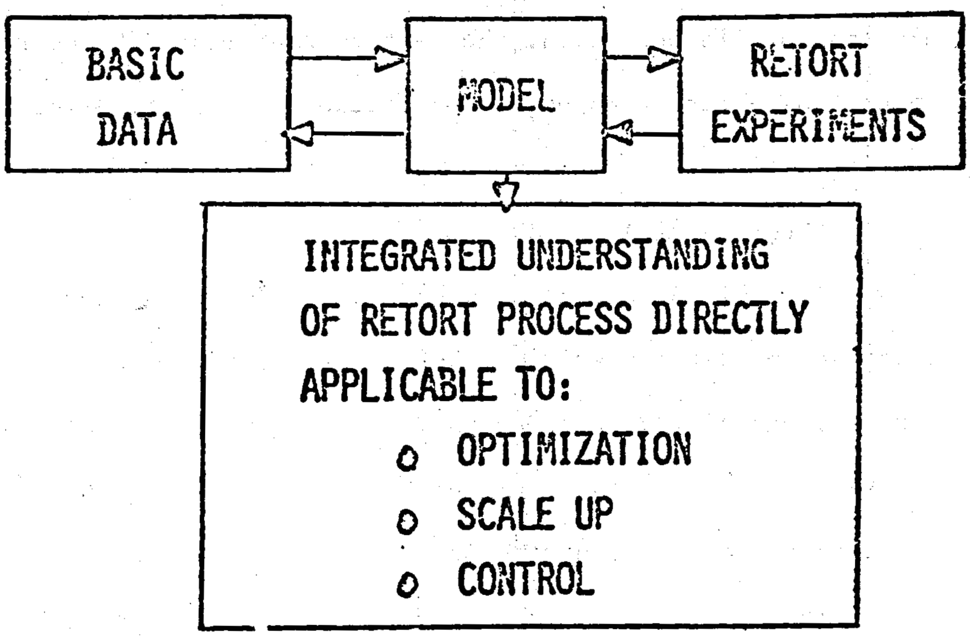
(Vugraph #13)

--depicts the need for further development of this type of model.

Just to give you an example of the kind of output that a model like that can produce, this next graph shows the temperature front as it is calculated to exist after passing some 40 meters downward into an in situ retort for two rather distinct particle sizes differing by an order of magnitude.

RETORTING - EXPERIMENTAL APPROACH

APPLIED RESEARCH



SCOPE OF PRESENT OIL SHALE RETORT MODEL

- One-dimensional model
- Hot-gas retorting and combustion retorting
- Shale particle size distribution
- Temperature and composition of shale particles
- Temperature, composition, and flow rate of gas stream
- Oil yield, rate of oil recovery, and rate of water recovery

FURTHER DEVELOPMENT OF MODEL

- Improvement in the numerical methods
- Improvement in the values of the sensitive chemical and physical properties
- Inclusion of additional gas and solid components
- Variations of initial bed properties in axial direction
- Chemical reaction of water with carbon residue
- Change of bed permeability due to softening of high-grade oil shale or due to accumulation of high-viscosity oil
- Loss of gas or heat to surroundings
- Water intrusion from surroundings
- Sweep efficiency of input gas

(Vugraph #14)

I think you can see that the smaller particle size distribution undergoes considerably different reactions and reaction rates than the larger ones.

In practice, of course, depending on how one prepares the deposit, which is a separate topic in itself, one might find an average or the situation peaked towards one or the others.

I've mentioned that an important, and I believe vital, component in this kind of business is field experimentation.

Let me take you very quickly through the status of some of these field activities.

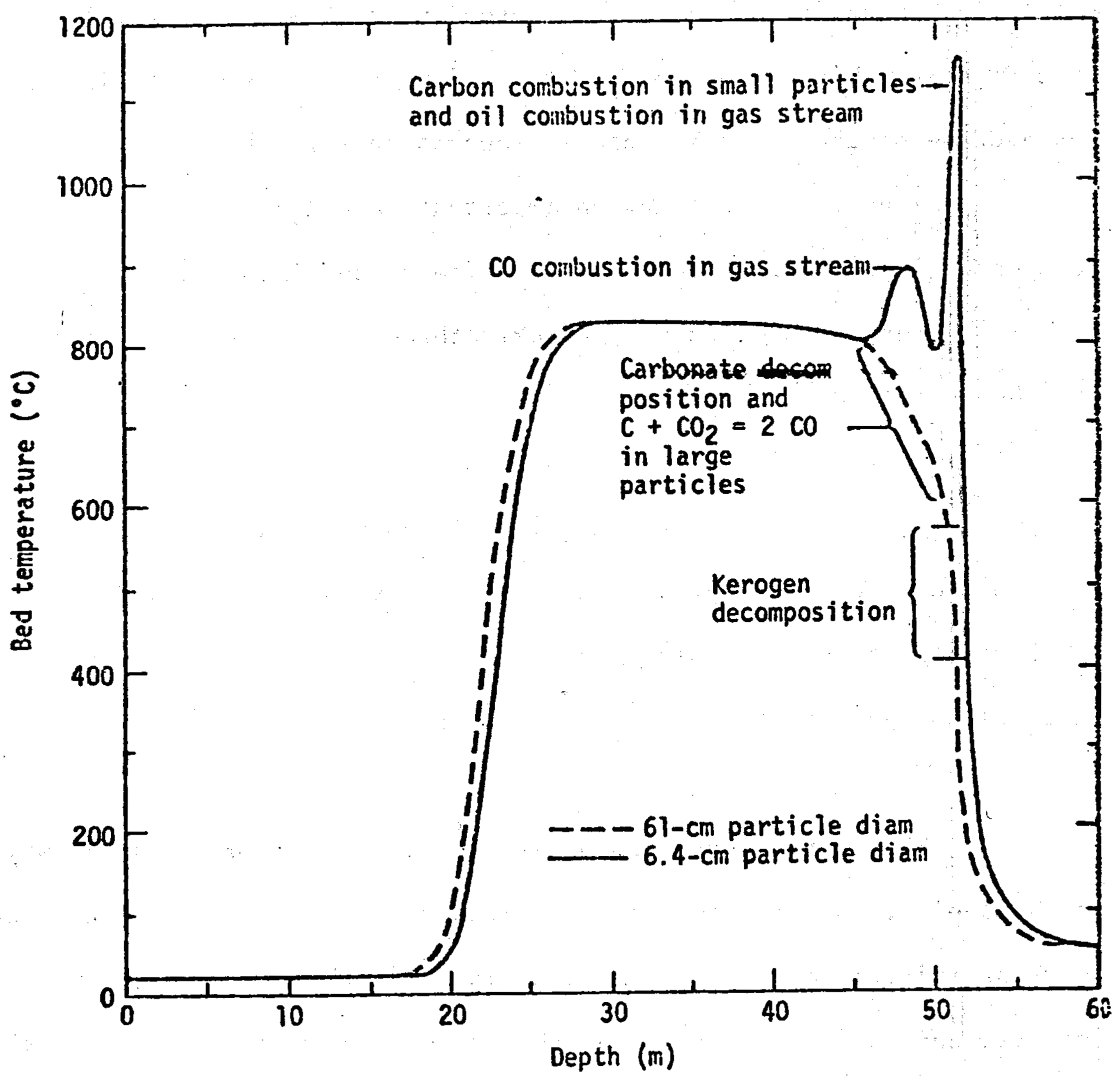
(Vugraph #15)

Here I show you a plan view of isotherms as a function of time, of what I believe is the most successful underground coal gasification experiment conducted to date, the one by the Laramie Energy Research Center near Hanna, Wyoming.

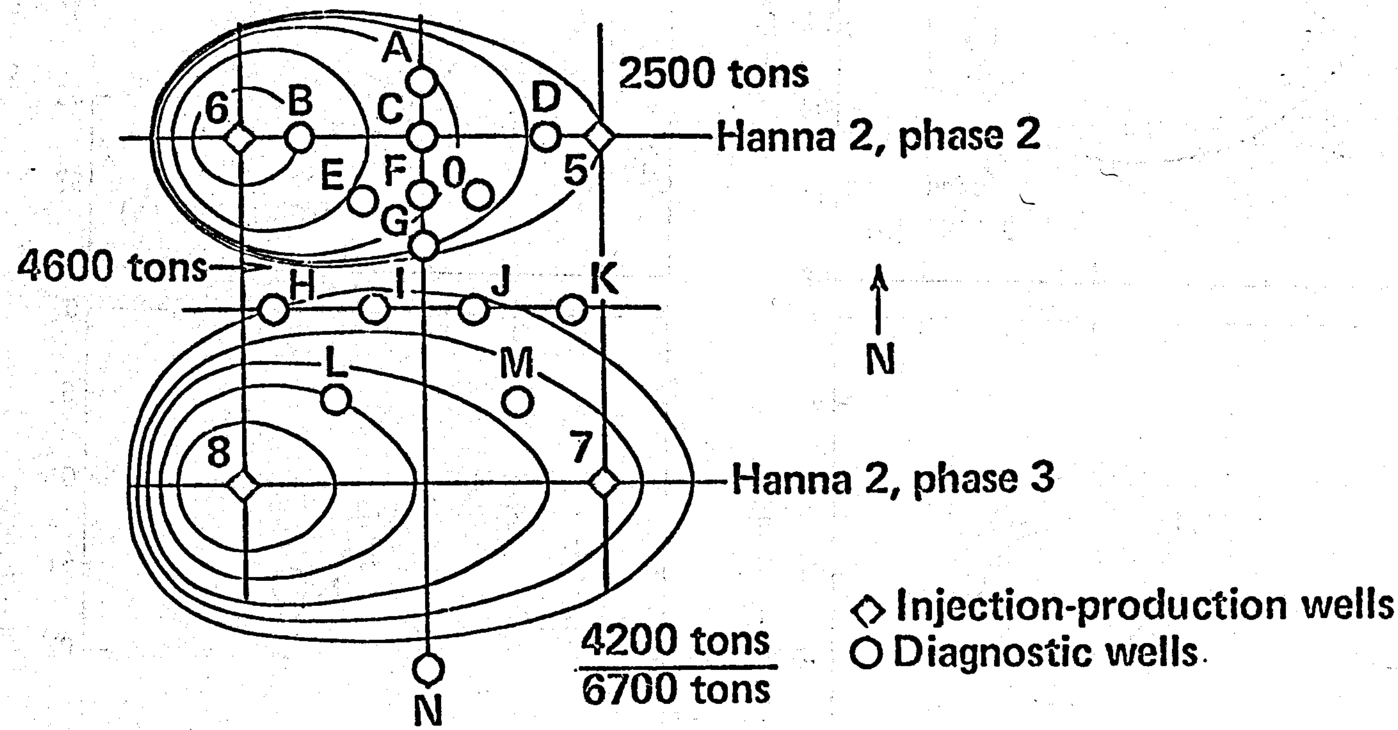
(Vugraph #16)

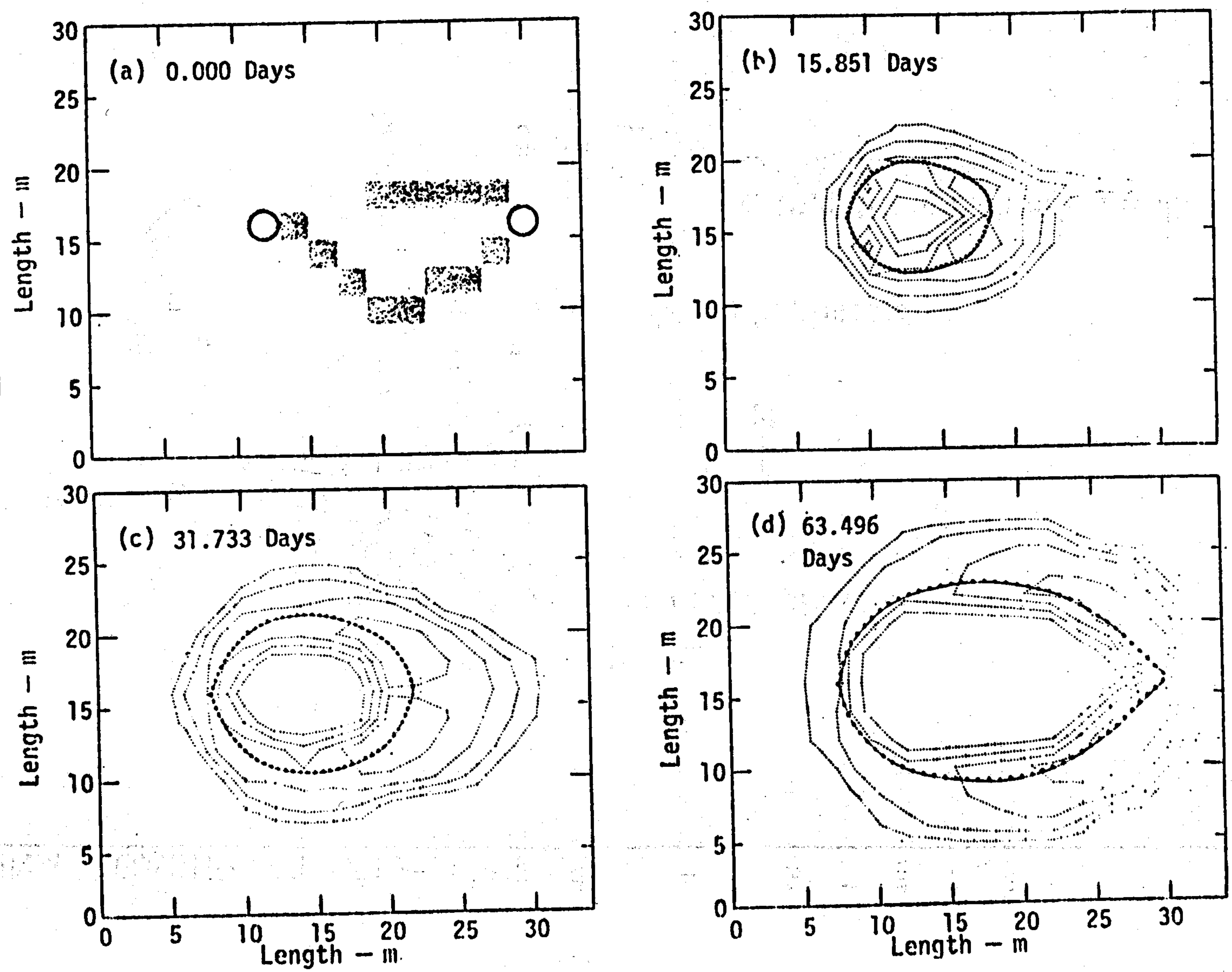
The next vugraph again depicts what can be done in the way of a model; these are model calculations of those isotherms, starting with an initial channel geometry, depicted in the upper left-hand square, and you can see that the channel was not very straight. It's determined by the initial permeability distribution of the material, and it is a credit to the instrumentation developed primarily by the Sandia Laboratories to even elucidate where that channel was.

ESTIMATED TEMPERATURE PROFILE FOR AN IN SITU RETORT WITH AIR INPUT



HANNA II GASIFICATION PATTERNS





(a) 0.000 Days
(b) 15.851 Days
(c) 31.733 Days
(d) 63.496 Days
Length — m
0
5
10
15
20
25
30

(Vugraph #17)

In this vugraph I attempt to list some of the instrumentation that has been employed at Hanna, as well as at other sites. Instrumentation consists of primarily two kinds. One, simple and practical instrumentation of temperature, pressure, gas composition, and the other, remote monitoring instrumentation, in which acoustic, seismic, as well as electrical systems, are used.

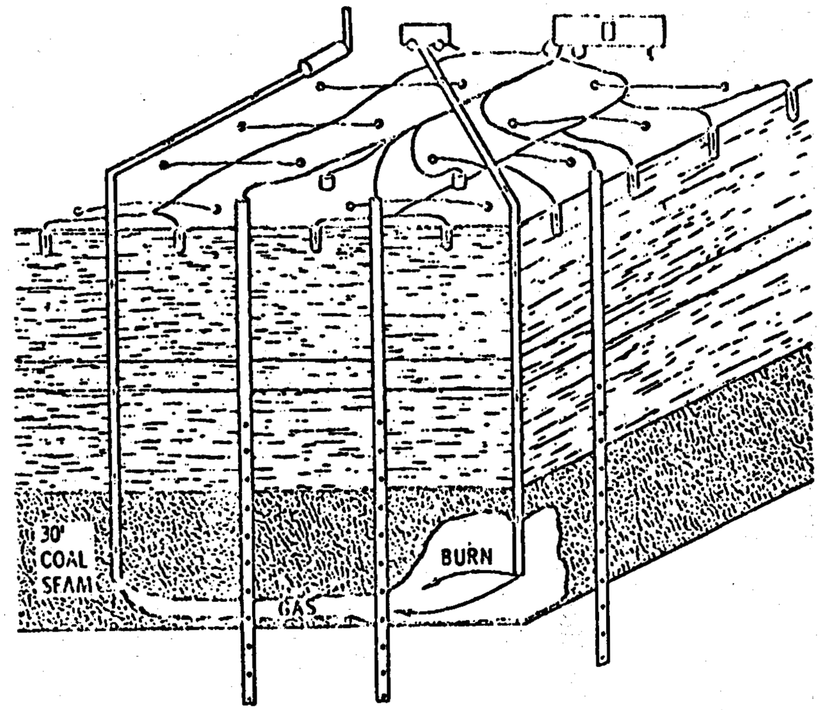
It is especially those latter ones that I personally feel need to be developed and pushed very vigorously, not only for their obvious utility in these experiments, but as we go deeper, measurement becomes more expensive and difficult. For a number of reasons, we need to look beyond the borehole, and I think mention has already been made of the Devonian shale problem, in which fractures beyond the borehole may be a key to the efficient recovery of gas from the resource.

I know I have left out many items and topics. However, let me just conclude by giving a summary of the research needs and opportunities, as I see them.

(Vugraph #18)

I have talked very little, as you can tell, about deposit preparation which entails the science of rock mechanics, both in the fragmentation aspect and the stability and subsidence aspect. There is a great deal more to be done in field instrumentation and field experimentation.

INSTRUMENTATION AND PROCESS CONTROL DEVELOPMENT FOR IN SITU COAL GASIFICATION



PARTICIPATION ON LERC TESTS:

Hanna I		1973-74
Hanna II	ϕ1	1975
Hanna III	ϕ2, 3	1976
Hanna IV		1977-78
Hanna V		1978-79

6-77

REMOTE MONITORING INSTRUMENTATION - PROCESS MAPPING

Electrical Potential
Electrical Resistivity
Induced Seismic
Passive Acoustic

DIAGNOSTIC INSTRUMENTATION - PROCESS UNDERSTANDING

Temperature
In Seam Gas Sampling and Pressure
Subsidence: Tilt and Displacement

ACCOMPLISHMENTS:

- Thermal Data/Analysis Provided Excellent Process Description
- In Seam Gas/Pressure Methods Proven Feasible
- Acoustic Emission Mapped Overburden Subsidence
- Electrical Techniques - Contour Maps of Changing Process
- Induced Seismic - Delineate Process Boundaries

SUMMARY OF TOPICS IN NEED OF FURTHER WORK

Material Behavior

- MECHANICAL PROPERTIES
- CHEMICAL REACTIONS AND KINETICS

Deposit Preparation

- RUBBLIZING, CHANNELING
- STABILITY, SUBSIDENCE

Process Models

- SENSITIVITY OF VARIABLES, FLUID INFLUX
- RETORT OPERATION, OPTIMIZATION

Instrumentation

- DEPOSIT CHARACTERIZATION
- PROCESS MONITORING

Field Experimentation

- OIL SHALE FIELD EXPERIMENTS
- STEAM-OXYGEN COAL GASIFICATION

We really have not had a good oil shale field experiment, although there have been one or two industrial experiments. But the information from those experiments is not available.

In the coal gasification area, even though things look exceedingly promising, much work needs to be done in trying to tailor a linkage between two wells, rather than let nature dictate what this linkage looks like, and work is proceeding on high explosive development, including shaped charge development. In order to upgrade gas energy content, gasification with steam and oxygen, instead of just air, seems a very promising and certainly indicated approach.

Thank you very much.

(Applause)

DR. PHILLIPS: Thank you, Fred.

DR. PHILLIPS: The Floor is open for comments and discussion. Yes, Dr. Smith?

DR. SMITH: Roland Smith, General Electric. You and the previous speaker both mentioned the work I believe Sandia is doing on instrumentation. How much of this instrumentation is applicable to, say, a commercial operation, as opposed to development operations, and how do you anticipate getting that information transferred to industrial use?

MR. HOLZER: I believe a good bit of that is applicable to commercial operation. Clearly, one would not want to go with the experimental type of instruments. I personally believe that one must go with the most reliable ones, which, at the present time, are thermocouples, although the emplacement of sufficient thermocouples which, after all, only measure the situation and temperature at any one specific point, has its obvious limitations.

I think, however, it is absolutely necessary for control and monitoring of an underground burn in order to know when to increase the flow rate, when to decrease it, and when to change the mixture of gases. In oil shale retorting, for instance, one has the liberty of changing the oxygen concentration or adding nitrogen, or water, in the form of steam.

I feel quite confident that all of the government installations having experience and capability in instrumentation (and that does not just include Sandia, of course) stand ready to transfer this experience and knowledge to industrial companies. And there is a very good base already there. There are a number of industrial companies that, with very little additional experience, would be very capable of doing this. EG&G is one company that comes to mind, and I know there are others.

DR. PHILLIPS: Yes.

DR. NELSON: Nelson. I presume this illustrates a lack of knowledge about the techniques that, in some degree, control the temperature in your in situ retorted shale oil; is that right?

MR. HOLZER: To some degree, yes.

DR. NELSON: That being the case, I would anticipate that the kind of problems are whether the carcinogens to be formed in the various cracking will vary in accordance with the temperatures.

Is there an orderly postured program to characterize these components? In other words, are you exploiting this present pilot stage to get that additional information?

MR. HOLZER: Yes, I think there definitely is. Whether it is of the same order in all experiments, I can't really tell you; I suspect it probably is not. But I do know that analysis for organic materials, things like phenols, and so on, are being analyzed and, in fact, the next experiment that the Laramie Research Center is carrying out at Hanna is specifically slanted towards the environmental monitoring. I know the Lawrence Livermore Laboratory in their coal gasification experiment near Gillette, Wyoming, has monitored phenols and particularly their transport in the groundwater system around the experimental site.

DR. NELSON: These are not carcinogenic, per se.

MR. HOLZER: You're correct.

DR. PHILLIPS: I would like to return to the first question on instrumentation. I think that those of you that know the history of one of the predecessor organizations of ERDA, AEC, know that out of AEC - in fact, the high energy physics program and nuclear physics program - came a line of instrumentation called KEMAC, and many factories across the nation and the world use that type of instrumentation.

I am sure you have a lot of NIM and KEMAC instrumentation in your hospital Dr. Nelson.

So this is a sample of the crosscutting technology that came out of the field that can certainly help other fields, as well.

Are there other comments or questions?

MR. HOLZER: One more question, I think.

MS. FOX: Phyllis Fox. Phil White, this morning mentioned some of the problems that may be associated with the intrusion of groundwater into abandoned in situ retort chambers. Do you have any research program in the area of identifying the impacts of these abandonments in in situ retort chambers - how the groundwater reacts, both on the short-term and long-term?

MR. HOLZER: You must realize that there are very, very few of the in situ reorting volumes in existence at this time, and they certainly have not been in existence for very long. So the long-term question is a very difficult one to answer. But, yes, indeed, these sites are being monitored by both gas and liquid withdrawals from wells around here, and analyzed for organic, as well as inorganic substances. And I might add, in that respect, ERDA, and the AEC previously, have a very long history of not walking away from those kinds of sites. I know we are monitoring similar experimental sites that were done 15 years ago.

MS. FOX: Have you thought about and anticipated what types of control technology might be utilized if a problem is identified, of which significant environmental impact could be expected?

MR. HOLZER: I'm a very poor person to answer that question, Phyllis. Perhaps, there is an expert who is willing to do that for me.

MR. HAYNES: Bill Haynes. I'm not really an expert. I think, Phyllis, we are trying to anticipate these problems. The simulated in situ retorts, the big ones that he showed the pictures of. We are taking the spent material from that, soaking it up in water, and trying to see what kind of things we would have. First, you have to see what the problem is, anticipate it, then you try to go at the control. But you have to see if you can anticipate this. And, true, it's kind of hard to do it down underground, but we're trying to do it on a - what shall I say, rather a large-small scale?

MR. HOLZER: I think the important thing is not to let the opportunities for this type of monitoring and evaluation and early detection of potential problems slip past us.

I personally believe that's exceedingly important. And, as I say, I've always taken the position that technology and environmental research are two very closely related aspects and need to be done concurrently.

DR. PHILLIPS: I think that's certainly right. We all agree on that. If it weren't for environmental questions, we would all still be burning coal and all cities would look like Pittsburgh used to look when I was a young man. Thank goodness it doesn't look that way now.

I believe we must proceed then with our program. The next talk, again on National Laboratory research, is by Alex Zucker.

DR. ZUCKER: Coal, gas, and oil are time-tested energy resources. Why, one may ask, should it now suddenly be necessary to mount multi-million dollar research programs in technologies where so much is known, so much experience exists? The answer is very simple: circumstances have changed and created conditions which require action, and moreover the fossil energy resource is crucial to the future of the nation. What we do about it in the next decade will affect our way of life for generations. We define four Fossil Energy Imperatives:

1) Easily recoverable oil and gas will be exhausted within the next few decades. This means that we have to produce transportable fuel from other sources, that we have to extract oil and gas from more untractable formations, and that we have to develop alternate technologies. We have to do something.

2) While there are many options open to us, only a few can be developed to mature technologies because the costs are so high in terms of capital investment and technical skill. We can not do everything.

3) The energy industry is enormous, and its impact on the economy, and finally on the well being of each us, is profound and difficult to alter with any short time constant. What we do can not cost too much.

4) The enormity of the energy industry reflects not only on the economy, but also on that vast and intricate system in which we live, that currently goes by the name of environment, safety, and health. A small deleterious effect, tolerable in an industry of modest size, can become ruinous when examined in the context of billions of tons. Doubts in this area can, and should, slow things down until the answers are clear. What we do can not harm us.

From my vantage point the situation calls for a research effort of proportions commensurate with the industry:

a) we depend on research to provide data, systematizations, and ideas which will enable us to develop alternatives to oil and gas at a price that will not be ruinous to the economic welfare of our citizens;

b) we depend on research to explore, by laboratory scale research, by mathematical modelling, by scientific analysis, the plenitude of options, and to narrow these to a promising few;

c) we depend on research to inform us of those deleterious consequences of energy industries that we now perceive only dimly, and thus avoid costly and time-consuming paths that lead nowhere.

National Laboratories are large multiprogram research institutions that have some characteristics which make them useful and productive partners in a field like fossil energy research.

First, National Laboratories possess a rich tradition of successful research. Reactors, accelerators, fusion devices, fuel cycles, and weapons, all offer concrete evidence that National Laboratories can produce concrete results. The vast panoply of research papers shows that multifaceted scientific research, from quarks to corrosion, from neutrino physics to nu bodies in chromatin, has found fertile soil there. Much knowledge relevant to fossil energy exists in these Laboratories, and in many cases, for example materials science, aqueous chemistry, or environmental research, the Laboratories lead the world.

Second, National Laboratories conduct their research in a multidisciplinary framework where organic chemists might work along with atomic physicists, or chemical engineers with microbiologists. This kind of scientific environment enables the scientist to attack a problem in a holistic fashion, while at the same time the very size of a National Laboratory places at his disposal equipment to which he would otherwise not have easy access. Furthermore, the Laboratory environment provides stimulating exchanges of ideas that not infrequently lead to important discoveries.

Third, in many National Laboratories research is carried out alongside mission-funded technical development. This assures a cross fertilization whereby real-life development problems are known to the scientist who may be doing long-range research and affect his line of work, while, conversely, it serves as a conduit of the newest scientific information through the scientist to the engineer who might be having problems with his process.

I'll illustrate the thesis set forth previously - namely that research is indispensable to the utilization of fossil energy under the new ground rules, and that National Laboratories can and are making important contributions toward the solution of fossil energy problems. I'll mention some representative examples, not their importance, and relate them to the overall fossil energy program. It is worth pointing out that in many instances National Laboratories, through the knowledge and experience of their staffs, have been able to provide quick fixes for acute problems, contrary to the popular belief that the payoff in scientific research is decades away.

Slide 1. Sandia accomplishments in materials research: a) extend drill life by a factor of five; b) altering 310 stainless steel alloy increases sulfidation resistance; c) developed TiB_2 coating resistant to erosion and corrosion.

Slide 2. Argonne has drawn on its high energy physics expertise to build superconducting magnet for MHD development.

Slide 3. Oak Ridge: microprobe analyses show variation of organic sulfur distribution in coals.

Slide 4. Solvent refined coal pilot plant has pipe-plugging problem. X-ray diffraction and microprobe analysis at ORNL diagnoses the trouble and suggests a cure.

Slide 5. Thermocouple failures plague synthane gasifier pilot plant. Argonne scientists diagnose the problem, recommend high-chrome stainless steel, and fix the problem.

Slide 6. The Argonne Biomedical and Environmental Research Program concerned with coal shows the breadth of the problem. Parallel efforts with different program elements are carried out at Brookhaven, Berkeley, Oak Ridge, Los Alamos, Battelle Northwest, Livermore.

Slide 7. Knowledge of chemical bonding in coal compounds may enable us to break linkages at low temperature and pressure. Oak Ridge chemists show that methyl-like bonds can be broken at 400°C with vitrinite as the hydrogen donor.

Fossil energy research is not a frill, it can not be regarded as an activity to be tolerated while the real work on coal liquefaction or tertiary oil recovery is carried out by performance-oriented achievers. Research in fossil energy is essential if the goals set out earlier are to be achieved at a price that is within our means. Let me illustrate. Slide 8 shows a conceptual design of a HYGAS coal gasifier. Note the enormous size (220 feet tall), the high temperatures (up to 1900°F), and the complex internal structure. Now we examine in Slide 9 metals currently available for high temperature service. Engineers like to design equipment for service at

SANDIA LABORATORIES

RESEARCH ACCOMPLISHMENTS

MATERIALS RESEARCH

DRILLING

USE OF A HIGH TEMPERATURE, HIGH STRENGTH BRAZING TECHNIQUE HAS EXTENDED THE LIFE OF THE GE COMPAX DRILL BIT BY A FACTOR OF 5.

SULFIDIZATION RESISTANCE

ADDITION OF 2% TI OR 3% AL TO 310 SS SIGNIFICANTLY INCREASES RESISTANCE TO SULFUR ATTACK WITHOUT CHANGING PROCESSABILITY.

EROSION

A VERY HARD TiB_2 COATING HAS BEEN DEVELOPED THAT IS VERY RESISTANT TO EROSION AND CORROSION.

1. Sandia accomplishments in materials research: a) extend drill life by a factor of five; b) altering 310 stainless steel alloy increases sulfidation resistance; c) developed TiB_2 coating resistant to erosion and corrosion.

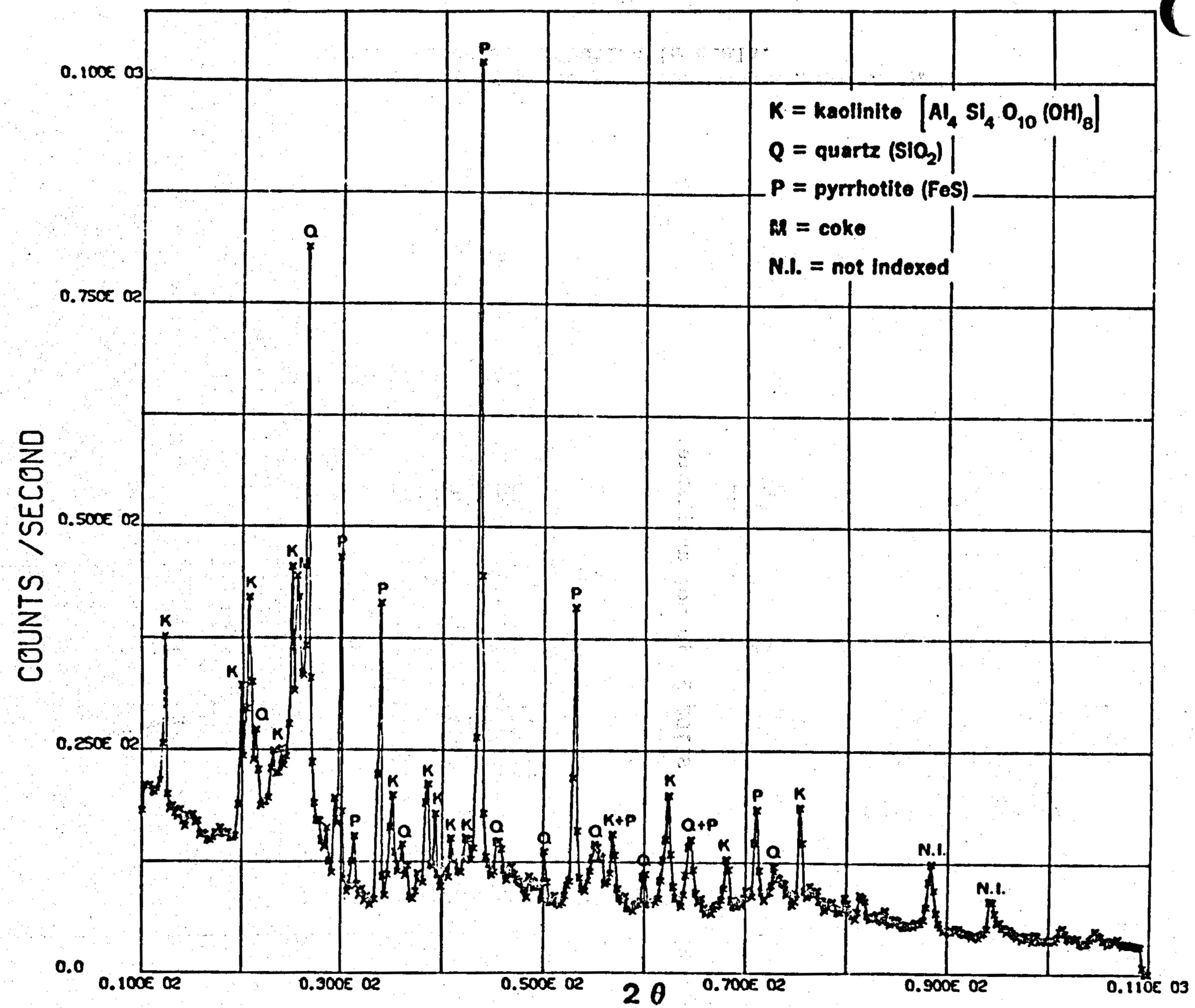
SLIDE 12 is not available.

O R N L

MICROPROBE ANALYSES OF ORGANIC SULFUR IN MACERALS OF FIVE HIGH-VOLATILE BITUMINOUS COALS

COAL NAME	LOCATION (STATE)	MACERAL GROUP SULFUR CONTENT EXINITE	VITRINITE	INERTINITE
HAZARD NO. 7	EAST. KENTUCKY	600	330	200
NO. 9 COAL	WEST. KENTUCKY	1925	810	250
DEAN SEAM	TENNESSEE	1250	800	300
NO. 5 BLOCK SEAM	W. VIRGINIA	600	330	270
NO. 6 ILLINOIS	ILLINOIS	1000	680	300

3. Oak Ridge: microprobe analyses show variation of organic sulfur distribution in coals.



X-RAY DIFFRACTION DATA FROM SRC COKE SAMPLE

4. Solvent refined coal pilot plant has pipe-plugging problem. X-ray diffraction and microprobe analysis at ORNL diagnoses the trouble and suggests a cure.

SLIDE 5 is not available.

BIOMEDICAL AND ENVIRONMENTAL RESEARCH PROGRAMS
CONCERNED WITH COAL

(W. K. Sinclair - - Associate Laboratory Director for Biomedical and Environmental Research)

	Program	Investigator	Division
Air	1. Multistate Atmospheric Power Production Pollution Study	Frenzen Cunningham	RER CEN
	2. Stack Pollutant Characterization Study	Cunningham	CEN
Water	3. Effects of Fossil Fuel Effluents in Aquatic Ecosystems (Non-nuclear portion of Great Lakes Program)	Edgington Harrison Sharma	RER EES EIS
Land	4. Effects of Fossil Fuel Effluents on Land Utilization	Miller	RER
	5. Land Reclamation after Strip Mining (revegetation, etc.)	Carter Cameron	EES EIS
Bio-edical	6. Fossil Fuel Effluent Toxicology in Animals	Norris	BIM
	7. Projects in Basic Biomedical Research	O'Connor	BIM
Assessment and Policy	8. Biomedical and Social-Costs of Energy Production	Grahn	BIM
	9. Regional Studies Program (National Coal Assessment)	Hoover	EES, EIS BIM
	10. Environmental Policy Analysis	Leppert	OEP
Environ-mental Control Technology	11. ECT for Coal Power Generation	Sather	EES, CEN CHM
	12. ECT for Eastern U.S. Strip Mining Sites	Johnson	EES

BIM - Biomedical Research
CEN - Chemical Engineering
CHM - Chemistry
EES - Energy and Environmental Systems
EIS - Environmental Impact Studies
OEP - Office of Environmental Policy
RER - Radiological and Environmental

6. The Argonne Biomedical and Environmental Research Program concerned with coal shows the breadth of the problem. Parallel efforts with different program elements are carried out at Brookhaven, Berkeley, Oak Ridge, Los Alamos, Battelle Northwest, and Livermore.

ORNL-DWG. 77-7235

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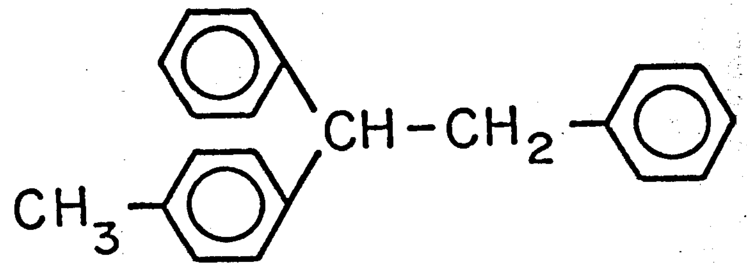

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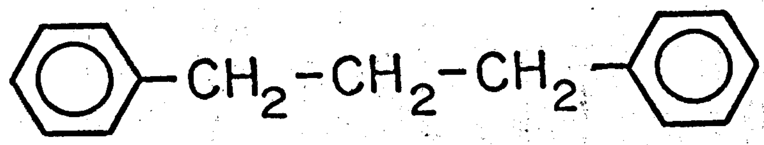

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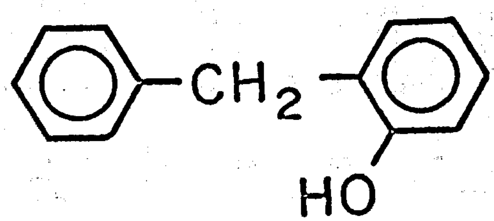

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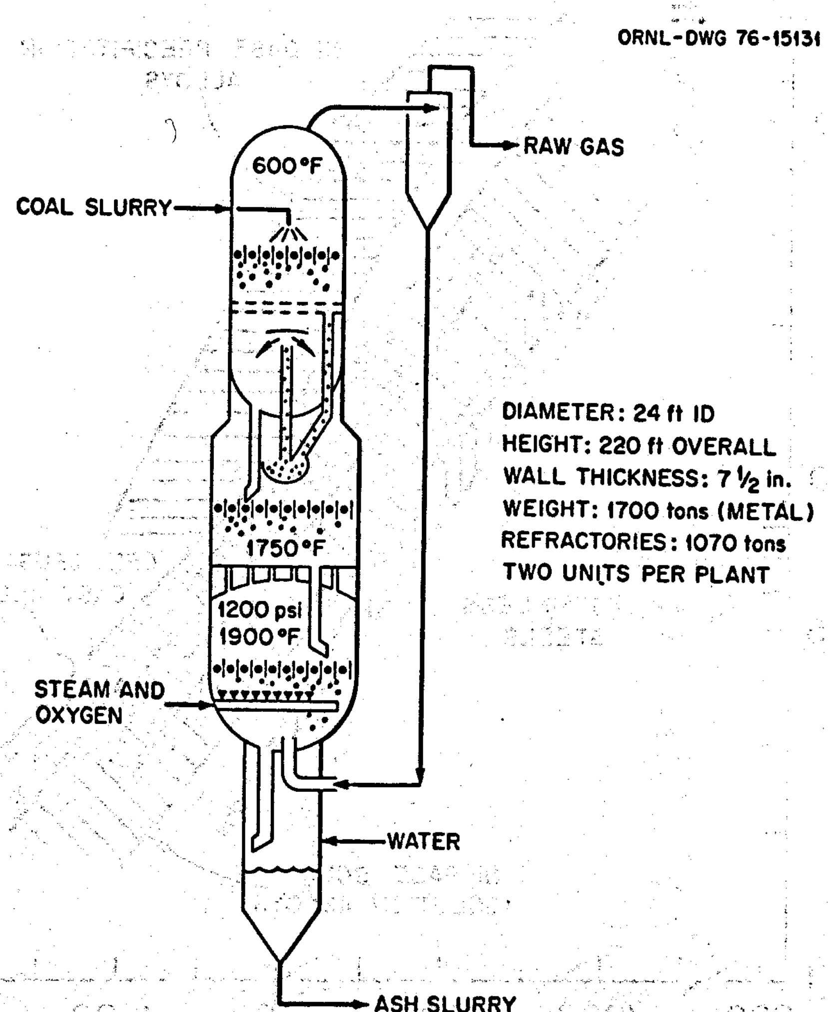
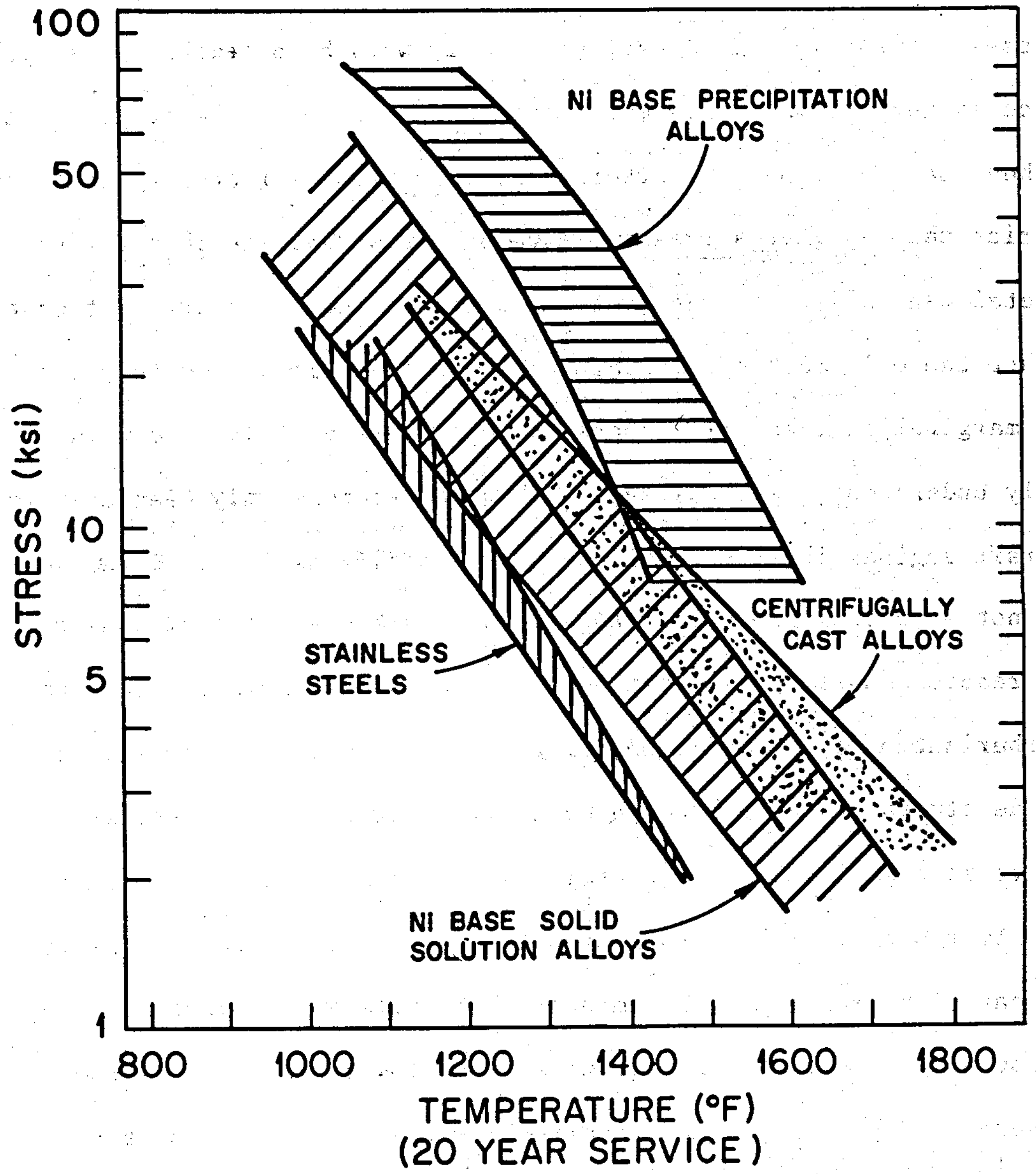
7. Knowledge of chemical bonding in coal compounds may enable us to break linkages at low temperature and pressure. Oak Ridge chemists show that methyl-like bonds can be broken at 400° C with vitrinite as the hydrogen donor.



8. Hygas Process
Fluidized Bed, Oxygen Addition, Dry Ash Gasifier.

ORNL-DWG 76-4986R



A COMPARISON OF THE STRESS RUPTURE PROPERTIES AS A FUNCTION OF TIME AND TEMPERATURE FOR CANDIDATE CONSTRUCTION MATERIALS FOR COAL CONVERSION SYSTEMS

From: The American Iron and Steel Institute Nuclear Steel Making Task Group - May 1975 stresses between 10 and 50 ksi, especially when high temperatures can induce larger thermal stresses. One hundred ksi would be better. It is thus plain why coal converters are lined with refractories that restrict the designer's freedom, and why parts that absolutely must be metal can only be in the cooler locations, and can bear no stresses. In fact the only metals available at these conditions, and they are very marginal at that, are superalloys that are difficult to weld, poorly understood, very costly, and have heretofore only been used in aircraft engines in thin sections. Intimidating as it is, Slide 9 does not even tell the whole story. Materials used in coal conversion reactors must, besides standing the high temperatures, survive decarburization under hydrogen, oxygen and sulfur; be resistant to sulfide stress cracking; remain ductile for twenty years; resist erosive attack of particles containing quartz crystals; etc. There are only two solutions to this problem: one, develop new materials that can withstand the high-temperature hostile environment; or two, develop processes that can operate at much lower temperatures and pressures and preferably be economical in smaller units than the mastodons of coal conversion that we now contemplate.

Both solutions imply large and long-term research programs, carefully planned and managed. Many parallel lines proceed at first, followed by gradual culling, until resources are more and more concentrated in the promising salients, even as others are carried on at lower levels of effort, as reserves, in case of the unexpected collapse of a front runner.

We have already seen the general problem in materials research: develop metals and refractories that can take the heat! And not only for coal conversion, but also for MHD, and for fluidized bed coal combustion.

Slide 10. Key development issues in fluidized-bed combustion. Note important materials and chemical problems that have to be solved.

We now turn to the possibility of lowering the temperature and pressure of coal converters, or more generally impacting on the entire coal conversion process. It is the thesis of this paper that fundamental understanding of the coal conversion process is a necessary and perhaps a sufficient condition to advance our cause in this instance. An example of this kind of research is contained in a list of projects currently carried out at Brookhaven:

- desulfurization of hot combustion gases;
- kinetics of reactions between gases and carbonaceous materials;
- reaction mechanisms in the transfer of hydrogen between coal and solvent (SRC)
- chemical reactivity of carbonaceous material at high temperatures.

Then, of course, there is the whole panoply of questions that goes by the words coal structure and constituents, catalysis (heterogeneous, homogeneous), process instrumentation, modeling, etc.

KEY DEVELOPMENT ISSUES IN FLUIDIZED-BED COMBUSTION

		Atmospheric FBC Systems	Pressurized FBC Systems
1.	Boiler tube corrosion, erosion and deposition	****	****
2.	Limestone requirements and solid waste disposal	****	**
3.	Hot flue-gas cleanup	N.A.	****
4.	Turbine blade corrosion, erosion and deposition	N.A.	****
5.	Coal, sorbent and ash solids handling system	***	**
6.	Sorbent regeneration and sorbent utilization improvement	****	**

Note: No. of stars indicates relative importance of issue

10. Key development issues in fluidized-bed combustion. Note important materials and chemical problems that have to be solved.

Another list from Sandia deals with MHD-related research:

- particle behavior;
- heat and mass transfer;
- seed interactions and condensation.

There are lists of research areas on an even deeper level that bear on many questions in fossil energy. A partial list from Lawrence Berkeley Laboratory includes research in fluid dynamics, thermodynamics, chemical forces, catalysis of hydrocarbon reactions by metal surfaces, etc.

We maintain that the economic utilization of fossil energy, in a way that is safe and environmentally prudent, is an incomplete technology. To bring it on stream in the next two decades calls for an expanded far-flung research effort. The National Laboratories stand ready, and are capable, to contribute to such a program.

National Laboratories have the staff, the equipment, and the management with a proven performance record in the basic and applied sciences, in engineering, and in synthesizing the results of many disciplines toward specific goals. By virtue of existing scientific strength, in a system that encourages multidisciplinary research, and by their deep involvement and commitment to the fossil energy technologies, the National Laboratories can: provide data needed by the developing technologies; explore the underlying physical sciences; provide quick responses to critical problems; work effectively in the complex area that spans science and engineering;

perform vitally needed enviroment, health and safety research; and may uncover new phenomena which would revolutionize the whole energy picture.

They can do this in partnership with industry, with universities, and with the Energy Research Centers. It is also necessary to consider the time scale. Some things the Laboratories must do fast: for example, would be to provide data needed by the developing technologies and to provide quick responses to critical problems. Others must be carried out in an orderly fashion over a long time period, avoiding if possible rapid fluctuations in direction and funding. Exploring the underlying physical sciences and performing vitally needed environment, health and safety research, fall into this category. It might be necessary to say here, that without research in the physical, environmental and health sciences, the development of fossil energy technologies will soon grind to a halt for a lack of knowledge. Working effectively in the complex area that spans science and engineering, we can even meet milestones, but there is no guarantee that we'll uncover new phenomena which would revolutionize the whole energy picture in a year or a decade. All we have to go on is past precedent + when able scientists work diligently to deepen our understanding of natural phenomena, useful things emerge, sometimes in the most unexpected ways. There is no reason to believe that this will not happen in the case of fossil energy.

Thank you.

DR. PHILLIPS: Thank you, Alex.

We are open for comments and discussion.

MR. BORIS: I'm Mr. Boris, formerly with a boiler manufacturing organization. I think my remarks bear more on that than on my present employer.

Your options seem to lack a feeling for the problems that the people who have to put the hardware into the field and make it work look at. You referred, during your talk, to the HYGAS problems - and I mention this only because it's representative of a family of these. The solutions that you've indicated include the development of materials and the development of processes that can work under less demanding circumstances.

I would submit that given these as problems, a third option, which was not mentioned, is the one that will probably be taken in most of the cases, and that will be to modify the design to use today's materials and today's developed processes, to put this hardware into the field and make it work in the near term.

To seek other options is going to put us into the far term. To develop new materials--if you wish to develop a new steel, as an example of this--will require very lengthy testing; and to get boiler code approval is not an easy thing; nor is it inexpensive.

I, therefore, feel that that kind of option is not going to be too viable. The development of a new process takes a long period of time; bench-scale PDU pilot plants being examples of these.

I would like to suggest that further thought and attention be given to what must be done by those charged with the responsibility of moving technology ahead. Along the lines of what it takes to move technology ahead, I believe a comment about technology moving to a halt was mentioned.

I think technology tends to stop moving ahead when it encounters a variety of regulatory things that consume much time. The R&D people have tried hard to develop these new processes but can only take them so far until other kinds of things need to be gotten out of the way so that those who must can get these into the field.

DR. ZUCKER: Let me comment on your last point first.

Government intervention in technologies is not totally capricious. Government intervention in technologies in many cases is designed to preserve the health of the people and of the environment. The problem is that very often a technology is developed without due regard to health, safety, and environmental matters, and then that technology grinds to a halt, or is at least retarded in its development. I would not call that simple government interference.

Your first point is very well taken. Of course, it takes 25 to 30 years to qualify a material. But I would suggest that the time to start on its development is now, and not 25 years from now.

I quite agree that the most likely thing to happen is the scenario you suggest.

But the question is not: Do we develop a HYGAS process? Rather it is: At what price are we going to supply a million Btu? If we do that at $6 or $8, is that a serious contribution? If we do that at $3, that's a different matter.

So it is not simply a matter of whether technology can do something. It is primarily a question of whether technology can do something at a price. My point is that if you want to lower the price, a time-tested mechanism is to try to understand the problem on a deeper level and see if it can not be solved by that understanding. There is no guarantee that it will be solved, but I think it is worth trying.

MR. LEE: Lee of IGT. You're stepping too close to HYGAS so I have to say something.

I believe your comment--I have nothing against research. I'm all in favor of that. All of us look for better materials. But I think your picture is distorted in that you show a situation wherein you expect a metal that takes simultaneously 1900 degrees, whatever it is, and 1200 psi pressure, when in fact the HYGAS reactor and the many other reactors operates with standard, conventional, buy-it-by-the-ton quantities refractory for lining, and the metal is standard carbon steel shell, and there are all the stresses taken on the pressure vessel, which only takes pressure but not temperature.

DR ZUCKER: I know that.

MR. LEE: I returned recently from visiting South Africa, seeing 3000-degree molten slag gasifiers operating under pressure. Now, obviously the part holding pressure doesn't have to see 3000-degrees simultaneously.

We've also seen coal gasification plants in operation, producing products, using conventional techniques, using conventional operators and technical key personnel like ourselves.

That doesn't say we shouldn't develop new materials, but to paint a picture as if nothing is going to work; we're going to start from scratch, developing new material--I think that's throwing the R&D picture out of focus. So I'd like to suggest that, fine, let's do R&D work; let's find better material; let's find better technology; let's understand kinetics better--I'm all in favor of that. But don't paint the picture as if coal converting is not a doable technology with today's material and today's manpower.

DR. ZUCKER: At what price?

MR. LEE: The prices are well established in the market price. If you read the design reports--they're not $6; they're not $8. And if you take it from the end-use point, from coal to your final point of use, there are reports that are available--I'd be happy to give it to you--that it's much cheaper than nuclear power.

DR. PHILLIPS: This is a very profound point. However--and it is certainly totally germane to our consideration of ERDA's research efforts in fossil energy, but this is not a group meeting of economists or people of that sort, and in particular we are not discussing details of demonstration plants and pilot plants.

Let me remind you to refocus your attention upon the definition, at this meeting, of research--

MR. LEE: He raised the cost picture.

DR. PHILLIPS: Yeah. Well, I think that is a very important point, because this morning we heard two speakers--that they consider a number like 30 plus dollars a barrel as the present state of the art for making synthetic oils from coal. Now, if there is a different opinion on your part, I think that we all would like to know about it.

However, I do not think this forum is the place to discuss it, but rather, if you would send us in some supporting material and whatnot, then we will distribute it in our final report.

DR. ZUCKER: Let me just make one point.

I do not wish to single out HYGAS as a particular target--nor did I say, in fact-that the pressures and the stresses are all applied at 1900 degrees. I merely put the slide on the screen to show what kinds of environments, what kinds of temperatures, what kinds of pressures one has to deal with. And the object of research, which you agree with, is to try to ameliorate that situation, and to work in areas where we can do things at lower temperatures, at lower pressures, and perhaps at lower costs.

That's really all I want to say.

DR. PHILLIPS: Are there other comments or questions?

MR. ZMOLA: Paul Zmola, Combustion Engineering.

I'm not certain that this one won't be ruled out of order also, but I feel that I have to ask. I wonder if Dr. Zucker would comment on how some of the technology that's being developed would be effectively transferred to the private sector.

I think he can take a rather broad approach to that, but I wanted to point out that I think most of us are interested in how to get into the situation of getting a good, rapid fix on problems we get into. And usually it just cannot be obtained directly from the book or the data bank; there's some application that has to be made.

DR. PHILLIPS: I rule that in order. It's very germane to talk about science and technology transfer from research to commercialization or demonstration.

DR. ZUCKER: I can comment on that starting from our experience in nuclear energy, where the laboratories and the nuclear industry grew up together, where the transfer back and forth of problems and fixes was rather simple.

This is not so here. The transfer of technology and the cooperation between the national laboratories and the ERCs is now pretty good, and getting better. The transfer of technology between the laboratories--(I don't know about the ERCs, but maybe Dr. Wender will speak to that)--and industry is complicated.

It's complicated by the patent question. And in some cases, the transfer of technology is complicated simply because we have worked together only for a few years. I believe it can be accomplished. There is interest in the laboratories--in fact, enthusiasm in the laboratories--for trying to do this kind of thing. I suggest there is also a measure of capability to do it.

DR. WENDER: Wender, Pittsburgh Energy.

Addressing the last question of course, the question of cost sharing has come up as one way of technology transfer. Another way, of course, is that the energy research centers, in contrast to the national laboratories, are completely open; and as such, the synthane process, the gasification, liquefaction processes, combustion things are open for inspection, for complete questioning outside of meetings and transfers. So there is a very good technology transfer that way.

DR. PHILLIPS: I think it's perhaps also important to point out, Dr. Wender, is it not true that the ERCs traditionally have had a significant measure of their support supplied by industry, not exclusive government support? Is that correct, sir?

DR. WENDER: Yes.

DR. ZUCKER: There is the precedent in nuclear energy; we have been able to make it work. There is really no good reason, except our own stupidity, if we do not succeed in fossil energy.

DR. PHILLIPS: Other questions or comments?

MR. CANONICO: Domenic Canonico, Oak Ridge National Labs.

I would just point out that the laboratories, too, are open to the public. I've been there a number of years and I have never had any problem having people come in for technical exchange in any way. I'm sure Alex would totally support that position.

Gentlemen, you're all invited. Any time you want--and ladies--come visit us.

DR. PHILLIPS: Very well.

I think it's a good time, right now, to take about a 15-minute coffee break. Let's come back at about 20 minutes of 4:00.

(Recess)

DR. PHILLIPS: I would like to call the meeting back to order, please.

I think that we are, remarkably, a small amount of time behind our schedule, considering the unplanned activities over on Capital Hill today.

I want to take this opportunity to say again to you what our plan for tomorrow afternoon is. We hope that we can get together as many small groups of you as possible to discuss with us the questions that we want you to respond to if possible.

I believe that each of you have a sheet that is called "The Purposes and Requested Responses of the Meeting." If you do not have one, it's available on the table up at the door. Attached to that--the last page, I believe--is a list of questions. There's about seven questions, that all have to do with the basic question that the administrator asked Dr. Kane to address and he in turn asked Kropschot and I to examine, which we now in turn are throwing the ball to you.

I believe that is all. Let's proceed, then, with our program. We have three more speakers for this afternoon.

Representing the energy research centers, research overview by Irving Wender.

DR. WENDER: The handout, available up front, contains more vugraphs than I will show.

I read some time ago that the head of GAO said that environmental effects will become more important than economics. I'd like you to think about that statement in terms of a word that I've heard a lot today, and that is "costs." I can imagine a very cheap process that someone comes up with, that works beautifully -- but no one wants to furnish a site for it, and its environmental effects will, of course, be too much for anybody to accept. It is important to keep this idea in mind.

I have not really listed research opportunities on my vugraphs. However, there are four pages of research opportunities listed at the end of the handout.

One of them, to bring it to your attention, is to determine the health effects of SO_2 and particulates, and to ask if SO_2 standards are properly set. Although this problem must be solved, most people are avoiding it. Fortunately, EPRI has instituted a research program in this area.

I, in particular, have never had any difficulty in defining basic research. I've been happy with my definition -- perhaps as happy as if I'm in my right mind.

(Laughter.)

Basic research to me has always conjured up the picture of a fellow who's doing research to discover some phenomenon or to verify an hypothesis. At the end of the experiment, he analyzes the data and then he does the next experiment based on deductions, interesting phenomena he has discovered, data needed to verify or validate his hypothesis, or just perhaps to satisfy a whim or a curiosity. He has no practical goal in his mind.

If, however, he has a goal in mind, he will use his findings to help reach that goal. That's what the British call, and what Dr. Mills calls, basic applied research.

The Energy Research Centers (the ERCs) essentially do mostly, I would say about 90 percent, basic applied research. In the past they did more basic research.

(Slide 1)

Those yellow dots on that map indicate the locations of the five Energy Research Centers. I'll start in Pennsylvania; that's the Pittsburgh Energy Research Center, called PERC; and the one below it in West Virginia is Morgantown and that's called MERC.

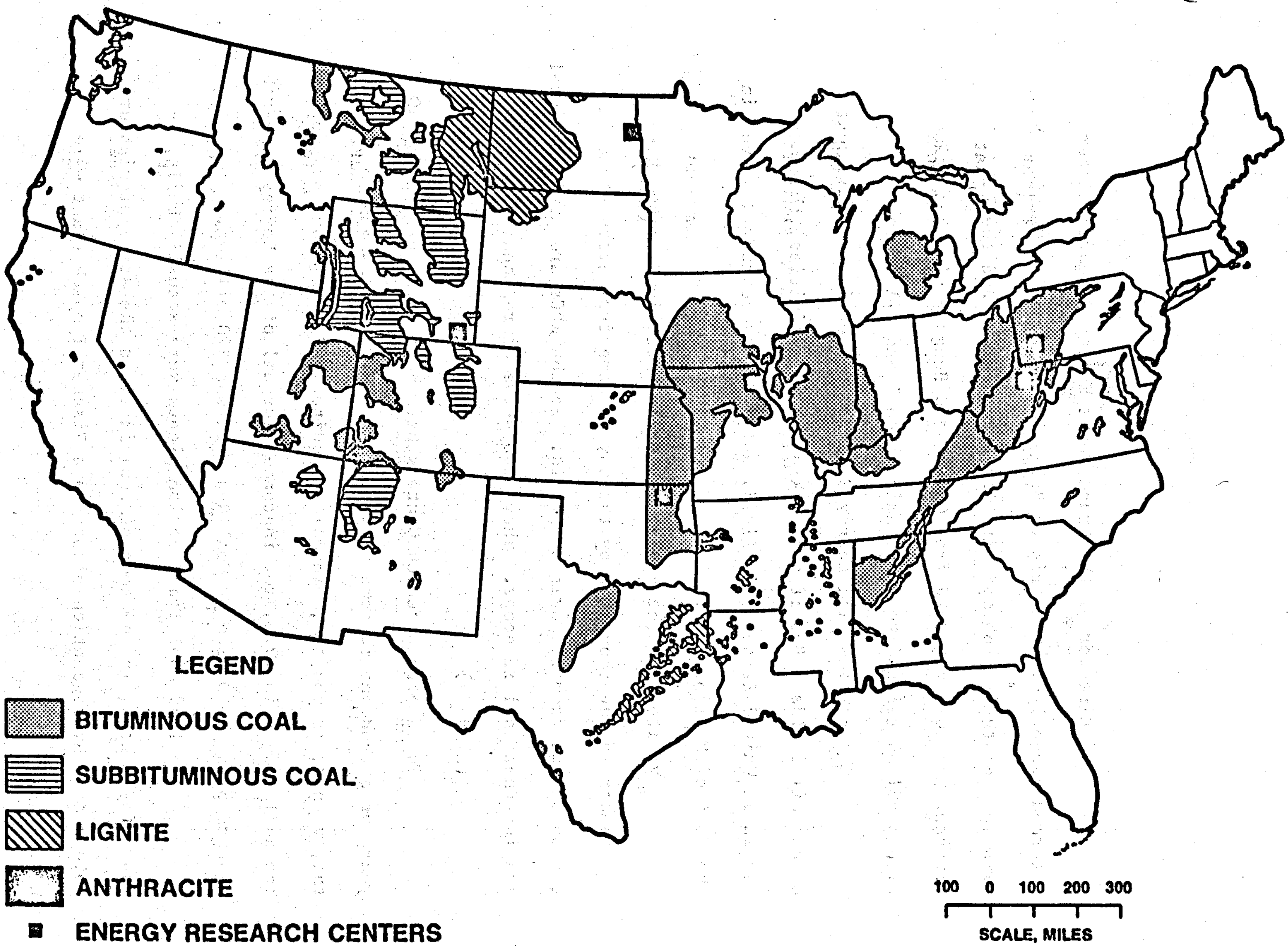
Then in Oklahoma you see Bartlesville. That's called BERC.

And the ERC in Laramie, where the pink color indicates deposits of subbituminous coal, is called LERC.

Finally, we go up north and, the acronym is somewhat funny, that's called GFERC for the Grand Forks Energy Research Center.

(Laughter.)

The Energy Research Centers are situated in regions that would lead one to believe that they are there because the resource is there. That's only partially true. For instance, the Grand Forks Energy Research Center is in North Dakota. I guess, because the lignite is there. However, the ERCs are national and international in scope. For instance, if you look at Texas you'll find a long band of lignite. It turns out that the personnel in Grand Forks are consulting with the utility people who are building a whole series of lignite-fired plants in Texas. The Grand Forks Energy Research Center is working with the people in Texas because, among other reasons, Texas lignite presents a very bad alkali ash problem; FGERC has excellent experience and know-how in this area.


LEGEND
BITUMINOUS COAL
SUBBITUMINOUS COAL
LIGNITE
ANTHRACITE
ENERGY RESEARCH CENTERS
100 0 100 200 300
SCALE, MILES

The Director of the Grand Forks Energy Research Center returned recently from a trip to Bulgaria and Rumania, helping them with some of their problems with low rank coals. And the LERC Director has just returned from Greece and Hungary, in connection with problems related to subbituminous coal and oil shale.

The Bartlesville Energy Research Center is near the center of our oil fields. But if you look at their activities, they cover the whole United States, oil fields all over the country and even in the Gulf of Mexico.

Visitors to the Energy Research Center in Pittsburgh -- who number in the thousands by the way -- come from every state in the Union and from all over the world. So the ERCs are truly national and international in scope. They also serve as regional centers.

(Slide 2)

The Energy Research Centers have been in existence for 50 years or so and one is some 60 years old. As time has gone on, they've had, as you see, minimal and quite inadequate funding support. The coal budget in 1970, for instance, for all of the Energy Research Centers plus the Office of Coal Research was $20 million.

In 1949 coal liquefaction plants were actually built, as most of you know, in the town of Louisiana, in the state of Missouri. Both a coal hydrogenation plant and a Fischer-Tropsch plant were built there.

SOME ERC BACKGROUND

- FROM 1950 TO EARLY 1970's, THE U.S. HAD MINIMAL AND INADEQUATE EFFORT ON COAL RESEARCH AND CONVERSION (BOM & OCR BUDGET IN 1970 WAS $20 MILLION).
- ERCs OBTAINED SIGNIFICANT SUPPORT (SOMETIMES MORE THAN 50%) FROM INDUSTRY AND OTHER GOVERNMENTAL AGENCIES.

The coal hydrogenation plant was operated from 1949 to 1953, producing several million gallons of gasoline. This was used to run a train from Louisiana, Missouri, to St. Louis, which is about a distance of 200 miles. The military ran some of their vehicles with these synthetic fuels from coal to demonstrate the usefulness of these fuels in current engines.

They also ran a Fischer-Tropsch plant. Here they only produced some 40,000 gallons of liquid product. This plant was started up later than the coal hydrogenation plant.

Then in 1953, someone came along with a big pair of scissors and cut these plants at the root, and they all died because of a glut of gas and oil. Hindsight is always better, of course, but it would have been of immense value to this country if those plants had been allowed to continue. I'm sure they would have been modified as demands and times changed and technology improved.

The second point is the one referred to by Dr. Phillips. With diminishing support from the government, we were forced to turn to industry and other government agencies. Fortunately, we were successful in this endeavor. We continued at a very low funding level with, at times, as much as half of an Energy Research Center's budget coming from outside sources. And we could have had more outside support but, for various reasons, the people in Washington insisted that everything done at the ERCs be related to fossil energy. So that we had to turn down quite a few industrial contracts.

It's an interesting sidelight that the Pittsburgh Energy Research Center was the laboratory which, because of its background in high pressure technology and because of the equipment it had, performed erosion and corrosion testing of the valves and piping for Admiral Rickover's nuclear submarines. That's sort of an odd turnaround.

(Slide 3)

The program of the Department of the Interior -- as you know, the Bureau of Mines is in the Department of the Interior -- kept us at a low funding level; but it was a low level over a long period of time. Under this set of circumstances the Energy Research Centers managed to do a lot of good work, and it resulted in some very useful and timely findings with resultant industrial applications.

We invented the so-called Benfield process for the cleanup of gas from oil or from coal. I'll talk about this later. There are now some 400 units -- and these are large units -- in many countries, on every continent. They are even being built in Red China now. All this came out of basic applied research on what is now called the SYNTHANE process for the conversion of coal to high Btu gas.

PERC also patented the process for the two-stage combustion of coal with low NO_x emissions.

And then ERDA came along. Dr. Neuworth, for instance, told you this morning that catalytic gasification is a third-generation

SOME ERC BACKGROUND (CON'T)

- COMPREHENSIVE, LONG-TERM PROGRAM OF THE DOI PROVIDED SIGNIFICANT ADVANCES IN COAL SCIENCE AND PROCESS TECHNOLOGY.
- ERC RESEARCH PROVIDED TECHNOLOGY BASE, INVENTED NEW GAS CLEAN-UP SYSTEM – NOW 400 PLANTS AROUND WORLD, PATENTED 2-STAGE COMBUSTION FOR LOW NO_x, ETC.
- TO SUCCEED, A FOSSIL ENERGY PROGRAM MUST PROVIDE AN ADEQUATE AND SUSTAINED RESEARCH EFFORT.

process in the sense that it doesn't need a water-gas shift reaction and practically no methanation. A very promising, simple and direct gasification process was invented by the Pittsburgh Energy Research Center. This HYDRANE (or hydrogasification) process involves the non-catalytic treatment of coal with hydrogen at about 1000°C. The product is essentially methane with no tars. No water gas shift reaction is needed and very little methanation is required. I think that a process development unit for this process should be built shortly. Its simplicity and high efficiency will make for a cheaper, more reliable route to high Btu gas from coal.

So we were ready with these discoveries and processes when ERDA came into being. And all this resulted from support over a long period of time, at a low Bureau of Mines funding level, plus significant help from industry and other governmental agencies. Over the past years, the ERCs have had long-term contracts with some large industrial firms. They gave the Energy Research Centers money to carry out needed research. And remember, the firms involved in these contracts with the ERCs had to give up all patent rights to the government.

This brings us to a most important point. To succeed, a fossil energy program must provide a sustained and adequate level of funding. If it isn't sustained, you throw away what you have discovered or invented, waste money, destroy morale -- and just don't get anywhere.

I visited Japan about two years ago, at their invitation. They used to mine about 60-odd million tons of coal a year. They are down to about 18. The result is a 99 percent dependence on oil. Unfortunately, they practically ended work on coal in their research institutes and their coal laboratories. They are now trying to build them up again, but it is an extremely hard thing to do. The cadre remaining is scattered and has gotten a bit old. And that is a lesson to all of us.

(Slide 4)

As to the ERC missions, I think this has been covered so I won't spend much time on it. We do the things shown on the vugraph. In the rest of the time, I will try to tell you some of the things that clarify and enhance this slide.

(Slide 5)

Remember that the Energy Research Centers are comprised of about 825 people who are all federal employees. The National Labs, as you know, are government owned and contractor operated. The ERCs have a different sort of outlook and a different mission, and one of our missions is to make the government a good buyer.

Fossil Energy headquarters often asks the ERCs to go out and look at a plant and then write a report. The ERCs have to be at the forefront of technology to be able to do this. The only way to be at the forefront of technology is to be doing something that is close to the cutting edge. And that is one of the important things

MISSIONS OF THE ERCs

PERFORM WORK IN FOSSIL ENERGY TECHNOLOGY AREAS

BASIC APPLIED RESEARCH AND TECHNOLOGY DEVELOPMENT

- INCREASE OIL AND GAS RESERVE BASE BY ENHANCED RECOVERY.
- RESEARCH AND DEVELOPMENT TO OBTAIN CLEAN ENERGY FROM COAL.
- MAINTAIN AND ENHANCE STRONG SCIENTIFIC AND TECHNOLOGICAL BASE.
- SOLVE PROBLEMS ARISING DURING R&D STAGES OF SCALE-UP.

MISSIONS OF THE ERCs (CON'T)

PERFORM WORK IN FOSSIL ENERGY TECHNOLOGY AREAS

PROVIDE MEANS TO:

- **MAKE GOVERNMENT A GOOD BUYER.**
- **TRANSFER TECHNOLOGY TO INDUSTRY.**
- **UNDERSTAND AND RESOLVE ENVIRONMENTAL ISSUES.**
- **SUPPORT HEADQUARTERS PLANNING/IMPLEMENTATION.**
- **MANAGE PROJECTS IN THE FIELD.**
- **INTERACT WITH INDUSTRY/ACADEMIC/PUBLIC/OTHER GOVERNMENT AGENCIES.**

the Energy Research Centers have to do to make the government a good buyer.

Regarding the transfer of technology to industry, I want to say that our relationships with industry over the years have been excellent. Somehow or other, industry has never considered the Energy Research Centers as rivals. Some of them have actually sent people who worked at our laboratories. We have had any number of visitors from industry. Our publications have been used by industry. Some time ago we wanted to jazz up our publications from the old, gray Bureau of Mines format, and we heard voices roaring back that said, "For God's sake, that's our bible. Don't put pink and yellow stripes on it, because when we see that gray cover we know we can depend on it."

I'll come back to environmental issues later. The support of headquarters and planning implementation are things that we do constantly, back and forth. We should do these even more thoroughly in the future. I think it was mentioned this morning by Dr. White that he envisages that more projects will be managed in the field.

It's important that you realize that the Energy Research Centers have been sort of a connecting link, you might say, between industry and government. We also have excellent relationships with the universities. We work with other government agencies. Research and technology transfer take place through the Energy Research Centers with ease.

(Slide 6)

About our so-called strategy, I think that the first one listed is very important: to maintain a proper mix of in-house expertise. What do I mean by that? Well, the people that we employ come from the coal industry; they come from the oil industry; they come from the chemical industry; and they come directly out of school. We have a mix of people who have a lot of experience in high pressure technology, in coal and petroleum desulfurization, in the basic chemical science; and we have a mix of chemical engineers, mechanical engineers, chemists, some physicists, and a fair number of mathematicians. This is the basic mix of personnel that we look for, and it's been very successful.

Maintaining the balance between in-house and out-of-house research is a constantly ongoing thing. We're working that out now. We identify and define promising areas of research -- as does everybody, I guess.

We do research which includes special know-how -- and I'll enlarge on that -- and in high-risk areas, which are by definition areas that government people should be in.

I guess now is about as good a time as any to discuss environmental impacts stemming from fossil energy research. We take this area, of course, extremely seriously, as does everybody in this room. In our Energy Research Centers for instance, the process people are responsible for the environmental consequences and health

STRATEGY OF ERCs

- MAINTAIN STRONG IN-HOUSE EXPERTISE WITH PROPER PERSONNEL MIX AND RESOURCES.
- MAINTAIN BALANCE BETWEEN IN-HOUSE RESEARCH AND MANAGING/MONITORING CONTRACT RESEARCH.
- IDENTIFY AND DEFINE PROMISING AREAS OF RESEARCH.
- DO RESEARCH INCLUDING EITHER SPECIAL KNOW-HOW AND EQUIPMENT OR IN HIGH RISK AREAS.
- ASSESS, AND MAKE ACCEPTABLE, ENVIRONMENTAL IMPACTS STEMMING FROM FOSSIL ENERGY R&D.

effects of their process from the time they are initiated. At the same time, at PERC, we have another group, called the Environment and Conservation Division, which looks over the shoulders of the process people, to make sure that they are carrying out their environmental duties. It's too easy to ignore environmental and safety problems when you are trying to get a process on stream. In spite of the fact that you say you're all for the environment, when something comes along that, in your research and development, you just want to get done as soon as possible, the attitude is: "Well, I'll take care of that later," and the problem manages to get swept under the rug. But we have an overseeing group who go around and talk to the process people; in several cases, they've identified potentially harmful environmental problems and pointed them out early in the game. We believe this overseeing group is absolutely necessary.

(Slide 7)

I think this just gives you a flavor of what an Energy Research Center is. It by no means gives you the type of facilities in the Centers. Fred Holzer of the National Laboratories told you this morning all about Laramie; it was a good talk, so I'll omit that.

But we do have high-pressure/high-temperature continuous process units, up to a ton a day. We're building a process development unit for coal liquefaction that will process up to 10 tons of coal per day.

ENERGY RESEARCH CENTERS . . . .

. . . . HAVE SPECIAL FACILITIES, KNOW-HOW AND SKILLED OPERATORS

- HIGH-TEMPERATURE, HIGH-PRESSURE CONTINUOUS PROCESS UNITS
- LARGE COMBUSTORS
- PRESSURIZED GASIFIERS
- HIGH-PRESSURE CONTINUOUS CATALYTIC UNITS
- ENGINE TESTING FACILITIES
- OUTSTANDING ANALYTICAL AND SUPPORTING EQUIPMENT

. . . . PERFORM AND MONITOR LARGE SCALE FIELD TESTS

We have large combustors, one of which is a 500 pound per hour combustor, the largest you'll find outside of a utility. It's an experimental unit.

We have pressurized gasifiers, and the rest you can read from the slide.

The last line on the slide mentions something that's very important. The Energy Research Centers monitor and perform large-scale field tests, especially at Laramie, Morgantown and Bartlesville.

There are huge amounts of Devonian shale in Ohio, Pennsylvania, Kentucky and contiguous states. Much field work is required to obtain gas from this shale. I don't know what percentage of work at the ERCs is actually carried out in the field, but it is large. At Pittsburgh, we have a 75 ton per day coal gasification pilot plant and a supporting process development unit. One of the advantages of having such units near you is that they feed back rather basic problems, problems that couldn't have been foreseen and that you go back to a laboratory and decide, my gosh, I will have to put someone on this right away. Occasionally, the researcher will have to start pretty far back to solve the problem. In science, you always find out that you know less than you think you did.

(Slide 8)

Let me illustrate this. Dr. Mills mentioned the oxy-desulfurization of coal. I bring this up to give you some idea as to how the ERCs do things. That process involves, as somebody said

SOME ACCOMPLISHMENTS FROM BASIC APPLIED RESEARCH

- OXYDESULFURIZATION OF COAL
- SOLUBILIZATION OF COAL (REDUCTIVE ALKYLATION)
- COSTEAM
- HOT CARBONATE GAS CLEANUP PROCESS
- SUPERCRITICAL GAS EXTRACTION

today at the break, the basic elements: earth, air, fire and water. The oxydesulfurization process involves treating coal with water and air, and you get out all of the inorganic sulfur. Ordinary coal cleaning only gets out about half of the inorganic sulfur. In addition, the process may remove up to 40 percent of the organic sulfur.

Now, where did that process come from? Well, if you just read your literature a bit, your organic chemistry, or in fact any chemistry, you will find that the free energies of formation of very stable molecules, like CO_2, CO, NO, water, SO_2, etc. are very favorable, and there is a tendency for these small molecules to form in what is called an extrusion reaction. So we said, let's take dibenzothiophene as a model compound. If you could oxidize that to a sulfone, (the sulfur atom in dibenzothiophene has two oxygens on it), SO_2 should extrude very easily. And so we treated dibenzothiophene sulfone with alkali and got a quantitative yield of 1-phenylphenol. In other words, all the sulfur was removed by this treatment.

We went from this to coal. Now I don't know if that's basic research or not, because the extrusion reaction was known and this is an extrusion to coal. It was an application of basic research to the removal of sulfur from coal.

The second one on the slide was on the solubilization of coal. Nobody has been able to really measure the molecular weight of coal, but we did this by reductively alkylating coal. I won't explain what that is, except to say that it simply adds a long hydrocarbon chain to coal; for instance we added a hexane chain to coal. And we found that when we did, coal became soluble in benzene, and even in hexane. And then we were able to determine the molecular weight of solublized coal.

Another example is the COSTEAM reaction. We said to a researcher one day, -- everybody hydrogenates coal with expensive hydrogen gas -- your job is to go into the laboratory and find a way of hydrogenating coal using some other (preferably cheaper) gas. And don't come back until you've found it.

And he came back with a coal liquefaction process that uses the gas, carbon monoxide, in the presence of water. This led to the COSTEAM process, which is applicable, we found at first, to low rank coals. The Australians, who have lots of low rank coal, as do we, are also very interested in this process.

At first, we thought this process was noncatalytic, but it turns out that the alkali in the low rank coal is a catalyst. Sodium formate is undoubtly the necessary intermediate, and a hydrogen atom from sodium formate is transferred to the coal.

The hot carbonate gas cleanup process (the Benfield process), with some 400 plants now built or building, came out of the simple reaction that's in all the chemistry books; water plus potassium carbonate plus CO_2 gives you $2KHCO_3$. This picks up CO_2. When you heat this solution up, CO_2 is released. The Benfield process also removes hydrogen sulfide. This process certainly stemmed from a basic reaction and is a good example of basic applied research.

Dr. Mills funded this last example on the slide, dealing with supercritical gas extraction. That's something that the British have developed to treat coal with a low-boiling solvent above its critical temperature. In this manner, they get out 20 to 30 percent of low-boiling material. But their process results in a large amount of residue.

You know that one of the big problems in the liquefaction of coal is solids-liquid separation. We have taken the solid-liquid mass after most of the oil has been removed and treated it with toluene under supercritical conditions. We find that we can cleanly remove all the usable oil from the residues with a quantitative recovery of toluene. Our remaining problem is to make this a continuous process, which does not seem at all difficult.

These are just a few examples of how work is conducted in the Energy Research Center.

(Slide 9)

I think I will just let you read this. I've said most everything on it. Next slide, please.

(Slide 10)

The next slide is an important one.

As Dr. White told you, tests are going on in Albany, Georgia, some 40 miles from Plains, on the burning of solvent refined

ERCs ARE FOCAL POINT FOR FOSSIL ENERGY RESEARCH

- EDUCATION AND TRAINING FOR UNIVERSITY, GOVERNMENT, INDUSTRY, FOREIGN SCIENTISTS.
- EXTENSIVE UNIVERSITY CONTACTS AND CONTRACTS.
- FREE ACCESS FOR INDUSTRY, GOVERNMENT, ACADEMIA – U.S. AND INTERNATIONAL.
- ERC EXPERTS SENT TO ALL FIVE CONTINENTS.
- TALKS, LECTURES, MEETINGS – NATIONAL AND INTERNATIONAL.
- 1000's OF PUBLICATIONS CONSTITUTE FOSSIL ENERGY INDUSTRY "BIBLE".

ERCs ARE RESPONSIVE TO CHANGING OPPORTUNITIES, NEEDS, DEMANDS

- SOLVENT-REFINED COAL COMMERICAL COMBUSTION TESTS
- COAL-OIL SLURRY COMBUSTION (NEAR-TERM)
- RE-REFINING OF LUBE OILS
- DEVONIAN SHALE DEVELOPMENT
- NATURAL GAS FROM COAL SEAMS
- FOSSIL ENERGY ENVIRONMENTAL PROBLEMS

coal (SRC). SRC, it turns out, is neither fish nor fowl. It's not a solid, so you can't burn it as you would in an ordinary coal combustor; it's not a liquid, so you can't burn it in an oil-type burner.

The combustion group of the Pittsburgh Energy Research Center, which has been doing basic and applied work in coal combustion, was asked to figure out a way of properly burning SRC. Well, the group devised a satisfactory method to burn SRC in a very short time and this is how the SRC is being burned in Albany, Georgia. Some three weeks ago, we had to send a man to Albany, Georgia to make sure that the SRC burned well. It burned beautifully and the test was a success. It's important to note that the Energy Research Center was ready to respond to this challenge in a short time. We must be and are ready for tasks of this sort.

Take the coal-oil slurry as another example. We were asked if we could get a coal-oil slurry unit set up in a very short time. In less than three months we had one operating at PERC. We found an old Bureau of Mines boiler, set up a coal-oil slurry unit, and furnished all the steam heat for the ERDA installation at Pittsburgh last winter. This unit ran for over 1,000 hours.

We are now building a 700-horsepower unit. This winter, we hope to put several of these coal-oil slurry units into small industries in the mid-Atlantic area.

A very good job has been done recently at BERC on the re-refining of lube oils -- these oils have been tested and they meet all specifications.

Devonian shale has been covered, natural gas from methane seams has been discussed and I have talked about environmental problems. Let's see what's on the next slide.

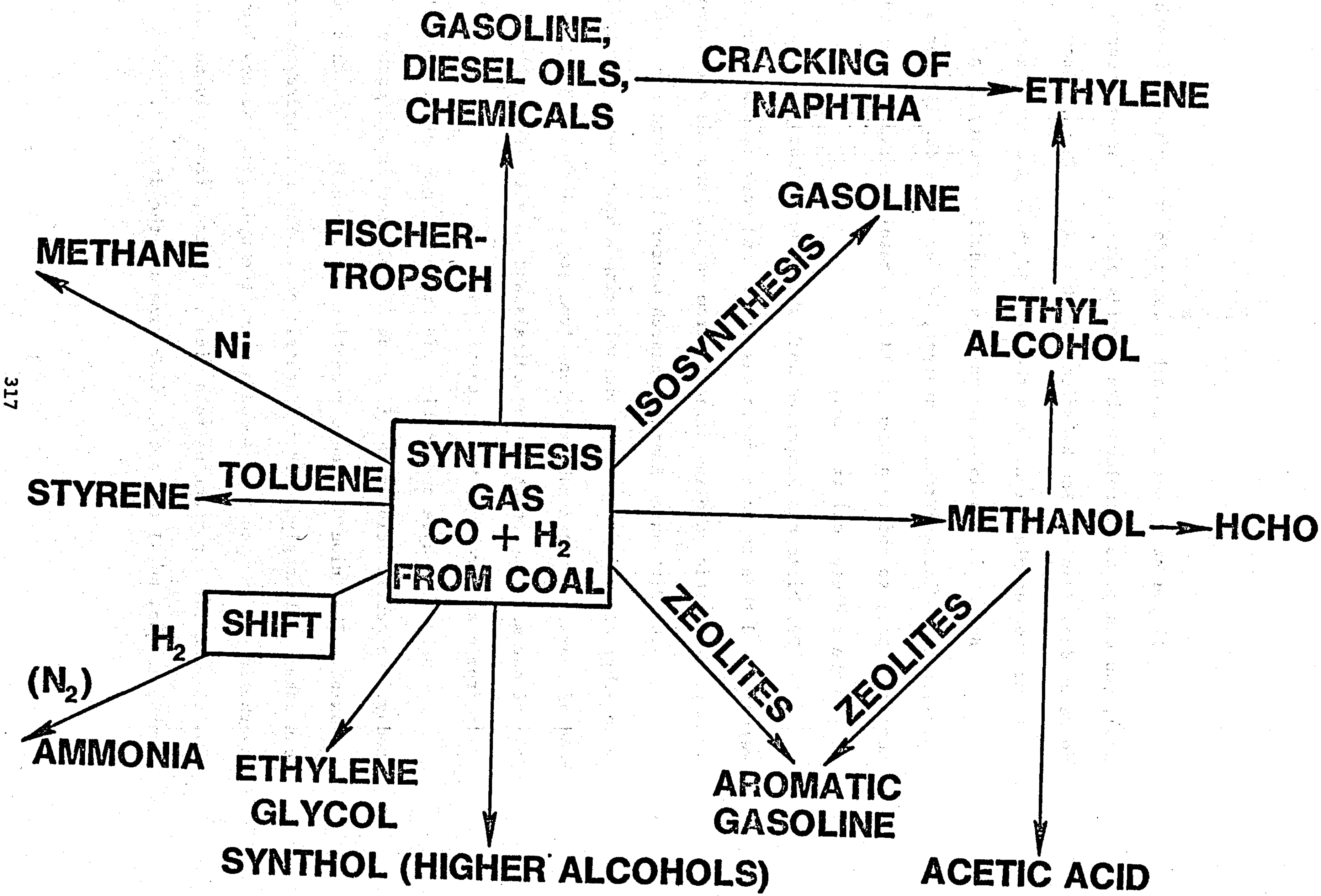
(Slide 11)

Let me talk about this, and then probably end up.

Most of the liquefaction that we have talked about has been hydrogenation of coal, which is something I believe in. In other words, adding hydrogen to coal is a promising route to low-sulfur liquid fuels. But you make a lot of aromatic (benzenoid) and poly-molecular materials during the hydrogenation of coal.

We are advocating a large program on what we call Project PLUS. One of the advantages of Project PLUS (Petroleum-like Liquids Using Synthesis Gas) is that you first gasify the coal to synthesis gas and then convert the gas to petroleum-like (aliphatic) oils. It should be pointed out that, even when you hydrogenate coal directly, about one third of the coal must be gasified to make hydrogen anyhow. In other words, you have to go through the gasification route to make your hydrogen in the first place. We know that in the next couple of years, there are going to be several good pressurized gasifiers. I think a number of people in the audience may know better than I what they are.

PROJECT PLUS



If you start out from carbon monixide and hydrogen (synthesis gas), you can go to petroleum-like liquids via the Fischer-Tropsch route as does Sasol in South Africa. That's fine. They are now building another plant ten times the size of their present plant.

But it is possible, by using a selective catalyst, not necessarily a Fischer-Tropsch catalyst, but an oxide catalyst or a zeolite, etc., to obtain a high yield of a gasoline fraction, or you could make a diesel oil fraction.

Dr. Mills has supported work which shows that you can go to methanol and then to an aromatic gasoline. And work is now going on in making aromatic gasoline directly from carbon monoxide and hydrogen.

The Pittsburgh Energy Research Center has found that you can make ethyl alcohol from methyl alcohol using a homogeneous catalyst. And of course, you can make ethylene from ethyl alcohol. Ethylene is one of our most important petrochemicals and it will eventually be made from coal, probably via synthesis gas.

Formaldehyde and acetic acid are made from methyl alcohol today, the acetic acid synthesis using methyl alcohol and carbon monoxide. The Union Carbide Corporation has recently shown that you can make ethylene glycol from synthesis gas. You make hydrogen from synthesis gas and you make ammonia using the hydrogen. We now know how to make the important petrochemical, styrene, from toluene using synthesis gas, but I won't take your time for the details.

Project PLUS thus gives us an environmentally clean route to gasoline, to diesel oil, and to other fuels and petrochemicals. All the sulfur and all the nitrogen are removed during gasification and the final products are not carcinogenic.

About 33 billion pounds of synthetic ammonia is made in this country every year. Happily, there is work going on transplanting microorganisms, Phizobium species, which grow on the roots of certain nitrogen-fixing plants. It may be possible for these microorganisms to be transplanted to wheat, rye, and oats, etc. It may well be a good idea for ERDA or someone else to support work to make all our ammonia (fertilizer) via microorganisms on the roots of growing plants. It is interesting to note that 100 billion pounds per year of ammonia are fixed naturally in this way each year.

Indeed, why not fix all our nitrogen in this way? If successful, this could pretty much wipe out the ammonia industry. It would be to our advantage to do this. We would save all the fuel necessary to make ammonia. Perhaps, even more importantly, we would be replacing the humus so badly needed in the soil. At present, we must add increasing amounts of fertilizer each year because humus is not replaced. The huge amount of synthetic ammonia results in eutrophication of our rivers with resultant killing of the fish present.

So this is a plan where I advise avoiding the petroleum or fossil energy route altogether. Instead put all your money into agricultural research. If you could get the dollars and will do this, you would not need the ammonia industry and it would be a tremendous boon to agriculture and to the environment.

Thank you.

(Applause.)

DR. PHILLIPS: Thank you. Now, I am going to ask you a question. What was your next slide? Could we see it, please?

DR. WENDER: I have taken up more than my allotted time. The rest of the slides are in my handout.

DR. PHILLIPS: Are there other questions or comments? Yes.

VOICE: What is your ratio between in-house and out-of-house research work?

DR. WENDER: That figure is not in the handout. It's a hard question to answer because most of the out-of-house work is funded from Washington. Bartlesville, for instance, monitors over $100 million worth of outside work. Is that not so Mr. Ball?

MR. BALL: That is right. We have about $7 million worth of in-house work, and $110 million worth of contracts.

DR. WENDER: That's an exceptional example. Morgantown has fluidized bed combustion. We only do direct combustion at the Pittsburgh Energy Research Center. The number you ask for is a hard number to come up with because these are really contracts that emanate from Washington, and we get to be the TPOs of these contracts.

The figure is available, I think, from Dr. White.

DR. PHILLIPS: Other comments or questions?

(No response.)

Very well. Thank you, sir.

We will go on then to our next-to-the-last talk for today's sessions, university research overview by William Reynolds, Stanford University.

DR. REYNOLDS: Thank you very much.

I am delighted to have this opportunity to provide you with information and perspective on the current and potential role of universities in fossil energy research. As Chairman of the Institute for Energy Studies and of the Department of Mechanical Engineering at Stanford I have had the occasion to discuss the ERDA program with many colleagues. In preparing this talk I spoke with several key people at leading universities to get their views on the messages that I should deliver today. I will present my analysis of the situation and interpretation of some widely held views.

My talk is organized in two parts. First, I will put forward a case that the universities have much to contribute to ERDA's fossil energy programs, but that many of the best minds have yet to be directed towards ERDA's research needs; some steps that ERDA might take to involve more of this top talent will be suggested. Second, I will examine the balance between research and development in the ERDA fossil energy program, and point to a serious gap which I perceive exists between the very basic research and the very applied development programs; recommendations will be made for ways in which the universities could assist in bridging this gap. Along the way you will hear a number of things that I hope you will find useful.

Universities have been the primary performers of basic research, not only for the federal government but for the nation as a whole. Table 1 shows the distribution of federal research support for universities, industry, and government laboratories for FY76. Note that universities are involved in both basic research, which is the advancement of knowledge potentially useful in a number of applications, and applied research, which is research for new knowledge undertaken with particular applications in mind. In addition, universities are sometimes involved in development, which is the technical activity concerned with non-routine problems encountered in translating existing knowledge into specific products or processes.

TABLE 1

FEDERAL OBLIGATIONS FOR BASIC RESEARCH, FY76
(Billions of Dollars)

	Basic Research	Applied Research
Universities	1.0	1.0
Industry	0.5*	1.5
Government Labs**	0.3	0.4

*Mostly aerospace
**Including those administered by universities

Source: NSF 75-323

Measures of university strength and productivity pertinent to fossil energy are given in Table 2, which shows the sources of recent publications in two major referred journals reporting research relevant to fossil energy, Combustion and Flame and the Journal of Catalysis. Note that nearly 70 percent of these publications are derived from work conducted at universities. Two pertinent review journals, Progress in Energy and Combustion Science and the Annual Reviews of Fluid Mechanics, use university people to an even greater degree. In the recent elections to the National Academy of Sciences, 80 percent of the new members were from universities. The fact that as many as 37 percent of the members of the National Academy of Engineering are in universities attests to the high concentration of applications-oriented talent in universities.

TABLE 2

MEASURES OF RESEARCH CONCENTRATION

	INDUSTRY	GOVERNMENT (incl. labs)	UNIVERSITIES
Referred Journals			
Combustion & Flame (1/75-6/77)	19%	12%	69%
J. Catalysis (6/75-5/76)	23%	10%	67%
Review Journals			
Prog. Energy & Combustion Sci.	23%	5%	73%
Ann. Reviews of Fluid Mech. (74-77)	2%	11%	87%
Academy Memberships			
Nat. Acad. Sciences (1977 elections)	10%	10%	80%
Nat. Acad. Engrg. (all)	55%	9%	37%