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FEB 21 1989

DOE/PC/90274--T1

DE89 014126

MHD Integrated Topping Cycle Project

First Quarterly Technical Progress Report

Report No. MHD-ITC-89-001

Date Submitted: January 1989

Period Covered: September 1987 through October 1987

Reporting Organization: Applied Technology Division
TRW Space and Technology Group
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Redondo Beach, California 90278

Sponsoring Organization: U.S. Department of Energy
Pittsburgh Energy Technology Center

Contract Number: DE-AC22-87PC90274

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EXECUTIVE SUMMARY

This first quarterly technical progress report of the MHD Integrated Topping Cycle Project presents the accomplishments during the period from the contract start on September 30, 1987 to October 31, 1987. The scope of work covered by this quarterly report encompasses only project startup activities since the contract award.

During the first month of the contract, project planning was initiated. Primarily, these activities related to subcontract administration and project scheduling.

A preliminary project schedule is presented in Figure 1.

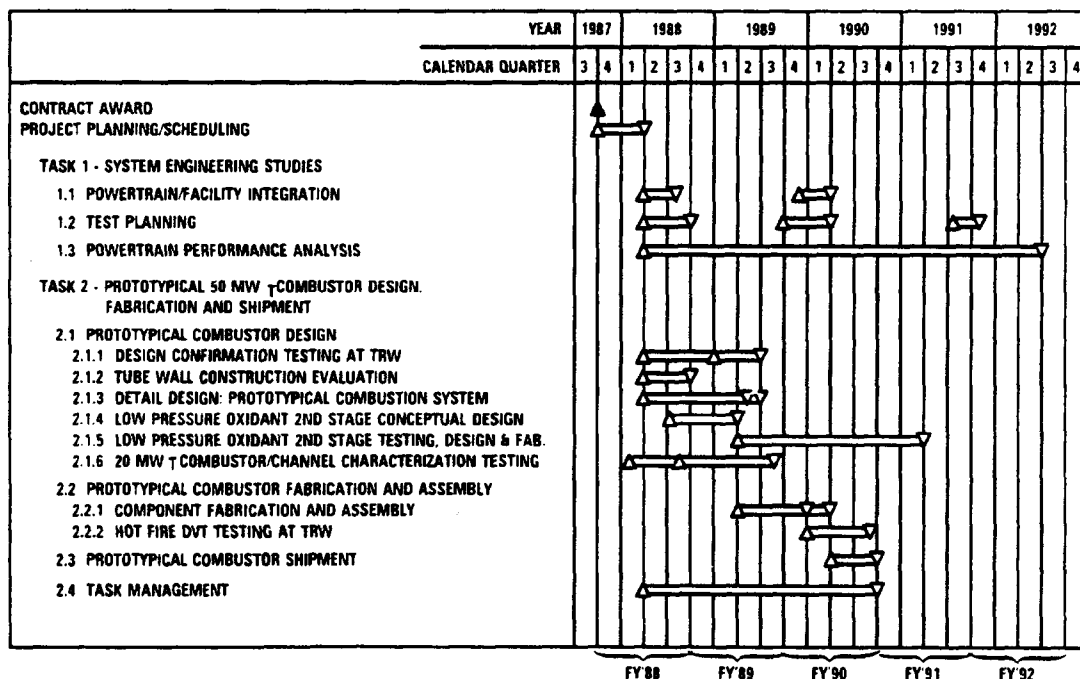


Figure 1. MHD Integrated Topping Cycle Preliminary Program Plan & Schedule

1. INTRODUCTION

The Magnetohydrodynamics (MHD) Integrated Topping Cycle (ITC) Project represents the culmination of the proof-of-concept (POC) development stage in the U.S. Department of Energy (DOE) program to advance MHD technology to early-commercial development stage utility power applications. The project is a joint effort, combining the skills of three topping cycle component developers: TRW, Avco, and Westinghouse. TRW, the prime contractor and system integrator, is responsible for the 50 megawatt slagging coal combustor. Avco is responsible for the MHD generator (channel), and Westinghouse is responsible for the power consolidation circuitry.

The ITC Project will advance the state-of-the-art in MHD power systems with the design, construction, and integrated testing of 50 megawatt power train components which are prototypical of the equipment that will be used in an early commercial scale MHD utility retrofit. Long duration testing of the integrated power train at the Component Development and Integration Facility (CDIF) in Butte, Montana will be performed, so that by the early 1990's, an engineering data base on the reliability, availability, maintainability and performance of the system will be available to allow scale up of the prototypical designs to the next development level.

Ten tasks comprise the ITC Project.

- Task 1 - Systems Engineering Studies
- Task 2 - 50 MW_t Combustor Design, Fabrication, and Shipment
- Task 3 - 50 MW_t Channel Design, Fabrication, and Shipment
- Task 4 - Diffuser Design, Fabrication, and Shipment
- Task 5 - Power Conditioning Design, Fabrication, and Shipment
- Task 6 - Test Engineering Activities at the CDIF
- Task 7 - Hardware Repair/Replacement
- Task 8 - MHD Technology Transfer/Integration
- Task 9 - Quality Assurance Plan
- Task 10 - Integrated Project Management

Work performed during the September 30 to October 31, 1987 reporting period focused on project planning. Revisions were made to the schedule contained in the ITC proposal to reflect an initial planning period of six months. Subcontract administration activities related to initiating the the major Avco and Westinghouse subcontracts were also begun. During the next reporting period, project planning will continue. Preliminary labor and cost plans will be developed, and a Management Plan will be submitted. Subcontract statements of work for Avco and Westinghouse will be developed in preparation for subcontract negotiations.

2. PROJECT DESCRIPTION

The overall objective of the project is to design and construct prototypical hardware for an integrated MHD topping cycle, and conduct long duration proof-of-concept tests of the integrated system at the U.S. DOE Component Development and Integration Facility in Butte, Montana. The results of the long duration tests will augment the existing engineering design data base on MHD power train reliability, availability, maintainability, and performance, and will serve as a basis for scaling up the topping cycle design to the next level of development, an early commercial scale power plant retrofit.

The components of the MHD power train to be designed, fabricated, and tested include:

- A slagging coal combustor with a rated capacity of 50 MW thermal input, capable of operation with an Eastern (Illinois #6) or Western (Montana Rosebud) coal,
- A segmented supersonic nozzle,
- A supersonic MHD channel capable of generating 1.5 MW of electrical power,
- A segmented supersonic diffuser to interface the channel with existing facility quench and exhaust systems,
- A complete set of current control circuits for local diagonal current control along the channel, and
- A set of current consolidation circuits to interface the channel with the existing facility inverter.

The overall approach to meeting the ITC project objectives is to (a) utilize the design and operational experience gained from workhorse hardware to design and construct prototypical hardware, (b) conduct design confirmation and design verification tests on the prototypical hardware at component developer facilities, and (c) integrate and operate the components as a complete power train at the CDIF.

2.1 SYSTEMS ENGINEERING STUDIES - TASK 1

2.1.1 Power Train/Facility Integration (Subtask 1.1)

One of the main objectives of this task is to refine the program technical approach and submit a preliminary design document to DOE for approval. This preliminary design document will include as a minimum: (a) the general layout, arrangement, dimensions and cost of the complete power train assembly, (b) power train to CDIF electrical, mechanical, and instrumentation interfaces, (c) consumable and utility requirements, (d) process flows, (e) special instrumentation and control devices, (f) recommended facility modifications and documented costs (bids), and (g) the request for use of any Government furnished equipment presently existing at the CDIF or elsewhere within the purview of DOE.

Another major objective of this subtask is to accurately define the system level requirements and specifications for the integrated topping cycle that will be needed to define the resulting component level requirements and specifications. TRW, with inputs

from Avco and Westinghouse, will prepare a Systems Project Requirements Document (PRD) which defines all the design and manufacturing system requirements for the complete ITC that are both DOE imposed and contractor imposed. This document will form the foundation for the component level PRD's that will be created during the Task 2, 3, 4, and 5 component design activities. In addition to the system level PRD, TRW will prepare, with inputs from Avco and Westinghouse, a system specification that will define the performance, interface, environmental and testing requirements and controls that pertain to the entire ITC system.

2.1.2 Test Planning (Subtask 1.2)

A detailed test plan will be prepared to be used by the CDIF operating contractor to set up and conduct the power train checkout, characterization and duration tests required for the topping cycle proof of concept. The test plan will include recommended power train diagnostics, facility requirements, electrical connection and loading, operating procedures and contingency plans. The plan will also contain the management and organizational structure required to direct the test program, including personnel requirements, schedules, test objectives, milestones, post-test data reduction, performance analyses, objective measurements and performance criteria that shall be used as a gauge in measuring the progress of the topping cycle program at specified benchmarks.

TRW will submit a test plan to DOE for review and approval. This plan will be prepared by TRW with inputs from Avco and Westinghouse. The CDIF operating contractor, MSE, will provide guidance and support in the test plan preparation. The test plan will be revised/updated on two occasions prior to initiating ITC testing at the CDIF in order to keep the test requirements and needs up-to-date and current with the requirements and technical approach of the program.

2.1.3 Performance Analysis (Subtask 1.3)

The activities under this task include the on-going analysis of the experimental data generated during power train operation at CDIF as well as the analysis of the performance data generated during the tests to be conducted at the contractors' facilities. The power train data includes the data generated with the 1A1 and 1A2 channels and the "work-horse" coal combustor presently operating at CDIF, prior to integration of the prototypical power train, as well as the prototypical power train data. The performance analysis activities will start at contract go-ahead and will continue through the duration of the program. The analysis will also include, as needed, analytical and cold flow modeling to help in the interpretation of the data.

2.2 PROTOTYPICAL 50 MW_t COMBUSTOR DESIGN, FABRICATION AND SHIPMENT – TASK 2

2.2.1 Prototypical Combustor Design (Subtask 2.1)

This subtask is structured into six separate sub-elements:

- Subtask 2.1.1 – Design Confirmation Testing at TRW
- Subtask 2.1.2 – Tube Wall Construction Evaluations

- Subtask 2.1.3 – Design Prototypical Combustor
- Subtask 2.1.4 – Low Pressure Oxidant Second Stage Conceptual Design
- Subtask 2.1.5 – Low Pressure Oxidant Second Stage
- Subtask 2.1.6 – 20 MW_t Combustor/Channel Characterization

2.2.1.1 Design Confirmation Testing at TRW (Subtask 2.1.1)

The overall objective of this subtask is to design and fabricate test hardware and conduct development testing to confirm that the impact of necessary design changes on the combustor will not have a deleterious effect on combustor operation and performance. The design confirmation test series results will be available to support the prototypical combustor designs (preliminary and critical), and will basically ensure that the prototypical end-product will perform per the requirements of this program. There are two areas of consideration: performance effects testing and configuration validation testing. The performance effects testing will investigate those areas where performance deficiencies either exist now, are anticipated to still exist, or have not yet been validated. Included in this test phase will be the evaluation of alternate oxygen and seed injection schemes, together with investigating the effects of slag tank water entrainment and the effect of alternate coals on combustor performance. The configuration validation testing will confirm that those internal configurational changes that will be required to produce a durable prototypical (tube-wall) 50 MW_t combustor will not significantly alter the operational or performance capability of the combustor.

2.2.1.2 Tube Wall Construction Evaluations (Subtask 2.1.2)

Material selection, availability and material life are of specific interest in designing the prototypical combustor. The major areas which make up the evaluations are: material and manufacturing options, materials evaluation, manufacturing development, and a report which summarizes the findings. The effort to define material and manufacturing options will be broken down into three areas: identification of requirements, preparation of a development plan, and the preparation of a manufacturing plan. Each of the three areas will be completed prior to or in conjunction with the initiation of materials evaluations.

Analytical and certain field data will be the inputs which comprise the materials evaluation subtask. Materials will be selected following a comprehensive review. The materials evaluation will be conducted via the following three steps: analytical ranking of material, correlation to available material data, and material selection review.

The manufacturing development effort will consist of several related areas which, after completion, will result in the selection of the material to be used in the final tube wall construction. The major areas are: ordering of long lead materials, design of weldments, manufacture of weldments, microscopic examinations of weldments, and additional weldment manufacturing.

2.2.1.3 Design of Prototypical Combustor (Subtask 2.1.3)

The work elements of the prototypical combustor design task include requirements and specifications, engineering layouts, preliminary design, and detailed design.

Requirements and Specifications

The areas included here represent work which must be accomplished prior to design initiation. Included will be: requirements definition, interface definitions, preparation of project and technical requirements documents, and preparation of a component specification. The prototypical combustor will be designed according to the following statement of work requirements:

● Nominal Thermal Power	50 MW _t
● Minimum Plasma Conductivity (channel inlet)	7.5 mhos/m
● Nominal Plasma Conductivity (channel inlet)	9.0 mhos/m
● Maximum Total Heat Loss	7.0%
● Slag Recovery (minimum)	60%
● Minimum Slag Rejection Capability	0.5 tons/hr
● Nominal Pressure	6 atmospheres
● Life	2000 hrs/500 cycle
● Coal Types	Montana Rosebud Illinois No. 6

Engineering and Layouts

Following the completion of the preliminary documentation as discussed above, the initial engineering and layout activities will be initiated. This portion of the subtask will be subdivided into these areas: engineering design and trade-offs, combustion system layout, and internal conceptual design review.

Preliminary Design

This activity follows acceptance of the conceptual design and will be the initial attempt at performing limited detailed design activity. Included in this subtask section will be: design activity, preparation of preliminary design review data package, preliminary design review meetings, and action items closeout activity.

Detail Design

Following the completion of the preliminary design process and implementation of all necessary changes, the detail design effort will begin. The process will include design activity, quality assurance (QA) and safety involvement, preparation of Critical Design Review (CDR) package, CDR meetings, action item close-out, and preparation of the design document.

2.2.1.4 Low Pressure Oxidant Second Stage Conceptual Design (Subtask 2.1.4)

The baseline approach is to operate the 50 MW_t combustor second stage using high pressure (greater than 200 psi) oxygen. This subtask will result in the preparation of a conceptual design of an alternate second stage approach using low pressure (approximately 90 psi), 1200oF oxygen-enriched air. The subtask will consist of four areas of work which include: engineering analysis, cold flow modeling, feasibility testing at CTS, and conceptual design.

2.2.1.5 Low Pressure Oxidant Second Stage (Subtask 2.1.5)

Subtask 2.1.5 will provide for the design, fabrication and testing of an alternate second stage utilizing low pressure oxidant. This task will be an extension of the subtask 2.1.4 conceptual design. Specifically this subtask involves: second stage detail design, second stage fabrication and development testing, prototypical design upgrade, fabrication and retrofit. The final outcome of this subtask will be the removal of the existing second stage oxidizer injection hardware and its replacement with the newly designed low pressure system.

2.2.1.6 20 MW_t Combustor/Channel Characterization (Subtask 2.1.6)

The purpose of this task is to evaluate power train performance and integration issues that can best be accomplished at reduced scale. These data will augment the data from the on-going integrated testing of the TRW 50 MW_t coal combustor and Avco 1A1 channel at the CDIF. TRW will prepare and ship to Avco for integration testing with the Mark VI channel the 20 MW_t combustor that was tested at Avco during the 1982 integrated test series.

Avco and TRW will collaborate in producing a 20 MW_t power train test plan for this test series. The following major areas of testing are tentatively planned:

- 1) Complete Power Train characterization on Rosebud coal with a fully controlled diagonally loaded channel at 4 Tesla. Definition of the maximum power point and its sensitivity to the variable operating parameters.
- 2) Development, testing and performance comparisons of several alternate seed injection designs/locations/techniques.
- 3) Operational investigations and diagnostic measurements of the combustion processes. In particular, the relative effects of first and second stage stoichiometry variations and testing of different O₂ injection methods and/or locations.
- 4) Comparison of the Mark VI channel performance on Rosebud coal vs. Rosebud ash injection to determine the adequacy of this type of operational simulation.

2.2.2 Prototypical Combustor Fabrication and Assembly (Subtask 2.2)

2.2.2.1 Fabrication and Assembly (Subtask 2.2.1)

The prototypical components of the combustion system that are designed as part of subtask 2.1.3 will be fabricated, assembled and check-out tested at TRW. Each of the

completed components (including spare components) will be subjected, at a minimum, to low pressure gas leak checks, hydrostatic proof tests, and water-flow calibrations prior to hot-fire testing at TRW.

2.2.2.2 Hot Fire DVT Testing at TRW (Subtask 2.2.2)

TRW's FETS Cell #2 will be used for testing. Upon arrival of the prototypical unit, the existing combustor workhorse combustor tested during subtask 2.1.1 will be removed from the stand. Functional checkout testing will be performed to ensure that all basic components are functioning properly. TRW will then conduct a Design Verification Test (DVT) program of the 50 MW_t prototypical combustor system to confirm the adequacy of the system to meet the required performance. The tests shall include validation of the precombustor, characterization of combustor performance and performance optimization. All testing will be accomplished with the Performance Evaluation Module (PEM) on-line which measures bulk average electrical conductivity of the second stage plasma.

2.2.3 Prototypical Combustor Shipment (Subtask 2.3)

Upon the completion of the Design Verification Testing (DVT) and confirmation that acceptance criteria have been met, the prototypical combustor will be shipped to CDIF. The precombustor, slagging stage, slag rejection tank, and second stage that were tested will each be disassembled into major subassemblies and will be cleaned, dried, dimensionally checked and ports capped. The subassemblies will be installed on shipping pallets with any loose parts packed into appropriate containers and shipped to CDIF. Additionally, the high pressure coolant subsystem will be drained of all water, lines plugged and prepared for shipment as a complete subsystem. Immediately prior to packaging and shipment, the subassemblies will be subjected to non-reactive testing. At a minimum, the following tests will be performed: water flow calibration, water flow tests to check for visible water leaks, low pressure gas leak tests, and hydrostatic proof tests. The spare components that are not hot fire tested but only functionally tested will be similarly packaged as components and shipped to the CDIF at the same time as the other hardware.

2.2.4 Task Management (Subtask 2.4)

The functions in this subtask revolve around the activities of overall management of the design, fabrication, testing and shipment of the prototypical 50 MW_t combustion system. Included in this subtask is the management and technical direction required by the TRW Project Manager together with the project control disciplines required to maintain all cost and schedule aspects of Task 2.

2.3 PROTOTYPICAL 50 MW_t CHANNEL - TASK 3

This task encompasses the design, fabrication, testing and shipment of the MHD channel, nozzle, and current controls to the CDIF together with the 20 MW_t power train test activities to be conducted at Avco in support of this design and fabrication task.

2.3.1 Prototypical Channel Design (Subtask 3.1)

The MHD channel includes the aerodynamic inlet nozzle, the power generating channel, diagonal current control circuits, and the required accessories for interface connections to existing CDIF facility subsystems. These include hydraulic and electrical connectors, instrumentation leads and structural supports. The MHD channel will interface with and be driven by a 50 MW_t coal combustor operating with Montana Rosebud or Illinois #6 coal at a stagnation pressure of six atmospheres and producing a minimum static gas conductivity of 7.5 mhos/meter (9 mhos/meter nominal) at the nozzle exit. This channel design task includes the following five subtasks:

- Subtask 3.1.1 – Sidewall Development
- Subtask 3.1.2 – Channel and Nozzle Design
- Subtask 3.1.3 – Current Control Design
- Subtask 3.1.4 – Prototypical Channel External Design
- Subtask 3.1.5 – Mark VI Power Train Engineering

2.3.1.1 Sidewall Development (Subtask 3.1.1)

This subtask is included as part of the design of the prototypical channel to insure that the statement of work design specification of 2000-hour life will be met. It involves the following basic elements: 1) a research and development program to alleviate or eliminate cathode slag shorting, 2) design of subscale sidewall hardware and evaluation tests, 3) long duration design verification tests on best candidate sidewalls, 4) an assessment of cermet peg wall construction, and 4) design, fabrication and shipment to the CDIF of a replacement set of 1A4 sidewalls with a 2000-hour life capability.

2.3.1.2 Channel and Nozzle Design (Subtask 3.1.2)

Preliminary and detail designs of a diagonal-loaded supersonic channel and a supersonic nozzle both with a rated lifetime of 2000 hours will be developed. Engineering designs developed and tested since 1970 in the Avco Mark VI and VII facilities and the CDIF will form the basis of the 1A4 channel mechanical, electrical and structural configurations and materials of construction.

A preliminary channel design review package will be submitted for review and approval by DOE and will contain the following data: 1) channel lofting and loading analysis, 2) predicted channel performance and internal electrical parameters, 3) channel layout and interface details, 4) gas-side element design and materials of construction, 5) layout, interface and circuit details of current control cabinets, 6) thermal and structural calculations, 7) operating procedures, 8) design limits, and 9) instrumentation and interlock requirements. Upon approval by DOE, Avco will complete the detail engineering design drawings and specifications which will be submitted for a Critical Design Review and approval by DOE prior to commencement of fabrication.

2.3.1.3 Current Control Design (Subtask 3.1.3)

The basic engineering design of the current control circuitry has been performed under a separate DOE contract. Sixty-four units designed for the CDIF 1A channels have been fabricated, tested and delivered to the CDIF. Only minimal "on channel" operation has been accomplished to date, however. The long duration capability and the operating reliability of these units has yet to be demonstrated. Design modifications will be made, as required to increase the operating life of these circuits to 2000 hours. Detail designs and assembly documentation will be prepared to allow for competitive fixed cost subcontracts for the fabrication and assembly of these units. Design and liaison effort is also required to document the installation procedures that will be required at the CDIF.

2.3.1.4 Prototypical Channel External Design (Subtask 3.1.4)

The purpose of this subtask is to conduct a preliminary engineering study of the external design of a commercial size MHD channel and the attendant magnet bore packaging considerations. The magnet bore must house many potentially destructive elements - high pressure, high temperature plasma, high pressure cooling water, very high voltage high current wires, high magnetic loads, high thermal and gas dynamic forces. Consequently, in this subtask, Avco will address some of these engineering problems and evaluate potential solutions. Avco will also clarify the cost/risk tradeoffs that will be necessary to achieve acceptable operational reliability in an affordable design.

2.3.1.5 Mark VI Power Train Engineering (Subtask 3.1.5)

This subtask entails the continued operation of the 20 MW Mark VI power train on a limited basis after completion of combustor/channel characterization tests in Subtask 2.1.6. The Mark VI facility (coal or AIC fired) will be available to resolve hardware problems or operational difficulties that may arise in the POC test program. There are also several engineering scaling issues which to date have not been addressed that will require resolution via some minimum amount of experimental development testing to provide the necessary data base to support the design and construction of an early commercial MHD power station.

2.3.2 Channel Current Controls Fabrication and Assembly (Subtask 3.2)

2.3.2.1 Channel/Nozzle Fabrication and Assembly (Subtask 3.2.1)

Fabrication of the 1A4 channel and nozzle will begin subsequent to DOE approval of the manufacturing drawings and specifications presented at the Critical Design Review. Channel hardware, material, and machining services will be procured via competitive fixed-price subcontracts. The most critical and most difficult manufacturing operation in MHD channel fabrication, furnace brazing of corrosion resistant caps onto the anodic surfaces of all electrodes and sidewall elements, will be performed by Avco. Installation of the finished (machined and brazed) parts into the channel assembly is another crucial operation which will be performed by Avco. Interspersed in the assembly operations are many functional quality checks such as water passage and electrical insulation integrity

that are required on a continuing basis to preclude a large disassembly operation later to fix a local problem not caught during assembly. Configuration control and quality assurance programs will be implemented to ensure that the channel is built in accordance with the approved design. Magnet templates and interface flange fixtures will be used to ensure adequate clearance and correct mating at the CDIF.

2.3.2.2 Current Control Fabrication and Assembly (Subtask 3.2.2)

The diagonal current control circuits consisting of inductively coupled transformers switched with GTO thyristors will be rack mounted in groups of 64 units to facilitate installation at the CDIF. These racks can be located in the test cell close to the channel or in a remote location such as the high voltage room at the CDIF. A temperature controlled deionized cooling water supply is required for the thyristor heat sinks. Magnetic and control components will be procured from specialty fabricators to Avco specifications and drawings. Certain subassemblies that are labor intensive involving mounting of components and interconnecting wiring will be subcontracted to electronic assembly type job shops. Three such shops have been qualified on the prior procurements of identical CDIF circuit hardware. Final assembly and operational testing of the completed circuits will be accomplished by Avco technicians. As an alternate approach to this subtask, Avco will solicit complete fabrication and assembly fixed cost subcontract proposals for a make-or-buy decision.

2.3.3 Prototypical Channel Test Preparations (Subtask 3.3)

2.3.3.1 Channel/Nozzle Non-Operating Tests (Subtask 3.3.1)

The following quality assurance tests will be conducted at Avco prior to shipment of the 1A4 channel to the CDIF: 1) leak tests of cooling water circuits, 2) flow calibration of cooling water circuits, 3) resistivity measurements of all insulators and electrically isolated channel, nozzle and control components, 4) continuity checks of all power wiring and electrical connectors, 5) gas side leakage check of channel and nozzle, and 6) interface checks between the channel, nozzle and diffuser flanges for proper alignment and sealing.

2.3.3.2 Current Control Checkout Tests (Subtask 3.3.2)

The current control circuits will undergo post-assembly quality checks followed by functional tests under loaded operation on the Avco Mark VI channel. Prior to the functional operation, all the circuits will have continuity and hi-pot tests of the electrical components and wiring and water flow calibration and leakage checks on the cooling circuits of the semi-conductor heat sinks. Following these checks, an 8-hour "burn in" test of each assembly will be conducted with a DC power supply at nominal current values. The final tests will be of a functional nature, with the circuits installed on the Mark VI channel. By appropriate channel loading and gas conditions the full operational range of the current controls will be tested prior to delivery to the CDIF.

2.3.4 Prototypical 50 MW_t Channel Shipping (Subtask 3.4)

In addition to the shipping of the channel, nozzle and current control circuit hardware (including spares) described in the foregoing sections, Avco will supply the following documentation to assist the CDIF personnel in the installation, operation and

maintenance of the equipment: 1) design report, 2) manufacturing and installation drawings, 3) recommended spare parts, 4) operation and maintenance manual, and 5) checkout and operational test plan.

2.3.5 Avco Task Management (Subtask 3.5)

This subtask includes the efforts of the Avco Program Manager for technical direction of all the work involved in Task 3, and also includes the work of an administrative engineer to prepare the required documentation and monitor contract costs and schedules.

2.4 DIFFUSER - TASK 4

2.4.1 Diffuser Design (Subtask 4.1)

Because of the tentative decision to retain the 1A1 loft and length for the 1A4 channel, the existing diffuser will require only minor changes. Two design changes are necessary. First, the wall material will be replaced by stainless steel explosion bonded copper to retard electrochemical corrosion. Second, the four wall box construction will be designed with electrical isolation between the wall sections to eliminate a short circuit current path. These two modifications will provide the diffuser with at least 2000 hours of operational life. The diffuser design and manufacturing details will be submitted along with the MHD channel documentation for the Preliminary and Critical Design Reviews.

2.4.2 Diffuser Fabrication (Subtask 4.2)

The explosion bonded copper/stainless walls of the diffuser require cooling passages that are machined by specialty deep hole drilling subcontractors. This is a common subcontract for Avco and Avco utilizes three qualified vendors that perform this operation. After the deep hole drilling, machined end flanges are welded to each wall. Post weld machining is required to obtain true sealing surfaces. All fabrication operations are by fixed cost competitive bids to Avco drawings. Final assembly operations are performed by Avco technicians.

2.4.3 Diffuser Testing at Avco (Subtask 4.3)

Non-reactive testing of the diffuser by Avco technicians will include the following: 1) gas side leakage, 2) water passage hydrostatic pressure, 3) water flow calibration, 4) electrical isolation of the assembled walls, and 5) mating flange check with the channel.

2.4.4 Diffuser Shipping (Subtask 4.4)

Following diffuser assembly and testing, the diffuser will be shipped to the CDIF for installation with the 1A4 power train. Avco will provide the necessary installation drawings and engineering liaison to support the installation operation at the CDIF.

2.5 POWER CONSOLIDATION - TASK 5

Westinghouse will design, manufacture, install, and commission the power conditioning equipment needed for consolidation and potential definition in the 1A4 power train at the CDIF.

2.5.1 Consolidation Circuit Breadboard Fabrication and Test (Subtask 5.1)

Westinghouse will construct breadboard consolidation circuits for installation and test on the Mark VII or Mark VI channel at the Avco Everett test facility, oversee the installation of those circuits, and participate in the concept verification tests carried out at Avco.

The electrical and mechanical design of these circuits is expected to be done under a previously referenced subcontract to Westinghouse by Avco. The present effort begins with the material, components, and hardware procurement for power circuits and controls, and the fabrication of any special components needed. The construction of two consolidation circuits is anticipated, each designed to span up to 16 electrodes on the Mark VII or Mark VI channel. The circuits will be built as transportable breadboards, in enclosures suitable for the laboratory environment at Avco.

These tests will be accomplished in parallel with the sidewall development tests (Subtask 3.1.1) or the 20 MW_t combustor/channel characterization tests (Subtask 2.1.6). The consolidation circuits will be laboratory tested for functional integrity at Westinghouse before shipping to Avco. Westinghouse will plan the tests in conjunction with Avco staff and management, and will provide all necessary instrumentation and data recording devices to collect data for evaluation of the circuit's performance. Westinghouse personnel will supervise installation of the consolidation circuits at Avco, perform checkout tests before the test runs with the generator, and will collect and record pertinent data and make adjustments and modifications to the circuits as necessary. Westinghouse will analyze the data and refine the consolidation circuit design requirements for CDIF as indicated by the test results and analyses.

2.5.2 Detailed Design of Consolidation Circuits (Subtask 5.2)

Westinghouse will carry out the detailed electrical and mechanical design of the consolidation circuits and their controls, for installation at CDIF. Based on the basic design criteria elicited from the testing at Avco and information on topping cycle channel parameter ranges furnished by Avco, Westinghouse will perform the detail designs of the two consolidation circuits to be installed at the CDIF as part of the topping cycle power train. These designs will involve component specifications and procurement information, mechanical design with layout and detail drawings, and instrumentation provisions. An integral part of this design process is the generation of the documentation needed for installation at the CDIF, in addition to that required for fabrication of the circuits.

2.5.3 Design of Potential Defining Converter (Subtask 5.3)

Westinghouse will execute the detailed electrical and mechanical design of the converter/inverter to be used for positive bus potential definition. This task embraces the same scope as Task 5.2, but for the potential defining converter.

2.5.4 Fabrication of Consolidation Circuits and Potential Defining Converter (Subtask 5.4)

Westinghouse will procure components and material and build the consolidation circuits and the potential defining converter for installation at the CDIF. This task begins with the procurement of all material, components, and hardware needed to construct the

consolidation circuits and the potential defining converter, both power circuits and controls. The consolidation circuits are expected to span 30 electrodes each, so there will be a requirement for 62 controls, 60 for the consolidation converters and two, essentially identical except for software, for the potential defining converter.

A printed circuit board development cycle is needed for the controls. The power circuits will be assembled as materials and components become available, any special parts needed being fabricated by Westinghouse or suitable local subcontractors.

Westinghouse will perform full functional tests on all the controls and converter assemblies and will test the complete equipment for functional integrity before shipping to CDIF.

2.5.5 Westinghouse Task Management (Subtask 5.5)

Westinghouse will perform the management functions necessary for the execution of its subtasks 5.1 through 5.4, including direction, review, and supervision of the necessary effort and personnel.

2.6 TEST ENGINEERING AT THE CDIF - TASK 6

This task consists of two subtasks: power train integration and DVT testing, and power train duration testing. A 1000-hour duration test will be performed, with the time accumulated in segments of 100 hours. TRW, Avco and Westinghouse will provide technical direction and support to CDIF personnel for the installation, DVT testing and duration testing of the 50 MW_t prototypical power train hardware and appropriate auxiliary equipment. The basic test support provided will consist of a resident Senior Integration Engineer whose primary responsibilities will be to provide the component developers interface with the CDIF management and operating staff regarding all power train related activities. The resident Integration Engineer will be assigned by TRW and will be supported by additional TRW, Avco and Westinghouse engineers who will provide support at the CDIF and at the contractor's facility to ensure the successful completion of the CDIF duration test activities.

2.6.1 Power Train Integration at the CDIF (Subtask 6.1)

The ITC component developers (TRW, Avco and Westinghouse) will supply the necessary support to the CDIF personnel to ensure proper installation and functional checkout of the MHD power train components. The planned tasks include 1) hardware receiving inspections, 2) component assembly and integration, 3) connection of facility systems to the power train, 4) power train and facility functional checks, 5) preparation of documentation and data analysis packages, and 6) conduct of a test readiness review. Component developers will review operation and maintenance manuals with the CDIF personnel and provide engineering personnel at the site for technical direction.

During the DVT hot-fire test phase, a series of parametric tests are initially planned to map out the performance envelope of the power train. Test variables include air preheat temperature, first and second stage stoichiometry, N/O ratio, percent seed concentration,

coal type, and total thermal input. A test frequency of two (2) tests per week and a test duration of 4 hours per test is expected. The performance of the combustor, channel, diffuser, and current controls will be analyzed and compared to analytical estimates to assure there are no performance or hardware deficiencies.

After completing the initial parametric testing, a performance optimization test series will begin. Only a limited number of parameters will be adjusted during this test phase to determine the "best" operating condition for the power train. The "best" operating condition is where maximum channel power can be extracted with minimum stress on the channel, the combustor and diffuser sections.

2.6.2 Power Train Duration Testing at the CDIF (Subtask 6.2)

Prior to the start of the duration test, the power train hardware and facility equipment will be inspected and all maintenance, repair and/or adjustments made at this time. The duration test will be 1000 hours in length, accumulated in 100 hour increments. Specific operating indicators will be determined during DVT testing. Power train hardware inspection, routine facility maintenance and repairs and replacement of instrumentation are planned during the off-test periods. If repair or replacement of power train components are required, these activities will also be performed during the off-test periods.

The ITC component developers will monitor the performance of the power train during the duration testing and provide test direction and facility impact recommendations to the CDIF operating engineers regarding changes to the plan, shutdown decisions, evaluation of anomalous behavior, hardware risk assessment and possible changes or modifications to improve either life or performance of the component hardware. ITC personnel will assist with recommendations to the CDIF operating staff relative to facility support system requirements and/or hardware or operational modifications to improve the power train performance or correct support system deficiencies.

Personnel at TRW, Avco, and Westinghouse will conduct continuing and timely data reduction and analyses of the CDIF power train performance and operational integrity. Recommendations for operational and/or design changes to improve life or performance of the component hardware will be made. Integrated systems analyses will also be conducted using existing computer models, as appropriate, to help identify shortfalls or anomalous operation of the integrated power train.

2.7 HARDWARE REPAIR/REPLACEMENT – TASK 7

2.7.1 Combustor Hardware Repair/Replacement (Subtask 7.1)

TRW will repair or replace 50 MW_t combustor components that may experience damage during the CDIF MHD power train testing. Design modifications of failed hardware and testing of the repaired items will be provided when necessary as part of this task.

2.7.2 Repair/Replace Channel Hardware (Subtask 7.2)

Avco will provide hardware repair and replacement support that will be required during the power train duration demonstration. This support will include engineering redesign, material, fabrication and assembly labor and subsistence and travel for those operations that are most efficiently accomplished in the field.

2.7.3 Repair/Replace Power Consolidation Hardware (Subtask 7.3)

Westinghouse will repair or replace power consolidation and potential defining converter components and subsystems that fail during testing, or that require design modifications to give satisfactory performance.

2.8 CHARTER AND PARTICIPATE IN AN MHD TECHNOLOGY TRANSFER, INTEGRATION AND REVIEW COMMITTEE (TTIRC) – TASK 8

2.8.1 Prepare and Submit Committee Charter (Subtask 8.1)

TRW will submit a charter for the TTIRC to DOE for approval. The approved charter will define the purpose, membership, and operation of the committee.

2.8.2 Semi-Annual Contractual Report (Subtask 8.2)

As part of this subtask, TRW will be responsible for publishing semi-annual contractual reports which summarize the integration meeting minutes and the progress information presented by the responsible contractors.

2.8.3 Integration Meetings (Subtask 8.3)

The meetings of the TTIRC will be cochaired by DOE and an individual designated by the MHD ITC contractor. Each participating organization will submit a person's name and an alternate to be responsible to the committee for accomplishment of the committee's objectives. The actual meeting location, arrangement, agenda, and minutes recording/distribution will be the responsibility of the MHD ITC contractor and the designated cochairman. The TRW deputy chairman for operations in conjunction with the designated cochairman will schedule the meetings, arrange for the locations, and prepare and distribute the agenda to the committee members.

2.8.4 Task Management (Subtask 8.4)

This subtask involves the overall management of the TTIRC activities and principally involves the activities of the deputy chairman of operations, who is responsible for coordinating all functions of committee activity.

2.9 QUALITY ASSURANCE PLAN – TASK 9

TRW will prepare and submit a quality assurance and control plan for all deliverable hardware. It will outline TRW's quality role as systems integrator, TRW's approach for ensuring the quality of combustor components, and the approach to be used by each team

member to ensure the quality of their respective hardware elements. This task is for the preparation of the QA plan only. The specific QA involvements for the various design and fabrication activities will be accomplished within the appropriate subtasks.

2.10 INTEGRATED PROJECT MANAGEMENT - TASK 10

This task involves the overall technical and programmatic management of all aspects of the integrated project. Prime consideration in this management task is to insure that all power train components are properly integrated by virtue of strict adherence to the Project Requirements Documents, interface control documents and the appropriate system and equipment specifications. This task involves the heavy participation of the MHD Integrated Topping Cycle Project Manager from TRW and the Associate Project Manager from Avco. Strict project control disciplines are needed in this task especially in the area of schedule control. Subtask and task level schedules will be coordinated with the overall project schedules to minimize project delays, and a network schedule system will be implemented that controls the schedule and identifies critical paths down to below the subtask levels.

3. PROJECT STATUS

Project planning activities were initiated during this reporting period. These activities relate to all aspects of managing and performing the ITC Project, and are intended to fully baseline all project schedules and budgets prior to initiating the major technical tasks on April 1, 1988.

4. PLANNED ACTIVITIES

During the next quarterly reporting period, project planning activities will continue. Specific planned activities, by task, are listed below.

Task 8

- A draft charter for the MHD TTIRC committee will be submitted to DOE for approval of the Charter Articles, and the committee organization and operation.
- Recommendations will be prepared regarding the establishment of an appropriate method for transferring technology within the MHD contractor/user community.

Task 10

- A management plan will be prepared and submitted to DOE.
- Project baselining activities (scheduling and budget allocations) will continue.
- Subcontract administration activities related to the startup of the Avco and Westinghouse subcontracts will continue.

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