**DOE/PC/95231-13
DIST. CATEGORY UC-112
UTSI-97-03**

**TECHNICAL PROGRESS REPORT
FOR
UTSI/CFFF MHD PROGRAM COMPLETION
AND RELATED ACTIVITY**

**For The Period
July 1, 1997 - September 30, 1997**

October 1997

Work Performed Under Contract No. DE-AC22-95PC95231

**Prepared for:
The United States Department of Energy**

**Prepared by:
The University of Tennessee
Space Institute
Energy Conversion Research and Development Programs**

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EXECUTIVE SUMMARY

Routine preventive maintenance of the DOE Coal Fired Flow Facility (CFFF) is being performed. Modernization programs, funded under subcontract from Foster Wheeler Development Corporation by the DOE HIPPS Program, have been completed on the coal processing system, the data acquisition and control system and the control room.

Environmental restoration actions continued with monitoring of groundwater wells and holding pond effluent. A plan for Groundwater Remediation was prepared, coordinated with DOE and forwarded to the State for approval. Actions are underway to dispose of spent seed/ash mixtures and excess coal remaining from the MHD POC program.

The status of six (6) High Temperature Superconductor (HTS) projects is reported.

TASK 1 - FACILITY AND PROPERTY MANAGEMENT

Activities this quarter were concentrated on the facility preventive maintenance /repairs required to maintain the Coal Fired Flow Facility in a standby condition. Weekly and monthly equipment maintenance procedures were performed for facility air compressor systems, cooling water pumps, coal processing system motors, steam boiler systems, ID and FD fans, and fire water system equipment.

As part of the preparation for testing of the Westinghouse combustor, checkout of the high pressure natural gas system was initiated and the crankshaft of one of the two compressors failed during checkout testing. Testing, repair and installation of this compressor crankshaft was completed this quarter. Successful checkouts were also performed on the oxidizing air compressors and the high pressure air compressor system.

Started updating facility maintenance procedures to comply with the State of Tennessee Minimum Fire/Life Safety Standards. Most of the standards are already in place but the frequency of some inspections is being increased.

Completed design, installation, and checkout of a new burner control circuit for the lower process gas heater. This circuit replaces a troublesome programmable logic controller (PLC) and the new design is much simpler and more reliable and represents a significant cost savings when compared to the cost of repairing the PLC.

Continued formal documentation of the instrumentation drawings to meet ISA standards. These drawings have made the new DCS system configuration much easier and will form part of a complete test documentation package. Work continued to configure the control system and to install data control modules into Test Bay 3 and Test Bay 1. Installation of a data control module at the Fuel Blending System also started this quarter. Reconstruction of the Gas Analysis System continued and parts were ordered to repair the gas sample lines from Test Bay 3 to the Gas Analysis Shelter.

TASK 2 - REPORTING AND ARCHIVING

The April - June 1997 Quarterly Technical Progress Report was approved on August 25, 1997.

All major pieces of equipment, mechanical and utility systems, and test hardware items in the CFFF have been documented with drawings and specifications. All hardware and systems added to the CFFF or modified since 1985 have been documented in AutoCAD format. Original drawings, microfilm copies and computer disks are maintained for archival purposes as well as daily use in maintaining the CFFF.

The Design Engineering Department continues to support the collection, filing and updating of CFFF mechanical system design documentation.

TASK 3 - SITE ENVIRONMENTAL COMPLIANCE AND REMEDIATION

The "loop is closed" on the spent water treatment chemical disposal that was reported in the July monthly report. The appropriate documentation is on file.

Arrangements are being made to employ another company to handle CFFF non-residential type wastes. This will require approval from the State to transfer our special waste permit. UTSI will not have to pay the \$500 fees again, however.

The TRW tote bins have been positively identified and arranged such that hopefully no further confusion will occur.

Remediation of the diesel area was not begun as of 9/31/97 because UTSI has received no approval from the State. This may be postponed until July/August of 1998 time frame due the weather considerations.

As of 9/31/97 no approval of the revised GW source plans had been received.

Several "slugs/bail tests" were completed for UTSI GW wells 5,6,7,11&13 (See Figure 1). The purpose of these data are to calculate a constant known as hydraulic conductivity (K) for each screened depth. The hydraulic conductivity, K, is a constant of proportionately and varies with the media (and fluid type). Our well soil (media) varies with depth. K can be used when evaluating inflow rates and velocity using Darcy's law. If the screen length ratio to well radius is greater than 8 (L/R) then a graphical method proposed by Hvorslev, and described by the concluding reference is handy and clever due to the inherent accuracy. An example has been provided below.

Figure 2 is from data taken at well 13 on 9/25/97, and is an example of the graphical method described in the reference. The purpose here is not one of accuracy, but practical example using real, but approximate measured values.

T_0 represents the time required to complete equalization of the head difference after a slug of water is removed IF THE ORIGINAL RATE OF INFLOW WERE MAINTAINED. Due to mathematical considerations the point 0.37 is unique using this method, and the corresponding point on the x-axis yields a time (T_0) graphically on the x-axis. This is then used in the equation $\{K=r^2 \ln(L/R)/2LT_0\}$ to calculate the hydraulic conductivity. (Ref: "Groundwater, Freeze, R.A. and Cherry, J.A., 1979, Prentice-Hall, Inc. pp. 339-341).

REV.	REVISION	DATE	BY	APPROV.
A	REVISED WELL TAG NUMBERS	9/1/91	DLP	
B	ADDED AIR HEATERS, WET ESP, ROTARY VACUUM FILTER, AND LIQUID SEED TANK	4/24/93	WTM	
C	ADDED WELL LOCATIONS #9 THROUGH #15 AND SOIL SAMPLE LOCATIONS	8/14/98	WTM	

LEGEND:
 ● WELL LOCATION
 ○ PRELIMINARY SOIL INVESTIGATION SAMPLE LOCATION

GROUND ENGINEERING AND TESTING SERVICE, INC. 4814 COMMERCIAL DRIVE, N.E. HARTSVILLE, ALABAMA 35818	JOB NO. EH5099
SITE DIAGRAM	DATE: 3-17-97
THE UNIVERSITY OF TENNESSEE SPACE INSTITUTE	DRAWN: ED
TULLAHOMA, TENNESSEE	SCALE: 1" = 300'

Figure 1. Groundwater Well Layout

NOTE: Drawing provided by USTI to map.

Figure 2. Well Recovery Data Plot

TASK 4 - SITE REACTIVATION

No work was scheduled or performed.

TASK 5 - DISASSEMBLY AND DISMANTLEMENT (D&D) OF THE CFFF

No work was scheduled or performed.

TASK 6 - ADVANCED TECHNOLOGY, RESEARCH, DEVELOPMENT AND ENGINEERING FOR OTHER FEDERAL OR DOE PROGRAMS

Subtask 6.02 Evaluation of Methods for Application of Epitaxial Layers of Superconductor and Buffer Layers

During the reporting period of July 1, 1997 to September 30, 1997, the following progress was made on the above project.

- A bench scale batch mode dip coating unit for the sol-gel process was assembled that includes a translation unit with a small motor and a clamping mechanism to hold a substrate sample inside a casing. The operation of the translation unit is controlled with a key-in pad computer to move the sample into the solution and then to withdraw it at a desired withdrawal rate/velocity. After assembled, this unit was used to coat LaAlO_3 on SrTiO_3 single crystals to reproduce the earlier results obtained at ORNL by the spin coating method. The films were examined for continuity using a profilometer.
- Fresh aliquots of LaAlO_3 solution/gel were prepared with different degrees of hydrolysis. These solutions/gels were coated onto SrTiO_3 single crystals in a systematic manner following a test matrix comprising the important variables. In this matrix, a base condition is determined based on the earlier knowledge and experience and the other variables are changed one at a time to determine the effect on the buffer layer. The parameters included in the test matrix are degree of hydrolysis, withdrawal velocity, aging temperature of solution, pyrolysis/annealing temperature, time and O_2 concentration. The coated samples are then tested by the XRD to determine phase and crystalline orientation. Several samples are now being tested at UTSI for the Omega and Phi scans using our newly acquired XRD machine.
- A fresh solution of the YBCO precursor was also prepared by the sol-gel

route. Efforts are now underway to reproduce the earlier results obtained at ORNL.

- Coating of LaAlO_3 solution on RABiTS nickel substrate will be carried out using the similar test matrix as the one used for the SrTiO_3 single crystals.
- A draft of the technical paper describing the process evaluation work carried out at UTSI has been prepared. It will then be submitted for possible publication in the Journal of Applied Superconductivity after internal and DOE reviews and approval.

Subtask 6.03 Coated Conductor Development Steering Committee and Program Management

The final draft of the Research and Development Roadmap to Achieve Electrical Wire Advancements from Superconducting Coatings was prepared and forwarded to DOE for approval this quarter.

Subtask 6.04 Optimum Coated Conductor

The following activities were accomplished in the July to September period:

- AFM measurements were made for step and spherical standards calibration methods
- AFM characterization of grain boundaries for small and large grain sizes was made
- 2-D model of grain boundaries constructed
- 3-D model of two-layer tape system started

Atomic force microscopy investigations of grain boundaries in RABiTS materials were continued. As part of the calibration matrix for an investigation of annealing characteristics on grain boundary grooving, a comparison of samples annealed at 600°C and 800°C was made. The 600°C sample showed evident grooving around small (~20 micron) grains, but the larger grains were very difficult to discern. Also, the rolling marks remained at this temperature. However at 800°C, the sample was fully annealed and there were significant increases in the grain boundary grooving compared to 600°C. Large (~100 micron) grains exhibited grooving, and the small grains were more pronounced than at 600°C. These results suggest that the planned investigation of an intermediate annealing temperature (or duration) should provide valuable information on minimizing grain boundary roughness.

Figure 3 illustrates a 2-D FEM model of a thermal groove under a cooling load from an anneal temperature of 700°C to ambient conditions. This model was constructed as a template, with the appropriate length dimensions to be obtained from AFM measurements. A 3-D model of a general tape-like configuration is also under development.

Figure 3. 2-D Model of Symmetric Grain Boundary Under Thermal Load

Future work in this area will include the AFM test matrix, dimensional characterization for 2-D groove model, and further development of 3-D tape model.

The objective of the other part of this subtask is to evaluate alternating current losses so that a conductor or cable can be configured in such a way as to minimize these losses. Work during this quarter has concentrated on the theory, calculational difficulties and planning experiments when sufficient lengths become available.

In this effort, the ac loss models for low temperature superconductors provide guidance. In general, variants of the Bean critical state model have been shown to be applicable to HTS conductors, especially in multifilament BSCCO wires and tapes. YBCO coated conductors differ from LTS and BSCCO/Ag conductors in that the metal components are electrically isolated from the superconductor and the YBCO superconductor is highly anisotropic if biaxially aligned. In the case of the former, parasitic eddy currents coupling multiple tapes in a conductor are precluded and in the latter, the orientation of applied field is important. Hysteretic losses due to irreversible flux motion will dominate many applications.

Subtask 6.05 Cost Performance Analyses of Potential Manufacturing Processes

Work continued this quarter on a comparative analysis of two processes that are similar except for methods of applying the superconductor. One process uses pulsed

excimer laser vaporization of YBCO. The other process uses electron beam vaporization of elemental Yttrium, Barium and Copper, controlled so that the stoichiometry at the deposition site is correct for the formation of YBCO superconductor. The factors leading to the study are that the vaporization energy is three orders of magnitude cheaper for electron beam deposition than for the pulsed excimer laser. However, the electron beam system requires more expensive measurement and control systems to control the Y, Ba and Cu stoichiometry, plus it requires a much higher vacuum (10^{-5} Torr) than the PLD (0.2 Torr).

This quarter, conceptual designs and capital cost estimates were completed for the rolling mill, heat treatment furnace and electron beam web coaters for applying the buffer layers of cerium oxide and yttrium stabilized zirconia. Vacuum chamber estimates were made for the two processes but additional work needs to be done to accurately reflect the differences in pumping required to operate at different pressure levels.

In addition, additional raw material cost estimates were received that permit comparing the cost of materials for the two processes, excluding coating costs, which remain to be investigated. To meet the performance goals of the R & D Roadmap mentioned above of current density in the superconductor of 10^6 in the superconductor and an engineering current density of 10^5 , the fill factor (superconductor cross-sectional area divided by total wire cross sectional area) of at least 10%. If superconductor layers are limited to 2 micron thickness and metal substrate must be at least 1.5 mills (38.1) microns, superconductor coating will be required on both sides of the substrate. Assuming these values and for the configuration shown in Figure 4, raw material costs have been calculated for both processes and are shown in Table 1 for the electron beam process and Table 2 for the PLD process. Note that these estimates show a significantly lower cost for the electron beam process but this must be viewed in the context of the total cost of production.

Next quarter, the additional capital cost estimates will be completed and a comparison of the cost of production by each process will be possible based on life cycle costs for the manufacturing facility.

Subtask 6.06 Development of Real Time Process Control Using In-Situ Diagnostics

The X-Ray diffraction system was installed and activated this quarter. Training was completed for one engineer, who will train additional personnel to operate the system in the future. Initial utilization was to do pole figures and phi scans for 26 samples prepared by the UTSI Graduate Research Assistant working at ORNL on the Sol Gel process. This will help to alleviate the backlog on the ORNL X-Ray diffraction systems and provides faster response times. This equipment will also be used to provide analytical capability to support small businesses working on the HTS program.

ASSUMED COATED CONDUCTOR

(Not to Scale)

Figure 4.

Table 1
MATERIAL COST ESTIMATES FOR ASSUMED COATED CONDUCTOR
ELECTRON BEAM

<i>Material</i>	<i>Thickness</i>	<i>Volume (cm³)</i>	<i>Weight Deposited (gm)</i>	<i>Weight Evaporated (gm)</i>	<i>Price (\$/kg)</i>	<i>Cost (\$/m)</i>
Y			.0349	.3299	345.	0.1137
Ba	2X2μ	4X10 ⁻²	.1083	1.0213	125.	0.1277
Cu	(YBCO)	(YBCO)	.0752	.7090	41.	0.0291
Ce	2X100Å	2X10 ⁻⁴	1.182X10 ⁻³	1.115X10 ⁻²	394.	0.0044
YSZ	2X100Å	2X10 ⁻⁴	1.120X10 ⁻³	1.057X10 ⁻²	1,298	0.1372
Ni	38.1μ	.381	3.382 (substrate)	--	38.27	0.1294
TOTAL						\$.46/m

for $J_c = 10^6$, $l = J_c A = 400$ Amps

$$\text{Cost/KAm} = \frac{0.46 \text{ \$ / m}}{0.4 \text{ KA}} = \$1.15 / \text{KAm}$$

Table 2
MATERIAL COST ESTIMATES FOR ASSUMED COATED CONDUCTOR
PULSED LASER DEPOSITION

<i>Material</i>	<i>Thickness</i>	<i>Volume (cm³)</i>	<i>Weight Deposited (gm)</i>	<i>Weight Evaporated (gm)</i>	<i>Price (\$/kg)</i>	<i>Cost (\$/m)</i>
YBCO	2X2μ	4X10 ⁻²	.2628	2.479	300.	0.744
Ce	2X100Å	2X10 ⁻⁴	1.182X10 ⁻³	1.115X10 ⁻²	394.	0.0044
YSZ	2X100Å	2X10 ⁻⁴	1.120X10 ⁻³	1.057X10 ⁻²	1,298	0.1372
Ni	38.1μ	.381	3.382 (substrate)	--	38.27	0.1294
TOTAL						\$1.01/m

for $J_c = 10^6$, $I = J_c A = 400$ Amps

$$\text{Cost/KAm} = \frac{1.01 \$ / \text{m}}{0.4 \text{ KA}} = \$2.54 / \text{KAm}$$

The Raman Spectroscopy experimental set-up was nearing operational status at the end of the quarter. This will permit evaluation of methodology for determining the status of crystal deposition in near real time. As such, it will be evaluated as an input to control systems for HTS production processes.

A new Graduate Research Assistant began work in September, whose work assignment will be to complete the apparatus for measuring the atomic absorption spectra of THMD compounds of Yttrium, Barium and Copper as they are separately vaporized in a chamber simulating MOCVD deposition. These results will show whether it is feasible to determine concentrations of Y, BA and Cu accurately enough by this method to control the stoichiometry in the vicinity of the deposition site. Additional work in support of Midwest Superconductivity, Inc., to determine the quality requirements for the THMD powders was delayed somewhat due to the need to get factory service on two of the instruments in the DOE chemistry laboratory.

No further work is planned on the detailed listings of control system requirements for each of the nine potential HTS production processes as published in the draft topical report submitted last quarter. These will be considered in more detail as needed for the selected processes.

Subtask 6.07 Innovative Manufacturing Processes for Coated Conductors

As mentioned in the last quarterly report (April - June 1997) the main aim of the present efforts was to achieve a spatter-free/contamination-free full and uniform coverage of the CeO_2 coating as a buffer layer on the nickel substrate. The approach was based on the following considerations.

- Inject the powder precisely into the core of the laser beam where energy density is high enough to evaporate the entire stock of the incoming powder.
- Deliver the powder closer and parallel to the sample surface to ensure all incoming powder particles experience the same thermal conditions.
- Use extremely fine (< 50 nm) powder to ensure the entire powder particle reaches the temperature equal to or above the evaporation temperature in very short duration (2 μs).
- Subject the coated sample to laser fluences, subsequently to clean up the spatter by evaporation and condensation (post-deposition cleaning).

Experimental:

In view of the above considerations, the present experiments were conducted using a Lumonics TEA-CO₂ laser operated in pulsed mode. Pure nickel substrate (25 mm x 25 mm x 3 mm) was mechanically polished on various grit papers followed by final polishing with 0.3 μ m diamond paste to mirror finish. The sample was traversed under the laser beam using a CNC system to provide constant linear translation of the work-piece. Several laser tracks were laid with overlap of about 20% to achieve entire surface coverage. A dynamic fluidized-bed powder feeder (refer to the April - June 1997 Quarterly Report) delivered the precursor powder (CeO₂ and MgO) at the laser-materials interaction region.

For a given combination of the laser beam delivery and the powder delivery systems, an angle of powder jet injection with respect to the laser beam axis can influence the thermal conditions that the powder particles experience prior to deposition as shown schematically in Figure 5. These thermal conditions will have a bearing on producing a spatter or spatter-free deposition. Based on our observations during present efforts, a 30° angle appears to provide optimum thermal conditions for the purpose.

Table 3 provides materials and range of laser processing parameters employed in the present study. Table 4 lists specific combinations processing parameters utilized for various samples.

Table 3. Materials and TEA-CO₂ Laser Processing Parameters

Precursor powder	CeO ₂ , 12 nm average particle size MgO, 35 nm average particle size
Powder flow rate	30 mg/min
Carrier/Shielding gas	Argon (90vol%) + Hydrogen (10 vol%)
Power	0.2 J/pulse
Pulse frequency	15-20 Hz
Pulse duration	2 μ s
Beam diameter	1 mm at the sample surface
Traverse speed	100 mm/min
Powder jet inclination	30° with laser beam axis

Figure 5. Spatter Formation Due to (a) Axial and, (b) Transverse Beam Intensity Distribution

Table 4. Laser Processing Parameters Used for Different Samples

Sample Number	Powder	Power (kV)	Pulse Frequency (Hz)	Index (mm)	Post Deposition Cleaning Pulse Frequency (Hz)
1	CeO ₂	35	15	1.0	20
2	CeO ₂	38	15	1.0	20
3	CeO ₂	35	20	0.5	20
4	MgO	35	20	0.5	20

The laser treated samples were evaluated for topographical features using SEM and for elemental and phase analyses using EDS and X-ray diffractometry.

Observations/Results:

The TEA-CO₂ laser as mentioned above in configuration with the powder feeder was expected to provide suitable thermal conditions for deposition of a thin layer with minimal, or without any, contamination and/or spatter. These expectations were further explored for pure nickel substrate exposed to the TEA-CO₂ fluences obtained with parameters mentioned in Table 4. Figure 6 includes the SEM micrographs of microstructures of the nickel sample (sample #1) after laser treatment. The calculations based on image analysis indicated that the coating coverage is about 65%. Such incomplete coverage could be due to inappropriate thermal conditions experienced by the powder particles during their traverse through the beam. However, elemental x-ray map analysis (Figures 6b and c) along with energy dispersive spectroscopic (EDS) (Figure 7) and x-ray diffractometry (Figure 8) analyses confirmed the uniform and spatter-free/contamination-free deposition of CeO₂ phase material.

Sample 2 was processed under all identical conditions as those used for the sample 1 except the laser power. The available highest operating voltage (38 kV) was employed to process this sample. The coating coverage increased to about 85% (Figure 9) and appeared very thick with rough topography. These processing conditions, however, provided uniform and spatter-free/contamination-free deposition (Figures 9b and c) of CeO₂ phase materials (Figures 10 and 11).

Based on the above observations for the sample 2, it was concluded that the change in the processing parameters such as beam pulse frequency and the index might provide suitable thermal conditions to produce thin, uniform and spatter-free coating for the entire coverage of the sample. Higher pulse frequency with lower index

Figure 6. Nickel Substrate Coated With CeO_2 Film (sample 1). (a) SEM Micrograph Showing Topographical Features (b) and (c) X-ray Elemental Maps for Ce and Ni Respectively

Figure 7. EDS Elemental Analysis of the Area Illustrated in Figure 6a

Figure 8. X-ray Diffractometry Spectrum of the Sample 1

Figure 9. Nickel Substrate Coated With CeO_2 Film (sample 2). (a) SEM Micrograph Showing Topographical Features, (b) and (c) X-ray Elemental Maps for Ce and Ni Respectively

Figure 10. EDS Elemental Analysis of the Area Illustrated in Figure 9a

Figure 11. X-ray Diffractometry Spectrum of the Sample 2

and operating voltage expected to condense vaporized powder particles. Accordingly, Figure 12 illustrates near 100% coverage of CeO₂ layer on the sample 3. The layer is uniform and smooth (Figure 13) compared to layers on the samples 1 and 2. Again EDS (Figure 14) and x-ray (Figure 15) diffractometry analyses proved the coating is CeO₂. The combination of processing parameters employed for sample 3 appears to provide optimum conditions to produce a spatter-free CeO₂ coating with 100% coverage on the nickel substrate.

Attempts were made to use this optimum combination of the processing parameters (used for the sample 3) to deposit MgO on the nickel substrate. The deposit was not uniform (Figure 16) and not free of spatter/contamination (Figure 17a), however, the deposit was of MgO phase (Figure 18). Presently, the difference between the morphology and the total coverage of CeO₂ and MgO deposits synthesized under identical processing conditions can be accounted for by the higher melting point of MgO (2800°C) compared to the melting point of CeO₂ (2600°C). The higher melting point of MgO may not vaporize the entire volume of the powder thereby depositing the solidified particles as contaminants. Attempts will be made to identify the processing conditions to address this problem.

OPEN ITEMS

A. UTSI: None

SUMMARY STATUS ASSESSMENT AND FORECAST

The CFFF continues in a standby status with preventive maintenance and repairs being accomplished as funding permits. Utilization of the facility for other work, with DOE authorization, provides assistance in maintaining operational capability. Currently, tests of the Westinghouse Electric Corporation topping combustor are the only tests scheduled in the facility.

High Temperature Superconductor work continued substantially as scheduled on the six subtasks (6.02 - 6.07) previously authorized. Additional cooperative programs are being discussed.

A Source Plan for groundwater remediation at the CFFF was prepared and forwarded to the State of Tennessee this quarter. Also, a meeting was held with DOE Headquarters and FETC personnel to discuss this program.

Figure 12. SEM Micrographs of Nickel Substrate Coated With CeO_2 Film (sample 3) Showing Film Coverage and Topographical Features. (a) Low Magnification View and, (b) High Magnification View

Figure 13. Nickel Substrate Coated With CeO_2 Film (sample 3). (a) SEM Micrograph Showing Topographical Features (b) and (c) X-ray Elemental Maps for Ce and Ni Respectively

Figure 14. EDS Elemental Analysis of the Area Illustrated in Figure 13a

Figure 15. X-ray Diffractometry Spectrum of the Sample 3

Figure 16. SEM Micrographs of Nickel Substrate Coated With MgO Film (sample 4) Showing Film Coverage and Topographical Features. (a) Low Magnification View and, (b) High Magnification View

Figure 17. Nickel Substrate Coated With MgO Film (sample 4). (a) SEM Micrograph Showing Topographical Features (b) and (c) X-ray Elemental Maps for Mg and Ni Respectively

Figure 18. EDS Elemental Analysis of the Area Illustrated in Figure 17a

TASK AND COST VARIANCES

The positive variance in Tasks 1 - 3 were due to funding below the Management Plan levels for these Tasks.

Overall, the Task 6 program expenditures are very close to planned levels. The negative variance in equipment reflects that a major purchase, the x-ray diffraction equipment, was budgeted in a prior quarter.

July 1, 1997 - September 30, 1997 QUARTERLY VARIANCE REPORT

Planned vs. Actual Expenditures (thousands of dollars)

TASK	PLANNED	ACTUALS	VARIANCE
1	179.7	124.6	55.1
2	86.9	25.8	61.1
3	93.6	21.6	72.0
4	0.0	0.0	0.0
5	0.0	0.0	0.0
6	434.8	433.4	1.4
TOTALS	795.0	605.4	189.6
COST ELEMENT			
DIRECT LABOR	300.7	207.1	93.6
FRINGE BENEFITS	75.3	46.8	28.5
EQUIPMENT	155.5	204.8	-49.3
EXPENDABLE MATERIAL	33.9	9.9	24.0
OUTSIDE CONTRACTS	9.7	4.9	4.8
TRAVEL	6.7	2.9	3.8
TOTAL DIRECT COSTS	581.8	476.4	105.4
INDIRECT COSTS	213.2	129.0	84.2
TOTAL	795.0	605.4	189.6

Planned vs. Authorized Funding Cumulative

TASK	PLANNED	AUTHORIZED FUNDING
1	1222.6	
2	807.9	
3	599.4	
4	153.0	
5	118.0	
SUBTOTAL	2900.9	1654.7
6	2431.2	2851.3
TOTAL	5332.1	4506.0