# ENVIRONMENTAL RESEARCH AT THE LARAMIE ENERGY TECHNOLOGY CENTER

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## ABSTRACT

Since the founding legislation in 1944, the Laramie Energy Technology Center (LETC) and the associated Anvil Points Oil Shale Facility have been affiliated with three different agencies: the Bureau of Mines, the Energy Research and Development Administration and currently the Department of Energy (DOE). The activities at the Center have ranged from nearly academic pursuits to the management of modular demonstration (precommercialization) projects in processing technology through Government/Industry Cooperatives. Current program plans are in terms of long range, high risk research at laboratory, bench and pilot scale to examine concepts. Current research programs at LETC in mitigation and monitoring of environmental impacts for air, water and land/solid waste are presented.

## INTRODUCTION

Research programs at LETC, which have been aimed principally at short-term problems in environmental monitoring and control technology development for air, water, and land/solid waste associated with various synfuel extraction techniques have been subject to reevaluation recently. The research facility at Laramie has had three agency affiliations in its period of existence with three corresponding sets of operational guidelines. As a Bureau of Mines, and later ERDA entity, the programs were structured to assemble data on small scale experiments related to oil shale and tar sand processing, underground coal gasification and petroleum utilization. In the recent past, as a DOE facility, the emphasis has been in project management for large scale Government/Industry Cooperative efforts where less LETC-centered research activity could be sustained. Contract management for large research, development and demonstration projects had replaced internal technology development. Current governmental restructuring appears to establish the third and current role for LETC closely related to the first, where internal research activity will be emphasized and accompanied by contract work structured to support that research. Activities in development of short-term solutions are being supplanted by those in areas of long range, high risk, conceptual definition and development.

In environmental research, the environmental concerns have not changed, but the approaches toward reducing uncertainties have. In general, prototype engineering demonstrations have given way to concept definition experiments. Experiments have been scaled to that necessary for fundamental chemical and physical process definition, and range from laboratory and bench scale

experiments through pilot/field scale. Where larger scale may be required to determine concept feasibility, experimentation might proceed in cooperation with industry where sufficient innovative benefits may be expected. This paper outlines the research technology base development activities in monitoring and mitigation of environmental impacts in oil shale resource development for air, water, and land/solid waste.

AIR

The principal effort in mitigation of impacts to air is in definition and development of concepts for environmental controls for off-gas and the development of the requisite sampling and characterization methodology to support this definition (1). In addition to the sampling and characterization methodology which will be developed, this program will also generate a data base of uniformly high quality in an area where good data are lacking. Experimentation will continue at the LETC North Site 150-ton (2,3) and 10-ton NTU-type (4) retorts and, as appropriate, at the Anvil Points Oil Shale Facility gas combustion-type retorts (5). Research supporting the pilot plant experiments will continue at laboratory and bench scale at LETC and selected laboratories in the DOE oil shale program.

Experimentation in emissions control is proceeding integrally with the retorting technology base development, which includes basic physical and chemical process definition and model development. With respect to the retorting process itself, of special interest are the mechanisms of mist/particulate formation and coalescence, origin and fate of gaseous sulfur and nitrogen species as well as the origin, transport and fate of gaseous (and aqueous) metallic species.

In an integrated processing system where environmental control may originate not necessarily in a unit operation or "black box" it seems appropriate to define a control element. This element is that array of factors within the system which determine the efficiency of the process toward a particular control objective. For example, a sulfur control element may be the mode of retorting itself. Associated with any control element, processes important in removal efficiencies are being identified and quantified. Removal efficiencies are being determined. Experiments scheduled for 1981 are a sequel to the September 1980 DOE/EPA cooperative 150-ton retort Venturi scrubber experiments just described in this symposium in papers from the Monsanto Research Corporation (sponsored by the EPA) and from the Denver Research Institute (sponsored by DOE). These experiments indicated that 50-75 percent ammonia removal from the off-gas was accomplished, and particulate removal efficiencies of up to 94 percent were observed. These results together with the commercial history of using ammonia-water solutions for the selective removal of $H_2S$ from coal-gas streams (6), suggest the possibility of using the Venturi scrubber as a combined mist/particulate removal and $H_2S$ removal device for oil shale retort off-gases. Removal of a significant fraction of the $H_2S$ in the off-gas would lower the demands on downstream acid-gas removal by amine scrubbers, Stretford or other devices.

Because large retort runs are expensive and currently relatively infrequent, active laboratory/bench scale retort and control element research projects will support the above work. The laboratory/bench experiments will be performed first to determine correlativity of these runs with the more real world of the pilot plants.

Then, if that is established, the large retorts will be used only for confirmation of lengthy extrapolations. The big retort runs are, however, considered quintessential in concept definition for technology base development.

The importance of reliable characterization of the experiments cannot be overemphasized. The sampling and analysis is not a trivial question. These off-gas and effluent streams are rarely homogeneous, even when all phases are considered. Although a variety of analytical devices are being integrated into the retort off-gas analytical system, particular study of the sampling methodology seems a basic need and is being addressed. On-line analyzers will include a mass spectrometric process gas analyzer, gas chromatographs with hydrocarbon and sulfur detectors and a variety of specific gas analyzers including absorption trains.

The potential for air emissions from ponded process waters will be evaluated in conjunction with some of the water treatment work described in the next section.

In summary, the LETC North Site retorts will serve as a focal laboratory for oil shale retort off-gas characterization and impact mitigation research which is planned and implemented integrally with retorting research. Water and waste treatment/utilization research is performed concurrently as described below.

WATER

The LETC wastewater control technology development program addresses two distinctly different needs from one research base. The first need is that of concept definition for oil shale processing technology base development; the other is that of regulatory compliance at DOE pilot plant and field site facilities. The compliance aspect implies, in contrast to the concept definition aspect, the anticipation of process demonstration for cleanup at existing facilities. The relationship of control technology research to compliance has been discussed earlier (7). Compliance activities often provide a meaningful stage and driving force for an R&D activity. Such is the case for process water treatment and, as will be seen in the next section, for solid waste disposal.

Quantities of water which have accumulated over long periods of oil shale retorting experiments at the LETC North Site must be disposed of in order to continue the operation of the site. Venturi scrubber operation requires real-time water recycle because of the very large holding capacities which might otherwise be required. To meet this need, a 100,000-gallon holding pond is being installed at the site.

Water treatment modules will be used to treat condensate water for recycle to the Venturi and also to devolatilize retort water from closed tankage for discharge to the evaporation pond. In addition, life testing of reverse osmosis modules will be performed on the ponded residues (8,9,10). Depending on the outcome of these tests, determination of how to dispose of the aqueous residuals will be determined.

In addition to the expediencies above, the current and near term water quality effort at LETC for oil shale research will involve the evaluation of various control technology strategies. As said above, the LETC programs will stress concept definition and development rather than hardware evaluation. Previous wastewater treatment evaluations at LETC paralleled other portions of DOE's oil shale program. That is, the majority of

the activity was directed toward an evaluation of those processes which would be supportive of first generation oil shale developments (11). In those programs involving joint DOE-industry cooperatives research approaches to control technology application were not employed. In their place, a system of vendor supplied hardware was chosen. Field level testing of this equipment in conjunction with the initial oil shale development activity was to determine overall treatment suitability for specific hardware selections. With the new direction of research activity, long term, higher risk projects will be undertaken. Those ideas and concepts which are not ready to be explored in the private sector may be researched under government auspices. A general description of the overall program structure and examples of current research efforts follow.

At the core of the synfuels wastewater treatment program at LETC is the concept of secondary or by-product recovery. The standard approaches to wastewater treatment for municipalities, as well as for industries, has been one where an unusable solid waste often results. This approach, if applied to synfuel wastewaters, is unacceptable as is the idea that these waters can be evaporated on a routine basis. With heavily laden waters biological treatment will create large volumes of solid waste, while disregarding the potential for recovering secondary materials such as heat, steam, additional hydrocarbons, various metallics, ammonia and sulfur. Evaporation, when practiced on an industry-wide scale disqualifies a potentially large water source from additional use. In addition, those efforts structured to assist an emerging industry by their very nature are ill equipped to address second generation problems.

The LETC control technology research approach is structured to follow a statistical control basis where the results of a single effort or investigation can be compared directly to those generated from another source. The statistical control basis demands overall control from collection through analysis. Inherent in this approach are structured similarities for different researchers.

- same wastewater
- same analytical methods
- same replicates
- same constituents
- same statistical procedures

With this approach results from one research project may be compared directly with those from another. Fundamental to this unified statistical control approach is the preparation of individual and overall coordinated research plans, no deviation from any individual plan, and the application of proper statistical models to draw comparisons and conclusions. Results from an effort following the above guidelines will be accorded maximum credibility for the samples and conditions selected.

The research effort at LETC is a combination of in-house and contractor labor. Bench scale reactors will be utilized to screen and further define and develop basic concepts or to plan larger experiments for oil shale and tar sand processing and underground coal gasification wastes. The most promising concepts as well as those limited in application to larger scale experiments will be tested at LETC's 150-ton retort or at existing or future field sites. Currently, LETC is retrofitting an existing laboratory to contain sufficient equipment to perform the full range of environmental engineering eval-

uations listed below. Oil shale conversion waste streams, as well as those subjected to various combinations of pretreatment, will be tested for constituent removal as well as secondary materials concentration and recovery. Various methods of waste stream segregation will be surveyed. The treatment efficacy of individual unit processes, as well as various process train combinations for these segregated waste streams, will be compared to that determined for the entire waste stream. Secondary product recovery potentials from each unit process will be determined. Examples of secondary materials which will be identified include steam, heat, supplemental hydrocarbons, select metallics, ammonia, and sulfur. The unit processes, which will be used in initial evaluations, whether singly or in process trains include:

- Flotation
- Filtration
- Coagulation
- Stripping
- Wet air oxidation
- Reverse osmosis
- Foam separation
- Biological processes

Any solids resulting from these efforts will be analyzed to determine heat content before and after dewatering. Dewatering schemes will include vacuum filtration, freeze-thaw, polymeric conditioning and gravity drainage. The environmental effects of the fluids, as well as leachates from the solids, will be determined by using standard biological toxicology testing on the products and selected fractions. Supplemental to this research, a comprehensive organic carbon identification program utilizing HPLC, GC, GCMS, and in some cases tritium-tracer technology will be implemented to track specific compounds and groups of materials through the treatment schemes. Models will be generated to compare the removal of traditional parametric variables such as COD, TOC, and alkalinity with those of more specifically determined constituents. Preliminary economic evaluations will assist in determining the efficacy of treatment and secondary materials recovery.

While these bench scale efforts are structured to be independent studies, they also serve to supplement pilot-scale research at LETC's North Site retorts described above. In addition, the refrigerated water sample repository established at LETC will be maintained to provide meaningful samples in large quantities for treatment and effects studies (12).

LAND/SOLID WASTE

The solid waste management activity will, as with the other commodities discussed above, focus on long-term generic research. This effort will investigate real world solid waste management practices via controlled research conditions. Portions of the LETC solid waste management research will be conducted at the DOE Anvil Points Oil Shale Facility located near Rifle, Colorado. The approach will be to construct a retorted shale fill, probably in East Anvil Points Gulch, with design provisions for field level experimentation for environmental impacts monitoring and mitigation.

The Anvil Points site has been utilized for development of oil shale mining and processing since the mid-1940's. Subsequently, both stream and drainage basin characteristics have been described in considerable detail (13): wastes from experimental processes have been stored in the gulch adjacent to the facility (referred to as

East Anvil Points Gulch); spent shale presently located at this site can be described as both weathered and fresh in the approximate proportions that would be expected in an operational commercial facility. On the whole, Anvil Points shale represents the "probable" best experimental conditions for retorted shale research to be found.

In addition, there is a compliance need to set the site in order for the State of Colorado with the cooperation of the Department of Natural Resources, Mined Land Reclamation Office. Any contemplated future activity at the facility would hinge on satisfaction of this need. If future retorting occurs there, it is planned to add on to the pile established and have a real working operation with respect to retorted shale disposal.

The LETC, Carbondale Mining Technology Center, and the U.S. Army Corps of Engineers (CE), Waterway Experiment Station (WES), have entered into an interagency agreement to develop the research spent shale pile design and ancilliary research provisions within the structure. It is the contention of LETC that a spent shale fill conservatively designed and equipped in an engineering sense is of paramount importance in mitigating existing environmental impacts at this site and for developing experimental monitoring and control strategies for future retorting experiments. Recognized expertise in soil mechanics, engineering geology, rock mechanics and structural design will be utilized. The WES is the principal research, testing, and development facility of the Corps of Engineers and has recently completed a 2-year project to determine the physical and engineering properties of retorted oil shales (14). The project was funded by the U.S. Bureau of Mines. Extensive testing was conducted on spent shale from the Paraho retorting processes. The WES project has generated complete static and dynamic properties for the spent shale. These properties are critical for conducting fill design and stability analyses. The design will use previously developed Paraho process retorted shale, together with physical, topographic, hydrologic (13,15) and chemical (16) characteristics at Anvil Points.

The shale fill will consist of an initial design for the approximately 400,000 cubic yards presently located at the site with incremental design provisions for a 40-year period of retorting research. The ultimate design will be for the stable configuration at a 1.25 million cubic yard fill. The initial through final construction design will be provided with instrumentation and wells to monitor groundwater above, in and below the fill, fill temperatures, settlement and embankment stability.

The DOE research design will include the following integrated engineering and scientific objectives:

- Permanent surface fills for spent, reject and run-of-mine shale
- Temporary surface fills for stockpiled raw feed shale for retorting and run-of-mine raw shale
- Fill location, foundation and hydrologic character
- Engineering fill properties of Paraho retorted shale
- Analysis of alternative fill configurations
- Stability analysis under static and dynamic conditions, both with and without seepage forces.

- Fill stability monitoring instrumentation alternatives
- Design compactive efforts required for spent shale embankment, including controlled channelization of seepage and runoff for shale leachate contaminant control
- Design compactive efforts for layered raw and spent shale to create impermeable barriers preventing combustion and water infiltration
- Alternative hydrologic and water quality monitoring well locations.

Design features to be provided by this study will be used to conduct long-term and condition intensive data base gathering control technology and reclamation studies at the site. First phase studies will emphasize literature and field study, groundwater characterizations, spent shale contaminants, and run off and seepage wake treatment strategies. Long term studies will include chemical and hydrologic monitoring. Continued investigations of breakthrough chemical indicators, contaminant release modeling, surface and subsurface water quality effects, erosion and reclamation and revegetation research studies.

It is believed that the best approach to research in retorted shale stabilization is through field testing of the best engineering concepts available. That is the intent of this activity.

## SUMMARY

Current research activities at DOE/LETC in mitigation and monitoring of environmental impacts for air, water and land/solid waste cover a full operational spectrum from laboratory/bench through pilot/engineering scale. Activities are aimed at data base and technology base development through concept definition using a systems approach, where the shale conversion engineering research and the environmental engineering research are planned and implemented concurrently. Energy and materials recovery/utilization is emphasized in the environmental research.

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