Vol I

NASA CR-
140382

OCTOBER 1974

NASA/JSC Contract NAS 9-13779 (DRD No. MA-129T)

DESIGN ANALYSIS AND COMPUTER-AIDED PERFORMANCE EVALUATION OF SHUTTLE ORBITER ELECTRICAL POWER SYSTEM

HUGHES
HUGHES AIRCRAFT COMPANY
SPACE AND COMMUNICATIONS GROUP

FINAL REPORT

OCTOBER 1974

NASA/JSC Contract NAS 9-13779 (DRD No. MA-129T)

●

DESIGN ANALYSIS AND COMPUTER-AIDED PERFORMANCE EVALUATION OF SHUTTLE ORBITER ELECTRICAL POWER SYSTEM

HUGHES

HUGHES AIRCRAFT COMPANY
SPACE AND COMMUNICATIONS GROUP

FINAL REPORT

VOLUME I
SUMMARY

Hughes Ref. No. D1191 • 74-085

REPORT NO. (S)^3 74-085

DRD MA-129T

A DESIGN ANALYSIS AND COMPUTER-AIDED PERFORMANCE EVALUATION OF THE SHUTTLE ORBITER ELECTRICAL POWER SYSTEM

FINAL CONTRACT REPORT, VOLUME I

NAS 9-13779

OCTOBER 1974

PRECEDING PAGE BLANK NOT FILMED

R. J. RECHTER
STUDY PROGRAM MANAGER

HUGHES

HUGHES AIRCRAFT COMPANY

M. FASHANO
ASSOC. STUDY MANAGER

ABSTRACT

This final report summarizes effort expended by Hughes Aircraft over the last ten months in the enhancement of time domain computer-simulation software[1], development of appropriate Shuttle Electrical Power Distribution and Control (EPDC) subsystem simulation models, and illustrative application of these computer simulations to systems analysis of the EPDC. The SYSTID simulation software previously developed had been utilized almost exclusively for telecommunications systems analysis, though it had more general capability. In particular, the SYSTID simulation language allows the user to generate system models of recurrent interest in a program library, which eases the mechanics of user application. The SYSTID software-related tasks addressed in this study under NAS 9-13779 included enhancement of the user utility aspects of the software, increased flexibility, conversion to the UNIVAC 1110 EXEC 8 operating system at Johnson Space Center (JSC), from its former EXEC 2 configuration and interactive graphics capability from the JSC MOPS terminals. In addition, a number of EPDC power generation (fuel cell), conversion (inverter) and control (remote power controller, remote-control circuit breaker, fuse) elements were defined and coded as SYSTID models. Similar attempts were made to characterize and code various EPDC load elements as SYSTID models. Unfortunately, due to the current state of design flux of the shuttle orbiter EPDC and user subsystems, a number of these elements (particularly the load elements) have not been defined by Rockwell International, the prime contractor. Thus, a certain amount of engineering judgement and prescience by the Hughes staff has been necessary to define the detailed electrical characteristics of these devices to a level appropriate for SYSTID coding. A corollary difficulty has been experienced, until very late in the contract effort, in defining the EPDC system topology.

---

[1] SYStems TIme Domain (SYSTID) simulation software, previously developed by the study team under NASA/JSC contract NAS 9-11743.

PRECEDING PAGE BLANK NOT FILMED

Recent data obtained from JSC on the topology employed in SEPAP[1] computer-aided analysis has been employed in the final systems-oriented SYSTID simulation runs (fault/circuit protection, power profile analysis). What has been accomplished by this study is; 1) significant enhancement of the SYSTID time domain simulation software, as a general tool, which also exhibits necessary capability to effectively simulate the EPDC, 2) generation of functionally useful shuttle EPDC element models, suitable for useage with SYSTID (though, with minor modification, these models could be extended to represent other spacecraft electrical power system elements), 3) illustrative simulation results in the analysis of EPDC performance, under the conditions of fault, (lightning) current pulse injection, and circuit protection sizing and reaction times. This Volume I is complimented by the SYSTID User Guide, Volume II, and the SYSTID Data Book, Volume III.

Key words: simulation; time-domain; electrical power systems, shuttle orbiter EPS; computer simulation; spacecraft electrical power systems.

---

[1] Shuttle Electrical Power Analysis Program (Lockheed Electronics Co.)

TABLE OF CONTENTS

GLOSSARY OF TERMS

SYSTID	SYStems TIme Domain (SYSTID) simulation software, the basic simulation language enhanced by this contract and resident on the UNIVAC 1110, EXEC 8 operating system.
EPDC	Electrical Power, Distribution and Control subsystem.
EPS	Electrical Power System (including user loads)
RPC	Remote Power Controller, a device for remotely current-limiting overload current or turning off current to various load elements, and providing a trip signal.
RCCB	Remote Control Circuit Breaker, a device which remotely allows utilization as either/both a relay and circuit breaker.
MEC	Master Events Controller, a fail-safe pyrotechnic ignition device, driven by the computer.
MIA	Multiplexer Interface Adapters, which provide interface with computer and data buses.
PIC	Pyrotechnic (PYRO) Ignition Circuits.
IMU	Inertial Measuring Unit.
CPU	Central Processing Unit (Computer).
FC	Fuel Cell (Hydrogen-Oxygen)
D & C	Display and Control.

1.0 SUMMARY

This study has pursued a number of objectives dealing with the refinement of computer simulation software, the generation and validation of mathematical models for subsequent reduction to computer code of certain shuttle EPDC elements and limited performance analysis of the EPDC system itself. These objectives, their scope and the technical approach employed in the study will be discussed below.

1.1 Objectives

Three primary objectives have been the basis of the contractual Statement of Work and study effort. These objectives have been: 1) enhancement of computer simulation software (SYSTID) previously developed for primary application to communications system analysis so that its user utility and flexibility would be increased and it would be made compatible with the JSC UNIVAC 1110 EXEC 8 computer system and interactive graphics terminals, 2) collection and distillation of descriptive data, generation of appropriate Shuttle electrical power and distribution (EPDC) subsystem mathematical models and subsequent coding of SYSTID models, and 3) delineation of EPDC topology and functional flow so that limited system analysis can be performed. These EPDC systems-level performance analyses include: fault analysis, inserted current (lightning) pulse sensitivity, circuit protection device validation.

These primary objectives, as well as a number of concurrent secondary objectives have been crystalized in the Statement of Work[1], as follows:

---

[1] Excerpted from the contract document

PRECEDING PAGE BLANK NOT FILMED

MAJOR TASK AREA:

TASK NAME/ NUMBER	TASK DESCRIPTION	EXPECTED OUTPUT
3.2	EPDC (EPS) ANALYSIS TASKS	
3.2.1	Define EPDC Load Profile Task Description: ● Define baseline EPDC topology and all shuttle load interfaces ● Generate time history of loads Output Expected ● EPDC block diagram showing load interfaces ● EPDC mode summary ● Load profile versus time for each subsystem load, and if possible each load element versus time	
3.2.2	Perform EPDC Redundant Switching & Circuit Protection Analysis Task Description: ● Establish reduncdancy switching and circuit protection topology ● Generate a matrix of switched modes and protected circuits ● Evaluate the switched modes for reducndancy capability Output Expected: ● Functional diagrams of redundant switching modes ● Evaluation of redundancy and circuit protection adequacy	

MAJOR TASK AREA:

TASK NAME/ NUMBER	TASK DESCRIPTION	EXPECTED OUTPUT
3.2.3	Determine EPDC Fault Conditions Task Description: ● Define possible fault modes ● Determine probable fault conditions ● Select an illustrative number of fault modes for SYSTID simulation Output Expected: ● Matrix of possible fault modes ● Sub-matrix of most probable fault modes ● SYSTID simulation topology	

MAJOR TASK AREA:

TASK NAME/ NUMBER	TASK DESCRIPTION	EXPECTED OUTPUT
3.3	COMPUTER-AIDED ANALYSIS AND SIMULATION	
3.3.1	Simulation Language Enhancement	
3.3.1.1	Multinode Models Present $I < \text{Model Reference } (arg_1, \ldots arg_n) \text{ or Expressions } > 0$ Planned $I < \text{Expression} > 0$ and $\left\{\begin{array}{l} I_1 - I_2 - \ldots I_K < \text{Model Reference } (arg_1, \ldots. arg_n) > 0_1 - 0 - \ldots 0_K \\ \text{or} \\ I < \text{Model Reference } (I_2, I_3 \ldots I_K, 0_2, 0_3 \ldots 0_K, arg_1, \ldots arg_n) > 0 \end{array}\right\}$ selection of the form will be based upon overall software development	

MAJOR TASK AREA:

TASK NAME/ NUMBER	TASK DESCRIPTION	EXPECTED OUTPUT
3.3.1.2	Simplify Expression Processing Present ● Model library references (permanent and/or temporary) ● Fortran library functions ● User written Fortran functions ● Fortran arithmetic expressions involving intrinsic parameters, constants, variables, functions, and "TAPS" ● Model reference scanning for valid form and number of arguments Planned ● Fortran arithemetic expressions involving "node" names (i.e., node names become formal variable names) ● Fortran expression scanning for proper form	

MAJOR TASK AREA:

TASK NAME/ NUMBER	**TASK DESCRIPTION**	**EXPECTED OUTPUT**
3.3.1.3	Provide Automatic Checkpoint Present None - any checkpoint functions are provided by the user Planned Automatic checkpointing under user control keyed to the system clocks	
3.3.1.4	Provide Conditional Termination See entry under "Misc. SYSTID Enhancements"	

MAJOR TASK AREA:

TASK NAME/ NUMBER	TASK DESCRIPTION	EXPECTED OUTPUT
3.3.1.5	Provide SYSTID Table Definition <u>Present</u> None - Tables currently are defined within Fortran models <u>Planned</u> ● Add a SYSTID instruction to allow arbitrary table sizing and data entry (equivalent to the Fortran "dimension" statement	
3.3.1.6	Provide SYSTID Save Feature <u>Present</u> ● Simulation results may be saved on tape or disc using a postprocessing routine <u>Planned</u> ● Provide a SYSTID instruction to automatically save the requested simulation results on tape or disc ● Provide a SYSTID instruction to reload the save file for post processing and/or plotting	

MAJOR TASK AREA:

TASK NAME/ NUMBER	TASK DESCRIPTION	EXPECTED OUTPUT
3.3.1.7	Modify Sort Processing <u>Present</u> ● SYSTID evaluates the system topology according to a rigid sort procedure (First In Last Out starting at node name "INPUT", ending at node name "OUTPUT") ● The "DEFINE" instruction allows expression re-evaluation at each reference ● The "SET" instruction allows expression evaluation prior to simulation <u>Planned</u> ● User defined processing sequence ● More exhaustive sort procedure	

MAJOR TASK AREA:

TASK NAME/ NUMBER	TASK DESCRIPTION	EXPECTED OUTPUT
3.3.1.8	Provide SYSTID Output Format Capability Present ● All formatting is fixed within the defined procedures utilized during the simulation phase ● Format changes can be made by changing the procedures prior to the generation phase Planned ● Provide the SYSTID instructions and controls to facilitate: Page numbering Titling Time and date labeling	
3.3.1.9	Provide Cross-Reference Output See entry under "Misc. SYSTID Enhancements"	

MAJOR TASK AREA:

TASK NAME/ NUMBER	TASK DESCRIPTION	EXPECTED OUTPUT
3.3.1.10	Provide Automatic Core Sizing Present • Under the current operating system (Exec II) core sizing of the simulation phase is of no concern as long as it fits • Core size can be controlled by modifying the defined procedures prior to the generation phase Planned • Under the new operating system (Exec 8) core size is a predominant cost factor and it is preferrable to control core dynamically. This is accomplished by interfacing with the Exec 8 operating system during the simulation • The generation phase currently requires ~ 45K words. The goal is to decrease this to < 20K words to facilitate generation in the demand (i.e., timesharing) environment	
3.3.1.11	Provide Automatic Library Directory Updating See entry under "Misc. SYSTID Enhancements"	

MAJOR TASK AREA:

TASK NAME/ NUMBER	TASK DESCRIPTION	EXPECTED OUTPUT
3.3.1.12	Provide Real & Complex Models __Present__ ● All nodes require two core locations ● All nodes are treated as complex quantities with complex arithmatic performed by the user within SYSTID models ● SYSTID expressions are treated as real Fortran expressions rather than complex expressions ● Complex arithmetic is accomplished via the use of some utility functions __Planned__ ● After further study, the development cost for handling both real & complex nodes far out weighs the anticipated advantage (i.e., one storage location for real nodes) ● The obvious and most useful modification is to allow direct complex expressions	
3.3.1.13	Provide Model Debugging Capability See entry under "Misc. SYSTID Enhancements"	

MAJOR TASK AREA:

TASK NAME/ NUMBER	TASK DESCRIPTION	EXPECTED OUTPUT
3.3.1.14	**Provide SYSTID Modeling Aid** **Present** ● Various utility routines and procedures to aid the user in writing a Fortran model **Planned** ● Additional aids for access to and control of internal SYSTID parameters and storage areas as they are implemented	
3.3.1.15	**Convert to SYSTID Univac 1108 Exec 8 System (1110 JSC System)** **Present** ● SYSTID is written to take advantage of the Univac 1108 system and processors under the Exec II operating system **Planned** ● Convert the current version of SYSTID to the Exec 8 operating system (Input/output routines) ● Provide JSC with the Exec 8 SYSTID for checkout at JSC ● Use the Exec 8 SYSTID as the starting point for coding modifications	

MAJOR TASK AREA:

TASK NAME/ NUMBER	TASK DESCRIPTION	EXPECTED OUTPUT
3.3.1.16	Provide SYSTID Interactive Graphics Interface __Present__ None - Calcomp and printer plotting are available __Planned__ ● Provide the software interface to allow access to simulation output data for display on the JSC MAPS graphics unit ● This task is a joint effort with JSC	
3.3.1.17	Provide Automatic Checkpoint Feature See entry under "Misc. SYSTID Enhancements"	

MAJOR TASK AREA:

TASK NAME/ NUMBER	TASK DESCRIPTION	EXPECTED OUTPUT
3.3.1.17	<u>Planned</u> ● Provide a SYSTID instruction to interrupt a simulation based upon any simulation parameter, computer run time, or real time to perform ancillary functions or terminate (e.g., the fortran "IF" statement) ● Provide a cross reference option for node name versus storage location ● Provide automatic permanent update capability to the library directory ● Provide additional coding in SYSTID models to facilitate debugging	

MAJOR TASK AREA:

TASK NAME/ NUMBER	TASK DESCRIPTION	EXPECTED OUTPUT
3.3.2	PMS Model Development Deleted	
3.3.3	Develop SYSTID EPDC Models Task Description: • Gather pertinent data on EPS elements • Group elements as possible to minimize the number of SYSTID models • Generate SYSTID models, defining boundary conditions Expected Output: • Reviewed baseline EPDC (JSC) • Major EPDC block diagram • SYSTID model code and documentation	

MAJOR TASK AREA:

TASK NAME/ NUMBER	TASK DESCRIPTION	EXPECTED OUTPUT
3.3.4	Provide SYSTID Software Validation (NOTE: This task was mislabeled in the contract SOW) Task Description: ● Obtain, review & select reliable empirical EPDC performance data ● Generate SYSTID runs, using empirical data ● Analyze the results Expected Output: ● Distilled empirical data base ● SYSTID results ● SYSTID validation report	

MAJOR TASK AREA:

TASK NAME/ NUMBER	TASK DESCRIPTION	EXPECTED OUTPUT
3.3.5	Develop SYSTID Measuring Techniques Task Description: ● Define and develop performance measuring techniques using SYSTID Expected Output: ● Set of current empirical EPS performance measures ● Selected list of performance parameters ● List of necessary revisions	
3.3.6	Identify SYSTID Simulation Areas Task Description: ● Using prior study results, and considering related JSC and Rockwell work, define areas which will be usefully attacked by SYSTID simulation Expected Output: ● List of potential study areas ● Selected list of SYSTID simulation possibilities ● Requirements list for necessary data base, measurements, or expected performance definition in each area	

1.2 Scope

The scope of the study, relative to the objectives given above was more inclusive for the software-related tasks, than for the EPDC performance analysis tasks. The former tasks utilized an available data base, in the form of prior SYSTID code, defined a series of tasks well understood (in detail) by JSC and Hughes personnel, and except for some potentially difficult operational details required interface with the well-defined JSC 1110 computer system (...and knowledgeable personnel in the JSC computer systems area). Therefore, it was reasonable to demand the widest scope for the simulation software enhancement, from fundamental algorithms to validated code and describing documentation.[1] On the other hand, the EPDC element modeling and systems performance analysis tasks required definition of a shuttle subsystem, the EPDC, at a detailed level, when in fact a number of the EPDC element vendors had not been chosen and explicit element characteristics were unavailable. Similarly, the EPDC bus assignments, and resultant EPDC subsystem topology were not finalized. A corresponding lack of intuition was also present in terms of EPDC element criticality for given system performance requirements. Thus, the scope of the EPDC element modeling, and performance evaluation tasks were truncated from what a static subsystem design might have allowed. For instance, the EPDC element modeling was accomplished on the basis of engineering judgement and extrapolation of generically similar device characteristics by Hughes personnel. (A consequence of this limitation is the possibility that devices, such as the Remote Power Controller (RPC) actually chosen for the EPDC may exhibit substantially different characteristics). Further, the performance analysis carried out by SYSTID simulation was limited to illustrative situations, since so little was known about the user load elements. For purposes of establishing a repeatable baseline EPOC topology, the topology employed in SEPAP[2] was selected, as were the electrical bus assignments employed by it [1].

1.3 Technical Approach

The technical approach used in defining the most critical SYSTID language enhancements, their order of completion, and algorithm design are given in more detail in Volume II of the Final Report, the SYSTID User Guide.

---

[1] See Volume II SYSTID User Guide of this Final Report

[2] Shuttle Electrical Power (System) Analysis Program, Lockheed Electronics Co./JSC

In general, a number of SYSTID characteristics and capabilities which had existed in the initial implementation[1] were found to be clumsy (the model TAP technique to achieve general multiport, multinode representation), or excessively rigid (the prior "sort" processing technique) by continued use of the language to simulate telecommunications systems. Therefore, a number of changes were deemed necessary and implemented, as matters of convenience to the user. In addition, the UNIVAC 1110 EXEC 8 operating system requirements imposed some brute force compatibility design tasks, as well as matters of economic operation (i.e., automatic core sizing to dynamically control core requirements and minimize run costs), including "save" and "checkpointing" features so that the user is guaranteed useful output, even with premature termination. A most important and convenient enhancement was the installation of an interactive[2] graphics capability, so that the CRT/keyboard I/O devices at JSC could be used with SYSTID.

The technical approach employed for EPDC element modeling recognized the lack of firm engineering data on critical units. Therefore, in parallel with data gathering efforts with Rockwell International (the shuttle orbiter prime contractor), generic data was collected and analyzed. For example, hydrogen-oxygen fuel cell modeling data [9] was obtained and scaled for the representative shuttle mission. This generic approach has serious failings, given the very nature of the detailed element responses desired for transient analysis of adequate fidelity. For example, the particular mechanization of a universally present device such as the remote power controller (RPC) has much to do with its transient response[3]. Thus, the mechanization chosen for the current SYSTID RPC model may not truly reflect the detailed microscopic response of RPC as procured. (The procurement specifications on this device as well as other EPDC elements generally describe the steady-state behavior, and are not complete with respect to the parameters which influence transient response).

---

[1] Reference prior work by the Hughes staff on contract NAS9-11743

[2] No light-pen, or direct user interaction with the CRT display is implied

[3] Nominally energy storage components, such as inductance and capacitance, in conjunction with disapative resistive losses determine this response.

2.0 RESULTS

The study results fall into the categories of SYSTID enhancement, EPDC element modeling, and EPDC performance analysis.

2.1 Software Development Results

Each software enhancement task item given in the SOW SUMMARY of Section 1.1 has been completed and documented. (Task 3.3)

Volume II (SYSTID User Guide) of this Final Report will contain all operational and descriptive data necessary for the user, as well as a task item-by-item description of changes generated during the study.

Volume III, (SYSTID Data Book) of this Final Report contains all program listings, flow charts and data listings.

2.2 EPDC Element Modeling

The shuttle orbiter EPDC subsystem can be characterized by functional subsets as follows:

1. Power source elements (only fuel cells, with the current deletion of stand-by battery power)
2. Power conversion elements (inverters)
3. Distribution elements (cables)
4. Control elements (RPC, RCCB, fuses, diodes)
5. User interface (load element characterization)

The following material will summarize the SYSTID models generated to date, in the order given above. The supporting analysis for these models is summarized in Section 5.3.

MODEL: FUEL CELL	GROUP ID SOURCE	PAGE	DATE

LIBRARY MODEL NAMES:
FUEL CELL

DESCRIPTION:

The fuel cell model outputs a voltage that is dependent on the load impedance and the dynamic source impedance of the fuel cell model. An input parameter is the nominal voltage output wanted.

USAGE:

IN < FUEL CELL (E, RL) > VOUT

Where: IN = ground node
E = nominal output voltage, volts (user-selected)
RL = instantaneous load impedance, ohms
VOUT = output voltage (node)

SYSTID CODE:

```
MODEL. IN . FUEL CELL(RL,E) . OUT
       DIMENSION EV(6)/37.48,36.71,36.03,35.44,34.99,34.56/
       DIMENSION R1(6)/.1575,.128,.157,.096,.091,.087/
       DIMENSION R2(6)/.00951,.0143,.0129,.00389,.00314,.00271/
       DIMENSION R3(6)/.256,.226,.227,.232,.217,.199/
       DIMENSION C1(6)/15.66,18.78,13.2,8.56,10.67,9.25/
       DIMENSION C2(6)/3.41,1.79,1.45,4.43,3.83,5.03/
       DEFINE RR1(I)=R1(I)
       DEFINE RR2(I)=R2(I)
       DEFINE RR3(I)=R3(I)
       DEFINE CC1(I)=C1(I)
       DEFINE CC2(I)=C2(I)
       DIMENSION ZV(1)
       EQUIVALENCE ( ZV,V)
       DEFINE IV=ZV(NZ+1)
       DEFINE D1A=V(NZ+6)
       DEFINE D0=V(NZ+7)
       DEFINE D1=V(NZ+8)
       DEFINE D2A=V(NZ+9)
       DEFINE D2=V(NZ+10)
       DEFINE R1X=RR1(IV)
       DEFINE R2X=RR2(IV)
       DEFINE R3X=RR3(IV)
       DEFINE C1X=1.E-2*CC1(IV)
       DEFINE C2X=1.E-2*CC2(IV)
     1 NZ=ZZ
     5 ZZ=ZZ+11
    10 IF(IV.GT.0) GO TO 100
    30 IV=5
    32 RL=1.E20
    35 OUT=32.4
    80 D0=R1X+R2X+R3X
    85 D1A=C1X*R2X + C2X*R3X + C1X*R3X
    90 D =C1X*(R1X*R2X+R1X*R3X)+C2X*R3X*(R1X+R2X
    95 D2A=C1X*C2X*R2X*R3X
    96 D2=D2A*R1X
   100 CONTINUE
   122 E8=32.4*(1.+D0/RL)-1.82/RL
       E8 . ZED2(   RL,0.,0.,D0+RL,D1+RL*D1A,D2+RL*D2A) . OUT
```

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

SYSTID LIBRARY MODEL DATA

MODEL: INVERTER	GROUP ID CONVERSION	PAGE	DATE

LIBRARY MODEL NAMES:
INVERTER

DESCRIPTION:

The inverter modulates the DC power flow as supplied by the fuel cell, at a 400 Hz rate, so as to provide single-phase AC user load power...suitable interconnection of three inverters then provides 3-phase AC power. The inverter consists of three sub-models, a multivibrator, filter, and output coupling transformer.

USAGE:

VIN < INVERTER (FRQ,E,CPF, RL) > VOUT, IS, RS

Where:

VIN	is the source node voltage, volts
FRQ	is the operating frequency, Hz
E	is the nominal output node (AC) voltage, volts peak
CPF	is the composite power factor of the loads
VOUT	is the AC output node voltage, volts
IS	is DC current drawn from source
RS	is the impedance presented to the source, ohms

SYSTID CODE:

```
MODEL*  VIN . INVERTER(FRG,E,CPF,RL) . VOUT,IS,RS
      DEFINE OLD=V(NZ+1)
    1 NZ=ZZ
    2 ZZ=ZZ+1
      VIN . MULTIVIBRATOR(FRQ,E) . N1
      N1 . FILTER(2,2,1,0.,1.25*FRQ,0.,1.,0.1,0.) . N2
      N2 . TRANSFORMER(CPF) . VOUT
   10 OLD=OLD+VOUT*VOUT/RL
   20 IS=OLD*DT/TIME/VIN
   30 RS=VIN/MAX(1.E-20,IS)
END
```

SYSTID LIBRARY MODEL DATA

MODEL: MULTIVIBRATOR (INVERTER)	GROUP ID CONVERSION	PAGE	DATE

LIBRARY MODEL NAMES: MULTIVIBRATOR

DESCRIPTION:

This sub-model of the inverter provides the modulation (chopping) capability of the inverter. It is typically a externally-clocked monostable circuit operating nominally at 400 Hz, but with the capability to be clocked at arbitrary rates.

USAGE:

VIN < MULTIVIBRATOR (FRQ, E) > VOUT

Where: VIN is the DC source voltage (node)
FRQ is the clock rate, Hz
E is the nominal output
VOUT is the AC output voltage (node)

SYSTID CODE:

```
MODEL*   VIN , MULTIVIBRATOR(FRQ,E) , VOUT
       DEFINE TON=V(NZ+1)
       DEFINE TOFF=V(NZ+2)
       DEFINE OLD=V(NZ+3)
       DEFINE A=V(NZ+4)
       DEFINE B=V(NZ+5)
1      NZ=ZZ
5      XN=E-2.8+.1*VIN
6      IF(A)10,,10
7      OLD=XN
8      A=.5/FRQ
9      B=.5/FRQ/LOG(3.)
10     ZZ=ZZ+5
30     VOUT=OLD
40     TR=B*LOG(3*E/XN)
45     IF(OLD.LE.0) GO TO 100
50     IF(T-TON.LT.TR) RETURN
60     VOUT=-XN
70     OLD=VOUT
80     TOFF=TIME
90     RETURN
100    TD=A-TR
105    IF(T-TOFF.LT.TD) RETURN
110    VOUT=XN
120    OLD=VOUT
130    TON=TIME
END
```

SYSTID LIBRARY MODEL DATA

MODEL: TRANSFORMER (INVERTER)	GROUP ID CONVERSION	PAGE	DATE

LIBRARY MODEL NAMES: TRANSFORMER

DESCRIPTION:

This sub-model of the inverter provides coupling of the filtered square-wave output of the multivibrator to the load elements. This is currently a linear transformer model...actual hardware mechanization may require this to be a saturating-core device (non-linear).

USAGE:

VIN < TRANSFORMER (CPF) > VOUT

Where: VIN is the filtered multivibrator (source) voltage (node)

CPF is the composite power factor of the load element(s)

VOUT is the AC output voltage (node)

SYSTID CODE:

```
MODEL*    VIN . TRANSFORMER(CPF) . VOUT
      VIN . 1.414*CPP*(VIN+SIGN(0.2,VIN)) . N1
      N1 . QFACTOR(1.,0.,1.0783,0.,1.5E-5,0.263,571.) . VOUT
END
```

MODEL:	GROUP ID	PAGE	DATE
CABLE	DISTRIBUTION		

LIBRARY MODEL NAMES:

CABLE

DESCRIPTION:

The cable model will output voltage, source current and instantaneous input impedance, as seen by the source. Its main use is as a connection between EPDC subassemblies/elements where the complex impedance transmission characteristics are of importance.

USAGE:

VIN < CABLE (R, C, XL, RL) > VOUT, IS, RS

Where: VIN = input voltage (node)
R = resistance/ft.
C = capacitance/ft.
XL = length of cable, ft.
RL = load impedance (instantaneous)
VOUT = output voltage (node)
IS = current drawn from the source, amperes
RS = instantaneous impedance viewed by source, ohms

SYSTID CODE:

```
MODEL*  VIN . CABLE(R,C,XL,RL) . VOUT,IS,RS
        DEFINE RX=R*XL
        DEFINE CX=MAX(C*XL,1.E-16)
        VIN . ZED1(1.,RL*CX,RX+RL,RL*RX*CX) . IS
        VIN . ZED1(RL,0.,RX+RL,RL*RX*CX) . VOUT
     10 RS=VIN/MAX(1.E-20,IS)
END
```

SYSTID LIBRARY MODEL DATA

MODEL:	GROUP ID	PAGE	DATE
REMOTE CONTROL CIRCUIT BREAKER (RCCB)	CONTROL		

LIBRARY MODEL NAMES:

RCCB

DESCRIPTION:

The remote control circuit breaker is basically a switch that cuts off* if any power exceeds some maximum power threshold. The power rating is a variable determined by the adjunct load and ID number.

USAGE:

VIN < RCCB (ID, RL) > VOUT, IS, RS

Where:
VIN = source voltage (node)
ID = identification (Rockwell/SEPAP six-digit number or an arbitrary index of event sequence)
VOUT = output voltage (node)
RL = load impedance, ohms
IS = current drawn from source, amperes
RS = impedance viewed by source, ohms

SYSTID CODE:

```
MODEL*   VIN , RCCB(ID,RL) , VOUT,IS,RS
         DIMENSION R(7)/1.E10,1.E-10,5*1.E10/
         DATA T0,CMAX/.01,35./
         DATA C2,C3/6.25E2,19.46E4/        # C2=6.25/T0  C3=19.46/T0/T0
         DEFINE BLOWN=V(NZ+1)
       1 NZ=ZZ
       2 ZZ=ZZ+1
4TRANS   XL=RL
4TRANS   CALL LOADON(ID,MODE)
      10 IF(BLOWN.GT..5) GO TO 35
4TRANS   IF(MODE.GT.1) XL=R(MODE)
      15 IF(VIN/XL.LT.CMAX) GO TO 40
      20 BLOWN=1
      25 WRITE(6,600)ID,TIME
     600 FORMAT(/' *** RCCB LOAD ', I8,' FAULT AT ',F15.4/)
      35 XL=1.E10
      40 CONTINUE
     100 IN=(VIN-.25)/XL
         IN , QFACTOR(1.,0.,0.,C3,1.,C2,C3) , IS
     110 VOUT=MIN(VIN,IS*XL)
     120 RS=VIN/MAX(1.E-20,IS)
END
```

---

*Model stays off once tripped, for the duration of the simulation. It also outputs the load element ID and time of trip-off.

SYSTID LIBRARY MODEL DATA

MODEL: REMOTE POWER CONTROLLER	GROUP ID CONTROL	PAGE	DATE

LIBRARY MODEL NAMES:
RPC

DESCRIPTION:

The remote power controller is essentially a current limiter and circuit breaker device that monitors the power drawn by the load, limits and controls[*] overload currents which can be reset by external command.

USAGE:

VIN < RPC (ID, RL) > VOUT, IS, RS

Where: VIN = source voltage (node)
RL = instantaneous load impedance, ohms
ID = identification (Rockwell/SEPAP) six-digit number or an arbitrary index of event sequence
VOUT = output voltage (node)
IS = source current, amperes
RS = instantaneous impedance viewed by source, ohms

SYSTID CODE:

```
MODEL*  VIN . RPC(ID,RL) . VOUT,IS,RS
        DIMENSION R(7)/1.E10,1.E-10,5*1.E10/
    10  XL=RL
    15  CALL LOADON(ID,MODE)
    21  IF(MODE.GT.0) XL=R(MODE)
        VIN . CURRENT LIMITER(XL,20.) . VOUT,IS,RS
END
```

---

[*] Once tripped, the model stays off for the duration of the simulation. An analogous output to the trip signal is given by model indication of load element ID number and time of trip-off.

SYSTID LIBRARY MODEL DATA

MODEL: CURRENT LIMITER (RPC)	GROUP ID CONTROL	PAGE	DATE

LIBRARY MODEL NAMES: CLIM
CUR-LIM

DESCRIPTION:

The current limiter sub-model of the RPC is both a current regulator and a cutoff switch. Its output is both a voltage that is a function of the load impedance and a current that is almost constant under varying load conditions. The cutoff occurs as a function of some maximum rated current.

USAGE:

VIN < CURRENT LIMITER (RL, CMAX) > VOUT, IS, RS

Where: VIN = input voltage (node)
CMAX = maximum (rated) allowed current, amperes
VOUT = output voltage (node)
RL = instantaneous load impedance, ohms
RS = instantaneous impedance viewed by source, ohms
IS = instantaneous current drawn from source, amperes

SYSTID CODE:

```
MODEL*   VIN . CURRENT LIMITER(RL,CMAX) . VOUT,IS,RS
      DEFINE CLIM=V(NZ+3)
      DEFINE COFF=V(NZ+4)
      DEFINE TX=V(NZ+1)
      DEFINE XLIM=V(NZ+2)
    1 NZ=ZZ
    2 ZZ=ZZ+4
    3 IF(CLIM),,6
    4 CLIM=1.5*CMAX
    5 COFF=1.25*CMAX
    6 IF(XLIM.LT.-.5) GO TO 50
    7 IN=MIN((VIN-.5)/RL,CLIM)
   10 IF(IN-COFF),,15
   11 XLIM=0
   12 GO TO 100
   15 IF(XLIM.GT.0.5) TX=TIME
   20 XLIM=1.
   40 IF(T-TX.LT.3) GO TO 100
   41 IF(IN.LE.COFF) GO TO 100
   45 XLIM=-1.
   46 WRITE(6,600)TIME
  600 FORMAT(/' *** CURRENT LIMITER FAULT AT ',F15.4/)
   50 IN=0
  100 CONTINUE
      IN . QFACTOR(1.,0.,0.,1.,2.026E-5,9.55E-3,1.) . IS
  200 RS=VIN/MAX(1.E-20,IS)
  210 VOUT=IS*RL
END
```

SYSTID LIBRARY MODEL DATA

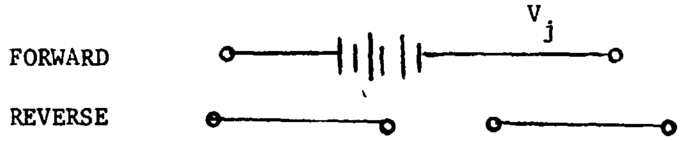
MODEL:	GROUP ID	PAGE	DATE
IDEAL DIODE	CONTROL		

LIBRARY MODEL NAMES:

IDEAL DIODE

DESCRIPTION:

The ideal diode equivalent circuit can be represented by a simple junction potential, if conducting in the forward direction, and an open circuit in the reverse current direction, as follows:



V_j = 0.7 volts

(junction potential)

USAGE:

VIN < IDEAL DIODE (RL) > VOUT, IS, RS

Where: VIN is input voltage (node)

RL is load impedance, ohms

IS is the current drawn from the source, amperes

RS is the impedance viewed by the source, ohms

SYSTID CODE:

```
MODEL*  VIN . IDEAL DIODE(RL) . VOUT,IS,RS
   10 RS=RL
   20 VOUT=VIN-.7
   30 IS=VOUT/RL
   40 IF(VIN.GE.IS*RL+.7) RETURN
   50 VOUT=0
   60 IS=0
   70 RS=1.E20
END
```

MODEL DESCRIPTION: REALISTIC DIODE	GROUP 1D CONTROL	PAGE	DATE
LIBRARY MODEL NAMES: REAL DIODE			

DESCRIPTION:

This diode model represents a more likely physical realization, employing the diode equation to relate the bulk resistance, to changes in the current flow and junction potential. It is still an ~ ideal device in that the reverse current is 1 ma.

USAGE:

VIN < REAL DIODE (RL) > VOUT, IS, RS

Where: VIN is the source voltage (node)
RL is the load impedance, ohms
IS is the current drawn from the source, amperes
RS is the impedance viewed by the source, ohms

SYSTID CODE:

```
MODEL*  VIN . REAL DIODE(RL) . VOUT,IS,RS
      DATA TH,XS/39.,.001/
    5 VX=MIN((VIN-VOUT)*TH,5.)
   10 RD=1./(TH*XS*EXP(VX))
   15 RS=RL+RD
   20 VOUT=VIN*RL/RS
   30 IS=VIN/RS
END
```

MODEL: FUSE	GROUP ID CONTROL	PAGE	DATE

LIBRARY MODEL NAMES:
FUSE

DESCRIPTION:

The fuse is a load current control device modeled by an instantaneous logical switch actuated* by a rated power threshold.

USAGE:

VIN < FUSE (ID, RL, PMAX) > VOUT, IS, RS

Where:
VIN = input voltage (node)
PMAX = maximum (rated) power allowed, watts
RL = instantaneous load impedance, ohms
VOUT = output voltage (node)
IS = source current, amperes
RS = instantaneous impedance viewed by source, ohms
ID = load element identification

SYSTID CODE:

```
MODEL*  VIN , FUSE(ID,RL,PMAX) , VOUT,IS,RS
      DIMENSION R(7)/1.E10,1.E-10,5*1.E10/
      DEFINE BLOWN=V(NZ+1)
    1 NZ=ZZ
    2 ZZ=ZZ+1
4,RANS  RS=RL
4TRANS  CALL LOADON(ID,MODE)
    3 IF(BLOWN-0.5),,20
    6 IF(MODE.GT.1) RS=R(MODE)
    7 VOUT=VIN
   11 IS=VIN/RS
   15 IF(VIN*IS.LT.PMAX) RETURN
   16 BLOWN=1
   17 WRITE(6,100)ID,TIME
  100 FORMAT(/' *** FUSED LOAD ',I8, ' BLOWN AT ',F15.4/)
   20 VOUT=0
   25 RS=1.E10
   40 IS=0
END
```

---

*Model stays off when tripped for the duration of the simulation. It also outputs the load element ID and time of trip-off.

SYSTID LIBRARY MODEL DATA

MODEL:	GROUP ID	PAGE	DATE
LOGICAL SWITCH	CONTROL		

LIBRARY MODEL NAMES:
SWITCH

DESCRIPTION:

The switch element is employed in the SYSTID simulation to provide a lossless connection between any two topological nodes. It is therefore used both for topological and sequence control.

USAGE:

VIN < SWITCH (ID, RL) > VOLT, RS

VOUT = VIN	WHEN THE SWITCH IS CLOSED OTHERWISE, VOUT IS ZERO,
RS = RL	RS IS INFINITE IN VALUE
ID =	ANY EVENT SEQUENCE IDENTIFICATION NUMBER

SYSTID CODE:

```
MODEL*  VIN , SWITCH(ID,RL) . VOUT,RS
    10 CALL LOADON(ID,MODE)
    20 IF(MODE),,60
    30 VOUT=VIN
    40 RS=RL
    50 GO TO 100
    60 VOUT=0
    70 RS=1.E10
   100 CONTINUE
END
```

SYSTID LIBRARY MODEL DATA

MODEL: FIRST ORDER BI-LINEAR Z-TRANSFORM WITH VARIABLE COEFFICIENTS	GROUP ID MATH	PAGE	DATE
LIBRARY MODEL NAMES: ZED1			

DESCRIPTION

This function is an extension of Q FACTOR where the coefficients may vary with time. The function takes a second order transfer function in the complex variable s,

$$F(s) = \frac{a_1 s + a_o}{b_1 S + b_o}$$

and produces

$$G(z) = \frac{\hat{a}_1 z^{-1} + \hat{a}_o}{\hat{b}_1 z^{-1} + \hat{b}_o}$$

the z-transform in the sampled data operator z^{-1}. The coefficients a_i, b_i are constants over the sample time interval, but are allowed to change with time.

USAGE

IN < ZED1 (A1, A0, B1, B0) > OUT

where:
- IN = input s transform
- A1 = first instantaneous numerator coefficient
- A0 = second instantaneous numerator coefficient
- B1 = first instantaneous denominator coefficient
- B0 = second instantaneous denominator coefficient
- OUT = z transform equivalent output

SYSTID CODE:

```
MODEL*   IN , ZED1(A0,A1,B0,B1) . OUT
       DEFINE OLDIN=V(NZ+1)
       DEFINE OLDOUT=V(NZ+2)
     1 NZ=ZZ
    10 ZZ=ZZ+2
    20 A11=A1*2/DT
    30 B11=B1*2/DT
    40 OUT=A11*(IN-OLDIN)+A0*(IN+OLDIN)+OLDOUT*(B11-B0)
    45 OUT=OUT/(B11+B0)
    50 OLDIN=IN
    60 OLDOUT=OUT
END
```

SYSTID LIBRARY MODEL DATA

MODEL DESCRIPTION: SECOND ORDER BI-LINEAR Z-TRANSFORM WITH VARIABLE COEFFICIENTS	GROUP ID MATH	PAGE	DATE
LIBRARY MODEL NAMES: ZED2			

DESCRIPTION:

This function computes the bi-linear z-transform for a second order transfer function in the s domain whose coefficients vary with time (though constant over a given sample period) i.e., maps

$$G(s) = \frac{a_2 s^2 + a_1 s + a_o}{b_2 s^2 + b_1 s + b_o} \quad \text{into} \quad G(z) = \frac{\hat{a}_2 z^{-2} + \hat{a}_1 z^{-1} + \hat{a}_o}{\hat{b}_2 z^{-2} + \hat{b}_1 z^{-1} + \hat{b}_o}$$

USAGE:

IN < ZED2 (A, A1, A2, BO, B1, B2) > OUT

Where:
IN = input transform in s domain
A0 = 1st numerator coefficient
A1 = 2nd numerator coefficient
A2 = 3rd numerator coefficient
BO = 1st numerator coefficient
B1 = 2nd denominator coefficient
B2 = 3rd denominator coefficient
OUT = output z-transform

SYSTID CODE:

```
MODEL*   IN , ZED2(A0,A11,A21,B0,B11,B21) , OUT
         DEFINE A1=A11*2/DT
         DEFINE A2=A21*4/DT/DT
         DEFINE B1=B11*2/DT
         DEFINE B2=B21*4/DT/DT
         DIMENSION C(3),D(3)
         DEFINE XO2=V(NZ+1)
         DEFINE XO1=V(NZ+2)
         DEFINE XI2=V(NZ+3)
         DEFINE XI1=V(NZ+4)
       1 NZ=ZZ
       5 ZZ=ZZ+4
      10 C(1)=A0+A1+A2
      20 C(2)=2*A0-2*A2
      30 C(3)=A0-A1+A2
      40 D(1)=B0+B1+B2
      50 D(2)=2*B0-2*B2
      60 D(3)=B0-B1+B2
      70 OUT=C(1)*IN+C(2)*XI1+C(3)*XI2 -D(2)*XO1-D(3)*XO2
      80 OUT=OUT/D(1)
      90 XI2=XI1
     100 XI1=IN
     110 XO2=XO1
     120 XO1=OUT
END
```

SYSTID LIBRARY MODEL DATA

MODEL: SEPAP LOADS	GROUP ID CONTROL	PAGE	DATE

LIBRARY MODEL NAMES:

LOADS

DESCRIPTION:

The LOADS model controls the composition and sequence of SEPAP load groups in terms of their load equipments (elements). The model connects the loads through either an RPC, RCCB, or Fuse as given in the equipment/load data base, and is controlled by the Events Generator. The output of the model is the impedance presented to the voltage source.

USAGE:

VIN < LOADS (IL) > RS

where: VIN = source voltage node
IL = SEPAP load number (load group)
RS = impedance presented to the source

SYSTID CODE:

```
MODEL*VIN*LOAD(ID)*RS
        DIMENSION ILOD(100)
        LOGICAL FIRST/.FALSE./
        DIMENSION IADD(3)/'@ADD,F  LOAD      , '/,IZ(1)
        EQUIVALENCE(IZ,V),(IU,IOLDE),(IH,MODE,MO),(IT,ITYP,NE)
        EQUIVALENCE (XWATT,XL,NC),(I,NEWE)
        DEFINE EQUIP=FLD(0,20,IZ(NZ+1))
        DEFINE TYPE=FLD(20,2,IZ(NZ+1))
4TRANS IF(FIRST) GO TO 1
4TRANS FIRST=.TRUE.
4TRANS DO 2 I=1,100
     2 READ(5,3,END=4)ILOD(I)
4TRANS I=I+1
     3 FORMAT(I3)
     4 NLOD=I-1
1       CONTINUE
4TRANS  NZ=ZZ+1
4TRAN S IF(IZ(ZZ+1).NE.0)GO TO 200
4TRANS DO 5 I=1,NLOD
     5 IF(ID.EQ.ILOD(I)) GO TO 6
4TRANS GO TO 22
6       CONTINUE
4TRAN  $ IH=ID/100
4TRAN  $ IU=ID-IH*100
4TRAN  $ IT=IU/10
4TRAN  $ IU=IU-10*IT
4TRAN  $ NC=0
4TRAN  $ IF(IU.EQ.0)GO TO 50
4TRAN  $ FLD(0,6,IADD(3))=IH+48
4TRAN  $ NC=1
10      FLD(NC*6,6,IADD(3))=IT+48
4TRAN  $ NC=NC+1
20      FLD(NC*6,6,IADD(3))=IU+48
4TRAN  $ IH=ERCSF(IADD)
4TRAN  $ IF(IH.EQ.0)GO TO 60
22      WRITE(6,100)ID,IH
100     FORMAT(' LOAD NOT FOUND:',I4,' STATUS OF ADD ='O13)
```

SYSTID LIBRARY MODEL DATA

MODEL: SEPAP LOADS	GROUP ID CONTROL	PAGE	DATE

LIBRARY MODEL NAMES:
LOADS

LOADS SYSTID CODE (CONTINUED)

```
4TRAN $ IZ(ZZ+1)=1
30      RS=1.E10
4TRANS   ZZ=ZZ+1
4TRAN $ RETURN
50      FLD(0,18,IADD(3))=' '
4TRAN $ IF(IT.NE.0) GO TO 10
4TRAN $ GO TO 20
60      IOLDE=0
4TRANS   WRITE(6,61)IADD(2),IADD(3)
61      FORMAT(1X,A6,A3/)
4TRAN $ NZ=NZ-3
70      READ(5,110,END=90)NEWE,MODF,ITYP,NTYP,XWATT
4TRANS   WRITE(6,110)NEWE,MODE,ITYP ,NTYP.XWATT
110     FORMAT(7X,I6,I1,2X,A2,26X,T1,F9.2)
4TRAN $ IF(NTYP.NE.1)GO TO 400
4TRAN $ IF(MODE.GT.1) GO TO 70
4TRAN $ IF(IOLDE.NE.NEWE) GO TO 80
75      V(MODE+NZ+2)=32.*32./XWATT
4TRAN $ GO TO 70
80      NZ=NZ+3
4TRAN $ IOLDE=NEWE
4TRAN $ EQUIP=NEWE
4TRAN $ NTYP=3
4TRAN $ IF(ITYP.EQ.'RC')NTYP=2
4TRAN $ IF(ITYP.EQ.'RP') NTYP=1
4TRAN $ TYPE=NTYP
4TRAN $ V(NZ+3)=1.E10
4TRAN $ V(NZ+2)=1.E10
4TRAN $ GO TO 75
400     GO TO 70
   THIS IS THE ENTRY POINT FOR NON RESISTIVE ELEMENTS
90      IZ(ZZ+1)=3+NZ-ZZ
200     IF(IZ(ZZ+1).EQ.1) GO TO 30
4TRAN $ NE=IZ(ZZ+1)/3
4TRAN $ NZ=ZZ+1
4TRANS   ZZ=ZZ+IZ(ZZ+1)+1
4TRAN $ RS=1.E10
4TRANS   DO 301 I=1,NE
4TRANS   XBLOW=2.*32.*32./V(NZ+2)
4TRAN $ CALL LOADCN(EQUIP,MO)
4TRAN $ IF(MO-2),220,230
4TRANS   XL=V(NZ+2+MO)
4TRAN $ GO TO 240
220     XL=1.E-10
4TRAN $ GO TO 240
230     XL=1.E10
240     MO=TYPE
4TRAN $ GO TO (250,260,270),MO
250     CONTINUE      @ RCPC
        VIN - CURRENT LIMITER (XL,20.) - VO , IS , R
4TRAN $ GO TO 300
260     CONTINUE    @ RCCB
        VIN . RCCB(-EQUIP,XL) . VO,IS,R
4TRAN $ GO TO 300
270     CONTINUE  @  FUSE AND OTHERS
        VIN . FUSE(-EQUIP,XL,XBLOW) . VO,IS,R
300     RS=1./(1./RS+1./R)
4TRAN $ IF(R.GT.1.E-5) GO TO 301
4TRAN $ ROUTXL=R
4TRAN $ NTYPO=EQUIP
4TRAN $ WRITE(6,8898) ROUTXL,NTYPO,ID,MO
8898    FORMAT(T50,2X,E14.6,3I10)
301     NZ=NZ+3
        END
```

2.3 EPDC Performance Analysis

The Events Generator, in conjunction with the LOADS and EPDC models listed in Section 2.2, was employed[1] to excite the step response of an RCCB, RPC, and FUSE driving a resistive load from the fuel cell source, as shown schematically in Figure 2.3-1. In addition, the inverter was also tested for step response when supplying a resistive load. Figures 2.3-2(a) and (b) display the fuel cell bus voltage, and bus current, respectively, as the RPC, RCCB, FUSE, and inverter are excited. Figures 2.3-3, 2.3-4, 2.3-5, and 2.3-6 display the transient current flow of the RPC, RCCB, inverter, and FUSE DC input paths.

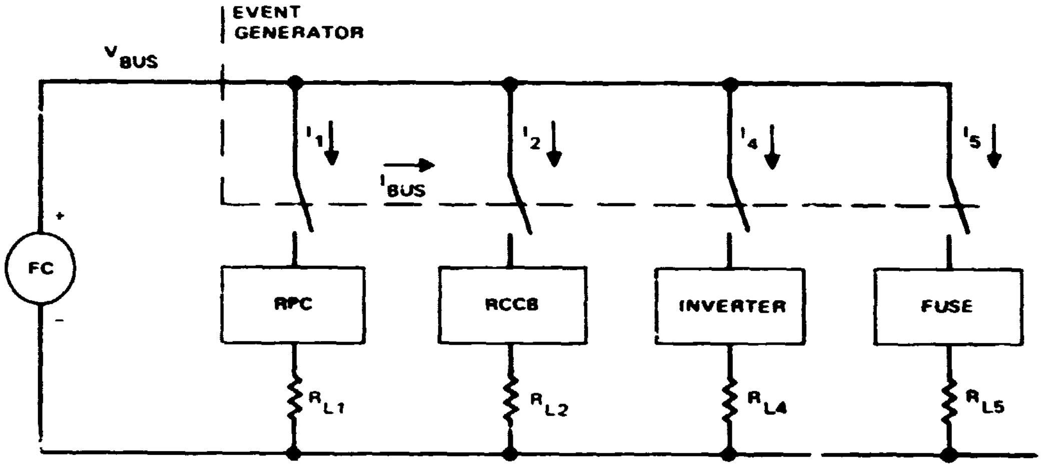


FIGURE 2.3-1. EPDC ELEMENT TRANSIENT RESPONSE SYSTID TEST CONFIGURATION

---

[1] The Event Generator actually drives logic internal to the device; the logical switches are shown external to the RPC, RCCB, FUSE, and inverter as a matter of convenience.

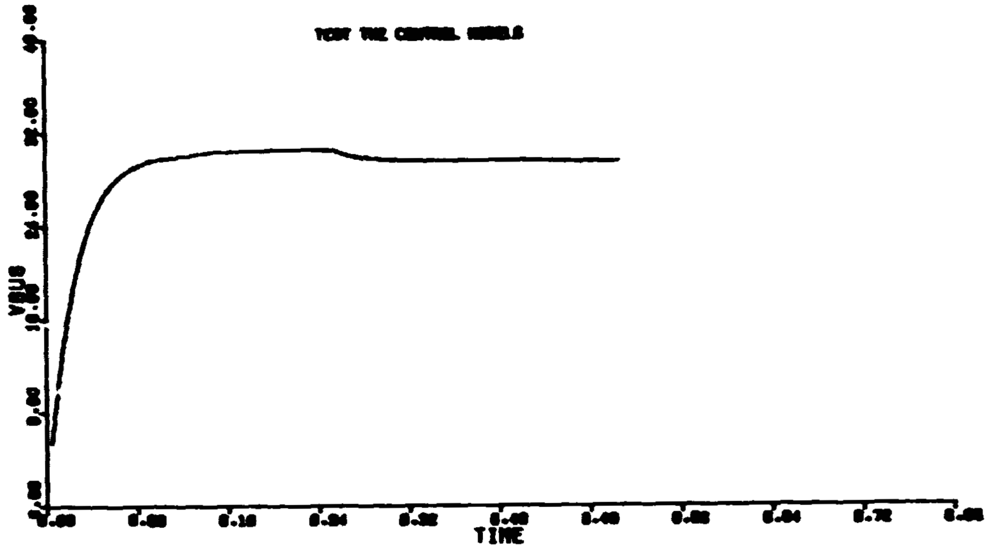


FIGURE 2.3-2a. FUEL CELL BUS VOLTAGE VERSUS TIME, FOR SEQUENCED LOADS

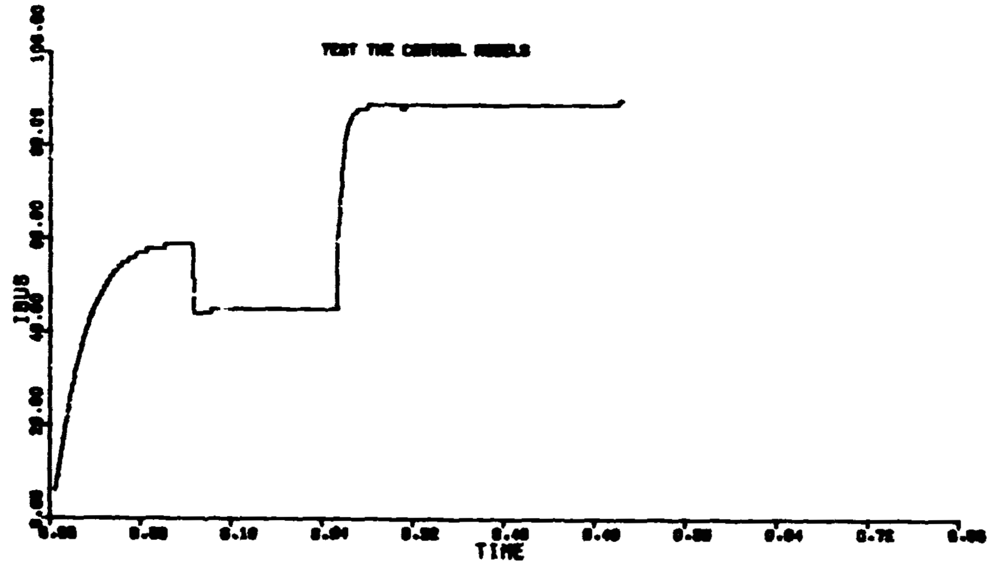


FIGURE 2.3-2b. FUEL CELL OUTPUT CURRENT VERSUS TIME, FOR SEQUENCED LOADS

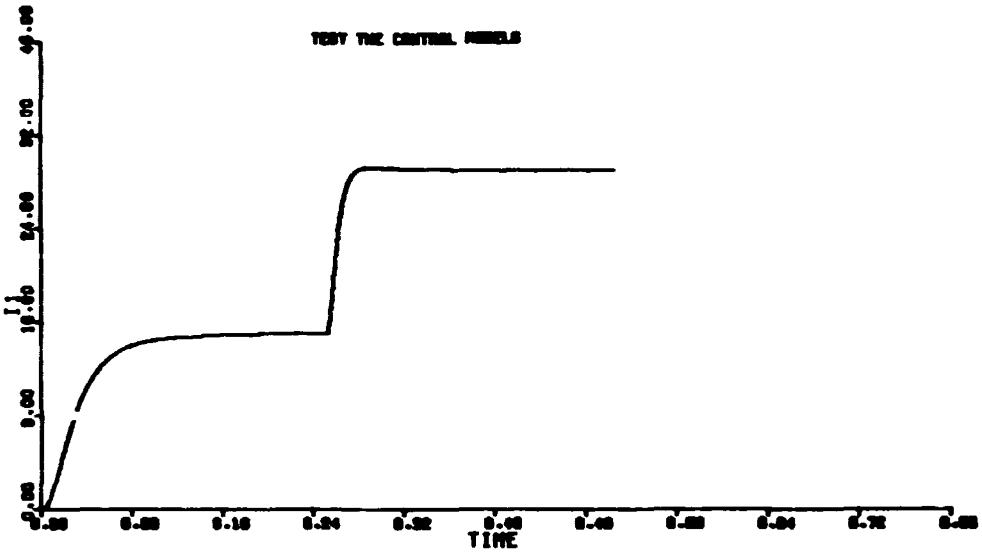


FIGURE 2.3-3. RPC INPUT CURRENT VERSUS TIME (SEQUENCED OFF/ON)

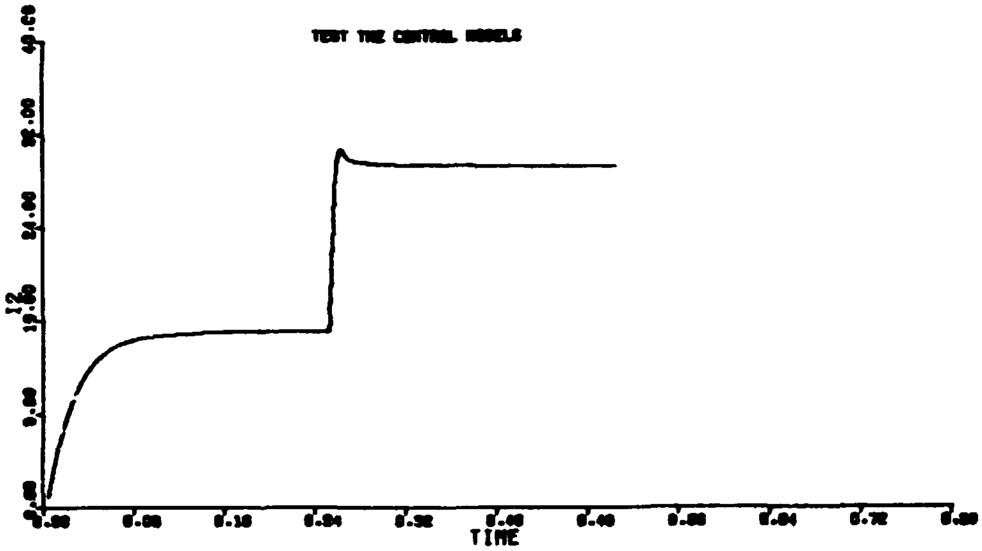


FIGURE 2.3-4. RCCB INPUT CURRENT VERSUS TIME (SEQUENCED OFF/ON)

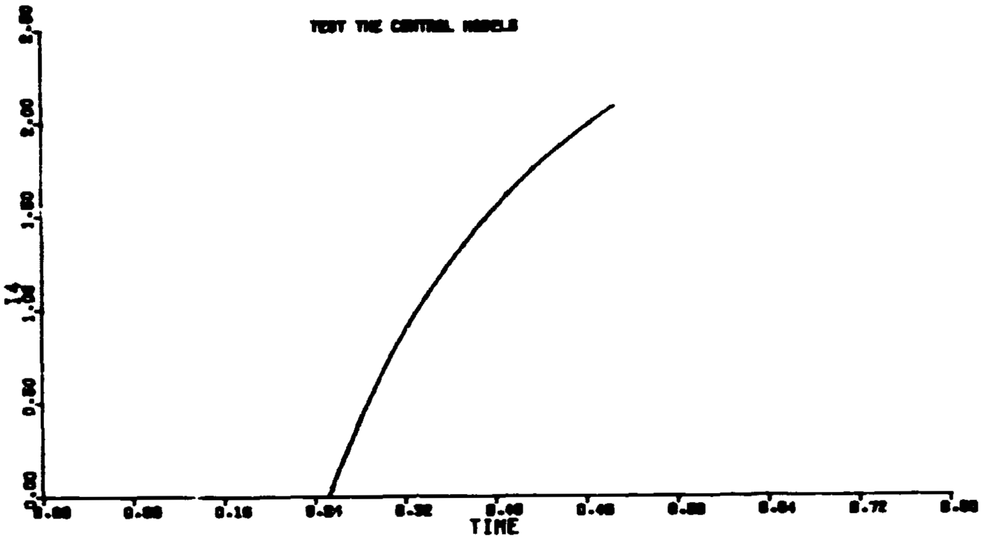


FIGURE 2.3-5. INVERTER DC INPUT CURRENT VERSUS TIME (SEQUENCED OFF/ON)

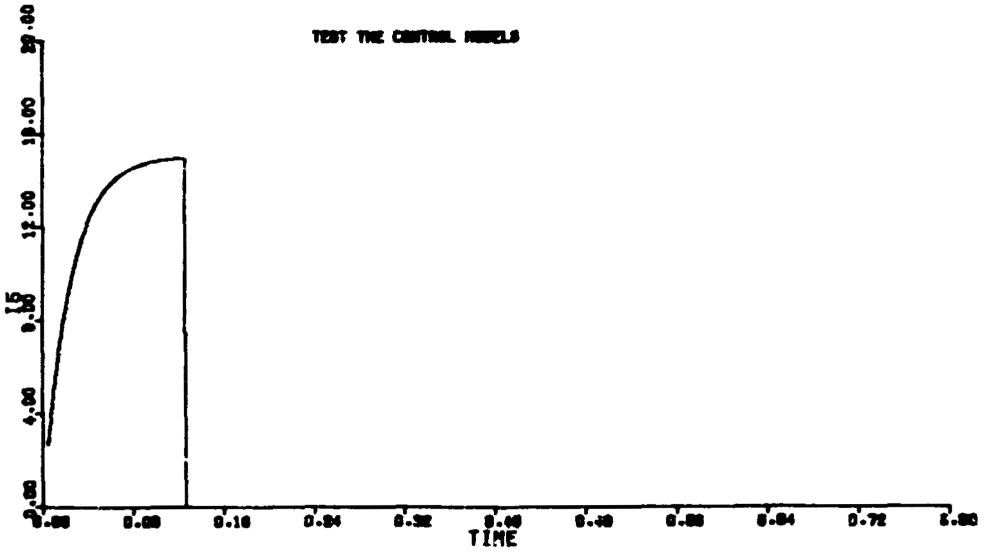


FIGURE 2.3-6. FUSE INPUT CURRENT VERSUS TIME (SEQUENCED OFF/ON)

The complete EPDC subsystem topology of Figure 7.1-1 was exercised by the Event Generator and LOADS model, in order to display the entire simulation capability of SYSTID. To minimize output data to manageable levels for this preliminary stage, only representative subsets of the EPDC topology were selected for output analysis.

These representative subsets included:

1) Main DC bus A, main bus B, main bus C voltage and currents
2) Local DC bus current fed by the main buses A, B, and C into local DC load groups
3) Currents of load group (DC) fed by local buses in A, B, and C main bus groups
4) DC current drawn by an inverter as fed by a local bus, for each main bus group (the AC output currents of inverters driving their load groups was not displayed to minimize computer output). A representative sample of the inverter AC output is given in Section 5.3.1.
5) Currents of dioded aft sub-bus loads, in groups A, B, and C
6) Essential bus currents in the main bus B group

Table 2.3-1 lists these outputs in greater detail by identifying nodes and branch numbers consistent with Figure 7.1-1. The appropriate responses are given in the same order listed in this table by the CALCOMP plots which follow.

TABLE 2.3-1. EPDC FAULT RESPONSE PLOTS IN SEQUENCE IN WHICH THEY FOLLOW

EPDC Element	Current/Voltage Identification*	Figure	Comments
Main bus A	I 101	2.3 - 7	Current drawn from fuel cell 1
Forward, local DC bus A	I 120	2.3 - 8	Current drawn from main bus A by local bus loads
Local bus A DC load group	I 121	2.3 - 9	Current drawn by load group 121
Inverter bus A	I 19	2.3 - 10	DC current drawn by inverter when supplying load group 123
Aft sub-bus AB	I 512A	2.3 - 11	Dioded current drawn by load group 512 from aft local bus A
Main bus A	V 10	2.3 - 12	Voltage output of fuel cell 1
Main bus B	I 201	2.3 - 13	Current drawn from fuel cell 2
Forward local DC bus B	I 220	2.3 - 14	Current drawn from main bus B by local bus loads
Local bus B DC load group	I 221	2.3 - 15	Current drawn by DC load group 221
Inverter bus B	I 29	2.3 - 16	DC current drawn by inverter when supplying load group 223

---

*Refer to Figure 7.1-1, the EPDC topology for symbol keying.

Table 2.3-1 (Continued)

EPDC Element	Current/Voltage Identification	Figure	Comments
Aft sub-bus BC	I 523 B	2.3 - 17	Dioded current drawn by aft load group 523 from aft local bus B
Main bus B	V20	2.3 - 18	Voltage output of fuel cell 2
Main bus C	I 301	2.3 - 19	Current drawn from fuel cell 3
Forward local DC bus C	I 320	2.3 - 20	Current drawn from main bus C by local forward DC loads
Local bus C DC load group	I 321	2.3 - 21	Current drawn by DC load group 321
Inverter bus C	I 39	2.3 - 22	DC current drawn by inverter when supplying load group 323
Aft sub-bus CA	I 531C	2.3 - 23	Dioded current drawn by aft load group 531 from aft local bus C
Main bus C	V 30	2.3 - 24	Voltage output of fuel cell 3
Essential bus 1BC	I 271 A	2.3 - 25	Current drawn from main bus A by essential load 271
	I 271 B	2.3 - 26	Current drawn from main bus B by essential load 271

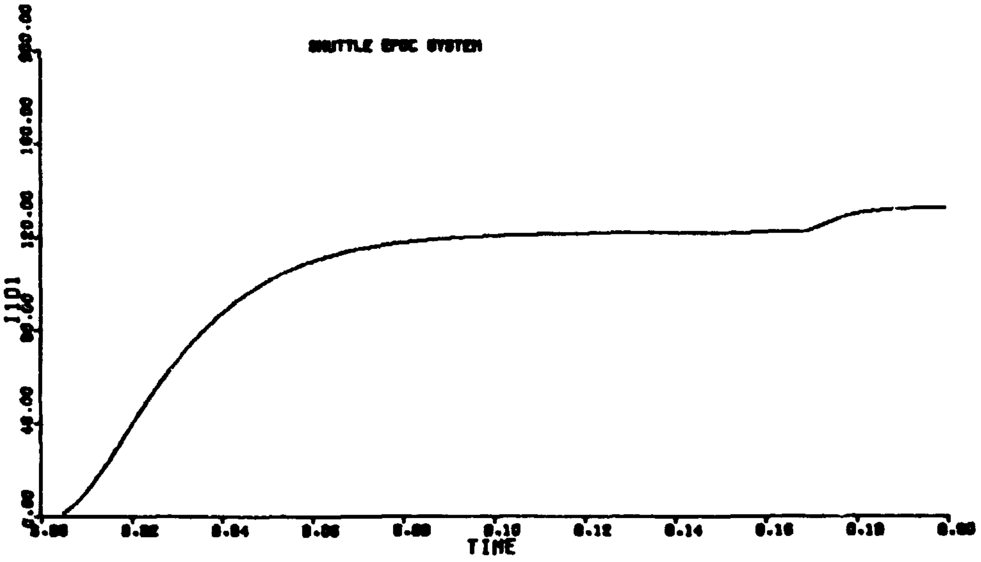


FIGURE 2.3-7.

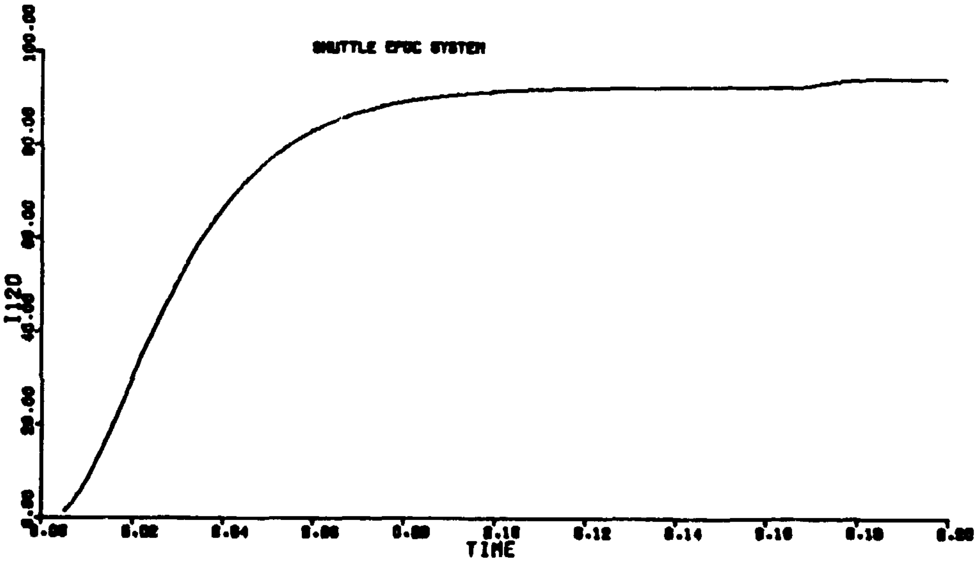


FIGURE 2.3-8.

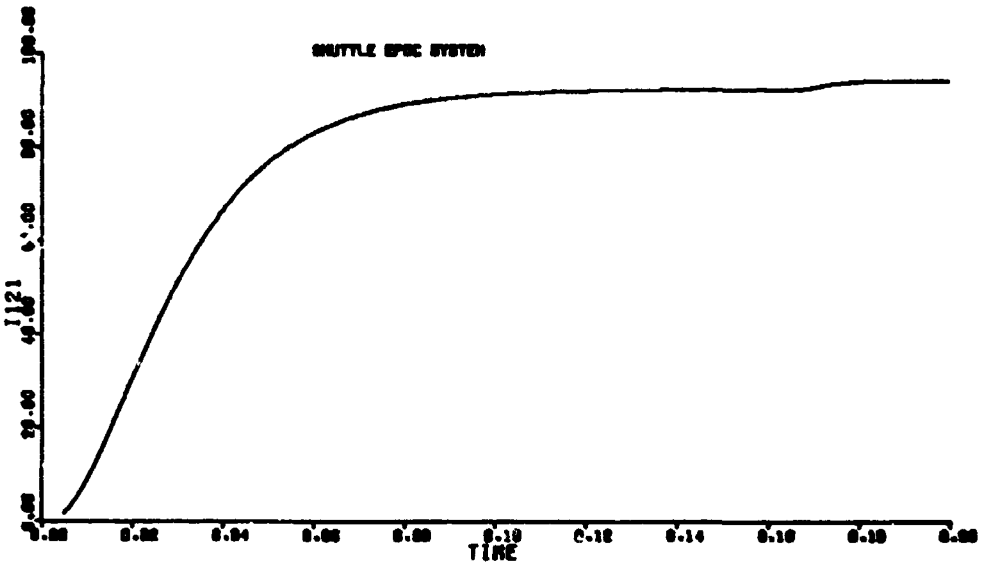


FIGURE 2.3-9.

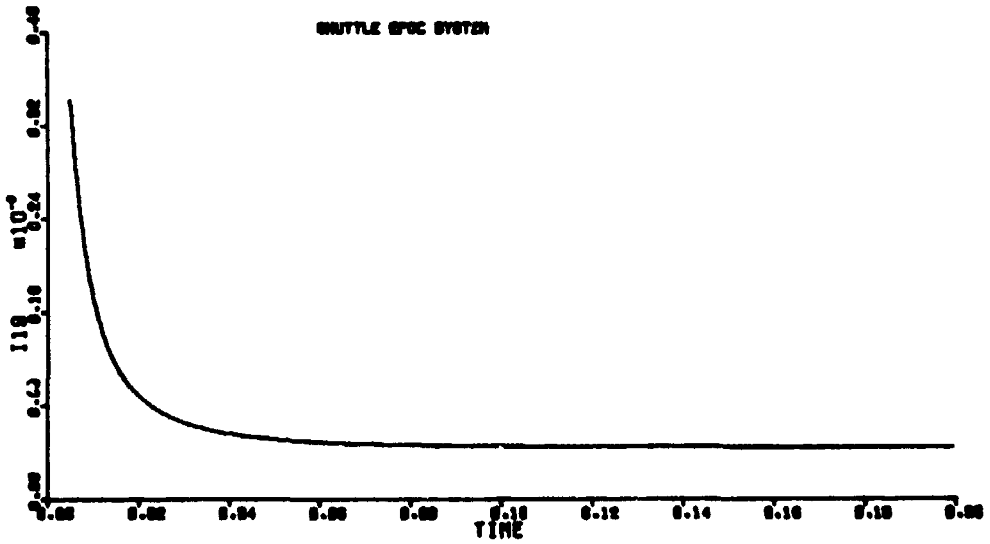


FIGURE 2.3-10.

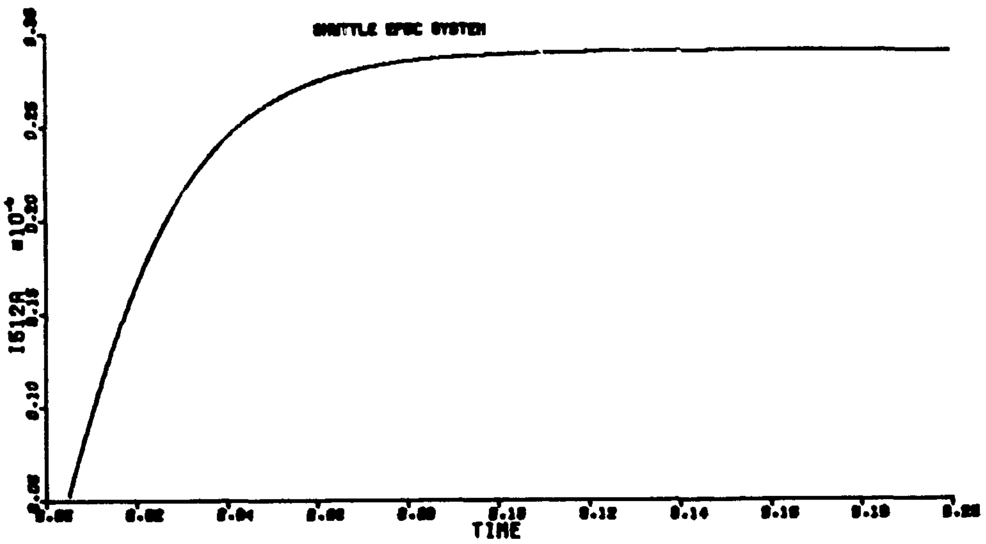


FIGURE 2.3-11.

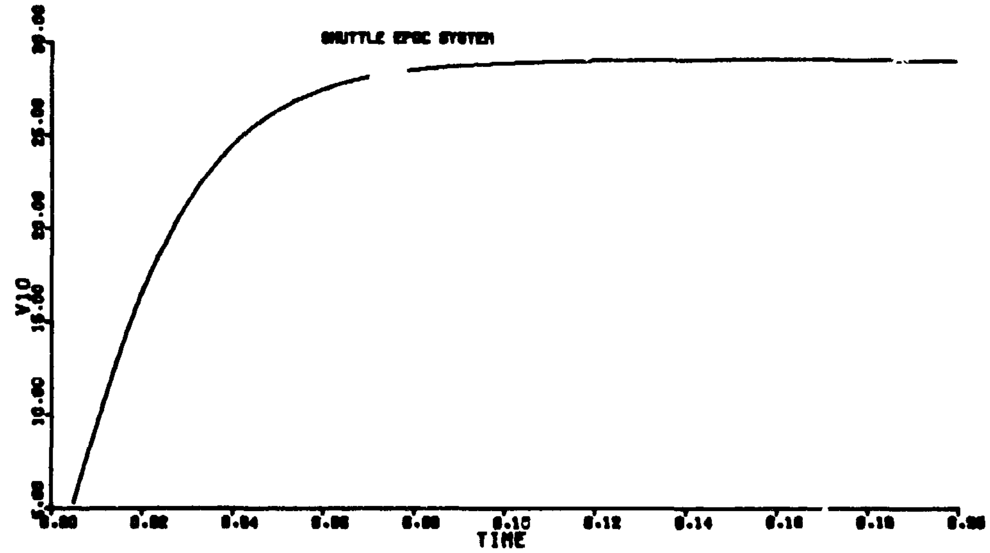


FIGURE 2.3-12.

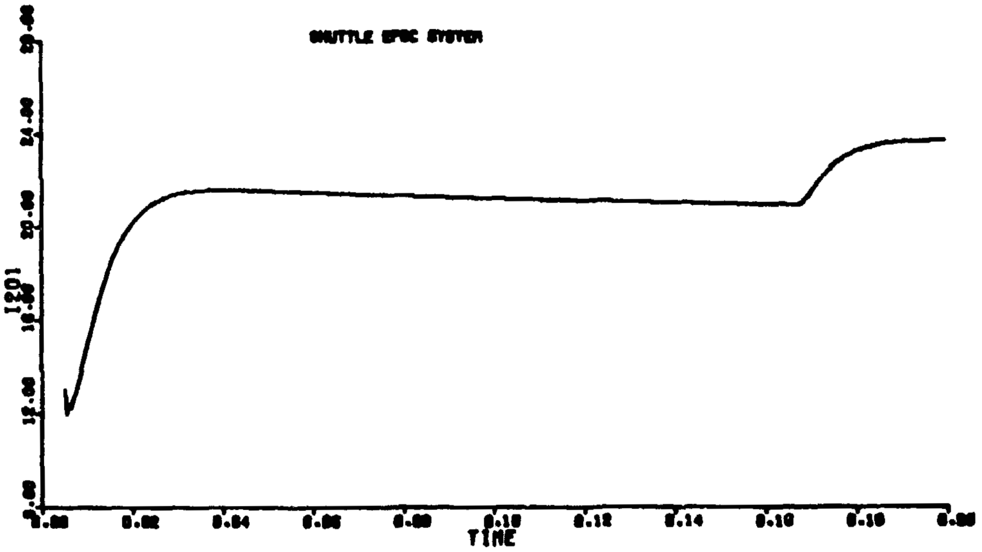


FIGURE 2.3-13.

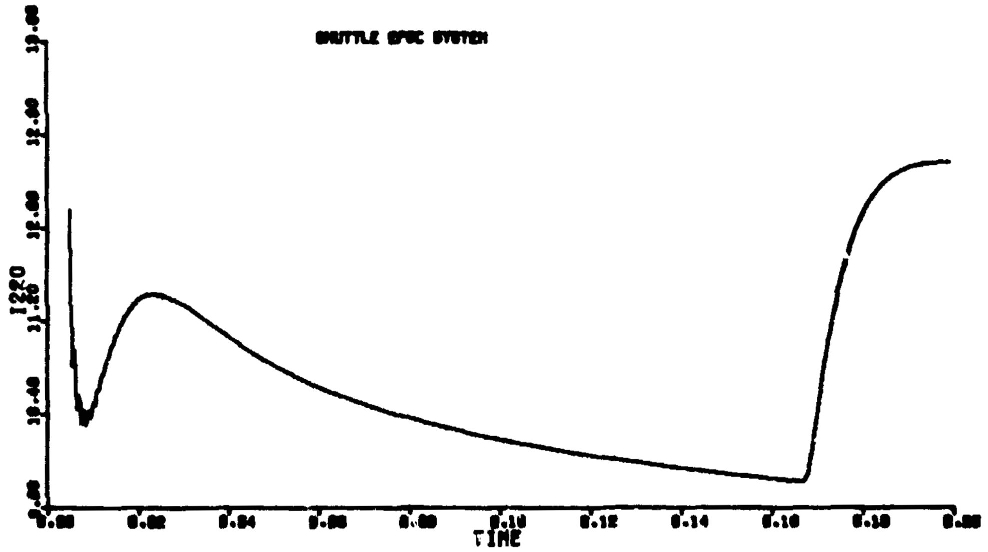


FIGURE 2.3-14.

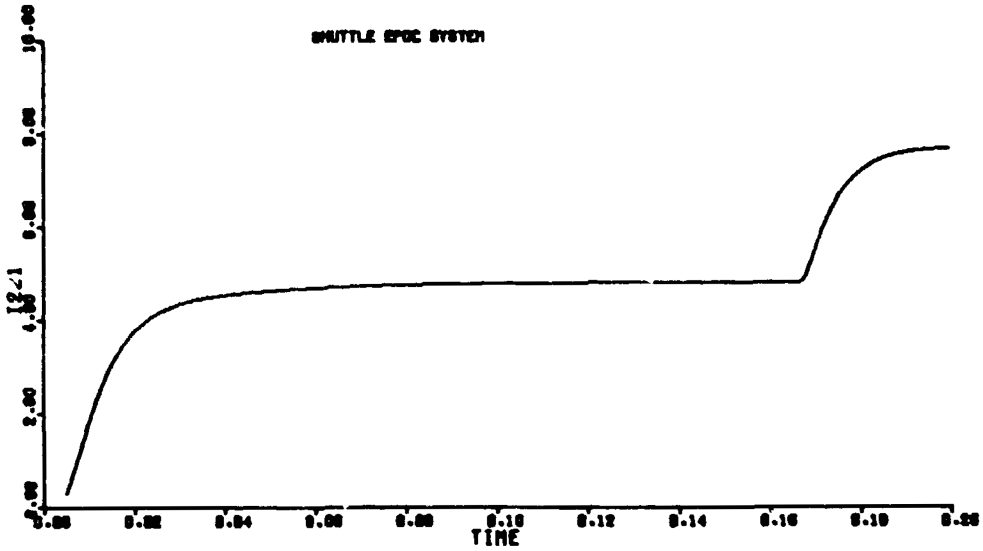


FIGURE 2.3-15.

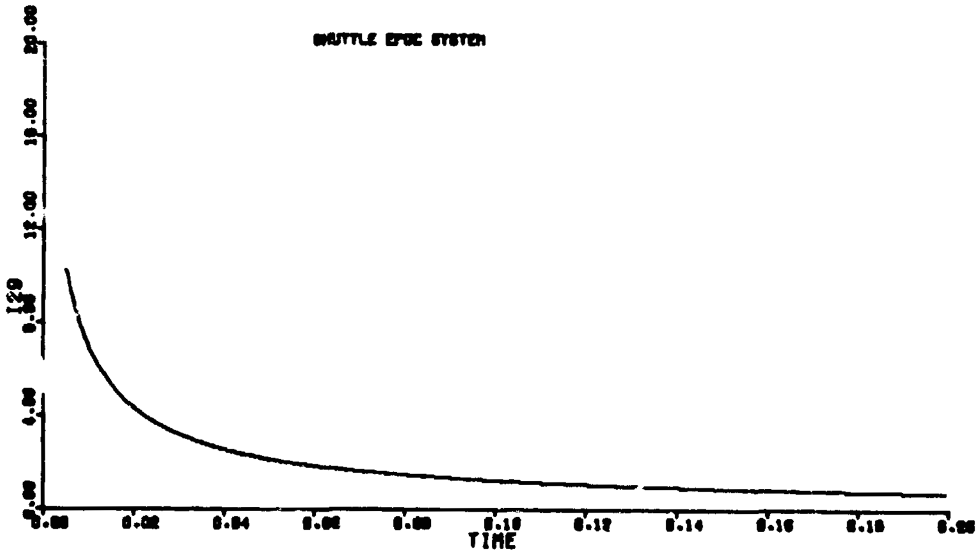


FIGURE 2.3-16.

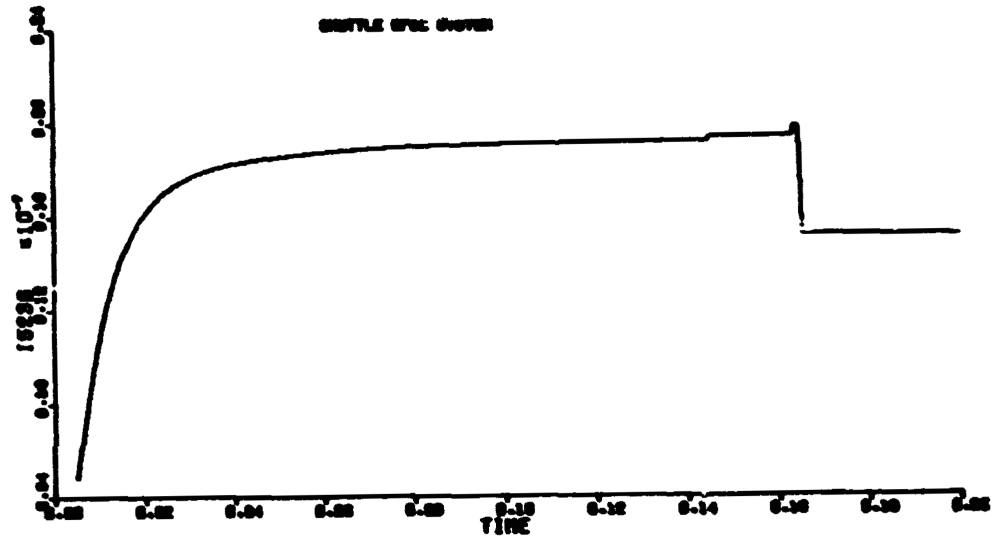


FIGURE 2.3-17.

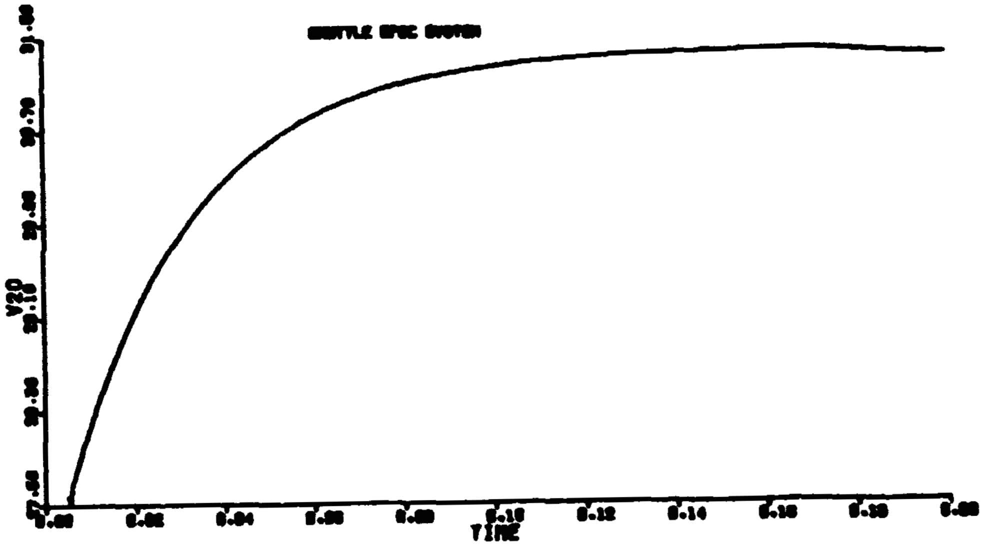


FIGURE 2.3-18.

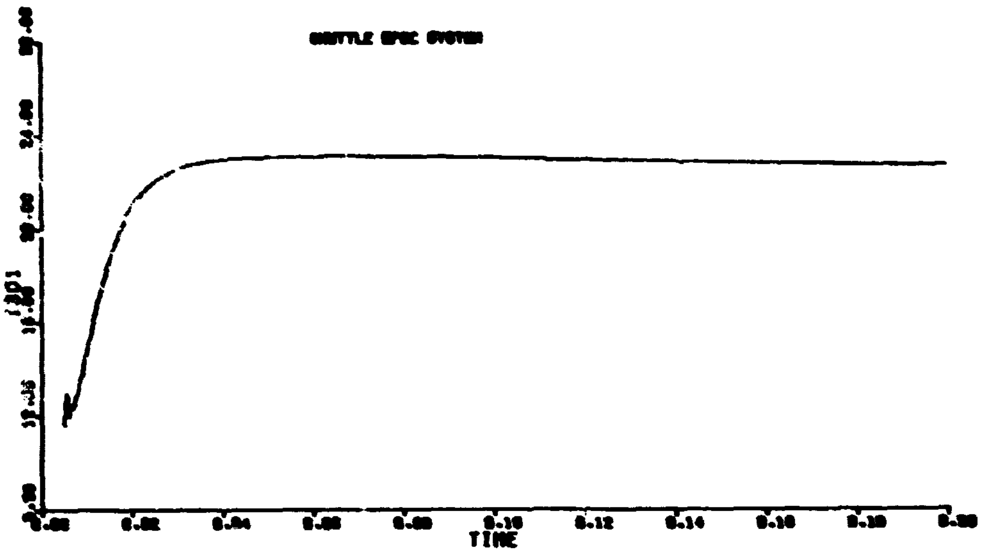


FIGURE 2.3-19.

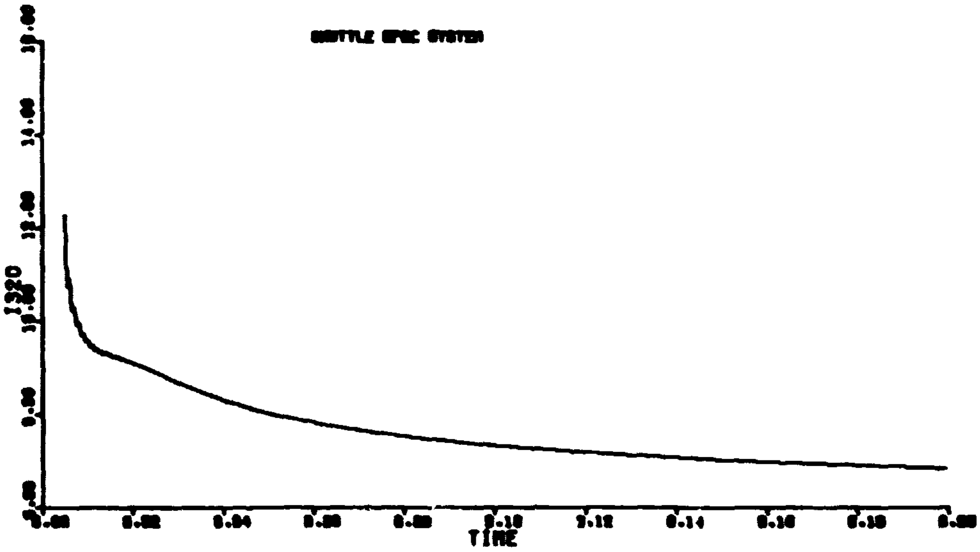


FIGURE 2.3-20.

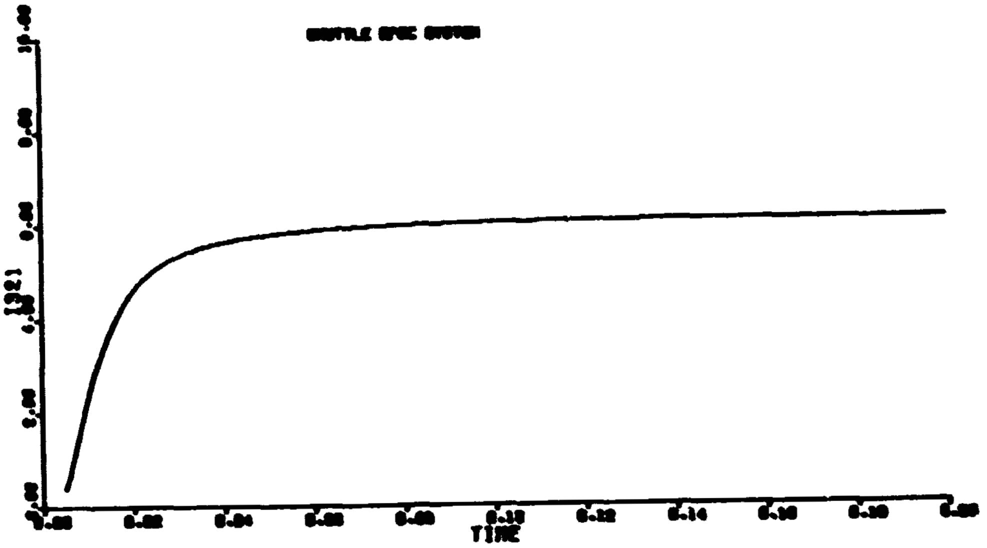


FIGURE 2.3-21.

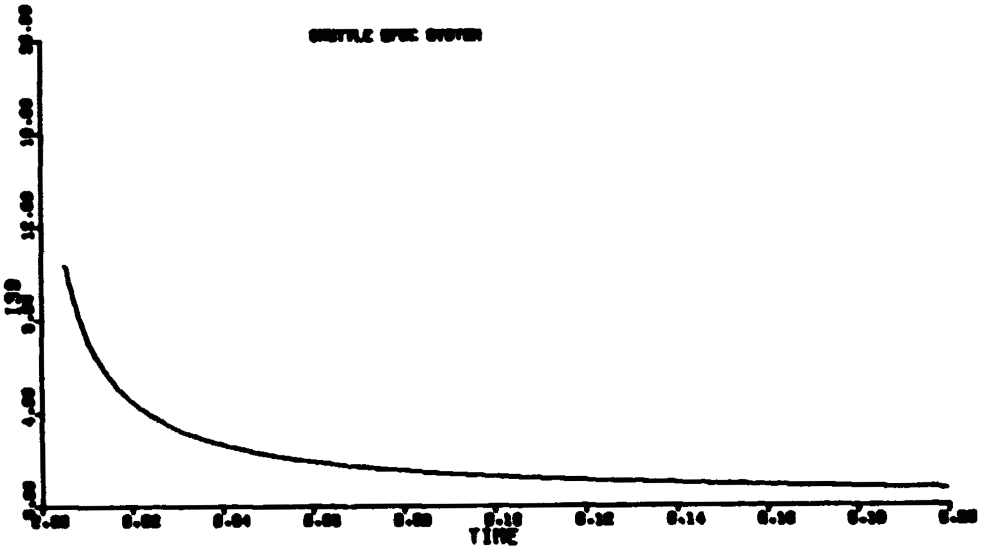


FIGURE 2.3-22.

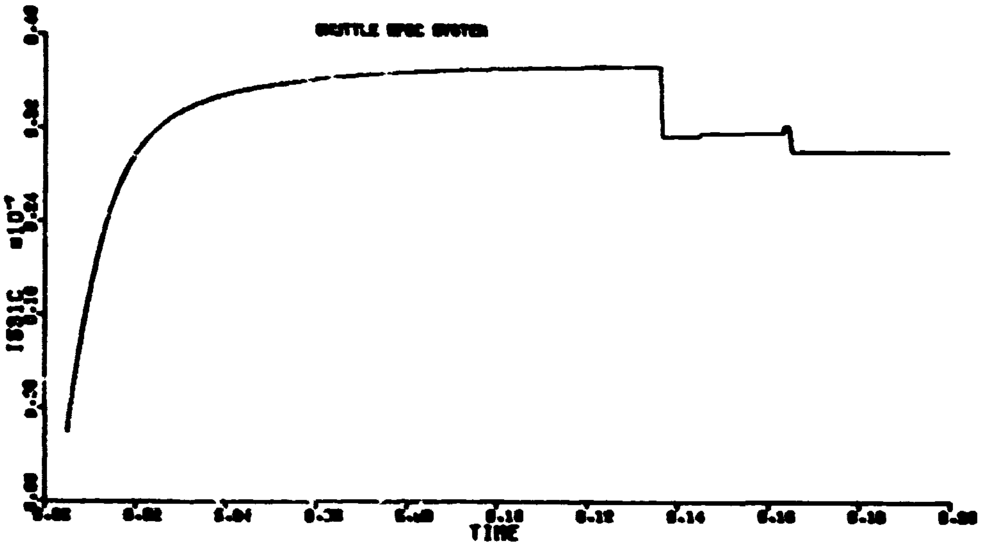


FIGURE 2.3-23.

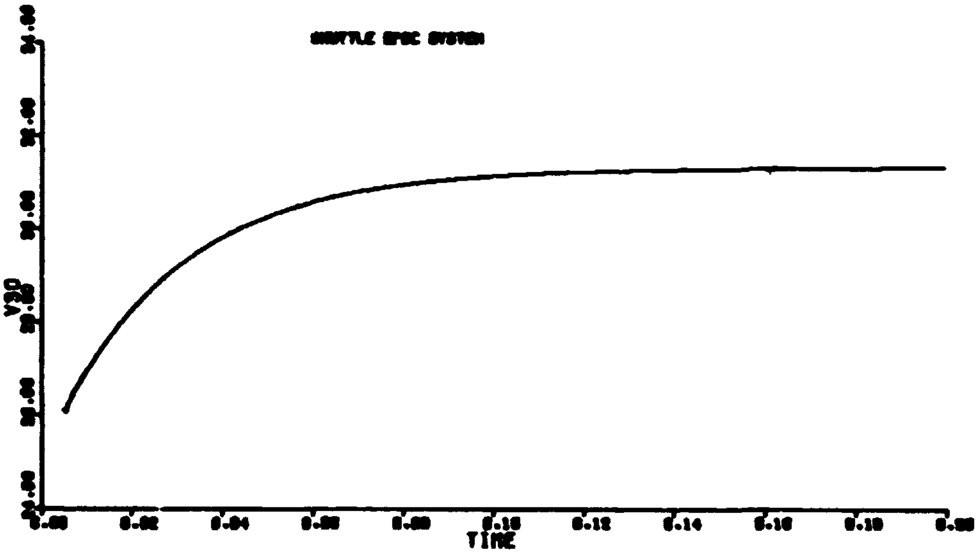


FIGURE 2.3-24.

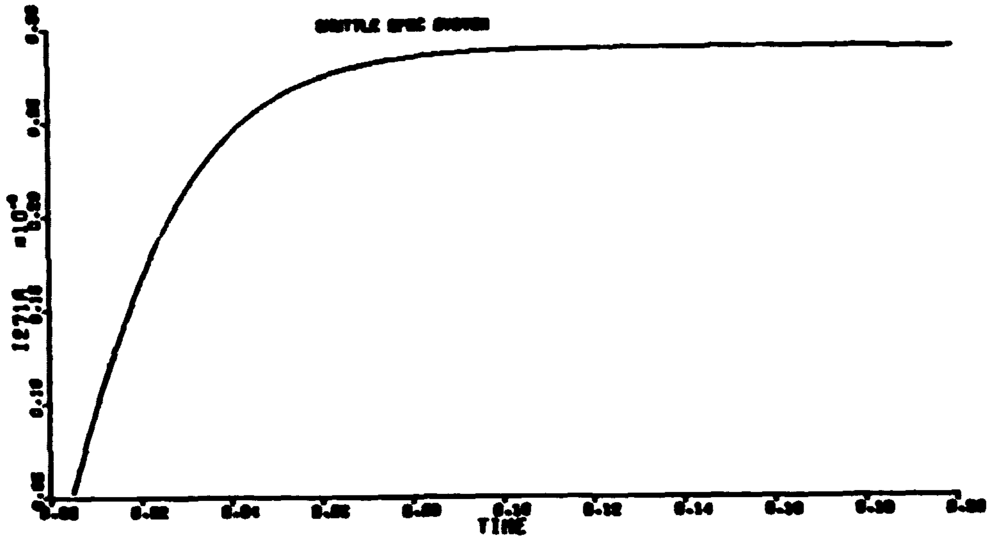


FIGURE 2.3-25.

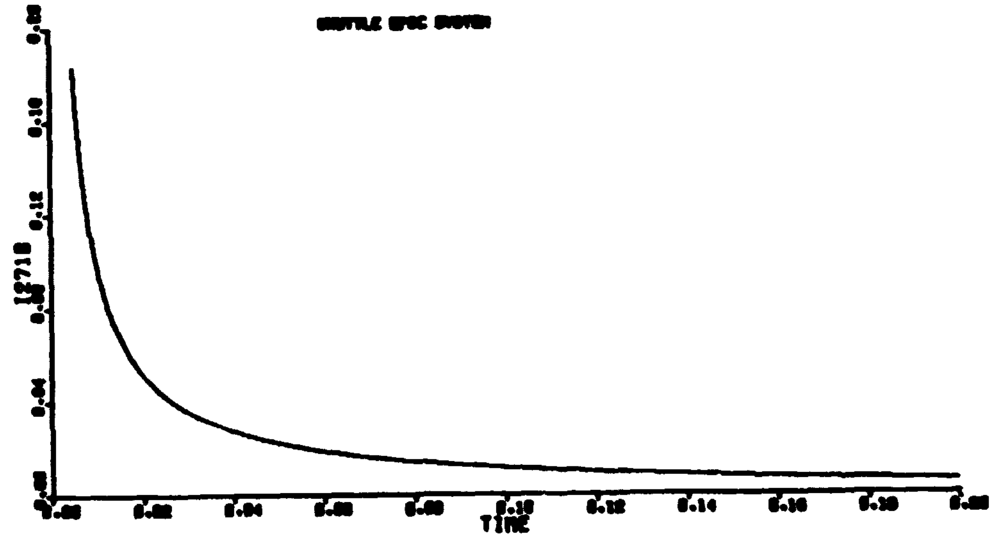


FIGURE 2.3-26.

3.0 CONCLUSIONS

All of the stated objectives for SYSTID simulation software enhancement were realized...in fact exceeded in some respects. The net result of this effort is the presence, on the NASA/JSC UNIVAC 1110 operating system, of a greatly improved SYSTID language, whose user utility and operational flexibility are much improved relative to the original SYSTID software. Incorporation of the JSC MOPS (Hazeltine 4000G) CRT terminal as a device for SYSTID user input/output has added another dimension of user convenience.

The study achievements in the tasked areas of shuttle electrical power system element modeling and performance analysis are more conditional than the clear-cut status of the software tasks. The preliminary discussion in the section on results, and the following general discussion section should make clear that a finalized EPDC topology and EPDC element data base do not currently exist. Therefore, at best, the SYSTID models describe generically similar devices, not necessarily the behaviour of devices which will eventually be specified by Rockwell/JSC. Similarly, due to lack of detail on EPDC elements, their bus assignments, and characterization of load devices, the performance analysis has necessarily been merely illustrative in terms of its utilization of SYSTID simulation capability and the nature of the performance measures, i.e., response of EPDC source/control elements to load shorts, etc.

What has been accomplished, therefore, in the EPDC modeling and performance task efforts, is 1) the establishment of generic models, which may be quite adequate (with parameter adjustment) in the representation of finalized hardware elements, 2) establishment of a "superset" EPDC topology, and associated event generator, which can be modified with additional detail, as the system design solidifies, 3) a qualitative measure of typical EPDC transient responses at certain interesting points, as load states are varied. The latter observations of SYSTID outputs at appropriate points can be used to size circuit protection devices (RPC, RCCB, fuses) determine bus current flows for redundantly-configured loads such as the essential buses, and computers, under fault conditions. In short, the addition of firm hardware characteristics to the model data base and minor changes to the system topology will allow utilization of the study performance simulations for useful system prediction and design analysis.

4.0 RECOMMENDATIONS

Based on the results of the study and the knowledge gained about the shuttle EPDC by Hughes study staff, it is possible to recommend that the following additional tasks, as described in the abbreviated statements below be pursued. A functional task flow overview of the proposed follow-on is presented in Figure 4.0-1.

The original EPDC/user subsystem SYSTID simulation and performance analysis goals continue to be worthy of implementation. However, given the continued fluidity of the EPDC and user (load) subsystem design, more immediate attention to valid detailed modeling of as many EPDC and user subsytem elements as have been defined would appear to be more productive than larger-scale system performance analysis.

Therefore, it is recommended that a well-researched, validated and documented EPDC/load subsystem element modeling effort be undertaken as a follow-on study effort. The enhanced SYSTID software and preliminary EPDC modeling efforts carried out in this contract have provided a secure foundation which will underlay the follow-on element modeling, and eventual system modeling and performance analysis.

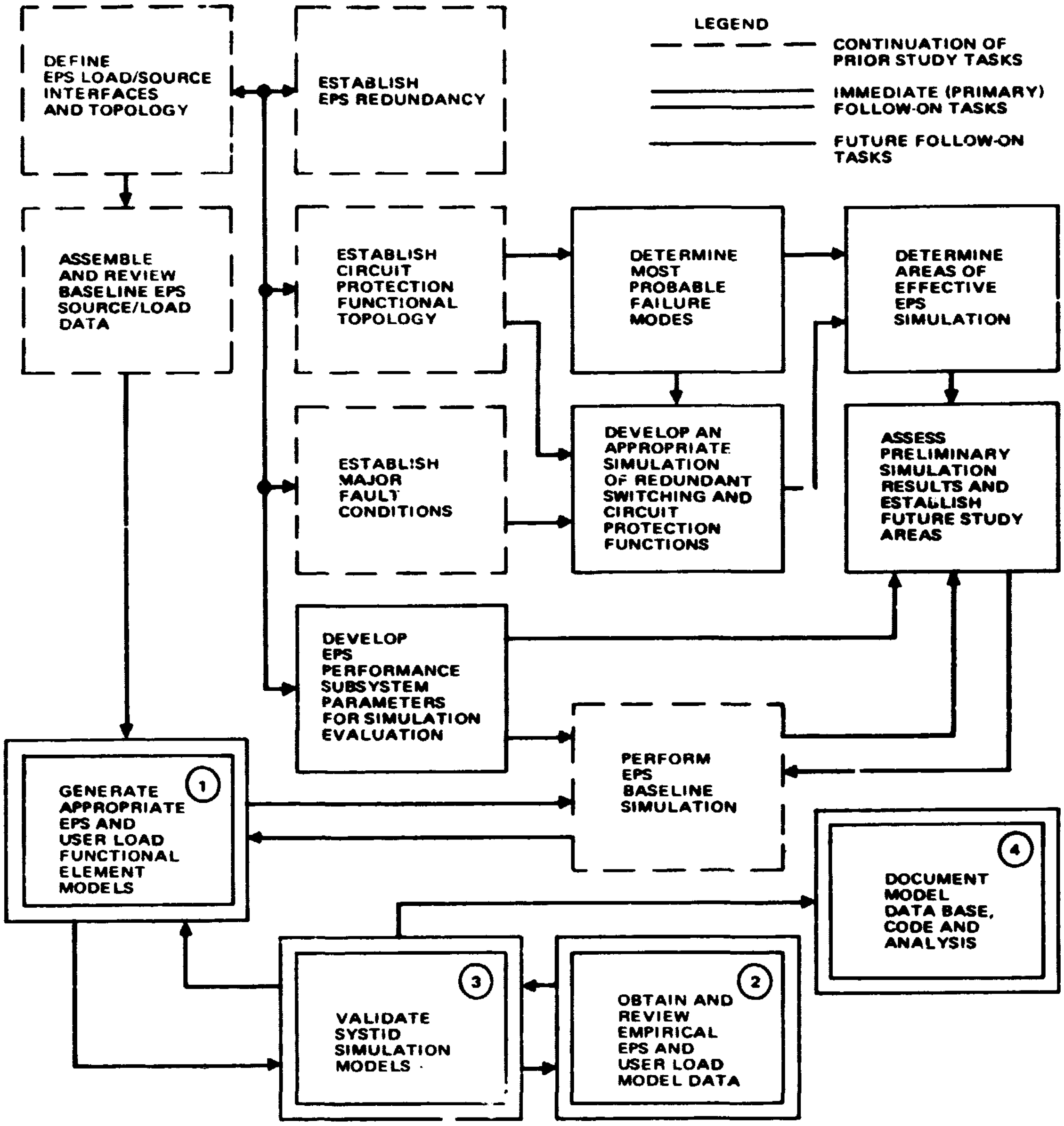


FIGURE 4.0-1. TYPICAL STUDY TASK FLOW DIAGRAM

MAJOR TASK AREA: SHUTTLE ELECTRICAL POWER, DISTRIBUTION, AND CONTROL (EPDC) SUBSYSTEM ELEMENT MODELING

TASK NAME/ NUMBER	TASK DESCRIPTION	EXPECTED OUTPUT
01	Establish a data base management scheme whereby EPDC and user load element characteristics and specifications are obtained in a timely manner with a formal NASA/JSC/Rockwell/Hughes interface, and clearly stated data requirements.	Organizational data flow, definite schedule and working group meetings, vendor visits.
02	Generate descriptive transfer function data, and equivalent mechanization for each EPDC source, control and distribution element based on current detailed element hardware performance specifications and vendor data.	Set of steady-state transfer functions; unit configuration and parameters.
03	Generate descriptive characteristics on each major important EPDC user subsystem including its admittance parameters, drive voltages or current detailed bus assignments, mission time profile (of adequate detail).	Set of user load characteristics.
04	Generate SYSTID model code for each of the models defined by the prior characterization tasks.	SYSTID code.
05	Obtain or generate transient response (i.e., step response) test data on all EPDC and user subsystem load elements, with adequate time resolution. Compare this data with SYSTID model simulated response data, for equivalent conditions, in order to validate these models...adjust SYSTID model parameters as necessary.	Comparitive transmit response plots and modified SYSTID model parameters.
06	Establish shuttle operating philosophy and mission mode criticality measures. Determine critical paths and EPDC/user elements, for subsequent fault simulation, and circuit protection analysis.	SYSTID simulation runs, and performance analysis.

5.0 GENERAL DISCUSSION

5.1 Introduction

The material in this section will, 1) introduce the basic concepts of the time-domain simulation of continuous systems, as exemplified by the SYSTID software enhanced and utilized in this study effort, 2) provide additional detail on the EPDC element model representations summarized in Section 2.2.

Acknowledgement is made at this point of those Hughes staff members who have contributed directly to this study, or to ancillary efforts. In particular, the outstanding SYSTID enhancements generated by Dale Paynter, with inter-active graphics I/O capability as added by John Forbes, must be noted. The EPDC data research and modeling efforts were carried out by Ivar Highberg, Nels Palmquist, and Johnetta MacCalla.

5.2 SYSTID Discussion

Some time ago, the need to accurately simulate real systems, particularly telecommunications systems, became apparent, and a time-domain simulation effort was initiated [78] at Hughes, on the Surveyor program. These efforts[1] of M. Fashano, W. Mayfield, N. Wagner and others were carried forward in succeeding years by D. Paynter and M. Fashano (and R. J. Rechter) under two NASA JSC contract efforts[2] [76, 77], culminating in the SYSTID time-domain simulation software. SYSTID represented a starting point for this study effort. Though the main thrust for SYSTID's genesis and application was to simulate telecommunications systems, its design was deliberately made sufficiently general to allow representation of a general set of physical systems. Thus, the application of SYSTID to the shuttle electrical power system was straight forward; only new library models, to represent the shuttle elements was necessary (Volume II, User Guide, report will list the telecommunications system model library currently available in SYSTID).

---

[1] The SAMDAT simulation software

[2] NAS9-11743

Program Description

SYSTID is a system of computer routines that provides the analyst with a powerful tool for the transient simulation and analysis of complete systems (e.g., telecommunication, power, electronic, and servocontrol subsystems).

The program accepts as input a topological black box description of a system, automatically generates the appropriate algorithms, and then proceeds to execute the simulation program. Thus the user is not necessarily required to write the algorithms in a computer language nor possess a great facility in computer programming. The system description, including both topology and element information, is supplied to the program in a free-form, user-controller engineering language which is easily learned.

SYSTID offers the user enormous flexibility in the representation of system elements (i.e., black boxes). An element may be defined as:

1) An SYSTID library model
2) A user-written, temporary SYSTID model
3) A FORTRAN arithmetic expression involving any intrinsic SYSTID parameter, constants, variables, FORTRAN library functions, SYSTID library functions, model output nodes and user-supplied FORTRAN functions.

The SYSTID model library consists of a set of computer routines either written in FORTRAN or SYSTID, which have been stored on a library file and cataloged in the SYSTID directory. The user, at any time, can modify or replace the library and directory as he may choose; thus every user can easily create his own library. One unique characteristic of SYSTID is the capability of nesting models to a level of 100; that is, any model (or system) can reference up to 100 models, excluding itself. The nesting feature provides the user with the tools necessary to build a model library to suit his needs based on a canonic set of models.

The basic, or canonic, SYSTID library consists mainly of a group of routines that aid in the simulation of continuous functions, which may thus be presented by functions of the complex variable, s, as G(s). The technique applied is that of the bilinear z-transform difference equation representation of G(s). The transfer function may be defined in several ways in terms of its poles and zeros or as one of the classical filter functions such as Bessel, elliptic, etc. The sample data routines accomplish all the necessary transformations in addition to the numerical processing such as integration and differentiation. In addition, all of the FORTRAN arithmetic features are an intrinsic part of the SYSTID library, although they do not appear in the directory.

The bilinear transform rather than the standard z-transform is used in the representation of continuous functions because it eliminates aliasing errors, making possible the realization of commonly encountered functions whose response does not approach zero at high frequencies. Note that aliasing of the system driving signals, however, is still possible if the user chooses an inappropriately low sampling rate.

Another aspect of the SYSTID model library is that it contains FORTRAN subroutines - that is, when a model (or system) is processed by SYSTID, the result is a FORTRAN subroutine (or main program) which is available to the user for any purpose, whether for SYSTID or not. Thus, SYSTID can be viewed as a FORTRAN program generator that converts a topological, nonprocedural input into a procedural language - FORTRAN. Although not unique to SYSTID, this aspect allows evaluation of mathematical problems via SYSTID with no concern for the input/output coding necessary in FORTRAN programs; that is, SYSTID may be used as a shorthand FORTRAN system.

The functional flow of SYSTID is sketched by Figure 5.2-1.

SYSTID flexibility is in part attained by designing the program to execute as a multipass processor in a batch mode of operation. The first phase reads the user input description of all models and/or a system and proceeds to formulate the corresponding FORTRAN algorithms. In this phase, the program checks for input errors such as erroneous model references, dangling nodes, etc. in which case appropriate error messages are issued. If the first phase terminates without fatal errors, the FORTRAN routines are automatically compiled and collected with the SYSTID library fo form the second phase, that of executing the simulation.

Output from the program includes plots as well as tabulated data. Conventional output is any system node which may be individually selected, or

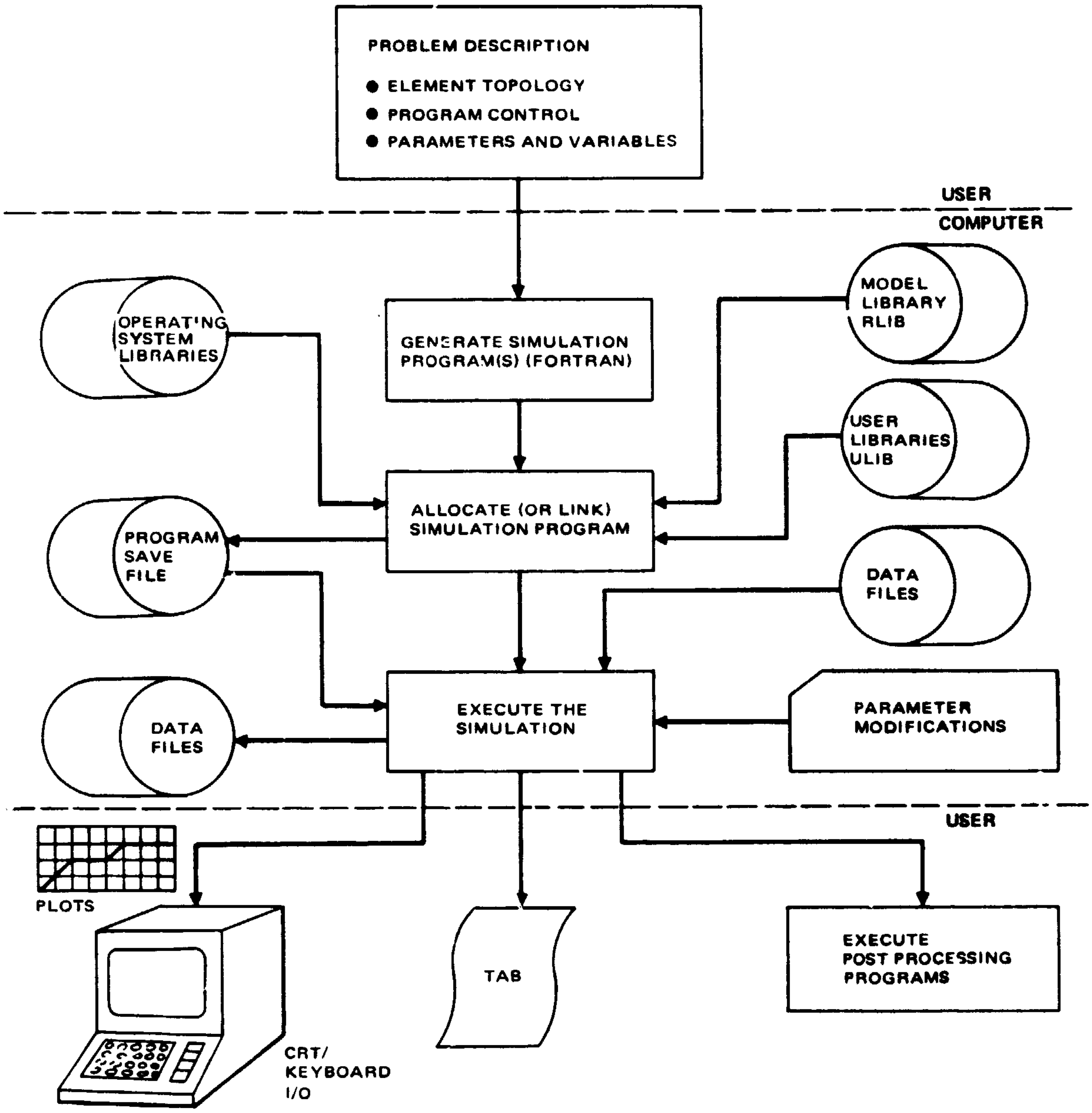


FIGURE 5.2-1. SYSTID TIME-DOMAIN SIMULATION SOFTWARE FUNCTIONAL FLOW

any variable whether intrinsic or user-defined. Plots can be produced on the printer as well as a digital plotter (e.g., CALCOMP, SC 4020). Printed data can be formatted, under user control, for either 8-1/2 by 11 inch pages or the full 11 by 14 inch page. In addition, input/output can be accommodated with a CRT/keyboard terminal, as exemplified by the JSC MOPS (Haxeltine 4000G) terminal. (Digital plotting is installation-dependent.)

The additional flexibility of linking to a user defined post processing routine is intrinsic to SYSTID when utilizing the POST system identifier. This feature allows the user to access the time histories of any node, or variable much the same way as the plot routines. As a matter of fact, the plot routines are indeed intrinsically named postprocessors. Utility routines are available to perform any necessary input/output for the user.

The user, because of the two phase aspect, has available to him several techniques for controlling his computer runs and ensuring that the most effective use is made of the machine time. The primary means is that of saving the results of the first phase (the collected simulation package) for subsequent reruns with alternate input data. Rerun would then simply entail a load-go operation, with input data provided at execution time by use of the DATA identifier in the first phase.

Some theoretical aspects of sampled data simulation which underlie SYSTID are summarized in Appendix 7.6.

5.3 Technical Discussion of SYSTID Models

As the figure below illustrates, the shuttle EPDC can be functionally represented by 1) source generation, 2) source conversion elements, 3) power/load distribution and control elements, 4) user subsystem load elements. The entire shuttle electrical power system (EPS), from the analysis and simulation viewpoint, must include the user load elements, since they influence the electrical power, distribution and control (EPDC) subsystem so extensively. The status of the EPDC topology and the characterization of the EPDC elements is still in flux at this report's submission. Some reference procurement specifications

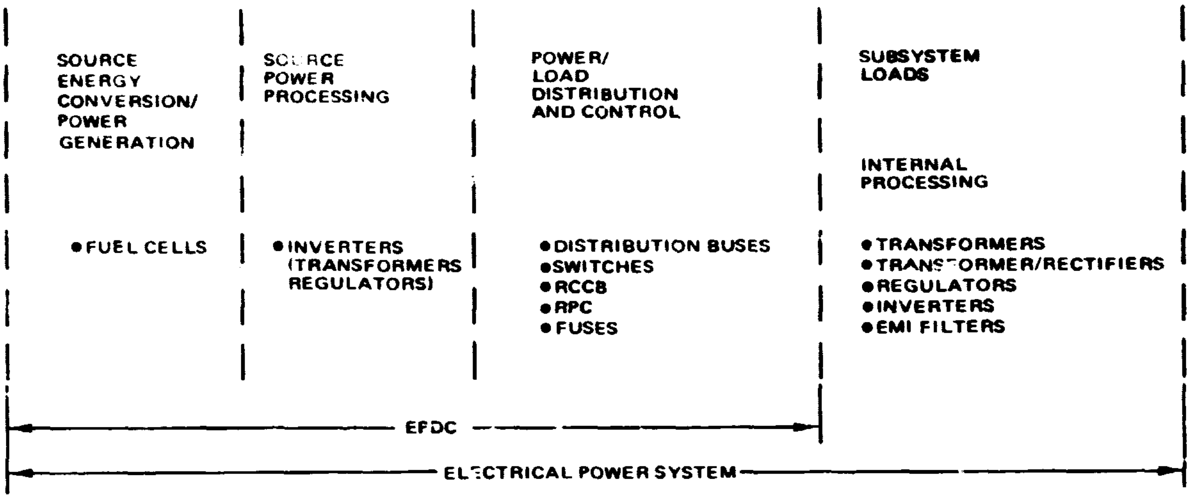


FIGURE 5.3-1. FUNCTIONAL ELEMENTS OF THE SHUTTLE ELECTRICAL POWER SYSTEM

are given in Appendix 7.5 for these EPDC elements, such as the inverter, RPC, RCCB, etc. The level of detail for the user load elements is much poorer, particularly (as the sample data sheets of Appendix 7.4 show) for transient response data, as opposed to steady-state response parameters.

The data to follow will be largely schematic in nature. Much of the detailed analysis is dependent on arbitrarily assumed equipment mechanizations, and lending an unjustified credence to the models should be avoided. Clearly, the modification to these SYSTID models can be made in a straightforward manner, as soon as the equipments are selected and are described in adequate detail for SYSTID modeling.

5.3.1 EPDC Models

Fuel Cell Model Development

The fuel cell is clearly an important, if not the most important EPDC element, in terms of its performance. Unfortunately, little explicit data was available which would indicate the transient response of the device as opposed to its steady-state response. Some data was obtained from an interesting analysis [78], which unfortunately did not cover a sufficiently wide range of output current variation, or peak current, relative to the fuel cells anticipated for shuttle use. The non-linear second order RC lowpass network proposed[1] by McKechnie as an equivalent circuit thus was not amenable to extrapolation over the wider output current changes anticipated for the shuttle EPDC simulation. Table 5.3-1 is reproduced from this reference. (The Apollo hydrogen-oxygen fuel cell system manufactured by Pratt and Whitney[2] was deemed most applicable to shuttle EODC simulation).

TABLE 5.3-1. SUMMARY OF TYPICAL FC DATA, IN TERMS OF PARAMETERS SHOWN IN FIGURE 5.3-3 (AFTER McKECHNIE)

I (Amps)	ΔI (Amps)	E_0 (Volts)	R_1 (Ohms)	R_2 (Ohms)	R_3 (Ohms)	C_1 (Farads)	C_2 (Farads)
				(Ptatt & Whitney, Hydrogen-oxygen)			
0	1.4	37.48	0.1575	0.00951	0.256	15.66	3.41
1.4	1.6	36.71	0.128	0.0143	0.226	18.78	1.79
3.0	1.2	36.03	0.157	0.0129	0.227	13.2	1.45
4.2	1.3	35.44	0.096	0.00389	0.232	8.56	4.43
5.5	1.3	34.99	0.091	0.00314	0.217	10.67	3.83*
6.8	1.2	34.56	0.087	0.00271	0.199	9.25	5.03
				(General Electric)			
0	1.6	6.232	0.038	0.00811	0.423	7.99	1.88
1.6	1.6	5.363	0.0561	0.00186	0.0969	5.38	2.445
3.2	1.6	5.132	0.0542	0.00166	0.0613	5.63	1.96
4.8	1.6	4.957	0.0486	0.00175	0.0414	5.46	3.56
6.4	1.6	4.818	0.0204	0.00111	0.0264	6.0	6.91
				(Hydrazine-oxygen)			
0	1.28	12.62	0.1755	0.179	0.344	0.244	0.957
1.28	1.12	11.8	0.1392	0.106	0.182	0.2208	0.55
2.4	1.12	11.26	0.170	0.133	0.230	0.167	0.433

*The nominal 34.99 volt case was chosen, with C_1, C_2 decreased by a factor of 10, in order to reduce the FC's rise time to convenient values.

---

[1] A set of circuit parameters was defined for each load increment.

[2] The transient responses specified for the SYSTID model are consistent with P and W data (see page 7.4-9).

In particular, the fuel cell supplied only DC loads, with a solid-state inverter (to be discussed next) for conversion to AC, as shown in Figure 5.3-2.

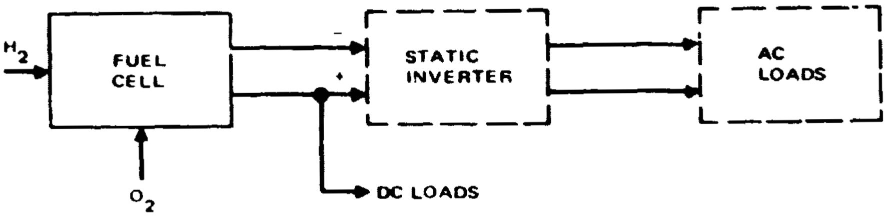


FIGURE 5.3-2. TYPICAL FUEL CELL/INVERTER SYSTEM

The equivalent circuit employed for the fuel cell is given by the simple[1] RC ladder network, as shown in Figure 5.3-3.

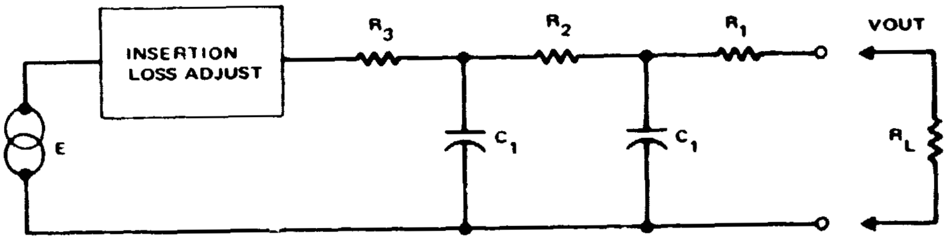


FIGURE 5.3-3. FC EQUIVALENT CIRCUIT

---

[1] Deceptively so, since R_1, R_2, C_1, C_2 are functions of nominal output voltage and load current. In particular, a variable gain compensates for insertion loss, so steady-state response is unaffected by the RC network.

The DC output voltage of this fuel cell versus output power after 5000 hours of performance is given in Figure 5.3-4.

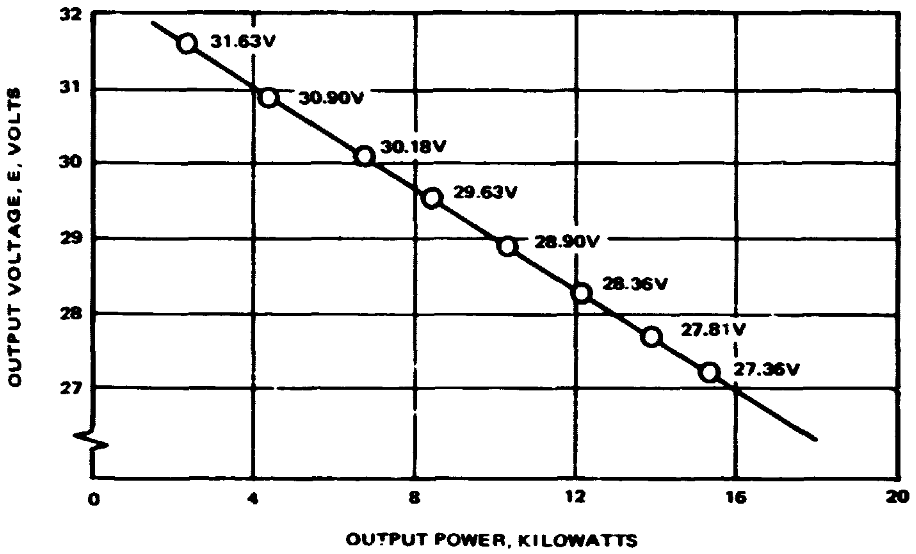
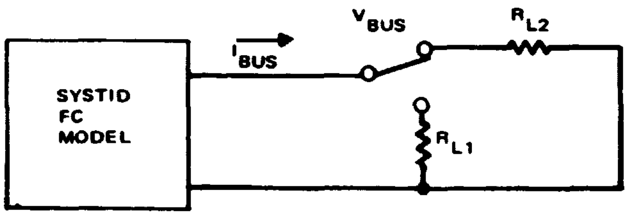


FIGURE 5.3-4. TYPICAL FUEL CELL OUTPUT VOLTAGE-POWER CHARACTERISTIC

In order to establish the reasonableness of the SYSTID model, with respect to its transient response, a step change in FC load was mechanized, as shown in Figure 5.3-5.



WHERE R_{L1} AND RL_2 TOOK ON VALUES OF 1.0 AND 0.001 Ω, RESPECTIVELY

FIGURE 5.3-5. SYSTID STEP RESPONSE TEST CIRCUIT

The resultant fuel cell terminal voltage, BUS, and current delivered to the load, IBUS are displayed in the CALCOMP plots of Figure 5.3-6(a) and (b).

Inverter Model Development

The inverter procurement specification (see Appendix 7.5) was used as a basis for generation of a representative block diagram. Functionally, the inverter can be represented as the cascade of elements shown in Figure 5.3-7.

This simplistic block diagram ignores some potentially important aspects of the inverter's performance, i.e., internal regulation and circuit protection, output transformer mechanization (nonlinear saturating-core operation with final waveform filtering for instance), and sensitivity to composite load power factor. Obtaining these and other detailed characteristics will require internal definition of the device by the vendor.

Monostable Multivibrator (Inverter)

The output of the multivibrator has an idealized waveform given in Figure 5.3-8.

where

$$t_r = t_d = A \ln\left(\frac{3 E_N}{E}\right)$$

and

$$A = \frac{T}{2 \ln 3}$$

E = nominal output voltage

E_N = E - (0.1)(28 - VIN), where VIN is the input DC fuel cell voltage

Waveshaping Filter (Inverter)

A lowpass filter is used to attenuate the odd harmonics present in this waveform, and produce an acceptable approximation to a sinusoidal waveform. In particular, a second order Chebyshev function with peak-to-peak ripple of 0.1 dB, and a ripple bandwidth 1.25 times the nominal multivibrator center frequency (clock rate) of 400 Hz.

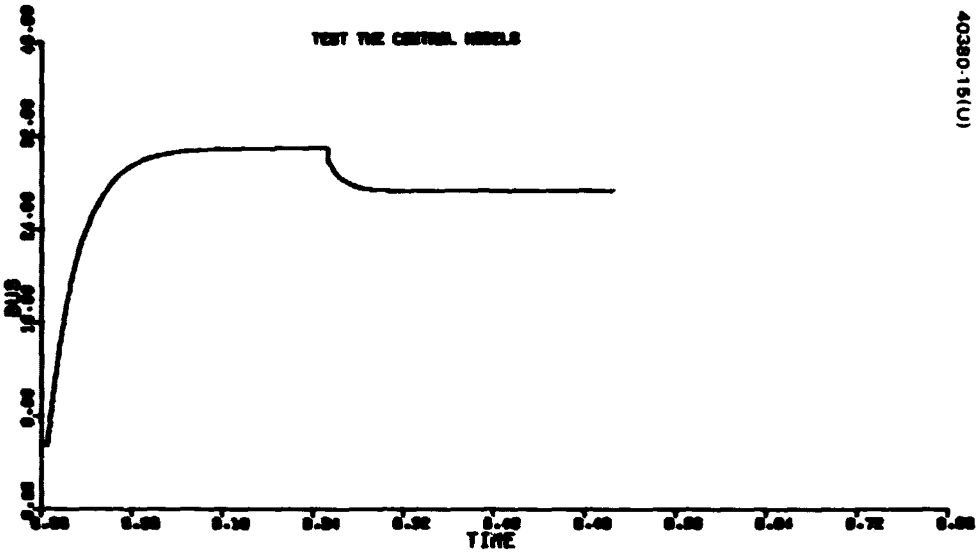


FIGURE 5.3-6a. FUEL CELL TERMINAL (LOAD OR OUTPUT) VOLTAGE VERSUS TIME WITH A STEP CHANGE IN LOAD CURRENT (RESISTANCE)

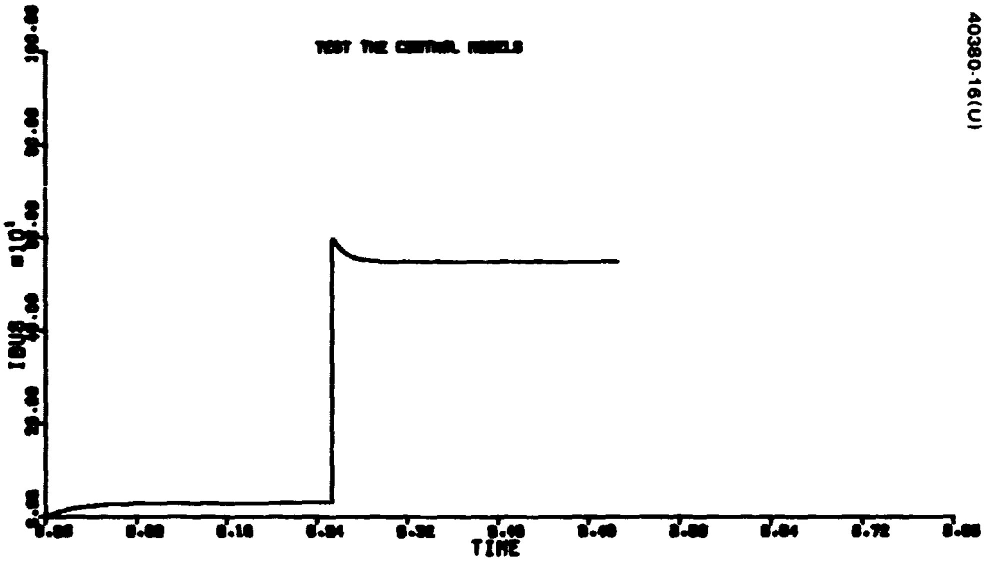


FIGURE 5.3-6b. FUEL CELL OUTPUT CURRENT, IBUS, DELIVERED TO LOAD FOR A STEP CHANGE IN LOAD RESISTANCE

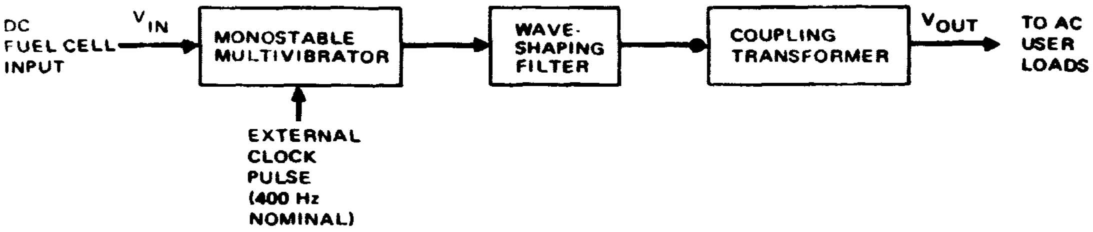


FIGURE 5.3-7. SYSTID INVERTER MODEL BLOCK DIAGRAM

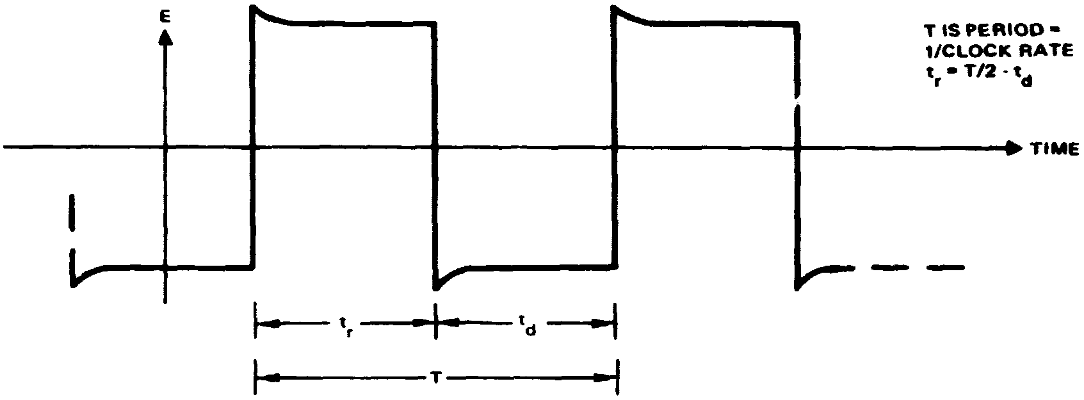
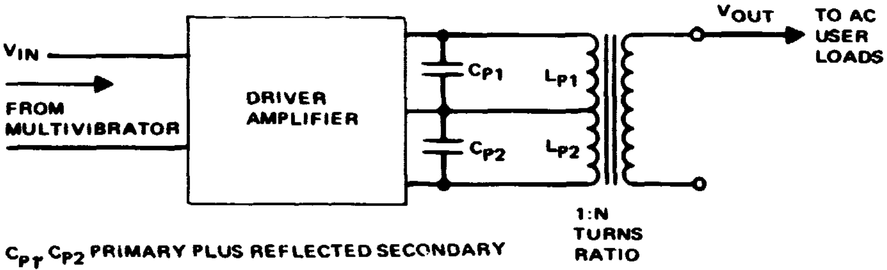


FIGURE 5.3-8. TYPICAL OUTPUT WAVEFORM OF THE SYSTID MULTIVIBRATOR SUBMODEL

Coupling Transformer (Inverter)

The coupling transformer can be represented by an ideal element, with unity coupling and linear operation over the range. (In order to preserve some inherent degree of self-regulation and minimize core weight, this transformer may actually be realized as a saturating core device.)

Given the linear model, a typical realization is shown in Figure 5.3-9.



C_{PT}, C_{P2} PRIMARY PLUS REFLECTED SECONDARY INTRA-WINDING CAPACITANCE

L_{P1}, L_{P2} PRIMARY WINDING INDUCTANCES

V_{IN} IS FILTERED AC INPUT, FROM MULTIVIBRATOR

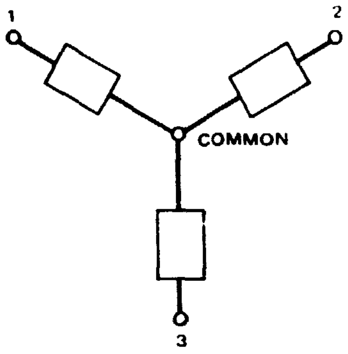
V_{OUT} IS AC VOLTAGE DELIVERED TO LOAD

FIGURE 5.3-9. TYPICAL DRIVER AMPLIFIER/COUPLING TRANSFORMER SCHEMATIC

For assumed values of active device and transformer parameters, a voltage transfer function can be written in terms of G(s) as

$$\frac{V_{out}}{V_{in}} = \frac{(1.414 \text{ CPF}) \ 1.07835}{1.5 \times 10^{-5} S^2 + .263 S + 571.0}$$

NOTE: For three-phase operation, the inverters are configured to effectively couple their outputs in a wye-connection, as sketched below:



In the simulation, the multivibrator outputs are sequenced in phase angle 0°, 120°, 240°, to achieve three-phase operation.

As in the case of the fuel cell, the SYSTID inverter model was tested for step response, as shown in Figure 5.3-10.

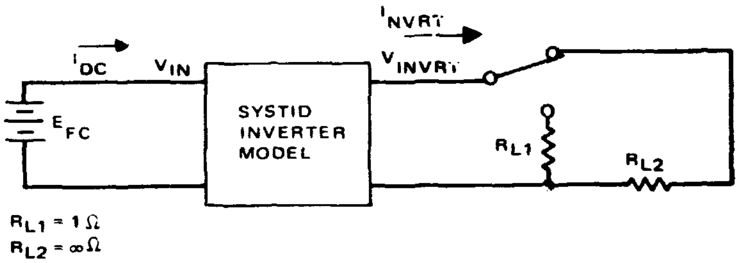


FIGURE 5.3-10. SYSTID INVERTER TEST STEP RESPONSE DIAGRAM

The resultant transient responses are given in Figures 5.3-11(a) and 5.3-11(b).

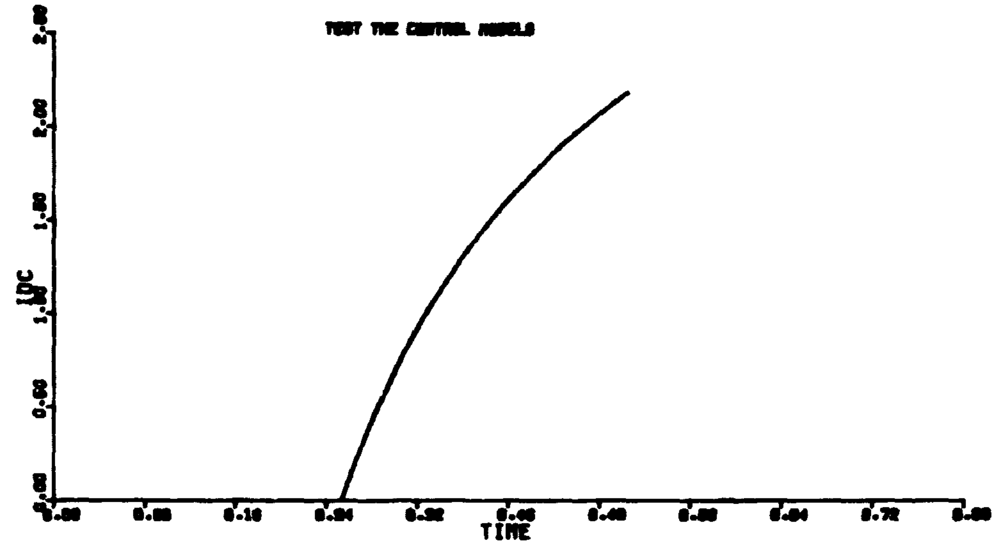


FIGURE 5.3-11a. INPUT DC CURRENT (REPRESENTING FUEL CELL) TO INVERTER VERSUS TIME, FOR A STEP CHANGE IN INVERTER LOAD IMPEDANCE

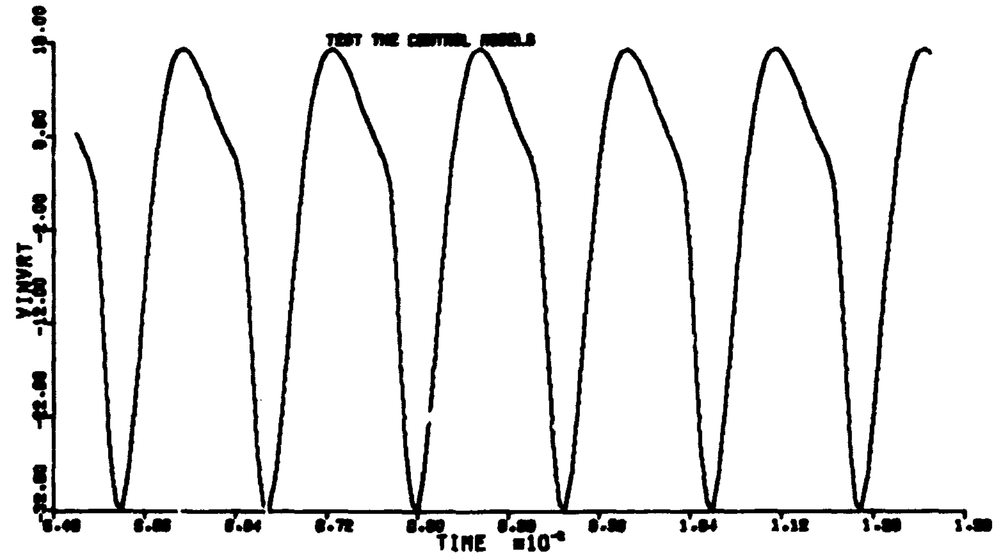
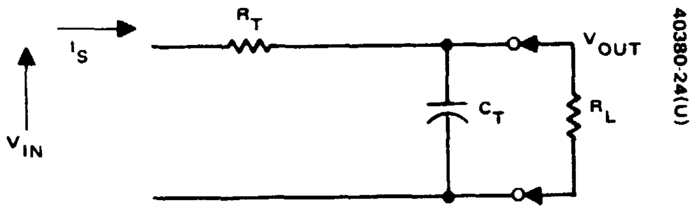


FIGURE 5.3-11b. INVERTER AC OUTPUT VOLTAGE VERSUS TIME, FOR A STEP CHANGE IN INVERTER LOAD IMPEDANCE

Distribution Bus (Cable) Model Development

A physically realizable power transmission cable is best represented by a distributed parameter equivalence. For purposes of convenience, we shall allow a simplified lumped-parameter equivalent circuit, namely a first order RC ladder network



R_T = total cable loss, ohms

C_T = total cable capacitance, farads

R_L = the load resistance, ohms

and where

$R_T = (R)\ (XL)$	XL, length of cable, feet
$C_T = (C)\ (XL)$	R, ohms/feet
	C, farads/feet

The overall transfer function can be shown to be

$$\frac{V_{out}}{V_{in}} = G(S) = \frac{R_L}{(RR_LC)S + (R + R_L)}$$

Diode Model Development

Two different representations are used for the diode model, one ideal, the other more closely representative of an actual device.

Ideal Diode:

> This is essentially a battery, whose voltage is identical to the diode junction potential, in series with a logical switch, to indicate conduction state.

__Real Diode__:

This representation employs the fundamental diode junction equation

$$I = I_{sat}\left[e^{TH\Delta V} - 1\right]$$

where

I_{sat} = junction reverse (saturation) current, amperes

TH = constant = q/KT

ΔV = junction potential, volts

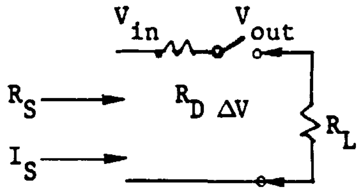
From which we may define

$$\frac{1}{R_D} = \frac{dI}{dV} = 39\ I_{sat} e^{TH\Delta V}$$

where

R_D = junction impedance.

An equivalent circuit may thus be drawn:



$$\frac{V_{out}}{V_{in}} = \frac{R_L}{R_D + R_L} = \frac{R_L\ 39\ I_S\ e^{39\Delta V}}{\left(R_L\ 39\right) I_S\ e^{39\Delta V} + 1}$$

and R_S, the impedance presented to the source, which delivers I_S amperes is given by

$$R_S = R_L + R_D$$

$$I_S = V_{in}/R_S$$

Remote Control Circuit Breaker (RCCB) Model Development

The RCCB passes load current based on its rating which ranges from 15 to 100 amperes for the various dash numbers utilized in the EPDC, with a voltage drop ≤ 0.25 volt. At some overload condition, given as a percentage of rated current, the RCCB must trip and relieve the load (200 percent of rated current is minimum trip limit with the trip time being a decreasing function of overload current). It is also capable of being remotely energized, i.e., set[1] or opened. The control voltage, applied through a 1.3K ohm source resistance, from a bus other than the main buses, over a range of 24.0 to 40.0 volts shall set the RCCB. Removal of this voltage automatically opens the load circuit. A 28 vdc backup bus circuit can also energize the RCCB, and its load.

The functional flow of the RCCB is given in Figure 5.3-12.

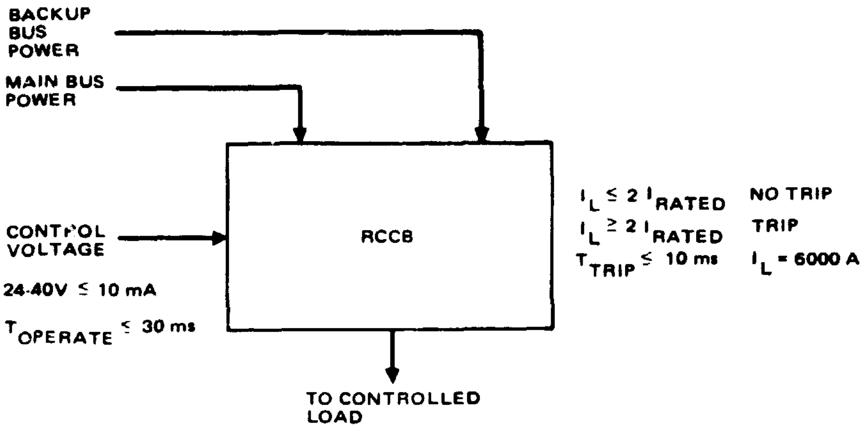


FIGURE 5.3-12. RCCB FUNCTIONAL FLOW DIAGRAM

---

[1] The RCCB cannot be closed while an overload condition exists (magnetically latched).

Operational Sequences: If both main and backup power bus voltages are removed, RCCB is not to change state.

If control voltage is removed, RCCB must open.

If overload occurs, main contacts will trip open. In order to close load circuit again, control voltage must turn RCCB OFF, then ON.

The RCCB was modeled in SYSTID by assuming a dual representation, one a logical control sequence, the other an RLC network simulating a typical relay mechanization. Pictorially,

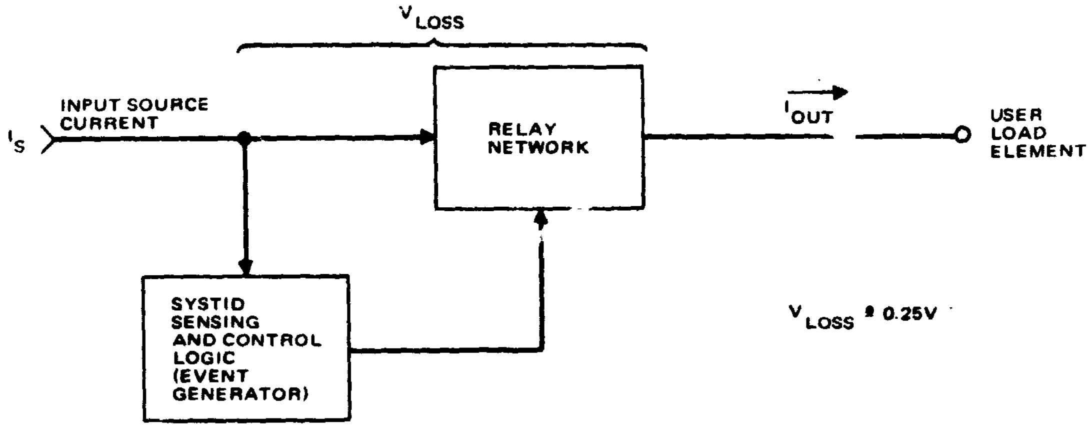


FIGURE 5.3-13. RCCB SYSTID MODEL FUNCTIONAL FLOW DIAGRAM

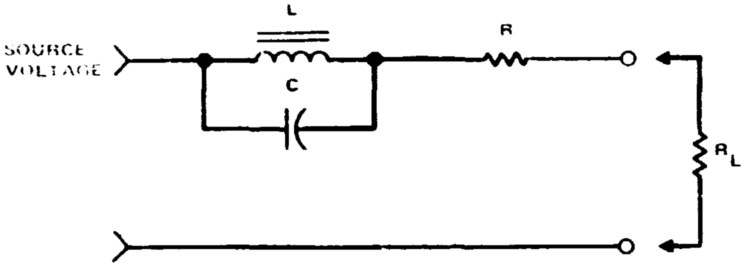
The RCCB transfer function representing load current flow thus becomes that of the relay network. A second order response given by the following G(s)

$$G(s) = \frac{\left(19.46/T_o^2\right)}{S^2 + (6.25/T_o)S + \left(19.46/T_o^2\right)}$$

where

T_o = 10 ms, ~the rise time

which represents an RLC network similar to



where R is the relay coil resistance; C its intrawinding (or discrete) capacitance, L the relay coil inductance.

Note that the circuit analyzed for transient response here is the load circuit. Presumably, a similar circuit exists for the control circuits (current simulation technique assumes no RCCB time constants directly in control path).

The transient response of the RCCB is tested in a SYSTID configuration similar to that shown for the inverter in Figure 5.3-10, i.e., driven by an ideal voltage source, allowing the measurement of RCCB input current, as shown in Figure 5.3-14.

Remote Power Controller (RPC) Model Development

The RPC is a power control device which can be controlled remotely, in similar fashion to the RCCB. The RPC differs from the RCCB mainly in its ability to limit the current delivered to the load, as well as provide trip-off overload protection. The RPC can be turned on with control voltages less than 14 volts, but more than 9 volts DC. For voltages between 6.5 volts and 9.0 vdc, the RPC will be shut off. No trip indication is currently anticipated for the RPC, although for analysis purposes, the SYSTID RPC model incorporates trip indication. The overlaod/trip characteristics of the RPC are given in Figure 5.3-15.

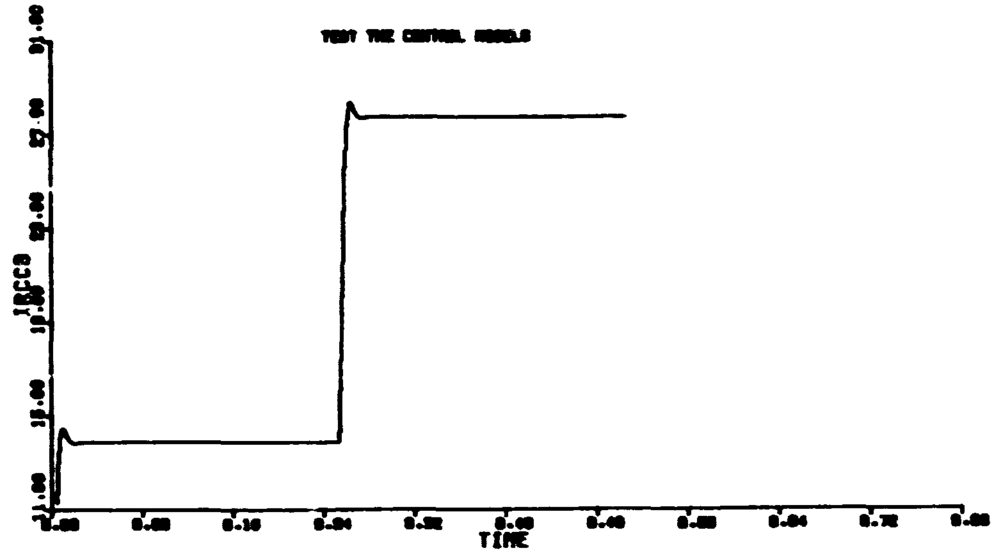


FIGURE 5.3-14. CURRENT DELIVERED TO THE LOAD BY THE RCCB VERSUS TIME, AS A FUNCTION OF A STEP CHANGE IN LOAD RESISTANCE

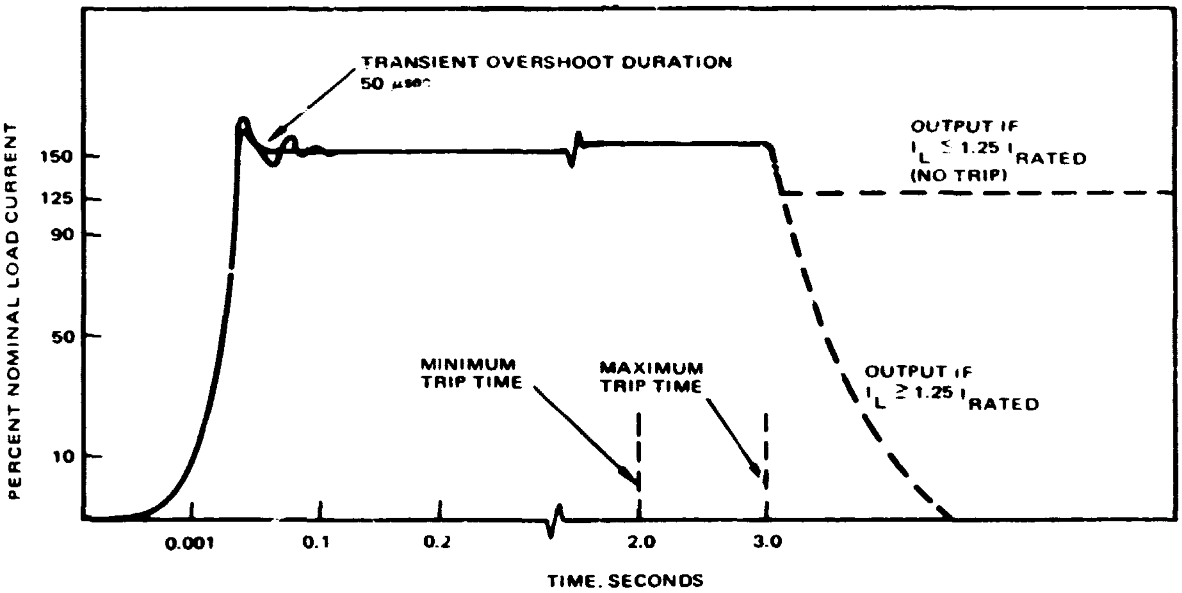


FIGURE 5.3-15. RPC CURRENT LIMITING CHARACTERISTIC

In addition, a fail-safe capability shall exist, i.e., a fusible link. The maximum load range of these devices is 20 amperes. The control voltages are generally supplied from the shuttle essential buses, and may be reset, subsequent to tripping, within 20 ms. Initial turn-on time is ≤2.5 ms, with turn-off times ≤4 ms. The rise times are generally ≤2 ms, the fall times ≤4 ms.

The RPC functional flow is given by Figure 5.3-16.

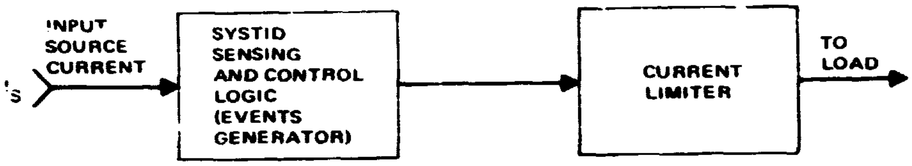


FIGURE 5.3-16. RPC FUNCTIONAL FLOW DIAGRAM

The functional flow in Figure 5.3-16 is similar to that of the RCCB, except that the relay element is replaced with the current limiter model. In similar fashion to that illustrated by Figure 5.3-10, the step response of the RPC is given by Figures 5.3-17(a) and 5.3-17(b).

5.3.2 LOAD MANAGEMENT AND SEQUENCING

In order to effectively interface with the enormous volume of data involved in the shuttle EPS, a model was developed for accessing a standardized load-defining data base. This model and its usage are implemented such that consistency is maintained between the SYSTID simulation and the SEPAP/RI available data format.

In conjunction with the LOADS model, a sequencer and associated software were developed such that a given sequence of events (or equipment time profiles) could be effectively used to control the SYSTID simulation.

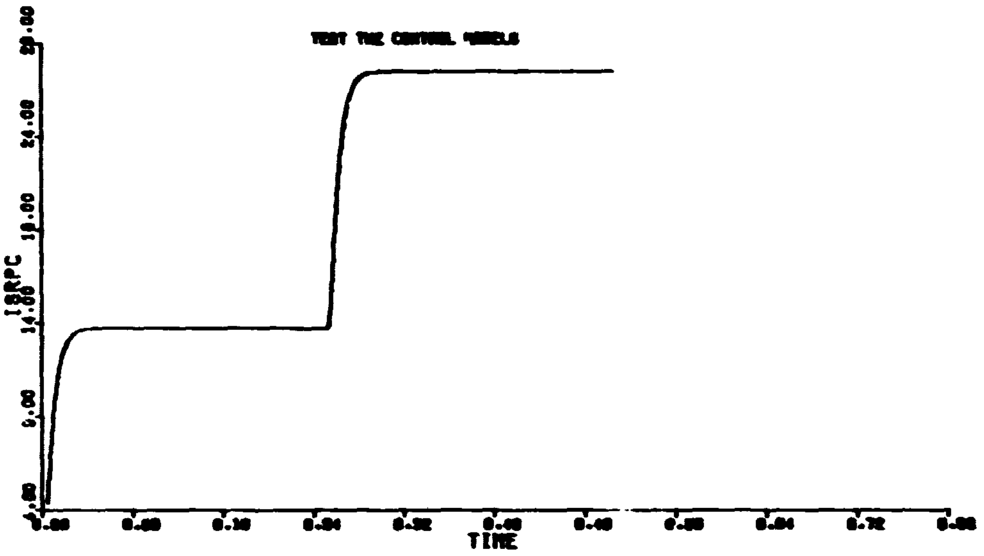


FIGURE 5.3-17a. SOURCE CURRENT DRAWN BY RPC VERSUS TIME, AS A FUNCTION OF A STEP CHANGE IN RPC LOAD IMPEDANCE (CURRENT)

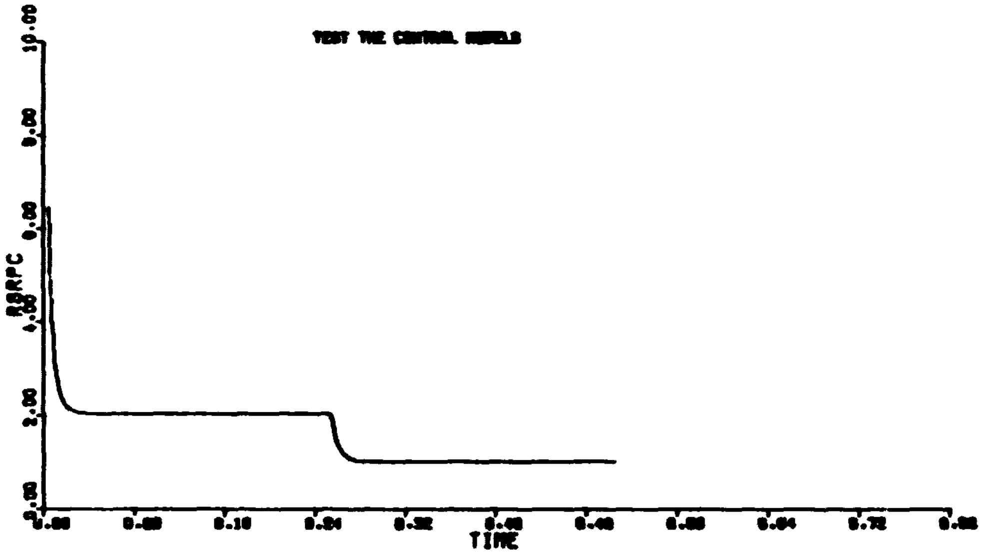


FIGURE 5.3-17b. RPC IMPEDANCE VIEWED BY SOURCE VERSUS TIME, AS A FUNCTION OF A STEP CHANGE IN LOAD IMPEDANCE (CURRENT)

The LOADS model uses input data which define a given SEPAP load number as follows:

- Equipment ID (6 digit RI code)
- Type of circuit protection device connection (RPC, RCCB, or FUSE)
- Type of load (resistive, inductive, etc.)

In conjunction with the above data, the model accesses the sequencer (LOADON) for definition of the equipment mode. Equipment modes have been defined as:

0 = ON
1 = standby
2 = short circuit failure
3 = open circuit failure
4-6 = open for definition
7 = OFF

Operation of the LOADS model requires UNIVAC data elements in TPF\$[1] named "LOADNNN" where NNN = 3 digit load number. If a data element is not available, the particular load is defaulted to an open circuit. The format of the data element can be seen in Appendix 7.1, which describes the procedure for building the load data base.

The sequencer routine LOADON is the interface to the Event Data File subroutine SHUTLE. Use of LOADON is as follows:

```
CALL LOADON (ID, MODE)
```

where

ID = 6 digit equipment number or 3 digit SEPAP switch number
MODE = mode of the device at this time

---

[1] UNIVAC EXEC 8 Temporary Program File.

Creation of the Event Data file is accomplished with the SORT routine, which reads data cards defining the time sequence for all equipment and system configuration and writes a compact data file organized for rapid access using minimal computer core.

Figure 5.3-18 describes the procedure necessary for preparation of the Load Data Base.

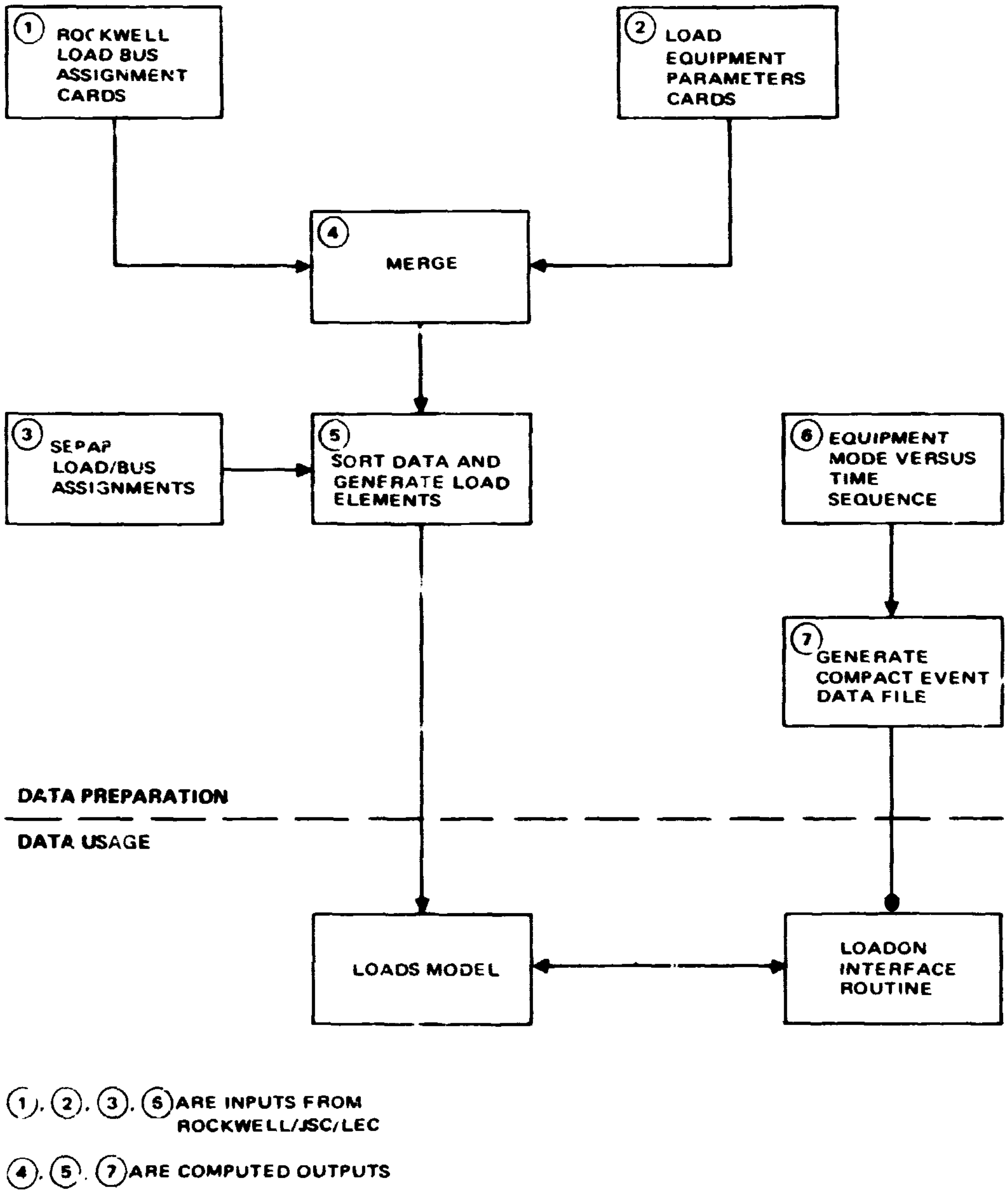


FIGURE 5.3-18. SYSTID EPDC LOAD DATA PREPARATION PROCEDURE AND SEQUENCE

6.0 REFERENCES AND BIBLIOGRAPHY

1. C. R. Murdock, "Shuttle Electrical Equipment Bus Assignment," 30 August 1974.
2. EPDC time Line, "Power Control Mission," Rockwell Listing.
3. K. E. Daly, "EPDC Status," February 22, 1974, LEC 2209-016.
4. RCA Power Dissipation Tables, October 3, 1974, Rockwell.
5. Procurement Specification, MC495-0012, "Inverter, Power Static, 115 volt, Single Phase, 400 Hz".
6. Procurement Specification, "Controller, Master Events".
7. Galen R. Frysinger and Robert M. McKechnie, "Chemical and Electrical Engineering of Fuel Cell Systems," AIAA Paper No. 64-743, Third Biennial Aerospace Power Systems Conference, Philadelphia, Pennsylvania, September 1-4, 1964.
8. Robert M. McKechnie, "Fuel Cell Electrical Response Analysis," IEEE Region 3 Annual Meeting and Technical Conference, Clearwater, Florida, May 4-5-6, 1964.
9. Robert M. McKechnie, "The Determination of an Electrical Equivalent Circuit for a Fuel Cell," Technical Report to be published in 1965 by U.S. Army Engineer Research and Development Laboratories, Fort Belvoir, Virginia.
10. Mike J. Coyle, "Designer's Guide to Circuit Protectors," MGG, EDN November 5, 1973.
11. Alvin H. Knoble, Electrical Power Systems Engineering, McGraw Hill, 1967.
12. Williams, Intro to Fuel Cells, Elservice Rule Comp.
13. Demitri Gidaspow and Sardajit Sareen, "Purge Dynamics of Fuel Cells," Institute of Gas Technology, Chicago.
14. Gourash, Pittsman, Heins, "Modularization of High-Power Inverters and Converters," Inter Soc. Energy Conv. Eng. Conf., 1969.
15. W. B. Collins and D. R. Newell, "Power Conditioning Requirements and Tradeoff Considerations for the Space Shuttle, Power Conditioning Specialists Conference, '71 Record, pp. 6-12, April 19-20, 1971.
16. R. M. Golden and J. F. Kaiser, "Design of Wideband Sampled Data Filters," B.S.T.J., pp. 1533- 1545, Vol. 43, Part 2, July 1964.

17. J. F. Kaiser, "Design Methods for Sampled-Data Filters," *Proc. First Allerton Conference on Circuit and System Theory*, pp. 221-236, Monticello, Illinois, November 1963.

18. R. M. Golden, "Digital Computer Simulation of a Sampled-Data Voice-Excited Vocoder," *J. Acoust. Soc. Am.*, *35*, pp. 1358-1366, September 1963.

19. C. H. Wilts, *Principles of Feedback Control*, pp. 197-207, Addison-Wesley, 1960.

20. R. W. Hamming, *Numerical Methods for Scientists and Engineers*, pp. 227-280, McGraw-Hill, New York, 1962.

21. J. L. Kelly, Jr., G. Lochbaum, and V. A. Vyssotasky, "A Block Diagram Compiler," *BSTJ*, *40*, pp. 669-676, May 1961.

22. J. E. Storer, *Passive Network Synthesis*, pp. 293-296, McGraw-Hill, New York, 1957.

23. F. F. Kuo and J. F. Kaiser, *System Analysis by Digital Computer*, J. Wiley and Sons, Inc., New York, 1966.

24. D. C. Baxter, *Digital Simulation Using Approximate Methods*, National Research Council, Ottawa, Canada, Report MK-15, Division of Mechanical Engineering, July 1965.

25. J. E. Gibson, *Nonlinear Automatic Control*, pp. 147-159, McGraw-Hill, New York, 1963.

26. K. Steiglitz, *The General Theory of Digital Filt[illegible] with Applications to Spectral Analysis*, AFOSR Report No. 64-1664, [illegible] York University, New York, May 1963.

27. K. Steglitz, "The Equivalence of a Digital and Analog Signal Processing," *Information and Control*, Vol. 8, No. 5, pp. 435-467, October 1965.

28. J. F. Kaiser, "Some Practical Considerations in the Realization of Linear Digital Filters," *Proceedings Third Allerton Conference on Circuit and System Theory*, pp. 621-633, Monticello, Illinois, October 1965.

29. G. E. Heyliger, *The Scanning Function Approach to the Design of Numerical Filters*, Report R-63-2, Martin Co., Denver, Colorado, April 1963.

30. R. J. Graham, *Determination and Analysis of Numerical Smoothing Weights*, NASA Technical Report No. TR-R-179, December 1973.

31. E. B. Anders et al, *Digital Filters*, NASA Contractor Report CR-136, December 1964.

32. D. G. Watts, Optimal Windows for Power Spectra Estimation, Mathematics Research Center, University of Wisconsin, MRC-TSR-506, September 1964.

33. E. Parzen, Notes on Fourier Analysis and Spectral Windows, Applied Mathematics and Statistical Laboratories, Technical Report No. 48, Stanford University, California, 15 May 1963.

34. G. A. Campbell and R. M. Foster, Fourier Integrals for Practical Applications, p 113, 872.1, D. Van Nostrand, 1948.

35. J. F. Kaiser, "A Family of Window Functions Having Nearly Ideal Properties," unpublished memorandum, November 1964.

36. D. Slepian and H. O. Pollak, "Prolate Spheroidal Wave Functions, Fourier Analysis and Uncertainty - I and II, BSTJ, Vol. 40, No. 1, pp. 43-84, January 1961.

37. P. E. Fleischer, "Digital Realization of Complex Transfer Functions," Simulation, Vol. 6, No. 3, pp. 171-180, March 1966.

38. M. A. Martin, Digital Filters for Data Processing, General Electric Co., Missile and Space Division, Tech. Info. Series Report No. 62-SD484, 1962.

39. S. A. Schelkunoff, "A Mathematical Theory of Linear Arrays," BSTJ, Vol. 22, pp. 80-107, January 1943. Mark Tsu-Han Ma, A New Mathematical Approach for Linear Array Analysis and Synthesis, PhD thesis, Syracuse University, 1961, University Microfilms No. 62-3050.

40. G. M. Jenkins, "A Survey of Spectral Analysis," Applied Statistics, Vol. XIV, No. 1, pp. 2-32, 1965.

41. H. H. Robertson, "Approximate Design of Digital Filters," Technometrics, Vol. 7, No. 3, pp. 387-403, August 1965.

42. W. K. Linvill, "Sampled-Data Control Systems Studied Through Comparison of Sampling with Amplitude Modulation," Trans. AIEE, Vol. 70, Part II, pp. 1779-1788, 1951.

43. A. Susskind, Notes on Analog-Digital Conversion Techniques, John Wiley, New York, 1957. See especially Chapter II, "Sampling and Quantization" by D. Ross.

44. D. T. Ross, Improved Computational Techniques for Fourier Transformation, Servomechanisms Laboratory Report, No. 7138-R-5, Massachusetts Institute of Technology Cambridge, Massachusetts, June 25, 1954.

45. C. Jordan, Calculus of Finite Differences, Chelsea, 1960, (Reprint of 1939 edition).

46. H. M. James, N. B. Nichols, and R. S. Phillips, Theory of Servomechanisms, McGraw-Hill, New York, pp. 231-261, 1947.

47. J. R. Ragazzini and G. F. Franklin, Sampled-Data Control Systems, McGraw-Hill, 1958.

48. E. I. Jury, Sampled-Data Control Systems, John Wiley and Sons, Inc., 1958

49. J. T. Tou, Digital and Sampled-Data Control Systems, McGraw-Hill, 1959.

50. E. Mishkin and L. Braun, Jr., Adaptive Control Systems, McGraw-Hill, New York, pp. 119-183, 1961.

51. E. I. Jury, Theory and Application of the z-Transform Method, John Wiley, New York, 1964.

52. H. Freeman, Discrete-Time Systems, John Wiley, 1965.

53. P. M. DeRusso, R. J. Roy, and C. M. Close, State Variables for Engineers, John Wiley, pp. 158-186, 1965.

54. R. B. Blackman, Linear Data-Smoothing and Prediction in Theory and Practice, Addison-Wesley, Reading, Massachusetts, 1965.

55. C. Lanczos, Applied Analysis, Prentice Hall, Inc., Englewood Cliffs, New Jersey, 1956.

56. R. B. Blackman and J. W. Tukey, The Measurement of Power Spectra from the Point of View of Communication Engineering, Dover, 1959.

57. M. A. Martin, "Frequency Domain Applications to Data Processing," IRE Transactions on Space Electronics and Telemetry, Vol. SET-5, No. 1, pp. 33-41, March 1959.

58. J. F. A. Ormsby, "Design of Numerical Filters with Applications to Missile Data Processing," Jour. ACM, Vol. 8, No. 3, pp. 440-466, July 1961.

59. A. J. Monroe, Digital Processes for Sampled Data Systems, John Wiley and Sons, Inc., New York, 1962.

60. R. M. Golden, "Digital Computer Simulation of Communication Systems Using the Block Diagram Compiler; BLODIB, "Third Annual Allerton Conference on Circuit and System Theory, pp. 690-70, Monticello, Illinois, October 1965.

61. A. Tustin, "A Method of Analyzing the Behavior of Linear Systems In Terms of Time Series," Jour. IEEE, Vol. 94, Part II A, pp. 130-142, May 1947.

62. J. M. Salzer, "Frequency Analysis of Digital Computers Operating In Real Time," Proc. IRE, Vol. 42, pp. 457-466, February 1954.

63. R. Boxer, S. Thaler, "A Simplified Method of Solving Linear and Non-Linear Systems," Proc. IRE, Vol. 44, pp. 89-101, January 1956.

64. R. Boxer, "A Note on Numerical Transform Calculus," Proc. IRE, Vol. 45, No. 10, pp. 1401-1406, October 1957.

65. D. C. Baxter, The Digital Simulation of Transfer Functions, National Research Laboratories, Ottawa, Canada, DME Report No. MK-13, April 1964.

66. H. L. Garabedian (Ed.), Approximation of Functions, Elsevier Publishing Co., 1965, see especially Walsh pp. 1-16 and Cheney pp. 101-110.

67. E. W. Cheney and H. L. Loeb, "Generalized Rational Approximation," J. SIAM, Numerical Analysis, B, Vol. 1, pp. 11-25, 1964.

68. J. W. Cooley and J. W. Tukey, "An Algorithm for the Machine Calculation of Complex Fourier Series," Mathematics of Computation, Vol. 19, No. 90, pp. 297-301, April 1965.

69. R. A. Gaskill, "A Versatile Problem-Oriented Language for Engineers," IEEE Transactions on Electronic Computers, Vol. EC-13, No. 4, pp. 415-421, August 1964.

70. R. D. Brennan and R. N. Linebarger, "A Survey of Digital Simulation: Digital Analog Simulator Programs," Simulation Vol. 3, No. 6, pp. 22-36, December 1964.

71. J. J. Clancy and M. S. Dineberg, "Digital Simulation Languages; A Critique and a Guide," AFIPS Conference Proceedings, Vol. 27, Part I, pp. 23-36, Spartan Books, Washington, D.C., 1965.

72. C. M. Rader and B. Gold, "Digital Filter Design Techniques in the Frequency Domain," Proc. IEEE, February 1967.

73. "Computation of Frequency Response for Standard Filters (Filter Subroutines)", Hughes IDC 2292/379, September 18, 1967, N. S. Wagner to R. J. Rechter.

74. "Computer Programs (SCAFLR, QUAFAC, and NOSBAN) for Scaling Filter Transfer Functions and Analyzing Filters for Analog Computer Simulations of Surveyor Telecommunications Links," Hughes IDC 2292/299, June 1967, W. W. Mayfield to R. J. Rechter.

75. "Advanced Communications System Time Domain Modeling Concepts," Vol I, Program User's Guide, August 1972, SAI No. R72-001, NAS9-11743, JSC.

76. "Advanced Communications System Time Domain Modeling Concepts," Vol. II, Program Support Documentation.

77. W. W. Mayfield to R. J. Rechter, "Computer Subroutines for Time Domain System Simulation Using Sampled Data Filters," Hughes IDC 2292/611, July 1, 1968.

78. R. M. McKechnie, "Fuel Cell-Inverter/Converter System Synthesis," Space Electronics Symposium, Vol. 8, 1965, pp. I-35, 45.

79. M. Fashano, "Simulation of Satellite Communications Channels," NATO Advanced Institute on Communications and controls, London, England, August 1974.

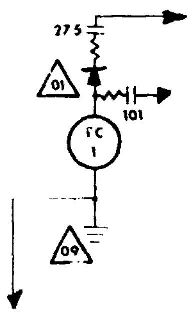
APPENDIX 7.1

EPDC TOPOLOGY AND LOAD BUS ASSIGNMENT DATA AS PROCESSED FOR SYSTID SIMULATION

APPENDIX 7.1 - EPDC TOPOLOGY AND LOAD BUS ASSIGNMENT AS PROCESSED FOR SYSTID SIMULATION

The data in this appendix subsection provides the following information: 1) an EPDC topology chosen for SYSTID simulation and performance analysis, namely the LEC schematic reproduced as Figure 7.1-1, 2) a listing of bus assignments derived from this schematic.

The load switches shown in Figure 7.1-1, as displayed in the small portion of the overal topology below, are <u>logical</u> in nature, i.e., for purposes of energizing a given load group in the LEC SEPAP time profile analysis.



Switches 275 and 101 in this topology sector are examples of logical elements found throughout the schematic of 7.1-1...in some instances they also correspond to actual devices.

The actual circuit protection devices, i.e., RPC, RCCB, or fuses are included within each load <u>group</u>...for instance, load group 171 includes load elements given by Table 7.1-1, each load element having its own circuit protection device. The listing of Table 7.1-2 displays the topology in tabular form as generated for SYSTID, from the connectivity data of Figure 7.1-1. The bus assignments shown are in terms of load <u>groups</u>, not yet in load <u>element</u> form.

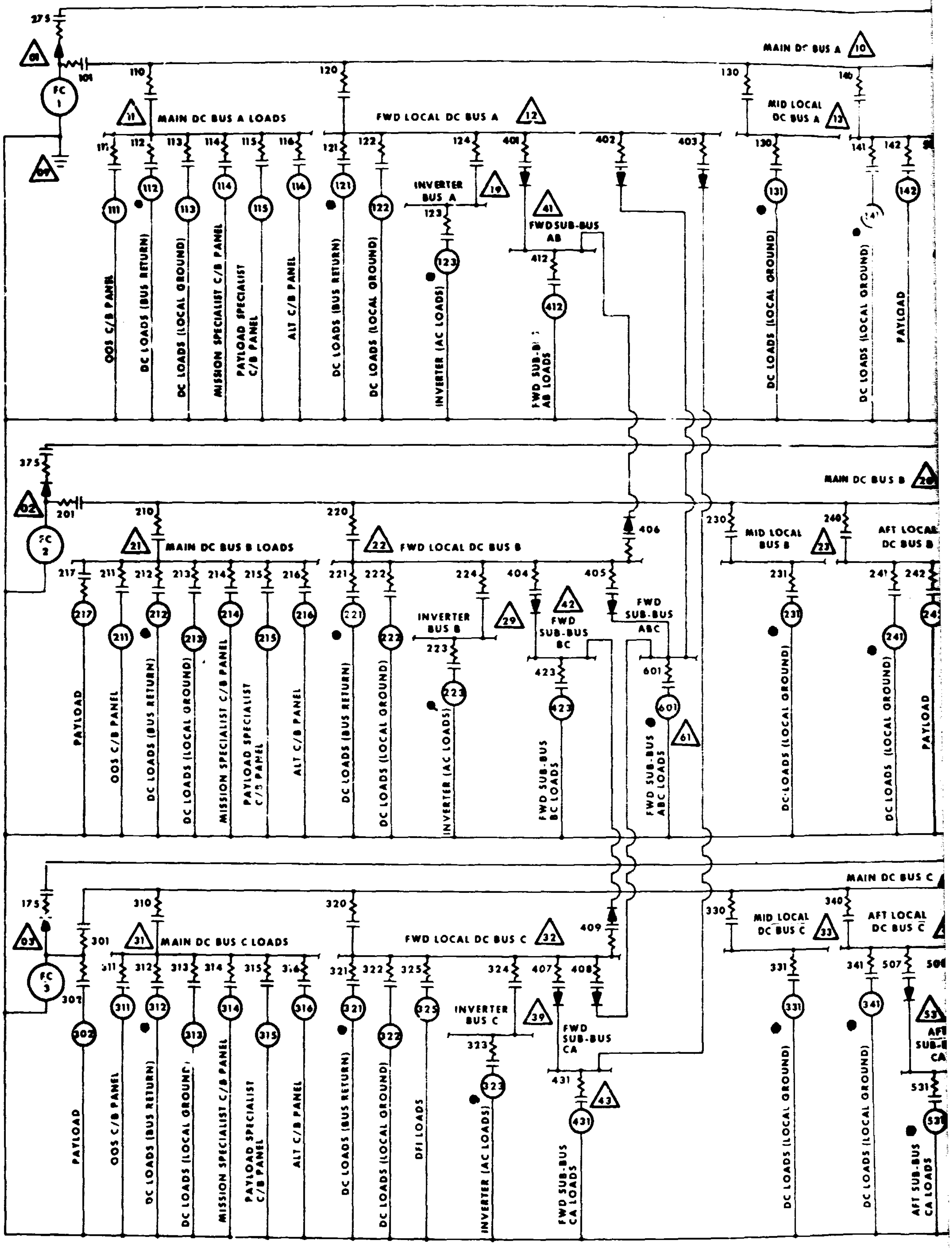
TABLE 7.1-1. EXAMPLE LISTING OF LOAD GROUP 171 ELEMENTS (ESSENTIAL SUB-BUS 3 AB/DIE)

ELEMENT ID NO.	ELEMENT NAME	LOAD SUBSYSTEM NAME	WATTS DISSIPATED
04090000	MASTER TIMING UNIT (WARM-UP)	ENVIRONMENTAL CONTROL AND LIFE SUPPORT	40
04090010	(OPERATE)		26
06040200	LOAD CONTROL ASSEMBLY UNIT #2	ELECTRICAL POWER DISTRIBUTION AND CONTROL	75
06040300	LOAD CONTROL ASSEMBLY UNIT #3		

Table 7.1-3 tabulates the load groups actually coded in SYSTID, in sequential order as read from left-to-right on Figure 7.1-1, first main bus A, then B, and finally C. Not all of the loads were coded, due to the ominous number of inconsistencies in the base data...a sufficient number were coded, to give a meaningful representation of the EPDC/user system. Straight-forward extension of the coding, given a validated data base, will rectify this situation. Due to discrepencies and omissions in the SEPAP bus assignment data (Appendix 7.2) as furnished to Hughes by LEC/JSC, some arbitrary assignments were made in the construction of these load groups.

As an example of how the Appendix 7.2 data has been utilized in generating these SYSTID load group assignments, we may take load group No. 171, and trace its development as summarized in Table 7.1-1 above.

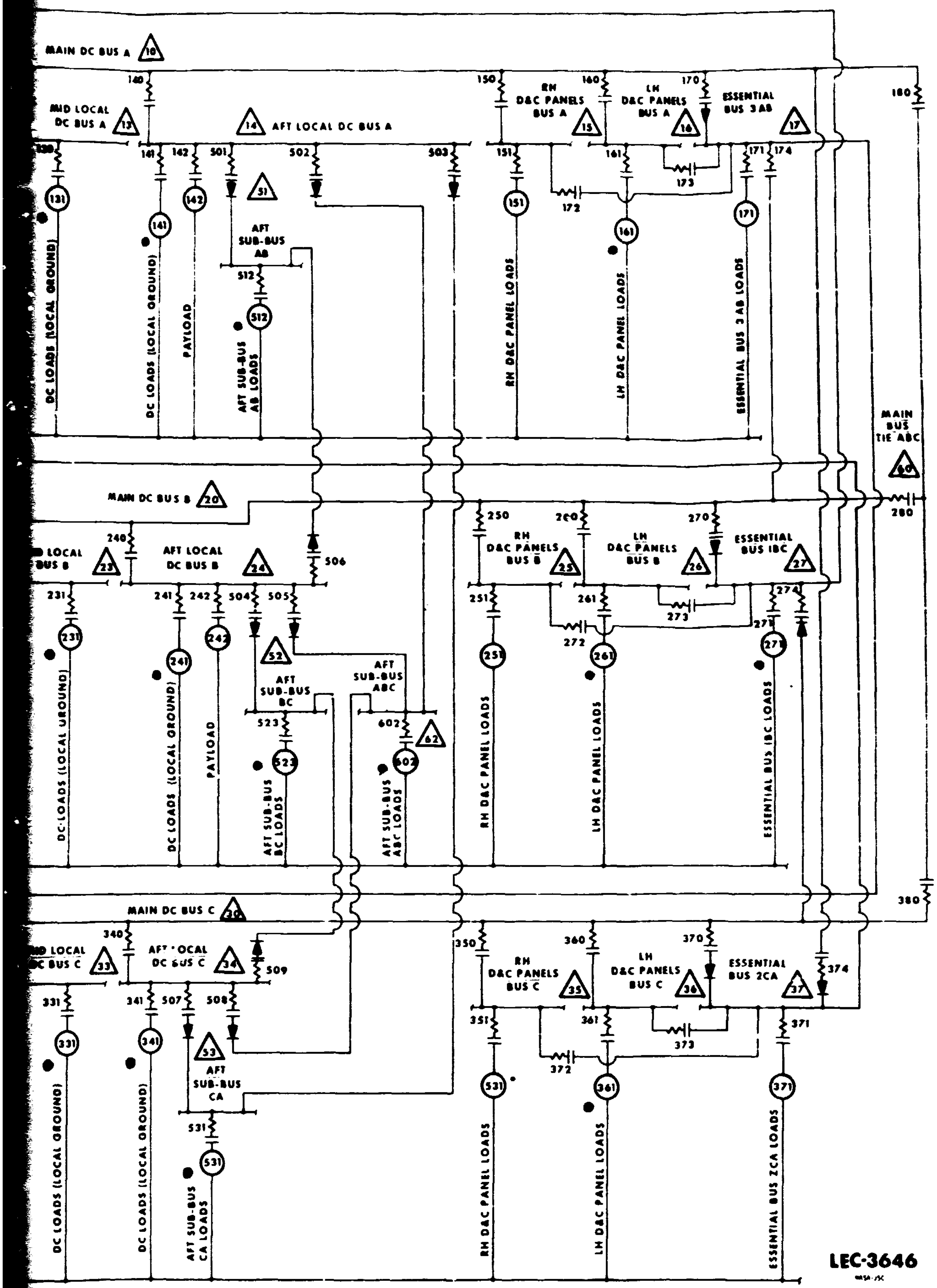
From Figure 7.1-1, we note that load group 171 is driven by "essential bus 3 AB" (alternately stated, fuel cell No. 1, cross-coupled to both main load group, DC buses A and B). From Table 7.2-1, the EPDC/user subsystem element



* SHOULD BE 351

FOLDOUT FRAME

FIGURE 7.1-1. SEPAP ELECTRICAL POWER DISTRIBUTION NETWORK SCHEMATIC



LEC-3646

NASA-JSC

FOLDOUT FRAME

bus assignments, that bus D1E, has three load elements. (D1E is the notation for DC load, main bus A, essential DC sub-bus). These three elements (one element has two states) were given in Table 7.1-4. Thus, at any given mission phase, the master timing unit will be in either its off, on or standby mode,[1] and one or both of the load control assembly units will be energized. Additional information can be gleaned from Table 7.2-1, namely, whether a particular circuit protection device has been selected for a given load element. For example, no particular device has been selected for the master timing unit (page 7.2-4, pointer); as a counter-example an RP(C) has been selected for the signal conditioning unit, ID#0413000 (see Appendix 7.3, page 7.3-7). In similar fashion, from Appendix 7.3, page 7.3-5, we determine that the load control assembly units #2 or #3 identified from Appendix 7.3, page 7.3-9, both employ fuses as circuit protection devices. The convention chosen for the illustrative simulation purposes of this study is that an fuse will be chosen as the representative circuit protection device unless otherwise indicated.

Further, to indicate which load groups have actually been represented by load element decomposition and modeled in SYSTID a solid dot has been placed adjacent to the load on the schematic of Figure 7.1-1.

Finally, Table 7.1-4 lists the load elements obtained from the LEC SEPAP card data supplied to Hughes, as a function of bus assignment. Note that this listing does not have load group sorting, per the topolgoy of Figure 7.1-1.

---

[1] As determined by the SYSTID Event Generator

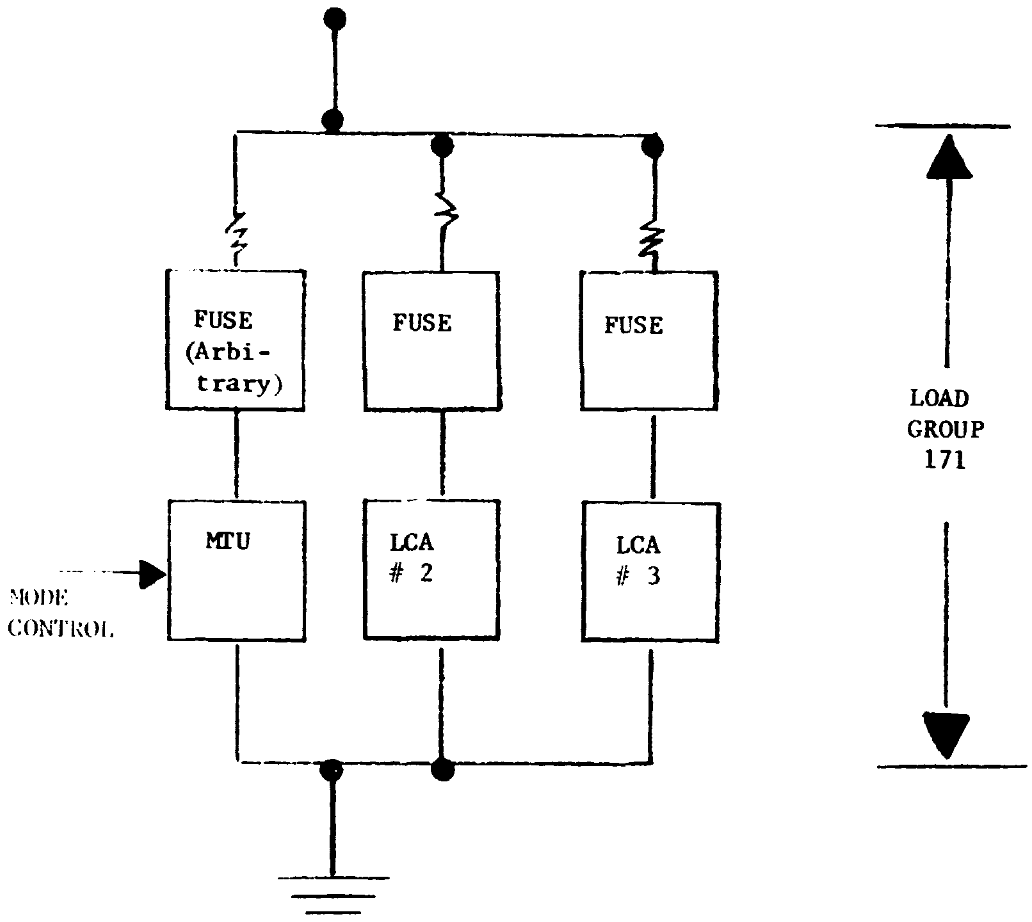


Figure 7.1-2. TYPICAL LOAD GROUP DECOMPOSITION INTO ITS CONSTITUENT LOAD ELEMENTS

TABLE 7.1-2

SYSTEM LOAD BUS ASSIGNMENT LISTINGS (EPDC TOPOLOGY)

```
SYSTEM*  SHUTTLE EPDC SYSTEM

DEFAULT,TSTOP= 205.,DT=.5E-3,VOLT=28.,CPF=1.,FREQ=400.,SETTLE=5.E-3
PLOT , I101,I120,I121,I512A,I201,I220,I221,I523B,I301,I320,I321,I531C,I271A,
, I271B,V10,V20,V30,I19,I29,I39
PAGE , SMALL
$TRANS IMPLICIT REAL(I)
 ****************************** MAIN BUS A ********************************
 *
      G * FUEL CELL(R101,28.) * V01
      V01 * SWITCH(101,R10) * V10,R101
 *
 *............MAIN DC BUS A LOADS
 *
      V10 * SWITCH(110,R11) * V11,R110
      V11 * LOAD(111) * R111
      V11 * LOAD(112) * R112
      V11 * LOAD(113) * R113
      V11 * LOAD(114) * R114
      V11 * LOAD(115) * R115
      V11 * LOAD(116) * R116
110   R11=1./(1./R111+1./R112+1./R113+1./R114+1./R115+1./R116)
 *
 *............ FWD LOCAL DC BUS A
      V10 * SWITCH(120,R12) * V12,R120
      V12 * LOAD(121) * R121
      V12 * LOAD(122) * R122
 *
 *........ INVERTER BUS A AND FWD SUB-BUS AB
      V12 * LOAD(123) * R123
      V12 * INVERTER(FREQ,VOLT,CPF,R123) * V19,I19,R19
      V12,V22 * LOAD2(412) * R412A,R412B
120   R12=1./(1./R121+1./R122+1./R19 +1./R412A+1./R601A+1./R431A)
 *
 *............ MID-LOCAL DC BUS A
      V10 * SWITCH(130,R13) * V13,R130
      V13 * LOAD(131) * R131
130   R13=R131
 *
 *............ AFT LOCAL DC BUS A
      V10 * SWITCH(140,R14) * V14,R140
      V14 * LOAD(141) * R141
      V14 * LOAD(142) * R142
 *
 *........ AFT SUB-BUS AB
 *
      V14-V24 * LOAD2(512) * R512A,R512B
140   R14=1./(1./R141+1./R142+1./R512A+1./R602A+1./R531A)
 *
 *........ BUS A PANELS AND ESSENTIAL BUS 3AB
 *
      V10 * SWITCH(150,R15) * V15,R150
      V10 * SWITCH(160,R16) * V16,R160
      V10 * SWITCH(170,R171A) * V17,R170
      V15 * SWITCH(172,R171D) * V172,R172
      V16 * SWITCH(173,R171E) * V173,R173
      V15 * LOAD(151) * R151
      V16 * LOAD(161) * R161
      V17,V20,V03,V172,V173 * LOAD5(171) * R171A,R171B,R171C,R171D,R171E
150   R15=1./(1./R151+1./R172)
151   R16=1./(1./R161+1./R173)
152   R17=R170
160   R10=1./(1./R110+1./R120+1./R130+1./R140+1./R150+1./R160+1./R170)
161   R10=1/(1./R10+1./R271A+1./R371A)
```

TABLE 7.1-2 SYSTID LOAD BUS ASSIGNMENT LISTINGS (EPDC TOPOLOGY)
(Continued)

```
******************************** MAIN BUS B ********************************
*
      G * FUEL CELL(R201,28.) * V02
      V02 * SWITCH(201,R20) * V20,R201
*
*...........MAIN DC BUS B LOADS
      V20 * SWITCH(210,R21) * V21,R210
      V21 * LOAD(217) * R217
      V21 * LOAD(211) * R211
      V21 * LOAD(212) * R212
      V21 * LOAD(213) * R213
      V21 * LOAD(214) * R214
      V21 * LOAD(215) * R215
      V21 * LOAD(216) * R216
210   R21=1./(1./R217+1./R211+1./R212+1./R213+1./R214+1./R215+1./R216)
*
*........ FWD LOCAL DC BUS B
*
      V20 * SWITCH(220,R22) * V22,R220
      V22 * LOAD(221) * R221
      V22 * LOAD(222) * R222
*
*........ INVERTER BUS B AND FWD SUB-BUSES AB AND ABC
*
      V22 * LOAD(223) * R223
      V22 * INVERTER(FREQ,VOLT,CPF,R223) * V29,T29,R29
      V22,V32 * LOAD2(423) * R423B,R423C
      V12,V22,V32 * LOAD3(601) * R601A,R601B,R601C
220   R22=1./(1./R221+1./R222+1./R29 +1./R423B+1./R601B+1./R412B)
*
*............. MID-LOCAL BUS B
*
      V20 * SWITCH(203,R23) * V23,R230
      V23 * LOAD(231) * R231
230   R23=R231
*
*............. AFT LOCAL DC BUS B AND AFT SUB/BUSES BC AND ABC
*
      V20 * SWITCH(240,R24) * V24,R240
      V24 * LOAD(241) * R241
      V24 * LOAD(242) * R242
      V24,V34 * LOAD2(523) * R523B,R523C
      V14,V24,V34 * LOAD3(602) * R602A,R602B,R602C
240   R24=1./(1./R241+1./R242+1./R523B+1./R602B)
*
*........BUS B PANELS AND ESSENTIAL BUS 1BC
*
      V20 * SWITCH(250,R25) * V25,R250
      V20 * SWITCH(260,R26) * V26,R260
      V20 * SWITCH(270,R271B) * V27,R270
      V25 * SWITCH(272,R271D) * V272,R272
      V26 * SWITCH(272,R271E) * V273,R273
      V25 * LOAD(251) * R251
      V26 * LOAD(261) * R261
      V01,V27,V30,V272,V273 * LOAD5(271) * R271A,R271B,R271C,R271D,R271E
250   R25=1./(1./R251+1./R272)
251   R26=1./(1./R261+1./R273)
252   R27=R270
260   R20=1./(1./R210+1./R220+1./R230+1./R240+1./R250+1./R260+1./R270)
261   R20=1./(1./R20+1./R171B+1./R371B)
```

TABLE 7.1-2 SYSTID LOAD BUS ASSIGNMENT LISTINGS (EPDC TOPOLOGY)
(Continued)

```
 *
 *******************************************MAIN BUS C ***********************************
      G * FUEL CELL([illegible]1,28.) * V03
      V03 * SWITCH(301,R30) * V30,R301
 *
 ...............MAIN DC BUS C LOADS
 *
      V30 * SWITCH(310,R31) * V31,R310
      V31 * LOAD(311) * R311
      V31 * LOAD(312) * R312
      V31 * LOAD(313) * R313
      V31 * LOAD(314) * R314
      V31 * LOAD(315) * R315
      V31 * LOAD(316) * R316
310   R31=1./(1./R311+1./R312+1./R313+1./R314+1./R315+1./R316)
 *
 .............FWD LOCAL DC BUS C
 *
      V30 * SWITCH(320,R32) * V32,R320
      V32 * LOAD(321) * R321
      V32 * LOAD(322) * R322
      V32 * LOAD(325) * R325
 *
 ........ INVERTER BUS C AND FWD SUB-BUS CA
 *
      V32 * LOAD(323) * R323
      V32 * INVERTER(FREQ,VOLT,CPF,R323) * V39,I39,R39
      V12,V32 * LOAD2(431) * R431A,R431C
320   R32=1./(1./R321+1./R322+1./R325+1./R39 +1./R431C+1./R601C+1/R423C)
 *
 ........MID LOCAL DC BUS C
 *
      V30 * SWITCH(330,R33) * V33,R330
      V33 * LOAD(331) * R331
330   R33=R331
 *
 ........ AFT LOCAL DC BUS C AND AFT SUB-BUS CA
 *
      V30 * SWITCH(340,R34) * V34,R340
      V34 * LOAD(341) * R341
      V14,V34 * LOAD2(531) * R531A,R531C
340   R34=1./(1./R341+1./R531C+1./R523C+1./R602C)
 *
 ........ BUS C PANELS AND ESSENTIAL BUS 2CA
 *
      V30 * SWITCH(350,R35) * V35,R350
      V30 * SWITCH(360,R36) * V36,R360
      V30 * SWITCH(370,R371C) * V37,R370
      V35 * SWITCH(372,R371D) * V372,R372
      V36 * SWITCH(373,R371E) * V373,R373
      V35 * LOAD(351) * R351
      V36 * LOAD(361) * R361
      V10,V02,V30,V372,V373 * LOAD5(371) * R371A,R371B,R371C,R371D,R371E
350   R35=1./(1./R351+1./R372)
351   R36=1./(1./R361+1./R373)
352   R37=R370
360   R30=1./(1./R310+1./R320+1./R330+1./R340+1./R350+1./R360+1./R370)
361   R30=1./(1./R30+1./R171C+1./R271C)
4TRANS I101=V10/R101
4TRANS I120=V10/R120
4TRANS I121=V12/R121
4TRANS I512A=V14/R512A
4TRANS I201=V20/R20
4TRANS I220=V20/R220
4TRANS I221=V22/R221
4TRANS I523B=V24/R523B
4TRANS I301=V30/R301
4TRANS I320=V30/R320
4TRANS I321=V32/R321
4TRANS I531C=V34/R531C
4TRANS I271A=V01/R271A
4TRANS I271B=V27/R271B
END
```

TABLE 7.1 -3

SYSTID LOAD DEFINITION LISTING

NOTE: DATA BELOW INCLUDES LOAD GROUP ITEM NO., BUS IDENTIFICATION,
LOAD ELEMENT ID NO. AND NAME, AND WATTAGE CONSUMED.

MAIN BUS A LOADS

```
                                                   LOAD112

 1.      D1G     30080100     FCP =1 START + SUST HTR   1  6000.00
 2.      D1G     50170000     ELEVON ACT SW VLV POS     1     1.00
 3.      D1G     50180100     RUD/SPDBRK ACT VL POS =1  1     1.00
 4.      D1G     50180200     RUD/SPDBRK ACT VL POS =2  1     1.00
 5.      D1G     50190000     TVC ACT SW VLV POS        1     1.00
 6.      D1G     50200100     RESVR =1 LOW LEVEL IND    1     2.00
 7.      D1G     50200200     RESVR =2 LOW LEVEL IND    1     2.00
 8.      D1G     50200300     RESVR =3 LOW LEVEL IND    1     2.00
 9.      D1G     50220100     BODYFLAP MTR 1 HTR =1/=2  1    50.00
10.      D1G     50220200     BODYFLAP MTR 2 HTR =1/=2  1    50.00
11.      D1G     50220300     BODYFLAP MTR 3 HTR =1/=2  1    50.00


                                                   LOAD121

 1.      D1F      1010100  RP IMU =1 OPERATE                1   160.00
 2.      D1F      1010110  RP IMU =1 STANDBY                1    55.00
 3.      D1F      1110100  RP REACTION JET DRVR =1 FWD      1    59.20
 4.      D1F      3150000     CAUT + WARNING UNIT           1    20.00
 5.      D1F      4030100  RP PCM MASTER UNIT(DACBU)=1      1    60.00
 6.      D1F      4030200  RP PCM MASTER UNIT(DACBU)=2      1    60.00
 7.      D1F      6010100  RC INVERTERS 1PH,750VA,80(       1      .00
 8.      D1F      6020100  RP PYRO EVENT CNTLR -FWD =1      1    25.00
 9.      D1F      6060100  RC DC PWR CNTLR ASSY-FWD =1      1   260.00
10.      D1F      6100100     INV DIST + CNTL ASSY =1       1    20.00
11.      D1F      7010100  RP COMPUTER =1                   1   600.00
12.      D1F      7010200  RP COMPUTER =2                   1   600.00
13.      D1F      7010300  RP COMPUTER =3                   1   600.00
14.      D1F      7010400  RP COMPUTER =4                   1   600.00
15.      D1F      7010500  RP COMPUTER =5                   1   600.00
16.      D1F      7030100  RP MDM FF1                       1    40.00
17.      D1F     22030000     THRUSTER-VERNIER (FWD)        1    15.00
18.      D1F     22060000     HP HELIUM ISOL VLV -FWD       1    84.00
19.      D1F     22070000     LP HEL ISOL VLV-FWD           1    84.00
20.      D1F     22130000     TANK ISO THRST VLV- FWD       1    84.00
21.      D1F     22170000     MAIN ENG HEATERS-FWD          1    10.00
22.      D1F     22210000     FEED SYS HTRS-FWD             1   160.00
23.      D1F     30030100     H2O RELIEF VENT HTR =1        1    16.00
24.      D1F     30030200     H2O RELIEF VENT HTR =2        1    16.00
25.      D1F     40070100  RP CABIN HEATER =1               1   333.33
26.      D1F     40070200  RP CABIN HEATER =2               1   333.33
27.      D1F     40070300  RP CABIN HEATER =3               1   333.33
28.      D1F     40100100  RP OVEN HEATER =1                1   150.00
29.      D1F     40120100  RC WATER HEATER =1               1   455.00
30.      D1F     40270100     FLASH EVAPORATOR HTR =1       1   310.00
31.      D1F     40270200     FLASH EVAPORATOR HTR =2       1   310.00
32.      D1F     40280100     FLASH EVAPORATOR EL =1        1     8.00
33.      D1F     40280200     FLASH EVAPORATOR EL =2        1     8.00
34.      D1F     40310100     AMMONIA BOILER SYSTEM =1      1    12.50
35.      D1F     40330100     DIVERTER VALVE =1             1    19.50
36.      D1F     52270000     BRAKE/SKID POWER SYS          1   140.00
37.      D1F     52300000  RP GN+C PROBE HEATERS            1  1100.00
```

TABLE [illegible]
(Continued)

```
                        [illegible]

                                                                 [illegible]

 1.       A1 3A    2501000      [illegible]                          1     [illegible]
 2.       A1 3A   20010100      [illegible]                          1     [illegible]
 3.       A1 3A   30030100      [illegible]                          1     [illegible]
 4.       A1 3A   40020100      WATER [illegible]                    1     [illegible]
 5.       A1 3A   40020300      [illegible]                          1     [illegible]
 6.       A1 3A   40050100      [illegible]                          1     [illegible]
 7.       A1 3A   40090100      [illegible] FAN #1                   1     [illegible]
 8.       A1 3AB  [illegible]   [illegible]                          1     [illegible]
 9.       A1 3AC  2001030[illegible] [illegible]                     1     [illegible]
10.       A1 3B   40[illegible]100 [illegible]                       1     [illegible]
11.       A1 3C    2170100      [illegible]                          1     [illegible]


                                                                 [illegible]

 1.       D1M      4080100  RR  [illegible] ASSY#1                   1       20.00
 2.       D1M      4120100      [illegible] ASSEMBLY #1              1       3[illegible].00
 3.       D1M     30010100      [illegible] VENT HTR #1              1     [illegible]
 4.       D1M     30020100      [illegible] VENT HTR #2              1     [illegible]
 5.       D1M     30070100  F   [illegible] PURGE VALVE              1     [illegible]
 6.       D1M     30150100      [illegible] LINE HEATER [illegible] #1   1     [illegible]
 7.       D1M     30170100      [illegible] THERMAL [illegible] MTR  1      150.00
 8.       D1M     31040000      SWITCHING UNIT [illegible]           1     [illegible]
 9.       D1M     31060010      SWITCHING UNIT [illegible]           1         .40
10.       D1M     31070000      SWITCHING UNIT H2-ON                 1        2.50
11.       D1M     31070010      SWITCHING UNIT H2-OFF                1         .20
12.       D1M     31120100  F   SOLENOID VLV FCP #1                  1       56.00
13.       D1M     31130100      SOLENOID VALVE ECLSS #1              1       56.00
14.       D1M     31130200      SOLENOID VALVE ECLSS #2              1       56.00
15.       D1M     31150100  F   SOL VLV MANIFOLD #1                  1       56.00
16.       D1M     31150400  F   SOL VLV MANIFOLD #4                  1       56.00
17.       D1M     51010000  RC  MANIPULATOR                          1     1600.00
```

TABLE 7.1-3 SYSTID LOAD DEFINITION LISTING
(Continued)

MAIN BUS A LOADS

```
                                                            L O A D 1 4 1

 1.        D1A      1080100  RP  ASCENT TVC DRVR #1 - AFT    1      94.50
 2.        D1A      1090100  RP  AERO SRF SRV AMP #1-AFT     1     107.77
 3.        D1A      1090300  RP  AERO SRF SRV AMP #3-AFT     1     107.77
 4.        D1A      1090400  RP  AERO SRF SRV AMP #4-AFT     1     107.77
 5.        D1A      1120100  RP  REACT JET OMS DRVR#1-AFT    1     152.70
 6.        D1A      1120200  RP  REACT JET OMS DRVR#2-AFT    1     152.70
 7.        D1A      1130100  RP  RATE GYRO ASSY-AFT #1       1      23.00
 8.        D1A      4060100  RP  SIG COND UNIT #1 - AFT      1      35.00
 9.        D1A      4120100  RP  SIG COND UNIT-OMS/RCS #1    1      35.00
10.        D1A      6030100  RP  MASTER EVENT CNTLR-AFT#1    1      25.00
11.        D1A      6050100  F   LOAD CNTLR ASSY-AFT #1      1      90.00
12.        D1A      6070100      DC PWR CNTLR ASSY-AFT #1    1     160.00
13.        D1A      7110100      MDM OFI AFT 1               1      40.00
14.        D1A      7110300      MDM OFI AFT 3               1      40.00
15.        D1A      7150100      ENG INTERFACE UNIT #1       1      50.60
16.        D1A     15010000  RP  MDM - OFI                   1      20.00
17.        D1A     20020100  RP  MAIN ENG HTR #1             1     300.00
18.        D1A     20030100  RP  LO2 PREVALVE SOLENOID       1      42.00
19.        D1A     20030200  RP  LO2 PREVALVE SOLENOID       1      42.00
20.        D1A     20030300  RP  LO2 PREVALVE SOLONOID       1      42.00
21.        D1A     20040100  RP  LH2 PREVALVE SOLENOID       1      42.00
22.        D1A     20040200  RP  LH2 PREVALVE SOLENOID       1      42.00
23.        D1A     20040300  RP  LH2 PREVALVE SOLONOID       1      42.00
24.        D1A     20060000  F   LO2 F+D VLV #2(O/B) SOL     1      42.00
25.        D1A     20070100  RP  LH2 F+D VLV #1(O/B) SOL     1      42.00
26.        D1A     20070200  RP  LH2 F+D VLV #1(O/B) SOL     1      42.00
27.        D1A     20080100  F   LH2 F+D VLV #2(O/B) SOL     1      42.00
28.        D1A     20080200  F   LH2 F+D VLV #2(O/B) SOL     1      42.00
29.        D1A     20100100  F   LH2 RECRC VLV OPEN SOL#1    1      42.00
30.        D1A     20110100  RP  ET/ORB LO2 FEED DISC S V    1      42.00
31.        D1A     20110200  RP  ET/ORB LO2 FEED DISC S V    1      42.00
32.        D1A     20120100  RP  ET/ORB LH2 FEED DISC S V    1      42.00
33.        D1A     20120200  RP  ET/ORB LH2 FEED DISC S V    1      42.00
34.        D1A     20130100  F   ET/ORB RECIRC DISC S V      1      42.00
35.        D1A     20130200  F   ET/ORB RECIRC DISC S V      1      42.00
36.        D1A     20160000      LH2 PRESSIN DISC BYPASS     1      42.00
37.        D1A     20170000  F   ET VENT VLV ISO SOL VLV     1      42.00
38.        D1A     20180100  F   LO2 FEEDLN REPRESS VLV#1    1      42.00
39.        D1A     20200100  F   HE CROSSOVER VLV #1         1      42.00
40.        D1A     20210100  F   ENG HE SUPPLY ISO SOL #1    1      42.00
41.        D1A     20220100  RP  VEH HE SUPPLY ISO SOL#1     1      42.00
42.        D1A     20220200  RP  VEH HE SUPPLY ISO SOL#2     1      42.00
43.        D1A     20230100  F   HE BLOWDN SOL VLV #1        1      42.00
44.        D1A     20240100  F   LO2 PRESSIN FL CNTL SV1     1      42.00
45.        D1A     20250100  F   LH2 PRESSIN FL CNTL SV1     1      42.00
46.        D1A     20270100      ET ULLAGE SIG CND PKG #1    1      33.33
47.        D1A     2027020       ET ULLAGE SIG CND PKG #2    1      33.33
48.        D1A     20270300      ET ULLAGE SIG CND PKG #3    1      33.33
49.        D1A     20280000      PROP LOW LEV SNSR SIGCND    1       7.00
50.        D1A     20290000      PROP LOADING SNSR SIGCND    1       7.00
51.        D1A     21010100  F   ENGINE CONTROL VALVE #1     1      56.00
52.        D1A     21010200  F   ENGINE CONTROL VALVE #2     1      56.00
53.        D1A     21010300  F   ENGINE CONTROL VALVE #3     1      56.00
54.        D1A     21010400  F   ENGINE CONTROL VALVE #4     1      56.00
55.        D1A     21020100  F   HE ISOL VLVS-SET 1          1      24.00
56.        D1A     21030100  F   VAPOR ISOL VLVS-SET 1       1      24.00
57.        D1A     21050100      QUANTITY GAGING PROBE #1    1      67.00

58.        D1A     21050200      QUANTITY GAGING PROBE #2 1         67.00
```

TABLE 7.1-3 SYSTID LOAD DEFINITION LISTING
(Continued)

MAIN BUS A LOADS

```
                                                          LOADS12
 1.    D1A   21050300     QUANTITY GAGING PROBE #3  1     67.00
 2.    D1A   21050400     QUANTITY GAGING PROBE #4  1     67.00
 3.    D1A   21060100 F   HE ISO VLV#1-AUX KIT      1     24.00
 4.    D1A   21070100 F   VAPOR ISO VLV#1-AUX KIT   1     24.00
 5.    D1A   21090100 RP  ENG GIMBAL ACTUATOR #1    1    134.50
 6.    D1A   21100000     PROP TNK ISO VLVS         1     32.00
 7.    D1A   21130100 F   CROSSFEED VLVS-SET 1      1     32.00
 8.    D1A   21140100 RP  THERMAL CNTL HTR #1       1    700.00
 9.    D1A   22010000     THRUSTER - FWD            1     56.00
10.    D1A   22020000     THRUSTER - AFT            1     56.00
11.    D1A   22080000 F   HP HELIUM ISOL VLV -AFT   1     84.00
12.    D1A   22090000 F   LP HELIUM ISOL VLV -AFT   1     84.00
13.    D1A   22120000     PROPELLANT ISOL VLV-VERN  1     56.00
14.    D1A   22140000     TANK ISO THRST VLV-AFT    1     84.00
15.    D1A   22150000 RP  TANK HEATERS-AFT LEFT     1     55.00
16.    D1A   22180000     MAIN ENG HEATERS-AFT      1     10.00
17.    D1A   32020100 RP  FUEL ISOLATION VALVE #1   1     40.00
18.    D1A   32020200 RP  FUEL ISOLATION VALVE #2   1     40.00
19.    D1A   32020300 RP  FUEL ISOLATION VALVE #3   1     40.00
20.    D1A   32030100 RP  APU #1 CONTROLLER         1    150.00
21.    D1A   32030200 RP  APU #2 CONTROLLER         1    150.00
22.    D1A   32030300 RP  APU #3 CONTROLLER         1    150.00
23.    D1A   32050100 RP  TANK HTR #1 - LH SIDE     1     50.00
24.    D1A   32050200 RP  TANK HTR #2 - LH SIDE     1     50.00
25.    D1A   32050300 RP  TANK HTR #3 - RH SIDE     1     50.00
26.    D1A   32070100 F   APU LINE HEATERS #1       1     50.00
27.    D1A   32070200 F   APU LINE HEATERS #2       1     50.00
28.    D1A   32070300 F   APU LINE HEATERS #3       1     50.00
29.    D1A   32080100 F   FUEL QTY GAGE #1          1      1.00
30.    D1A   32080200 F   FUEL QTY GAGE #2          1      1.00
31.    D1A   32080300 F   FUEL QTY GAGE #3          1      1.00
32.    D1A   32090100 F   APU OIL LINE HTR #1       1    100.00
33.    D1A   32090200 F   APU OIL LINE HTR #2       1    100.00
34.    D1A   32090300 F   APU OIL LINE HTR #3       1    100.00
35.    D1A   32100100 F   APU #1 TURB VLV HTR       1     68.30
36.    D1A   32100200 F   APU #2 TURB VLV HTR       1     68.30
37.    D1A   32100300 F   APU #3 TURB VLV HTR       1     68.30
38.    D1A   32110100 F   APU #1 TURB GAS GEN HTR   1     68.30
39.    D1A   32110200 F   APU #2 TURB GAS GEN HTR   1     68.30
40.    D1A   32110300 F   APU #3 TURB GAS GEN HTR   1     68.30
41.    D1A   40010000     CABIN PRESS CNTL SYSTEM   1     84.00
42.    D1A   40030010     CAB PRESS CNTL-AIRLK SP   1     30.60
43.    D1A   40030020     CAB PRESS CNTL-EMERG MD   1     23.00
44.    D1A   50010000 F   LG EXTEND VALVE           1     20.00
45.    D1A   50020100 F   MAIN LDG GEAR UPLK VL #1  1     20.00
46.    D1A   50030100 F   LDG GEAR DUMP VLV #1      1     20.00
47.    D1A   50040000 F   LG RETRACT CIRC VLV       1     20.00
48.    D1A   50060100 F   MAIN PUMP #1 DEPRES VLV   1     20.00
49.    D1A   50070100 RC  CIRC MOTOR PUMP #1        1   1561.00
50.    D1A   50090100 F   SSME #1 SYS S/O VALVE     1     20.00
51.    D1A   50100100     LI ELEVON HTR BKT #1/#2   1     50.00
52.    D1A   50100200     LO ELEVON HTR BKT #1/#2   1     50.00
53.    D1A   50100300     RI ELEVON HTR BKT #1/#2   1     50.00
54.    D1A   50100400     RO ELEVON HTR BKT #1/#2   1     50.00
55.    D1A   50120100     H2O BOILER #1 XFER VLV    1     50.00
56.    D1A   50150100 RP  H2O BOILER #1 HEATER      1    100.00
57.    D1A   52010000     RUD/SPD BRKE S/V (RUD )   1     15.00

58.    D1A   52020000     RUD/SPD BRKE S/V          1     15.00
```

TABLE 7.1-3 SYSTID LOAD DEFINITION LISTING
(Continued)

MAIN BUS A LOADS

```
                                                          L O A D 1 6 1

 1.      D1L      1030100      STAR TRKER + LT SHLD #1      1      20.00
 2.      D1L      1040100      AIR DATA XDCR ASSY #1        1      45.00
 3.      D1L      1040400      AIR DATA XDCR ASSY #4        1      45.00
 4.      D1L      2110100      S-BAND FM XMITR #1           1     100.00
 5.      D1L      3010100      ATTITUDE DIR IND-FWD #1      1      14.60
 6.      D1L      3030100      HORZ SIT IND#1               1      35.00
 7.      D1L      3040100      AS/MACH IND(AMI) #1          1      40.00
 8.      D1L      3050100      ALT VER VEL IND #1           1      40.00
 9.      D1L      3060000      TAPE METERS(HYD-APU-MPS)     1     132.00
10.      D1L      3120000      CROSS POINTER IND            1       2.00
11.      D1L      3140000      QTY IND OMS/RCS              1       6.00
12.      D1L      3170100      MISSION TIMER #1             1       4.00
13.      D1L      3180100      EVENT TIMER #1               1       4.00
14.      D1L      3190100      CRT DISPLAY UNIT #1          1      90.00
15.      D1L      3210100      DISPLAY ELECT UNIT #1        1     207.30
16.      D1L      3220100      DISP DRVR UNIT-CRW FWD#1     1     120.00
17.      D1L      3220300      DISP DRVR UNIT-CRW AFT#3     1     120.00
18.      D1L      4040000      MAINT RECORDER               1      40.00
19.      D1L      4050100      SIG COND UNIT-FWD #1         1      35.00
20.      D1L      7040100  RP  MDM FA1                      1      40.00
21.      D1L      7040200  RP  MDM FA2                      1      40.00
22.      D1L      7090100      MASS MEM#1(TAPE) OPER        1      53.00
23.      D1L      7090110      MASS MEM#1(TAPE) STBY        1       8.00
24.      D1L      7100100      MDM OF 1                     1      40.00
25.      D1L     22190000      PROP FEED LINE HTRS-AFT      1      16.00
26.      D1L     22200000      PRESS PANEL HTRS             1      20.00
27.      D1L     40040100      WATER SUBLIMATOR SYS #1      1     101.00
28.      D1L     40111000      INSTR + CONTROLS (WATER)     1      10.00
29.      D1L     40180000      DUMP NOZZLE-URINE            1      10.00
30.      D1L     52260000      NOSE WHEEL STEERING UNIT     1      10.00


                                                          L O A D 1 7 1

 1.      D1E      4090000      MASTER TIMING UNIT-WMUP      1      40.00
 2.      D1E      4090010      MASTER TIMING UNIT-CPR       1      26.00
 3.      D1E      6040200  F   LOAD CNTLR ASSY-FWD #2       1      75.00
 4.      D1E      6040300  F   LOAD CNTLR ASSY-FWD #3       1      75.00
```

TABLE 7.1-3 SYSTID LOAD DEFINITION LISTING
(Continued)

MAIN BUS B LOADS

```
                                                   L O A D 2 2 1

1.        D2F      1010200 RP IMU #2 OPERATE              1    160.00
2.        D2F      1010210 RP IMU #2 STANDBY              1     55.00
3.        D2F      1110200 RP REACTION JET DRVR #2 FWD    1     59.20
4.        D2F      4110000    SIG COND UNIT-F/C AREA      1     35.00
5.        D2F      4140000    SIG COND UNIT-FWD RCS       1     35.00
6.        D2F      6010200 RC INVERTERS 1PH,750VA,80(     1       .00



                                                 L O A D 2 1 2

1.        D2G     30080200    FCP #2 START + SUST HTR  1  6000.00



                                                 L O A D 2 2 3

1.        A2 3A    3310100    INTEGRAL LIGHTS-LEFT/CTR 1    132.00
2.        A2 3A    3310200    INTEGRAL LIGHTS-OVHD     1    138.00
3.        A2 3A    3310300    INTEGRAL LIGHTS-RIGHT    1    134.00
4.        A2 3A    3310400    INTEGRAL LIGHTS-REAR     1    134.00
5.        A2 3A   30050200    FCP #2 PUMP + H2O SENSOR 1    150.00
6.        A2 3C    2170200    TACAN #2                 1    150.00
```

TABLE 7.1-3 SYSTID LOAD DEFINITION LISTING (Continued)

MAIN BUS B LOADS

```
                                                    L O A D 6 0 1

1.        D2F      6020200 RP PYRO EVENT CNTLR -FWD #2 1     25.00
2.        D2F      6060200 RC DC PWR CNTLR ASSY-FWD #2 1    260.00
3.        D2F      6100200    INV DIST + CNTL ASSY #2  1     20.00
4.        D2F      7030200 RP MDM FF2                  1     40.00
5.        D2F      7030400 RP MDM FF4                  1     40.00
6.        D2F     40120200 RC WATER HEATER #2          1    455.00
7.        D2F     40510200    AMMONIA BOILER SYSTEM #2 1     12.50
```

```
                                                      L O A D 2 3 1

1.         D2M      6060200 RP MAIN DC DIST+CNTL ASSY#2 1      20.00
2.         D2M      6120200    DC PWR CNTL ASSY-MID #2  1      30.00
3.         D2M     30010200    GO2 PURGE VENT HTR #2    1      53.00
4.         D2M     30020200    GH2 PURGE VENT HTR #2    1      61.00
5.         D2M     30060100 F  FCP #1 GO2 PURGE VALVE   1      33.00
6.         D2M     30060200 F  FCP #2 GO2 PURGE VALVE   1      33.00
7.         D2M     30070200 F  FCP #2 GH2 PURGE VALVE   1      10.00
8.         D2M     30150200    H2O LINE HEATER-FCP #2   1      15.00
9.         D2M     30170200    FCP #2 THERMAL CNTL HTR  1     150.00
10.        D2M     31120200 F  SOLENOID VLV FCP #2      1      56.00
11.        D2M     31150200 F  SOL VLV MANIFOLD #2      1      56.00
12.        D2M     31170100 RC HEATERS (OXYGEN) SET 1   1     394.50
13.        D2M     31180100 RP HEATERS (HYDROGEN) SET 1 1      81.00
```

```
1.         D2A      1080200 RP ASCENT TVC DRVR #2 - AFT 1      94.30
2.         D2A      1130200 RP RATE GYRO ASSY-AFT #2    1      23.00
3.         D2A      6030200 RP MASTER EVENT CNTLR-AFT#2 1      25.00
4.         D2A      6050200 F  LOAD CNTLR ASSY-AFT #2   1      90.00
5.         D2A      6070200    DC PWR CNTLR ASSY-AFT #2 1     160.00
6.         D2A      7110200    MDM OFI AFT 2            1      40.00
7.         D2A      7150200    ENG INTERFACE UNIT #2    1      50.60
8.         D2A     16010100    RATE GYRO ASSY           1      42.00
9.         D2A     16020100    MDM - SET 1              1      15.00
10.        D2A     16040100    MDM OFI #1               1      35.00
11.        D2A     16050100    PIC IGNITION - SET 1     1        .00
12.        D2A     16060100    PIC SEPARATION-SET 1     1        .00
13.        D2A     16070100    SIG COND - SET 1         1      20.00
```

TABLE 7.1-3 SYSTID LOAD DEFINITION LISTING (Continued)

MAIN BUS B LOADS

```
                                                          L O A D 5 2 3

 1.      D2A     20020200 RP  MAIN ENG HTR =2               1    300.00
 2.      D2A     20100200 F   LH2 RECRC VLV OPEN SOL=2      1     42.00
 3.      D2A     20150000 F   LH2 FEEDLN RELF SHUTOFF       1     42.00
 4.      D2A     20180200 F   LO2 FEEDLN REPRESS VLV=2      1     42.00
 5.      D2A     20190100 F   LH2 FEEDLN REPRESS VLV=1      1     42.00
 6.      D2A     20200200 F   HE CROSSOVER VLV =2           1     42.00
 7.      D2A     20210200 F   ENG HE SUPPLY ISO SOL =2      1     42.00
 8.      D2A     20230200 F   HE BLOWDN SOL VLV =2          1     42.00
 9.      D2A     20240200 F   LO2 PRESSIN FL CNTL SV2       1     42.00
10.      D2A     20250200 F   LH2 PRESSIN FL CNTL SV2       1     42.00
11.      D2A     21020200 F   HE ISOL VLVS-SET 2            1     24.00
12.      D2A     21030200 F   VAPOR ISOL VLVS-SET 2         1     24.00
13.      D2A     21060200 F   HE ISO VLV=2-AUX KIT          1     24.00


                                                          L O A D 6 0 2

 1.      D2A     21070200 F   VAPOR ISO VLV=2-AUX KIT       1     24.00
 2.      D2A     21090200 RP  ENG GIMBAL ACTUATOR =2        1    134.50
 3.      D2A     21130200 F   CROSSFEED VLVS-SET 2          1     32.00
 4.      D2A     21140200 RP  THERMAL CNTL HTR =2           1    700.00
 5.      D2A     21150100     ENG ARMING SOL VALVE =1       1     56.00
 6.      D2A     21150200     ENG ARMING SOL VALVE =2       1     56.00
 7.      D2A     21160000 RP  THERML CNTL HTRS-AUX KIT      1    700.00
 8.      D2A     21180000     PROP TNK ISO VLV-AUX KIT      1     32.00
 9.      D2A     22040000     THRUSTER VERNIER (AFT)        1     15.00
10.      D2A     22160000 RP  TANK HEATERS-AFT RIGHT        1     55.00
11.      D2A     50020200 F   MAIN LDG GEAR UPLK VL =2      1     20.00
12.      D2A     50060200 F   MAIN PUMP =2 DEPRES VLV       1     26.00
13.      D2A     50070200 RC  CICR MOTOR PUMP =2            1   1561.00
14.      D2A     50090200 F   SSME =2 SYS S/O VALVE         1     20.00
15.      D2A     50120200     H2O BOILER =2 XFER VLV        1     50.00
16.      D2A     50150200 RP  H2O BOILER =2 HEATER          1    160.00
                                                          L O A D 2 6 1

 1.      D2L      1030200     STAR TRKER + LT SHLD =2       1     20.00
 2.      D2L      1040200     AIR DATA XDCR ASSY =2         1     45.00
 3.      D2L      3010200     ATTITUDE DIR IND-FWD =2       1     14.60
 4.      D2L      3030200     HORZ SIT IND=2                1     35.00
 5.      D2L      3040200     AS/MACH IND(AMI) =2           1     40.00
 6.      D2L      3050200     ALT VER VEL IND =2            1     40.00
 7.      D2L      3170200     MISSION TIMER =2              1      4.00
 8.      D2L      3190200     CRT DISPLAY UNIT =2           1     90.00
 9.      D2L      3190300     CRT DISPLAY UNIT =3           1     90.00
10.      D2L      3210200     DISPLAY ELECT UNIT =2         1    207.30
11.      D2L      3210300     DISPLAY ELECT UNIT =3         1    207.30
12.      D2L      3220200     DISP DRVR UNIT-CRW FWD=2      1    120.00
13.      D2L      4050200     SIG COND UNIT-FWD =2          1     35.00
14.      D2L      7040300 RP  MDM FA3                       1     40.00
15.      D2L      7090200     MASS MEM=2(TAPE) OPER         1     53.00
16.      D2L      7090210     MASS MEM=2(TAPE) STBY         1      8.00
17.      D2L     40040200     WATER SUBLIMATOR SYS =2       1    101.00
18.      D2L     40111100     INST/CNTLS-OVEN FANS =1       1      5.00
19.      D2L     40111200     INST/CNTLS-OVEN FANS =2       1      5.00
20.      D2L     40130000     DUMP NOZZLE - WATER           1     10.00
21.      D2L     40190000     INSTR + CONTROLS(WASTE)       1     10.00
```

TABLE 7.1-3 SYSTID LOAD DEFINITION LISTING
(Continued)

```
                              MAIN BUS B LOADS
                                                     L O A D 2 7 1
1.        D2E      6040100 F  LOAD CNTLR ASSY-FWD #1    1     75.00
```

TABLE 7.1-3 SYSTEM LOAD DEFINITION LISTING
(Continued)

MAIN BUS C LOADS

```
                                                     L O A D 3 1 2
 1.         D3G     30080300     FCP #3 START + SUST HTR  1  6000.00



                                                      L O A D 3 2 1
 1.         D3F       1010300 RP IMU #3 OPERATE              1    160.00
 2.         D3F       1010310 RP IMU #3 STANDBY              1     55.00
 3.         D3F       6010300 RC INVERTERS 1PH,750VA,80(     1       .00
 4.         D3F       6060300 RC DC PWR CNTLR ASSY-FWD #3    1    260.00
 5.         D3F       6100300    INV DIST + CNTL ASSY #3     1     20.00
 6.         D3F       6160000    EVLSS BAT CHARGER           1      5.00
 7.         D3F       6180000    EVLSS PWR SUPPLY            1     75.00
 8.         D3F       7030300 RP MDM FF3                     1     40.00
 9.         D3F      22100000 F  PROP MANIF ISOL VLV -FWD    1     84.00
10.         D3F      40100200 RP OVEN HEATER #2              1    150.00
11.         D3F      40330200    DIVERTER VALVE #2           1     19.50



                                                      L O A D 3 2 3
 1.          A3 3A   30050300    FCP #3 PUMP + H2O SENSOR 1     150.00
 2.          A3 3C    2170300    TACAN #3                 1     150.00



                                                      L O A D 3 3 1
 1.         D3M       6080300 RP MAIN DC DIST+CNTL ASSY#3    1     20.00
 2.         D3M       6120300    DC PWR CNTL ASSY-MID #3     1     30.00
 3.         D3M      30060300 F  FCP #3 GO2 PURGE VALVE      1     33.00
 4.         D3M      30070300 F  FCP #3 GH2 PURGE VALVE      1     10.00
 5.         D3M      30150300    H2O LINE HEATER-FCP #3      1     15.00
 6.         D3M      30170300    FCP #3 THERMAL CNTL HTR     1    150.00
 7.         D3M      31120300 F  SOLENOID VLV FCP #3         1     56.00
 8.         D3M      31150300 F  SOL VLV MANIFOLD #3         1     56.00
 9.         D3M      31170200 RC HEATERS (OXYGEN) SET 2      1    394.50
10.         D3M      31170300 RC HEATERS (OXYGEN) SET 3      1    394.50
11.         D3M      31180200 RP HEATERS (HYDROGEN) SET 2    1     81.00
12.         D3M      31180300 RP HEATERS (HYDROGEN) SET 3    1     81.00
```

TABLE 7.1-3 SYSTID LOAD DEFINITION LISTING
(Continued)

MAIN BUS C LOADS

```
                                                          LOAD341

  1.      D3A      1080300 RP ASCENT TVC DRVR =3 - AFT  1     94.50
  2.      D3A      1090200 RP AERO SRF SRV AMP =2-AFT   1    107.77
  3.      D3A      1130300 RP RATE GYRO ASSY-AFT =3     1     23.00
  4.      D3A      4060200 RP SIG COND UNIT =2 - AFT    1     35.00
  5.      D3A      4060300 RP SIG COND UNIT =3 - AFT    1     35.00
  6.      D3A      4120200 RP SIG COND UNIT-OMS/RCS =2  1     35.00
  7.      D3A      5060000    SIG COND UNIT -MID =1-12  1     35.00
  8.      D3A      5080100    WIDEBAND FDM UNIT-MID =1  1     50.00
  9.      D3A      5080200    WIDEBAND FDM UNIT-MID =2  1     50.00
 10.      D3A      5130100    WIDEBND SIG CND UNIT MID  1       .60
 11.      D3A      5130200    WIDEBND SIG CND UNIT MID  1       .60
 12.      D3A      5160100    STRAIN GAGE SIG CND MID   1      5.60
 13.      D3A      5160200    STRAIN GAGE SIG CND MID   1      5.60
 14.      D3A      6050300 F  LOAD CNTLR ASSY-AFT =3    1     90.00
 15.      D3A      6070300    DC PWR CNTLR ASSY-AFT =3  1    160.00
 16.      D3A      7060000    MDM DFI - MID             1     40.00
 17.      D3A      7150300    ENG INTERFACE UNIT =3     1     50.60
 18.      D3A     16010200    RATE GYRO ASSY            1     42.00
 19.      D3A     16020200    MDM - SET 2               1     15.00
 20.      D3A     16040200    MDM DFI =2                1     35.00
 21.      D3A     16050200    PIC IGNITION - SET 2      1       .00
 22.      D3A     16060200    PIC SEPARATION-SET 2      1       .00
 23.      D3A     16070200    SIG COND - SET 2          1     20.00
 24.      D3A     20020300 RP MAIN ENG HTR =3           1    300.00

                                                          LOAD331

  1.      D3A     20050000 F  LO2 F+D VLV =1(O/B) SOL   1     42.00
  2.      D3A     20090000 F  LH2 TOPPING VLV OPEN SOL  1     42.00
  3.      D3A     20100300 F  LH2 RECRC VLV OPEN SOL=3  1     42.00
  4.      D3A     20140000 F  LO2 FEEDLN RELF SHUTOFF   1     42.00
  5.      D3A     20190200 F  LH2 FEEDLN REPRESS VLV=2  1     42.00
  6.      D3A     20200300 F  HE CROSSOVER VLV =3       1     42.00
  7.      D3A     20210300 F  ENG HE SUPPLY ISO SOL =3  1     42.00
  8.      D3A     20240300 F  LO2 PRESSIN FL CNTL SV3   1     42.00
  9.      D3A     20250300 F  LH2 PRESSIN FL CNTL SV3   1     42.00
 10.      D3A     21020300 F  HE ISOL VLVS-SET 3        1     24.00
 11.      D3A     21030300 F  VAPOR ISOL VLVS-SET 3     1     24.00
 12.      D3A     21030400 F  VAPOR ISOL VLVS-SET 4     1     24.00
 13.      D3A     21090300 RP ENG GIMBAL ACTUATOR =3    1    134.50
 14.      D3A     21090400 RP ENG GIMBAL ACTUATOR =4    1    134.50
 15.      D3A     21130300 F  CROSSFEED VLVS-SET 3      1     32.00
 16.      D3A     22110000 F  PROP MANIF ISOL VLV -AFT  1     84.00
 17.      D3A     50020300 F  MAIN LDG GEAR UPLK VL =3  1     20.00
 18.      D3A     50020400 F  MAIN LDG GEAR UPLK VL =4  1     20.00
 19.      D3A     50030200 F  LDG GEAR DUMP VLV =2      1     20.00
 20.      D3A     50030300 F  LDG GEAR DUMP VLV =3      1     20.00
 21.      D3A     50060300 F  MAIN PUMP =3 DEPRES VLV   1     26.00
 22.      D3A     50070300 RC CICR MOTOR PUMP =3        1   1561.00
 23.      D3A     50090300 F  SSME =3 SYS S/O VALVE     1     20.00
 24.      D3A     50120300    H2O BOILER =3 XFER VLV    1     50.00
 25.      D3A     50150300 RP H2O BOILER =3 HEATER      1    100.00
                                                          LOAD361

  1.      D3L      1030300    STAR TRKER + LT SHLD =3   1     20.00
  2.      D3L      1040300    AIR DATA XDCR ASSY =3     1     45.00
  3.      D3L      3010300    ATTITUDE DIR IND-AFT =3   1     14.60
  4.      D3L      3130000    SURF POSITION IND         1      5.00
  5.      D3L      3180200    EVENT TIMER =2            1      4.00
  6.      D3L      3190400    CRT DISPLAY UNIT =4       1     90.00
  7.      D3L      3210400    DISPLAY ELECT UNIT =4     1    207.30
  8.      D3L      4050300    SIG COND UNIT-FWD =3      1     35.00
  9.      D3L      7040400 RP MDM FA4                   1     40.00
 10.      D3L      7100200    MDM OFI 2                 1     40.00
 11.      D3L      7100300    MDM OFI 3                 1     40.00
 12.      D3L      7100400    MDM OFI 4                 1     40.00
```

TABLE 7.1-4

LISTING OF LOAD ELEMENT BUS ASSIGNMENTS, AS PROCESSED FROM LEC CARD DATA (APPENDIX 7.2)

```
@XQT

*************************     BUS ID   A3        *************************
  2521100    2521200

*************************     BUS ID   D2F       *************************
 22210000

*************************     BUS ID   D3F       *************************
 22210000

*************************     BUS ID  A          *************************
  2180000    3330100    3330200    3330300   20320000   31010100   31010200
 31010300   31010400   40080000   40110100   40110200   40140000   40160000
 40170000   40320100   40320200   50080100   50080200   50080300   50160100
 50160200   50160300   51020000   51030000   51050000   51060100   51060200
 51070100   51070200   51080000   51090000   51100000   51110000   51120100
 51120200   51150000   51160000   51170000   51180000   52040000   52050000
 52060000   52070000   52080000   52100000   52160000   52170000   52180000
 52200000   52320000   52330000   52340000   52350000

*************************     BUS ID  A   3A     *************************
  2511000   40010200   40010300   40020200   40050100   40050200   40050300
 40050400   40050500   40050600   40060200   40060300   40090200   40090300
 40290100   40290110   40290120   40290200   40290210   40290220

*************************     BUS ID  A   3B     *************************
  2511000   40010200   40010300   40020200   40050100   40050200   40050300
 40050400   40050500   40050600   40060200   40060300   40090200   40090300
 40290100   40290110   40290120   40290200   40290210   40290220

*************************     BUS ID  A   3C     *************************
  2511000   40010200   40010300   40020200   40050100   40050200   40050300
 40050400   40050500   40050600   40060200   40060300   40090200   40090300
 40290100   40290110   40290120   40290200   40290210   40290220
```

TABLE 7.1-4 (Continued) LISTING OF LOAD ELEMENT BUS ASSIGNMENTS, AS PROCESSED FROM LEC CARD DATA (APPENDIX 7.2)

```
10/30/74  13:09:31 100748 000155074     000155            S29   50
************************    BUS ID A1         ************************
 50110100  50140100

************************    BUS ID A1 3A      ************************
  2501000  20010100  30050100  40010100  40020100  40020300  40060100
 40090100

************************    BUS ID A1 3A      ************************
 20010200

************************    BUS ID A1 3A      ************************
 20010300

************************    BUS ID A1 3B      ************************
  2501000  30050100  40010100  40020100  40020300  40060100  40090100

************************    BUS ID A1 3C      ************************
  2170100   2501000  30050100  40010100  40020100  40020300  40060100
 40090100

************************    BUS ID A2         ************************
 50110200  50140200

************************    BUS ID A2 3A      ************************
  3310100   3310200   3310300   3310400  30050200

************************    BUS ID A2 3B      ************************
 30050200

************************    BUS ID A2 3C      ************************
  2170200  30050200

************************    BUS ID A3         ************************
  2531100   2531200  50110300  50130100  50130200  50130300  50140300
```

TABLE 7.1-4 LISTING OF LOAD ELEMENT BUS ASSIGNMENTS, AS PROCESSED FROM
(Continued) LEC CARD DATA (APPENDIX 7.2)

```
10/30/74  14:09:31 10074B 000155074    000155            S29    50
*************************      BUS ID A3 3A      *************************
  3310100    3310200    3310300    3310400  30050300

*************************      BUS ID A3 3B      *************************
 30050300

*************************      BUS ID A3 3C      *************************
  2170300   30050300

*************************      BUS ID D          *************************
  2140000    2150000    2210100    2210200    3550000    3560000    3560010
  6190100    6190200    6190300    7160100    7160110    7160200    7160210
  9010000    9020000   16080000   16090000   21190000   21200100   21200200
 21210000   21220000   21230100   21230200   32120100   32120200   32120300
 40210000   40340100   40340200   40350100   40350200   50050100   50050200
 50240100   50240200   50240300   50250100   50250200   50250300   50250400
 50250500   50250600   50260100   50260200   50260300   51140000

*************************      BUS ID D G        *************************
  7120000    7130000

*************************      BUS ID D1         *************************
  4150000

*************************      BUS ID D1A        *************************
  1080100    1080300    1090100    1090300    1090400    1120100    1120200
  1130100    4060100    4120100    6030100    6050100    6070100    7110100
  7110300    7150100    7150300   15010000   20020100   20030100   20030200
 20030300   20040100   20040200   20040300   20060000   20070100   20070200
 20080100   20080200   20100100   20110100   20110200   20120100   20120200
 20130100   20130200   20160000   20170000   20180100   20200100   20210100
 20220100   20220200   20230100   20240100   20250100   20270100   20270200
 20270300   20280000   20290000   21010100   21010200   21010300   21010400
 21020100   21030100   21050100   21050200   21050300   21050400   21060100
 21070100   21090100   21100000   21130100   21140100   22010000   22020000
 22040000   22080000   22090000   22120000   22140000   22150000   22180000
 32020100   32020200   32020300   32030100   32030200   32030300   32050100
 32050200   32050300   32070100   32070200   32070300   32080100   32080200
 32080300   32090100   32090200   32090300   32100100   32100200   32100300
 32110100   32110200   32110300   40030000   40030010   40030020   50010000
 50020100   50030100   50040000   50060100   50070100   50090100   50100100
 50100200   50100300   50100400   50120100   50150100   52010000   52020000
```

TABLE 7.1-4 (Continued)	LISTING OF LOAD ELEMENT BUS ASSIGNMENTS, AS PROCESSED FROM LEC CARD DATA (APPENDIX 7.2)

```
10/30/74  14:09:31  100738 000155074     000155            S29    50

*************************     BUS ID D1E        *************************

  4000000    4090010    6040200    6040300

*************************     BUS ID D1F        *************************

  1010100    1010110    1010300    1010310    1110100    3150000    4030100
  4030200    4130000    6010100    6020100    6060100    6100100    7010100
  7010200    7010300    7010400    7010500    7030100    7030300   22030000
 22060000   22070000   22130000   22170000   22210000   30030100   30030200
 40070100   40070200   40070300   40100100   40120100   40270100   40270200
 40280100   40280200   40310100   40330100   52270000   52300000

*************************     BUS ID D1G        *************************

 30080100   50170000   50180100   50180200   50190000   50200100   50200200
 50200300   50220100   50220200   50220300

*************************     BUS ID D1L        *************************

  1030100    1040100    1040400    2110100    3010100    3030100    3040100
  3050100    3060000    3120000    3140000    3170100    3180100    3190100
  3210100    3220100    3220300    4030000    4050100    4050300    7040100
  7040200    7090100    7090110    7100100    7100300    7100400   22190000
 22200000   40040100   40140000   40180000   52260000

*************************     BUS ID D1M        *************************

  6080100    6120100   30010100   30020100   30070100   30150100   30170100
 31060000   31060010   31070000   31070010   31120100   31130100   31130200
 31150100   31150400   51010000

*************************     BUS ID D1R        *************************

  1140100    1160100    1170100    1170200    1180100    1190100    2010100
  2040100    2050100    2060100    2070000    2100100    2120000    2200100
  2200110    2200200    2200210    2200300    2200310    2280100    2280200
  2280300    2280400    2330100    2340100    2350000    2420100    2420200
  2420300    2470100    2500000    2510000    3350100    3350200    3350300
  3350400    3350500    3360000    3390000    3410000    3450100    3450200
  3510000    3540000    4070000   22220000   22230000   30040100   31020000
 31030100   31040100   31040200   31040300   31040400   31050100   31050200
 31050300   31050400   40200100   40200200   40200300   40200400   40300100

*************************     BUS ID D16        *************************

  4110000

*************************     BUS ID D2         *************************
```

TABLE 7.1-4 (Continued) LISTING OF LOAD ELEMENT BUS ASSIGNMENTS, AS PROCESSED FROM LEC CARD DATA (APPENDIX 7.2)

```
10/3 /7/  10109151 100785 600150070     000155           529    50
  4150000

*************************     BUS TO D2A       *************************

   1080100    1080200    1090100    1090200    1120100    1130200    4060100
   4060200    4060300    4120100    4120200    6030100    6030200    6050200
   6070200    7110100    7110200    7150100    7150200   16010100   16020100
  16040100   16050100   16060100   16070100   20020200   20030100   20030200
  20030300   20040100   20040200   20040300   20060000   20070100   20070200
  20100200   20110100   20110200   20120100   20120200   20130100   20130200
  20150000   20180200   20190100   20200200   20210200   20220100   20230200
  20240200   20250200   20270100   20270210   20270300   20240000   20260000
  21020200   21030200   21060200   21070200   21090200   21130200   21140200
  21150100   21150200   21160300   21170000   22010000   22020000   22040000
  22080000   22090000   22140000   22150000   22160000   22180000   32020100
  32020200   32020300   32030100   32030200   32030300   32050100   32050200
  32050300   32070100   32070200   32070300   32080100   32080200   32080300
  32090100   32090200   32090300   32100100   32100200   32100300   32110100
  32110200   32110300   50020200   50060200   50070200   50090200   50100100
  50100200   50100300   50110200   50120210   50150200

*************************     BUS TO D2E       *************************

   6040100    6040300

*************************     BUS TO D2F       *************************

   1010100    1010110    1010200    1010210    1110100    1110200    3150000
   4030100    4030200    4130000    4140000    6010200    6020100    6020200
   6060200    6100200    7010100    7010200    7010300    7010400    7010500
   7030100    7030200    7030400   22030000   22060000   22070000   22170000
  40120200   40270100   40270200   40280100   40280200   40310200   52270000

*************************     BUS TO D2G       *************************

  30180200

*************************     BUS TO D2L       *************************

   1030200    1040200    3010200    3030200    3040200    3050200    3140000
   3170200    3190200    3190300    3210200    3210300    3220100    3220200
   4050100    4050200    7040300    7090200    7090210    7100100    7100200
  22190000   22200000   40040200   40110100   40111200   40130000   40190000

*************************     BUS TO D2M       *************************

   6050200    6120200   30010200   30020200   30060100   30060200   30070200
  30150200   30170200   31060000   31060010   31070000   31070010   31120200
  31150200   31170100   31180100
```

TABLE 7.1-4 (Continued)   LISTING OF LOAD ELEMENT BUS ASSIGNMENTS, AS PROCESSED FROM LEC CARD DATA (APPENDIX 7.2)

```
10/30/74  14100131  100748  00100570     000155          S20    50

**************************     BUS ID D2C      **************************

  1140200    1160200    1170300    1180200    1190200    2010200    2020000
  2030000    2040200    2050200    2060200    2070000    2080100    2100200
  2110200    2120000    2130100    2130200    2160000    2200100    2200110
  2200200    2200210    2200300    2200310    2280100    2280200    2280300
  2280400    2300100    2310100    2330200    2340200    2340100    2400100
  2470200    3350100    3350200    3350300    3350400    3350500    3360000
  3380100    3850100    3850200   22220000   22230000   30040200   31020000
 31030200   31040100   31040200   31040300   31040400   31050100   31050200
 31050300   31050400   40200100   40200200   40200300   40200400   40300200

**************************     BUS ID D3       **************************

  4150000

**************************     BUS ID D3A      **************************

  1030200    1080300    1090200    1090300    1090400    1120200    1130300
  4050200    4060300    4120200    4960000    5080100    5080200    5130100
  5130200    5160100    5160200    6030200    6050300    6070300    7060000
  7110200    7110300    7150200    7150300   16010000   16010200   16020200
 16040200   16050200   16060200   16070200   20020300   20030100   20030200
 20030300   20040100   20040200   20040300   20050000   20060000   20090000
 20100300   20140000   20100200   20210300   20210500   20220200   20240300
 20250300   20270100   20270200   20270300   20280000   20290000   21020300
 21030300   21030400   21040500   21090400   21130300   22010000   22020000
 22040000   22080000   22090000   22110000   22160000   22180000   32020100
 32020200   32020300   32030100   32030200   32030300   32050100   32050200
 32050300   32070100   32070200   32070300   32080100   32080200   32080300
 32090100   32090200   32090300   32100100   32100200   32100300   32110100
 32110200   32110300   50020300   50020400   50030200   50030300   50060300
 50070300   50090300   50100200   50100200   50100300   50100400   50120300
 50150300

**************************     BUS ID D3F      **************************

  6030200    1040010    6040010    2040200

**************************     BUS ID D3F      **************************

  1010200    1010210    1010300    1010310    1110200    3150000    4030100
  4030200    4120000    6010300    6020200    6040300    6100300    6160000
  6180000    7010100    7010200    7010300    7010400    7010500    7030200
  7030300    7030400   22030000   22040000   22070000   22100000   22170000
 30030100   30030200   40100200   40330200   52270000

**************************     BUS ID D3G      **************************

 30080300
```

TABLE 7.1-4 (Continued) LISTING OF LOAD ELEMENT BUS ASSIGNMENTS, AS PROCESSED FROM LEC CARD DATA (APPENDIX 7.2)

```
10/30/78  18109131  100704  00115507      000155           529   50
************************     BUS ID 03L        ************************

   1030300    1040300    3010300    3130400    3160200    3190400    3210400
   3220200    3220300    4050200    4050300    4110000    7040400    7100200
   7100300    7100400   22100000   22200000   40111100   40111200   40141000
  40130000   40190000

************************     BUS ID 03M        ************************

   6080300    6120300   30060310   30071300   30150300   30170300   31120300
  31130100   31130200   31150300   31170200   31170300   31180200   31180300

************************     BUS ID 03P        ************************

   3250000

************************     BUS ID 03R        ************************

   1140300    2080200    2160000    2200100    2200110    2200200    2200210
   2200300    2200310    2260100    2260200    2280300    2280400    2300200
   2310200    2350000    2390200    2410200    2420400    2480000    2490000
   2520100    2520200    2530100    2530200    2540000    3350100    3350200
   3350300    3350400    3350500    3360000    3380000    3390000    3410000
   3420100    3420200    3420300    3420400    3420500    3420600    3430000
   3450100    3450200    3490000    3500100    5030100    5030200    5040000
   5050100    5050200    5050300    5050400    5070000    5090000    5120000
   5150100    5180000    7050000   30040300   31020000   31030300   31030400
  40200100   40200200   40200300   40200400

************************     BUS ID 03W        ************************

   8010100    8010200    8020000    8030000    8040000    8040100    8050000
   8060000


OFT
```

APPENDIX 7.2

SEPAP DATA BASE (CARD IMAGE DATA AS FURNISHED BY LEC)

APPENDIX 7.2

SEPAP DATA BASE

Table 7.2-1 displays the images of card data supplied by LEC. The listed equipment items, reading across are bus identification, circuit protection device (if selected), EPDC or load element procurement specification number, and element identification number. The nomenclature will be defined in the following tables. The equipment list was obtained from the Electrical Equipment List dated July 23, 1974 with modifications based on the data in the latest Rockwell power profile analysis document dated June 26, 1974. The bus description nomenclature used the following format:

Character	Description
1st	POWER TYPE A = ac component D = dc component
2nd	MAIN BUS IDENTIFIERS 1 = Main dc bus A 2 = Main dc bus B 3 = Main dc bus C 4 = P/L Direct from F/C 3
3rd	SUB-BUS ASSIGNMENT F = Forward Local dc bus M = Midbody local dc bus A = Aft local dc bus E = Essential dc bus D = DFI dc bus L = LH D&C Panel R = RH D&C Panel O = OOS CB Panel P = P/L Specialist Panel S = Mission Specialist Station T = ALT Panel W = P/L Bus P = General (any other direct loads)

Character	Description
4th	LOAD CLASSIFICATION 1 = Direct to ground 2 = Return to ground 3 = Inverter or AC 4 = P/L
5th	AC PHASE DESCRIPTION A or B or C = 1 phase For 2Ø or 3Ø loads enter phase letters consecutively. (NOTE: This is different than Rockwell which requires entry of 2 or 3 BUS IDS).

For instance, BUS ID D1F2 represents the following information: The item (IMU) is a DC load, on main (DC) BUS A, in particular on forward local (DC) bus, with a single point (return wire) ground. Similarly, A2F3B indicates a load element the GSE from bypass control requiring a power, on main BUS B, forward local bus, inverter output.

The EPDC or load element nomenclature convention used in the listing of Table 7.2-1 reading from left-to-right is:

```
XX    XX    XX    X    X
|     |     |     |    |
|     |     |     |    |Used for header
|     |     |     |
|     |     |     |Mode, i.e., standby = 0, operate = 1 (CEC)
|     |     |
|     |     |Particular unit No., i.e., #1,2,3...
|     |
|     |Generic unit ID, i.e., master timing unit
|
| Subsystem, i.e., communications, G & N
```

Table 7.2-2 is a reproduction of a SEPAP topology definition obtained from a LEC memorandum to JSC [1].

TABLE 7.2-1 SHUTTLE BUS IDENTIFICATION CARD IMAGE DATA AS SUPPLIED BY LEC (R. MURDOCK)

						01000001
3.	D1F	D2F	RP	MC409=000416.3	A6	01010100
4.	D1F	D2F	RP	MC409=000416.3	A63	01010110
5.	D2F	D3F	RP	MC409=000416.3	A63	01010200
6.	D2F	D3F	RP	MC409=000416.3	A63	01010210
7.	D3F	D1F	RP	MC409=000416.3	A63	01010300
8.	D3F	D1F	RP	MC409=000416.3	A63	01010310
9.	D1L			MC431=012616.3	A63	01030100
10.	D2L			MC431=012816.3	A63	01030200
11.	D3L			MC431=012816.3	A63	01030300
12.	D1L			MC409=0011		01040100
13.	D2L			MC409=0011		01040200
14.	D3L			MC409=0011		01040300
15.	D1L			MC409=0011		01040400
16.						01070001
17.	D1A	D2A	0.92RP	MC621=004316	E6	01080100
18.	D2A	D3A	0.92RP	MC621=004316	E6	01080200
19.	D3A	D1A	0.92RP	MC621=004316	E6	01080300
20.	D1A	D2A	0.81RP	MC621=004316.2	B41	01090100
21.	D3A	D2A	0.81RP	MC621=004316.2	B41	01090200
22.	D1A	D3A	0.81RP	MC621=004316.2	B41	01090300
23.	D1A	D3A	0.81RP	MC621=004316.2	B41	01090400
24.	D1F	D2F	RP	MC621=004316.1	D14	01110100
25.	D2F	D3F	RP	MC621=004316.1	D14	01110200
26.	D1A	D2A	0.92RP	MC621=004316.1	C10	01120100
27.	D1A	D3A	0.92RP	MC621=004316.1	C10	01120200
28.	D1A		RP	MC493=0015		01130100
29.	D2A		RP	MC493=0015		01130200
30.	D3A		RP	MC493=0015		01130300
31.	D1R		RP	MC621=004316.3	A65	01140100
32.	D2R		RP	MC621=004316.3	A65	01140200
33.	D3R		RP	MC621=004316.3	A65	01140300
34.	D1R			MC621=0043		01160100
35.	D2R			MC621=0043		01160200
36.	D1R			MC621=0043		0117[illegible]
37.	D1R			MC621=0043		0117[illegible]
38.	D2R			MC621=0043		01170[illegible]
39.	D1R			MC621=0043		01180100
40.	D2R			MC621=0043		01180200
41.	D1R			MC621=0043		01190100
42.	D2R			MC621=0043		01190200
43.						02000001
44.	D1R			ICD 3-005017	F4	02010100
45.	D2R			ICD 3-005017	F4	02010200
46.	D2R			ICD 3-005017	E7	02020000
47.	D2R			ICD 3-005017	F5	02030000
48.	D1R			ICD 3-005017	F5	02040100
49.	D2R			ICD 3-005017	E5	02040200
50.	D1R			ICD 3-005017	E5	02050100
51.	D2R			ICD 3-005017	E5	02050200
52.	D1R			ICD 3-005017	F8	02060100
53.	D2R			ICD 3-005017	F8	02060200
54.	D2R	D1R		ICD 3-0050		02070000
55.	D2R			MC476=013717	D16	02080100
56.	D3R			MC476=013717	D16	02080200
57.	D1R			MC409=000517	9	02100100

TABLE 7.2-1 (Continued)

```
                                           BUSIO(1)                                DATE 110174
 58.        D2R                                                 MC409-000517    =9  021[illegible]0200
 59.        D1L                                                 MC478-01061[illegible]  [illegible]  02110100
 60.        D2R                                                 MC478-010618    [illegible]  02110200
 61.        D2R      D1R                                        MC478-010617    B21 0212[illegible]
 62.        D2R                                                 MC478-010617    D23 02130100
 63.        D2R                                                 MC478-010617    D23 02130200
 64.        D                                                   MC478-0106          02140000
 65.        D                                                   MC478-0106          02150000
 66.        D2R      D3R                                        MC476-010617    G21 02160000
 67.        A1  3C                                              MC409-001417.1  F14 02170100
 68.        A2  3C                                              MC409-001417.1  F14 02170200
 69.        A3  3C                                              MC409-001417.1  F14 02170300
 70.        A                                                   MC452-0132          02180000
 71.                                                                                02190001
 72.        D1R      D2R      D3R                               MC409-001717.1  F17 02200100
 73.        D1R      D2R      D3R                               MC409-001717.1  F17 02200110
 74.        D1R      D2R      D3R                               MC409-001717.1  F17 02200200
 75.        D1R      D2R      D3R                               MC409-001717.1  F17 02200210
 76.        D1R      D2R      D3R                               MC409-001717.1  F17 02200300
 77.        D1R      D2R      D3R                               MC409-001717.1  F17 02200310
 78.        D                                                   MC409-001517.1  G19 02210100
 79.        D                                                   MC409-001517.1  G19 02210200
 80.        D1R      D2R      D3R                               GFE-TBD     17  F17 02260100
 81.        D1R      D2R      D3R                               GFE-TBD     17  F17 02260200
 82.        D1R      D2R      D3R                               GFE-TBD     17  F17 02260300
 83.        D1R      D2R      D3R                               GFE-TBD             02260400
 84.        D2R                                                 MC478-010517    D20 02300100
 85.        D3R                                                 MC478-010517    D20 02300200
 86.        D2R                                                 MC476-013818    D17 02310100
 87.        D3R                                                 MC476-013818    D17 02310200
 88.        D1R                                                 ARC150-80117.1  E7  02330100
 89.        D2R                                                 ARC150-80117.1  E7  02330200
 90.        D1R                                                 ARC150-80117.1  E7  02340100
 91.        D2R                                                 ARC150-80117.1  E7  02340200
 92.        D1R      D3R                                        TBD                 02350000
 93.        D2R                                                 MC478-010617    D23 02390100
 94.        D3R                                                 MC478-010617    D23 02390200
 95.        D2R                                                 MC476-015117    F3  02400100
 96.        D3R                                                 MC476-015117    F3  02400200
 97.                                                                                02410001
 98.        D1R                                                 MC409-0005          02420100
 99.        D1R                                                 MC409-0005          02420200
100.        D1R                                                 MC409-0005          02420300
101.        D3R                                                 MC409-0005          02420400
102.        D1R                                                 MC409-0005          02470100
103.        D2R                                                 MC409-0005          02470200
104.        D3R                                                 MC478-0115          02480000
105.        D3R                                                 MC478-0016          02490000
106.        D1R                                                 MC409-0025          02500000
107.        A1  3A   A1  3B   A1  3C                            MC409-0025          02501000
108.        D1R                                                 MC409-0025          02510000
109.        A   3A   A   3B   A   3C                            MC409-0025          02511000
110.        D3R                                                 MC409-0025          02520100
111.        D3R                                                 MC409-0025          02520200
112.          A3                                                MC409-0025          02521100
113.          A3                                                MC409-0025          02521200
114.        D3R                                                 MC409-0025          02530100
```

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

TABLE 7.2-1 (Continued)

```
                                           BUSID(1)                                  DATE 110174

115.     D3R                                                  MC409-0025                 02530200
116.     A3                                                   MC409-0025                 02531100
117.     A3                                                   MC409-0025                 02531200
118.     D3R                                                  MC409-0025                 02540000
119.                                                                                     03000001
120.     D1L                                                  MC432-023516.3  C74        03010100
121.     D2L                                                  MC432-023516.3  C74        03010200
122.     D3L                                                  MC432-0235                 03010300
123.     D1L                                                  MC432-021816.3  B74        03030100
124.     D2L                                                  MC432-021816.3  B74        03030200
125.     D1L                                                  MC432-022416.3  B74        03040100
126.     D2L                                                  MC432-022416.3  B74        03040200
127.     D1L                                                  MC432-00207     H12        03050100
128.     D2L                                                  MC432-00207     H12        03050200
129.     D1L                                                  MC432-0232                 03060000
130.     D1L                                                  MC432-0233                 03120000
131.     D3L                                                  MC432-02217     E6         03130000
132.     D1L     D2L                                          MC432-02297     C13        03140000
133.     D1F     D2F     D3F                                  MC409-00127     B17        03150000
134.     D1L                                                  MC456-005418.2  F5         03170100
135.     D2L                                                  MC456-005418.2  F5         03170200
136.     D1L                                                  MC456-00537     C22        03180100
137.     D3L                                                  MC456-00537     C22        03180200
138.     D1L                                                  MC615-000616.3  H74        03190100
139.     D2L                                                  MC615-000616.3  H74        03190200
140.     D2L                                                  MC615-000616.3  H74        03190300
141.     D3L                                                  MC615-000616.3  H74        03190400
142.     D1L                                                  MC615-00087     G7         03210100
143.     D2L                                                  MC615-00087     G7         03210200
144.     D2L                                                  MC615-00087     G7         03210300
145.     D3L                                                  MC615-00087     G7         03210400
146.     D1L     D2L                                          MC409-0023                 03220100
147.     D2L     D3L                                          MC409-0023                 03220200
148.     D1L     D3L                                          MC409-0023                 03220300
149.     D3R                                                  TBD                        03250000
150.                                                                                     03300001
151.     A2  3A  A3  3A                                       MC434-0072                 03310100
152.     A2  3A  A3  3A                                       MC434-0072                 03310200
153.     A2  3A  A3  3A                                       MC434-0072                 03310300
154.     A2  3A  A3  3A                                       MC434-0072                 03310400
155.     A                                                    MC434-0070                 03330100
156.     A                                                    MC434-0070                 03330200
157.     A                                                    MC434-0070                 03330300
158.     D2R     D1R     D3R                                  MC434-0068                 03350100
159.     D2R     D1R     D3R                                  MC434-0068                 03350200
160.     D2R     D1R     D3R                                  MC434-0068                 03350300
161.     D2R     D1R     D3R                                  MC434-0068                 03350400
162.     D2R     D1R     D3R                                  MC434-0068                 03350500
163.     D2R     D1R     D3R                                  MC434-0068                 03360000
164.     D2R     D3R                                          MC434-0068                 03380000
165.     D1R     D3R                                          TBD                        03390000
1 6.     D1R     D3R                                          MC434-0077                 03410000
167.     D3R                                                  MC434-0068                 03420100
168.     D3R                                                  MC434-0068                 03420200
169.     D3R                                                  MC434-0068                 03420300
170.     D3R                                                  MC434-0068                 03420400
171.     D3R                                                  MC434-0068                 03420500
```

TABLE 7.2-1 (Continued)

```
                                                BUSIC(1)                                  DATE 110174

172.      D3R                                                     MC434-0066          03420600
173.      D3R                                                     MC434-0065          03430000
174.      D2R    D1R    D3R                                       MC434-0066          03450100
175.      D2R    D1R    D3R                                       MC434-0065          03450200
176.      D3R                                                     MC434-0066          03490000
177.      D3R                                                     MC434-0065          03500000
178.      D1R                                                     MC434-0065          03510000
179.                                                                                  03520001
180.      D1R                                                     MC434-0065          03540000
181.      D                                                       MC409-0012          03550000
182.      D                                                       MC434-0069          03560000
183.      D                                                       MC434-0069          03560010
184.                                                                                  04000001
185.      D1F    D2F    D3F         RP                            MC476-01301H.1      04030100
186.      D1F    D2F    D3F         RP                            MC476-0130          04030200
187.      D1L                                                     ICD 3-002118.1  F8  04040000
188.      D1L    D2L                                              MC476-013118.1  C1204050100
189.      D2L    D3L                                              MC476-013118.1  C1204050200
190.      D3L    D1L                                              MC476-013118.1  C1204050300
191.      D1A    D2A                RP                            MC476-013118.1  C1504060100
192.      D3A    D2A                RP                            MC476-013118.1  C1504060200
193.      D3A    D2A                RP                            MC476-013118.1  C1504060300
194.      D1R                                                     ICD 3-002118.1  E6  04070000
195.      D1E    D3E                                              MC409-005118.1  D4  04090000 ←
196.      D1E    D3E                                              MC409-005118.1  D4  04090010
197.      D1A    D3L                                              MC476-013617    F4  04110000
198.      D1A    D2A                RP                            MC476-0131          04120100
199.      D3A    D2A                RP                            MC476-0131          04120200
200.      D2F    D1F                                              MC476-0131          04130000 ←
201.      D2F    D3F                                              MC476-0131          04140000
202.      D1     D2     D3                                        TBD                 04150000
203.                                                                                  05000001
204.      D3R                                                     MC476-0130          05030100
205.      D3R                                                     MC476-0130          05030200
206.      D3R                                                     GFE-MCR61518    G6  05040000
207.      D3R                                                     MC476-0131          05050100
208.      D3R                                                     MC476-0131          05050200
209.      D3R                                                     MC476-0131          05050300
210.      D3R                                                     MC476-0131          05050400
211.      D3A                                                     MC476-0131          05060000
212.      D3R                                                     MC409-001018    D8  05070000
213.      D3A                                                     MC409-0010          05080100
214.      D3A                                                     MC409-0010          05080200
215.      D3R                                                     ICD 3-002118    G1205090000
216.      D3R                                                     MC476-0132          05120000
217.      D3A                                                     MC476-0132          05130100
218.      D3A                                                     MC476-0132          05130200
219.      D3R                                                     MC476-0134          05150000
220.      D3A                                                     MC476-0134          05160100
221.      D3A                                                     MC476-0134          05160200
222.      D3R                                                     TBD                 05180000
223.                                                                                  06000001
224.      D1F                       RC                            MC495-00129.0   C5  06010100
225.      D2F                       RC                            MC495-00129.0   C5  06010200
226.      D3F                       RC                            MC495-00129.0   C5  06010300
227.      D1F    D2F                RP                            MC450-00408.9   E8  06020100
228.      D2F    D3F                RP                            MC450-00408.9   E8  06020200
```

TABLE 7.2-1 (Continued)

```
                                                  B U S I D ( 1 )              DATE 110174
229.      D1A   D2A             RP    MC450-0010            06030100
230.      D2A   D3A             RP    MC450-0010            06030200
231.      D2F   D3F             F     MC450-XXXX            06040100
232.      D1E   D3E             F     MC450-XXXX            06040200
233.      D1E   D2E             F     MC450-XXXX            06040300
234.      D1A                   F     MC450-XXXX            06050100
235.      D2A                   F     MC450-XXXX            06050200
236.      D3A                   F     MC450-XXXX            06050300
237.      D1F                   RC    V070-76325            06060100
238.      D2F                   RC    V070-76327            06060200
239.      D3F                   RC    V070-76329            06060300
240.      D1A                         V070-765209.2      G5 06070100
241.      D2A                         V070-765229.2      G5 06070200
242.      D3A                         V070-765249.2      G5 06070300
243.      D1M                   RP    V070-764209.0      H6 06080100
244.      D2M                   RP    V070-764229.0      H  06080200
245.      D3M                   RP    V070-764239.0      H6 06080300
246.      D1F                         V070-763389.1      G6 06100100
247.      D2F                         V070-763389.1      G6 06100200
248.      D3F                         V070-763389.1      G6 06100300
249.                                                        06110001
250.      D1M                         V070-76432            06120100
251.      D2M                         V070-76432            06120200
252.      D3M                         V070-76432            06120300
253.      D3F                         TBD       9.0      C5 06160000
254.      D3F                         TBD                   06180000
255.      D                           TBD                   06190100
256.      D                           TBD                   06190200
257.      D                           TBD                   06190300
258.                                                        07000001
259.      D1F   D2F   D3F       RP    MC615-0001            07010100
260.      D1F   D2F   D3F       RP    MC615-0001            07010200
261.      D1F   D2F   D3F       RP    MC615-0001            07010300
262.      D1F   D2F   D3F       RP    MC615-0001            07010400
263.      D1F   D2F   D3F       RP    MC615-0001            07010500
264.      D1F   D2F             RP    MC615-0004            07030100
265.      D2F   D3F             RP    MC615-0004            07030200
266.      D3F   D1F             RP    MC615-0004            07030300
267.      D2F   D3F             RP    MC615-0004            07030400
268.      D1L                   RP    MC615-0004            07040100
269.      D1L                   RP    MC615-0004            07040200
270.      D2L                   RP    MC615-0004            07040300
271.      D3L                   RP    MC615-0004            07040400
272.      D3R                         MC615-0004            07050000
273.      D3A                         MC615-0004            07060000
274.      D1L                         MC615-000516.3    G7907090100
275.      D1L                         MC615-000516.3    G7907090110
276.      D2L                         MC615-000516.3    G7907090200
277.      D2L                         MC615-000516.3    G7907090210
278.      D1L   D2L                   MC615-0004            07100100
279.      D3L   D2L                   MC615-0004            07100200
280.      D3L   D1L                   MC615-0004            07100300
281.      D3L   D1L                   MC615-0004            07100400
282.      D1A   D2A                   MC615-0004            07110100
283.      D2A   D3A                   MC615-0004            07110200
284.      D1A   D3A                   MC615-0004            07110300
285.      D G                         MC615-0004            07120000
```

TABLE 7.2-1 (Continued)

```
                                                 B U S I D ( 1 )                                DATE 110174
286.        D G                                                      MC615-0004            07130000
287.                                                                                       07140001
288.        D1A    D2A                                               MC409-0009            07150100
289.        D2A    D3A                                               MC409-0019            07150200
290.        D3A    D1A                                               MC409-0009            07150300
291.        D                                                        MC409-0019            07160100
292.        D                                                        MC409-0019            07160110
293.        D                                                        MC409-0019            07160200
294.        D                                                        MC409-0019            07160210
295.                                                                                       08000001
296.        D3W                                                      MC615-0004            08010100
297.        D3W                                                      MC615-0004            08010200
298.        D3W                                                                            08020000
299.        D3W                                                                            08030000
300.        D3W                                                                            08040000
301.        D3W                                                                            08040100
302.        D3W                                                                            08050000
303.        D3W                                                                            08060000
304.                                                                                       09000001
305.        D                                                        MC450-0023            09010000
306.        D                                                                              09020000
307.                                                                                       15000001
308.        D1A    D3A            RP                                                       15010000
309.                                                                                       16000001
310.        D2A                                                                            16010100
311.        D3A                                                                            16010200
312.        D2A                                                                            16020100
313.        D3A                                                                            16020200
314.        D2A                                                                            16040100
315.        D3A                                                                            16040200
316.        D2A                                                                            16050100
317.        D3A                                                                            16050200
318.        D2A                                                                            16060100
319.        D3A                                                                            16060200
320.        D2A                                                                            16070100
321.        D3A                                                                            16070200
322.        D                                                                              16080000
323.        D                                                                              16090000
324.                                                                                       20000001
325.        A1 3A                                                    ICD13M150012     C5   20010100
326.        A1 3AB                                                   ICD13M150012     C5   20010200
327.        A1 3AC                                                   ICD13M150012     C5   20010300
328.        D1A                   RP                                 ICD13M1500            20020100
329.        D2A                   RP                                 ICD13M1500            20020200
330.        D3A                   RP                                 ICD13M1500            20020300
331.        D1A    D2A    D3A     RP                                 MC284-0404            20030100
332.        D1A    D2A    D3A     RP                                 MC284-0404            20030200
333.        D1A    D2A    D3A     RP                                 MC284-0404            20030300
334.        D1A    D2A    D3A     RP                                 MC284-0404            20040100
335.        D1A    D2A    D3A     RP                                 MC284-0404            20040200
336.        D1A    D2A    D3A     RR                                 MC284-0404            20040300
337.        D3A                   F                                  MC284-0404            20050000
338.        D1A    D2A    D3A     F                                  MC284-0404            20060000
339.        D1A    D2A            RP                                 MC284-0404            20070100
340.        D1A    D2A            RP                                 MC284-0404            20070200
341.        D1A                   F                                  MC284-0404            20080100
342.        D1A                   F                                  MC284-0404            20080200
```

TABLE 7.2-1 (Continued)

MUSID(1)   DATE 110174

343.	D3A			F	MC284-0404		20090000
344.	D1A			F	MC284-0404		20100100
345.	D2A			F	MC284-0404		20100200
346.	D3A			F	MC284-0404		20100300
347.	D1A	D2A		RP	MC284-0404		20110100
348.	D1A	D2A		RP	MC284-0404		20110200
349.	D1A	D2A		RP	MC284-0404		20120100
350.	D1A	D2A		RP	MC284-0404		20120200
351.	D1A	D2A		F	MC284-0404		20130100
352.	D1A	D2A		F	MC284-0404		20130200
353.	D3A			F	MC284-0404		20140000
354.	D2A			F	MC284-0404		20150000
355.							20150901
356.	D1A				MC284-0403		20160000
357.	D1A			F	MC284-0403		20170000
358.	D1A			F	MC284-0403		20180100
359.	D2A			F	MC284-0403		20180200
360.	D2A			F	MC284-0403		20190100
361.	D3A			F	MC284-0403		20190200
362.	D1A			F	MC284-0403		20200100
363.	D2A			F	MC284-0403		20200200
364.	D3A			F	MC284-0403		20200300
365.	D1A			F	MC284-0403		20210100
366.	D2A			F	MC284-0403		20210200
367.	D3A			F	MC284-0403		20210300
368.	D1A	D2A		RP	MC284-0403		20220100
369.	D1A	D3A		RP	MC284-0403		20220200
370.	D1A			F	MC284-0403		20230100
371.	D2A			F	MC284-0403		20230200
372.	D1A			F	MC280-0017		20240100
373.	D2A			F	MC280-0017		20240200
374.	D3A			F	MC280-0017		20240300
375.	D1A			F	MC280-0017		20250100
376.	D2A			F	MC280-0017		20250200
377.	D3A			F	MC280-0017		20250300
378.	D1A	D2A	D3A		MC476-0148		20270100
379.	D1A	D2A	D3A		MC476-0148		20270200
380.	D1A	D2A	D3A		MC476-0148		20270300
381.	D1A	D2A	D3A		MC432-0205		20280000
382.	D1A	D2A	D3A		MC432-0205		20290000
383.	A				MC449-0164		20320000
384.							21000001
385.	D1A			F	MC621-000913.1		21010100
386.	D1A			F	MC621-000913.1		21010200
387.	D1A			F	MC621-000913.1		21010300
388.	D1A			F	MC621-000913.1		21010400
389.	D1A			F	MC621-005913	F3	21020100
390.	D2A			F	MC621-005913	F3	21020200
391.	D3A			F	MC621-005913	F3	21020300
392.	D1A			F	MC621-005913	G4	21030100
393.	D2A			F	MC621-005913	G4	21030200
394.	D3A			F	MC621-005913	G4	21030300
395.	D3A			F	MC621-005913	G4	21030400
396.	D1A				MC621-005913.1	C22	21050100
397.	D1A				MC621-005913.1	C22	21050200
398.	D1A				MC621-005913.1	C22	21050300
399.	D1A				MC621-005913.1	C22	21050400

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

TABLE 7.2-1 (Continued)

```
                                                    BUSID(1)                             DATE 110174

400.      D1A                      F                             MC621-0059              21060100
401.      D2A                      F                             MC621-0059              21060200
402.      D1A                      F                             MC621-0059              21070100
403.      D2A                      F                             MC621-0059              21070200
404.      D1A                      RP                            MC621-000913      FB    21090100
405.      D2A                      RP                            MC621-000913      FB    21090200
406.      D3A                      RP                            MC621-000913      FB    21090300
407.      D3A                      RP                            MC621-000913            21090400
408.      D1A                                                    MC284-043013.1    F4    21100000
409.      D1A                      F                             MC284-0430              21130100
410.      D2A                      F                             MC284-0430              21130200
411.      D3A                      F                             MC284-0430              21130300
412.      D1A                      RP                            MC621-005913      B5    21140100
413.      D2A                      RP                            MC621-005913      B5    21140200
414.                                                                                     21140901
415.      D2A                                                    MC621-0059              21150100
416.      D2A                                                    MC621-0059              21150200
417.      D2A                      RP                            MC621-0059              21160000
418.      D2A                                                    MC284-0430              21180000
419.      D                                                      TBD                     21190000
420.      D                                                      MC621-0009              21200100
421.      D                                                      MC621-0009              21200200
422.      D                                                      MC284-0430              21210000
423.      D                                                      MC284-0430              21220000
424.      D                                                      MC621-0059              21230100
425.      D                                                      MC621-0059              21230200
426.                                                                                     22000001
427.      D1A    D2A    D3A                                      MC467-0028              22010000
428.      D1A    D2A    D3A                                      MC467-0028              22020000
429.      D1F    D2F    D3F                                      MC467-0029              22030000
430.      D2A    D1A    D3A                                      MC467-0029              22040000
431.      D1F    D2F    D3F                                      MC284-041914            22060000
432.      D1F    D2F    D3F                                      MC284-0420              22070000
433.      D1A    D2A    D3A        F                             MC284-041914            22080000
434.      D1A    D2A    D3A        F                             MC284-0420              22090000
435.      D3F                      F                             MC284-043014            22100000
436.      D3A                      F                             MC284-043014            22110000
437.      D1A                                                    MC284-0427              22120000
438.      D1F                                                    MC284-0430              22130000
439.      D1A    D2A                                             MC284-0430              22140000
440.      D1A    D2A               RP                            TBD                     22150000
441.      D2A    D3A               RP                            TBD                     22160000
442.      D1F    D2F    D3F                                      MC467-0028              22170000
443.      D1A    D2A    D3A                                      MC467-0028              22180000
444.      D1L    D2L    D3L                                      TBD                     22190000
445.      D1L    D2L    D3L                                      TBD                     22200000
446.      D1F     D2F    D3F                                     TBD                     22210000
447.      D1R    D2R                                             MC467-0029              22220000
448.      D1R    D2R                                             MC467-0029              22230000
449.                                                                                     30000001
450.      D1M                                                    MC363-0023              30010100
451.      D2M                                                    MC363-0023              30010200
452.      D1M                                                    MC363-0023              30020100
453.      D2M                                                    MC363-0023              30020200
454.      D1F    D3F                                             MC363-0023              30030100
455.      D1F    D3F                                             MC363-0023              30030200
456.      D1R                                                    MC464-0115              30040100
```

TABLE 7.2-1 (Continued)

457.	D2R				MC464-0115			30040200
458.	D3R				MC464-0115			30040300
459.	A1 3A	A1 3B	A1 3C		MC464-0115			30050100
460.	A2 3A	A2 3B	A2 3C		MC464-0115			30050200
461.	A3 3A	A3 3B	A3 3C		MC464-0115			30050300
462.	D2M			F	MC464-0115A			30060100
463.	D2M			F	MC464-0115A			30060200
464.	D3M			F	MC464-0115A			30060300
465.	D1M			F	MC464-0115B		F9	30070100
466.	D2M			F	MC464-0115B		F9	30070200
467.	D3M			F	MC464-0115B		F9	30070300
468.	D1G				MC464-0115			30080100
469.	D2G				MC464-0115			30080200
470.	D3G				MC464-0115			30080300
471.	D1M				MC363-0023			30150100
472.	D2M				MC363-0023			30150200
473.	D3M				MC363-0023			30150300
474.	D1M				MC464-0115			30170100
475.	D2M				MC464-0115			30170200
476.	D3M				MC464-0115			30170300
477.								31000001
478.	A				MC282-00638.5		C10	31010100
479.	A				MC282-00638.5		C10	31010200
480.	A				MC282-00638.5		C10	31010300
481.	A				MC282-00638.5		C10	31010400
482.	D1R	D2R	D3R		TBD	8.5	G17	31020000
483.	D1R				MC282-00638.5		F9	31030100
484.	D2R				MC282-00638.5		F9	31030200
485.	D3R				MC282-00638.5		F9	31030300
486.	D3R				MC282-00638.5		F9	31030400
487.	D1R	D2R			TBD			31040100
488.	D1R	D2R			TBD			31040200
489.	D1R	D2R			TBD			31040300
490.	D1R	D2R			TBD			31040400
491.	D1R	D2R						31050100
492.	D1R	D2R						31050200
493.	D1R	D2R						31050300
494.	D1R	D2R						31050400
495.	D1M	D2M						31060000
496.	D1M	D2M						31060010
497.	D1M	D2M				8.5	F1	31070000
498.	D1M	D2M						31070010
499.	D1M			F		8.5	D4	31120100
500.	D2M			F		8.5	D4	31120200
501.	D3M			F		8.5	D4	31120300
502.	D1M	D3M						31130100
503.	D1M	D3M						31130200
504.	D1M			F		8.5	D5	31150100
505.	D2M			F		8.5	D5	31150200
506.	D3M			F		8.5	D5	31150300
507.	D1M			F		8.5	D5	31150400
508.								31160001
509.	D2M			RC	MC282-00638.5		E17	31170100
510.	D3M			RC	MC282-00638.5		E17	31170200
511.	D3M			RC	MC282-00638.5		E17	31170300
512.	D2M			RP	MC282-006315		E9	31180100
513.	D3M			RP	MC282-006315		E9	31180200

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

TABLE 7.2-1 (Continued)

```
                                                 B U S I D ( 1 )                              DATE 110174
514.        D3M                      RP                                  MC282-006315   E9   31180300
515.                                                                                             32000001
516.        D1A    D2A    D3A        RP                                  MC284-0393          32020100
517.        D1A    D2A    D3A        RP                                  MC284-0393          32020200
518.        D1A    D2A    D3A        RP                                  MC284-0393          32020300
519.        D1A    D2A    D3A        RP                                  MC201-0001          32030100
520.        D1A    D2A    D3A        RP                                  MC201-0001          32030200
521.        D1A    D2A    D3A        RP                                  MC201-0001          32030300
522.        D1A    D2A    D3A        RP                                  MC363-0025          32050100
523.        D1A    D2A    D3A        RP                                  MC363-0025          32050200
524.        D1A    D2A    D3A        RP                                  MC363-0024          32050300
525.        D1A    D2A    D3A        F                                   MC363-0026          320701 0
526.        D1A    D2A    D3A        F                                   MC363-0026          32070200
527.        D1A    D2A    D3A        F                                   MC363-0026          32070300
528.        D1A    D2A    D3A        F                                   TBD                 32080100
529.        D1A    D2A    D3A        F                                   TBD                 32080200
530.        D1A    D2A    D3A        F                                   TBD                 32080300
531.        D1A    D2A    D3A        F                                   MC363-0027          32090100
532.        D1A    D2A    D3A        F                                   MC363-0027          32090200
533.        D1A    D2A    D3A        F                                   MC363-0027          32090300
534.        D1A    D2A    D3A        F                                   MC201-0001          32100100
535.        D1A    D2A    D3A        F                                   MC201-0001          32100200
536.        D1A    D2A    D3A        F                                   MC201-0001          32100300
537.        D1A    D2A    D3A        F                                   MC201-000115.1   C1232110100
538.        D1A    D2A    D3A        F                                   MC201-000115.1   C1232110200
539.        D1A    D2A    D3A        F                                   MC201-000115.1   C1232110300
540.        D                                                            TBD                 32120100
541.        D                                                            TBD                 32120200
542.        D                                                            TBD                 32120300
543.                                                                                             40000001
544.        A1 3B  A1 3C  A1 3A                                          MC621-0006          40010100
545.        A  3A  A  3B  A  3C                                          MC621-0008          40010200
546.        A  3A  A  3B  A  3C                                          MC621-0008          40010300
547.        A1 3A  A1 3B  A1 3C                                          MC621-0008          40020100
548.        A  3A  A  3B  A  3C                                          MC621-0008          40020200
549.        A1 3A  A1 3B  A1 3C                                          MC621-0008          40020300
550.        D1A                                                          MC250-0002          40030000
551.        D1A                                                          MC250-0002          40030010
552.        D1A                                                          MC250-0002          40030020
553.        D1L                                                          TBD                 40040100
554.        D2L                                                          TBD                 40040200
555.        A  3A  A  3B  A  3C                                          MC621-0006          40050100
556.        A  3A  A  3B  A  3C                                          MC621-0008          40050200
557.        A  3A  A  3B  A  3C                                          MC621-0008          40050300
558.        A  3A  A  3B  A  3C                                          MC621-0008          40050400
559.        A  3A  A  3B  A  3C                                          MC621-0008          40050500
560.        A  3A  A  3B  A  3C                                          MC621-0008          40050600
561.        A1 3A  A1 3B  A1 3C                                          MC621-0008          40060100
562.        A  3A  A  3B  A  3C                                          MC621-0008          40060200
563.        A  3A  A  3B  A  3C                                          MC621-0008          40060300
564.        D1F                      RP                                  MC621-0006          40070100
565.        D1F                      RP                                  MC621-0008          40070200
566.        D1F                      RP                                  MC621-0008          40070300
567.        A                                                            MC621-0008          40080000
568.        A1 3A  A1 3B  A1 3C                                          MC621-0008          40090100
569.        A  3B  A  3A  A  3C                                          MC621-0008          40090200
570.        A  3A  A  3B  A  3C                                          MC621-0008          40090300
```

TABLE 7.2-1 (Continued)

```
                                                     BUSID(1)                                   DATE 110174

571.          D1F                 RP                                     TBD-GFE         40100100
572.          D3F                 RP                                     TBD-GFE         40100200
573.                                                                                     40100901
574.          A                                                          TBD-GFE         40110100
575.          A                                                          TBD-GFE         40110200
576.          D2L    D3L                                                 TBD-GFE         40111100
577.          D2L    D3L                                                 TBD-GFE         40111200
578.          D1F                 RC                                     TBD-GFE         40120100
579.          D2F                 RC                                     TBD-GFE         40120200
580.          D2L                                                        TBD             40130000
581.          A                                                          MC250-0010      40140000
582.          D1L    D3L                                                 MC250-0010      40141000
583.          A                                                          MC282-0009      40160000
584.          A                                                          MC282-0009      40170000
585.          D1L    D3L                                                 TBD             40180000
586.          D2L    D3L                                                 MC282-0009      40190000
587.          D1R    D2R    D3R                                          MC431-0127      40200100
588.          D1R    D2R    D3R                                          MC431-0127      40200200
589.          D1R    D2R    D3R                                          MC431-0127      40200300
590.          D1R    D2R    D3R                                          MC431-0127      40200400
591.          D                                                          MC431-0127      40210000
592.          D1F    D2F                                                 MC250-0017      40270100
593.          D1F    D2F                                                 MC250-0017      40270200
594.          D1F    D2F                                                 MC250-0017      40280100
595.          D1F    D2F                                                 MC250-0017      40280200
596.          A  3A  A  3B  A  3C                                        MC250-0001      40290100
597.          A  3A  A  3B  A  3C                                        MC250-0001      40290110
598.          A  3A  A  3B  A  3C                                        MC250-0001      40290120
599.          A  3A  A  3B  A  3C                                        MC250-0001      40290200
600.          A  3A  A  3B  A  3C                                        MC250-0001      40290210
601.          A  3A  A  3B  A  3C                                        MC250-0001      40290220
602.          D1R                                                        MC203-0002      40300100
603.          D2R                                                        MC203-0002      40300200
604.                                                                                     40300901
605.          D1F                                                        MC250-0005      40310100
606.          D2F                                                        MC250-0005      40310200
607.          A                                                          MC250-0001      40320100
608.          A                                                          MC250-0001      40320200
609.          D1F                                                        MC250-0001      40330100
610.          D3F                                                        MC250-0001      40330200
611.          D                                                          TBD             40340100
612.          D                                                          TBD             40340200
613.          D                                                          MC250-0001      40350100
614.          D                                                          MC250-0001      40350200
615.                                                                                     50000001
616.          D1A                 F                                      MC621-0029      50010000
617.          D1A                 F                                      MC621-0029      50020100
618.          D2A                 F                                      MC621-0029      50020200
619.          D3A                 F                                      MC621-0029      50020300
620.          D3A                 F                                      MC621-0029      50020400
621.          D1A                 F                                      MC621-0046      50030100
622.          D3A                 F                                      MC621-0046      50030200
623.          D3A                 F                                      MC621-0046      50030300
624.          D1A                 F                                      MC621-0046      50040000
625.          D                   F                                      MC621-0046      50050100
626.          D                   F                                      MC621-0046      50050200
627.          D1A                 F                                      MC281-0029      50060100
```

TABLE 7.2-1 (Continued)

```
                                                        BUSID(1)                                          DATE 110174
628.        D2A                         F                                             MC281-0029        50060200
629.        D3A                         F                                             MC281-0029        50060300
630.        D1A                         RC                                            MC621-0016        50070100
631.        D2A                         RC                                            MC621-0016        50070200
632.        D3A                         RC                                            MC621-0016        50070300
633.        A                                                                         MC282-0062        50080100
634.        A                                                                         MC282-0062        50080200
635.        A                                                                         MC282-0062        50080300
636.        D1A                         F                                             MC621-0046        50090100
637.        D2A                         F                                             MC621-0046        50090200
638.        D3A                         F                                             MC621-0046        50090300
639.        D1A      D2A      D3A                                                     MC621-0014        50100100
640.        D1A      D2A      D3A                                                     MC621-0014        50100200
641.        D1A      D2A      D3A                                                     MC621-0014        50100300
642.        D1A      D2A      D3A                                                     MC621-0014        50100400
643.                                                                                                    50100901
644.        A1                          F                                             MC621-0022        50110100
645.        A2                          F                                             MC621-0022        50110200
646.        A3                          F                                             MC621-0022        50110300
647.        D1A                                                                       MC621-0022        50120100
648.        D2A                                                                       MC621-0022        50120200
649.        D3A                                                                       MC621-0022        50120300
650.        A3                          F                                             MC621-0022        50130100
651.        A3                          F                                             MC621-0022        50130200
652.        A3                          F                                             MC621-0022        50130300
653.        A1                          F                                             MC621-0022        50140100
654.        A2                          F                                             MC621-0022        50140200
655.        A3                          F                                             MC621-0022        50140300
656.        D1A                         RP                                            MC621-0022        50150100
657.        D2A                         RP                                            MC621-0022        50150200
658.        D3A                         RP                                            MC621-0022        50150300
659.        A                                                                         MC621-0022        50160100
660.        A                                                                         MC621-0022        50160200
661.        A                                                                         MC621-0022        50160300
662.        D1G                                                                       MC621-0014        50170000
663.        D1G                                                                       MC621-0053        50180100
664.        D1G                                                                       MC621-0053        50180200
665.        D1G                                                                       MC621-0015        50190000
666.                                                                                                    50190901
667.        D1G                                                                       MC282-0062        50200100
668.        D1G                                                                       MC282-0062        50200200
669.        D1G                                                                       MC282-0062        50200300
670.        D1G                                                                                         50220100
671.        D1G                                                                                         50220200
672.        D1G                                                                                         50220300
673.        D                                                                                           50240100
674.        D                                                                                           50240200
675.        D                                                                                           50240300
676.        D                                                                                           50250100
677.        D                                                                                           50250200
678.        D                                                                                           50250300
679.        D                                                                                           50250400
680.        D                                                                                           50250500
681.        D                                                                                           50250600
682.        D                                                                                           50260100
683.        D                                                                                           50260200
684.        D                                                                                           50260300
```

TABLE 7.2-1 (Continued)

```
                                                    BUSID(1)                                    DATE 111174
685.                                                                                            51000001
686.       D1M               RC                                          MC621-0052             51010000
687.       A                                                             MC287-00[illegible]3   51020000
688.       A                                                             MC287-002[illegible]   51030000
689.       A                                                             MC287-00[illegible]    51050000
690.       A                                                             MC621-0054             51060100
691.       A                                                             MC621-0054             51060200
692.       A                                                             MC621-005[illegible]   51070100
693.       A                                                             MC621-005[illegible]   51070200
694.       A                                                             MC287-003[illegible]   51080000
695.       A                                                             MC287-0040             51090000
696.       A                                                             MC287-0037             51100000
697.       A                                                             MC287-0036             51110000
698.       A                                                             MC287-0026             51120100
699.       A                                                             MC287-0026             51120200
700.       D                                                             TBD                    51140000
701.       A                                                             MC287-0020             51150000
702.       A                                                             MC287-0041             51160000
703.       A                                                             MC287-0020             51170000
704.       A                                                             MC287-0041             51180000
705.                                                                                            52000001
706.       D1A                                                           MC621-0053             52010000
707.       D1A                                                           MC621-0053             52020000
708.       A                                                             MC287-0019             52040000
709.       A                                                             MC287-0023             52050000
710.       A                                                             MC287-0023             52060000
711.       A                                                             MC287-0023             52070000
712.       A                                                             MC287-0022             52080000
713.       A                                                             MC387-0022             52100000
714.       A                                                             MC162-0008             52160000
715.       A                                                             MC162-0008             52170000
716.       A                                                             MC432-0206             52180000
717.       A                                                             MC432-0206             52200000
718.       D1L                                                           MC621-0058             52260000
719.       D1F    D2F    D3F                                             MC621-0055             52270000
720.       D1F               RP                                          MC432-0206             52300000
721.       A                                                             MC147-0007             52320000
722.       A                                                             MC147-0008             52330000
723.       A                                                             MC147-0009             52340000
724.       A                                                             MC147-0010             52350000
```

TABLE 7.2-1 (Continued)

```
                                                  L O A D S                                     DATE 110174

 1.   OCTOBER 10, 1974   PART 1
 2.   GUIDANCE + NAVIGATION                                                                   01000001
 3.   IMU #1 OPERATE                 0101     160.00        CV        AC        010101010100
 4.   IMU #1 STANDBY                 0101      55.00        CV        AC        010101010110
 5.   IMU #2 OPERATE                 0101     160.00        CV        AC        010101010200
 6.   IMU #2 STANDBY                 0101      55.00        CV        AC        010101010210
 7.   IMU #3 OPERATE                 0101     160.00        CV        AC        010101010300
 8.   IMU #3 STANDBY                 0101      55.00        CV        AC        010101010310
 9.   STAR TRKER + LT SHLD #1        0101      20.00        CV        OT        010301030100
10.   STAR TRKER + LT SHLD #2        0101      20.00        CV        OT        010301030200
11.   STAR TRKER + LT SHLD #3        0101      20.00        CV        OT        010301030300
12.   AIR DATA XDCR ASSY #1          0101      45.00        S         A1        010401040100
13.   AIR DATA XDCR ASSY #2          0101      45.00        S         A1        010401040200
14.   AIR DATA XDCR ASSY #3          0101      45.00        S         A2        010401040300
15.   AIR DATA XDCR ASSY #4          0101      45.00        S         A2        010401040400
16.   FLIGHT CONTROLS                                                                         01070001
17.   ASCENT TVC DRVR #1 - AFT0101             94.50        CV        F4        010801080100
18.   ASCENT TVC DRVR #2 - AFT0101             94.50        CV        F5        010801080200
19.   ASCENT TVC DRVR #3 - AFT0101             94.50        CV        F6        010801080300
20.   AERO SRF SRV AMP #1-AFT        0101     107.77        CV        F4        010901090100
21.   AERO SRF SRV AMP #2-AFT        0101     107.77        CV        F5        010901090200
22.   AERO SRF SRV AMP #3-AFT        0101     107.77        CV        F6        010901090300
23.   AERO SRF SRV AMP #4-AFT        0101     107.77        CV        F6        010901090400
24.   REACTION JET DRVR #1 FWD0101             59.20        CV        W1        011101110100
25.   REACTION JET DRVR #2 FWD0101             59.20        CV        W2        011101110200
26.   REACT JET OMS DRVR#1-AFT0101            152.70        CV        F4        011201120100
27.   REACT JET OMS DRVR#2-AFT0101            152.70        CV        F6        011201120200
28.   RATE GYRO ASSY-AFT #1          0101      23.00        CV        F4        011301130100
29.   RATE GYRO ASSY-AFT #2          0101      23.00        CV        F5        011301130200
30.   RATE GYRO ASSY-AFT #3          0101      23.00        CV        F6        011301130300
31.   ACCELEROMETER ASSY-FWD#10101              2.90        CV        A1        011401140100
32.   ACCELEROMETER ASSY-FWD#20101              2.90        CV        A2        011401140200
33.   ACCELEROMETER ASSY-FWD#30101              2.90        CV        A3        011401140300
34.   TRANS HAND CONTROL #1          0101       4.00                  AC        011601160100
35.   TRANS HAND CONTROL #2          0101       4.00                  AC        011601160200
36.   ROT HAND CONTROL #1            0101      10.60                  AC        011701170100
37.   ROT HAND CONTROL #2            0101      10.60                  AC        011701170200
38.   ROT HAND CONTROL #3            0101      10.60                  AC        011701170300
39.   RUDDER PEDAL XDCR ASY #10101              3.30                  AC        011801180100
40.   RUDDER PEDAL XDCR ASY #20101              3.30                  AC        011801180200
41.   SPEED BRK THRUST CNTL #10101              6.00                  AC        011901190100
42.   SPEED BRK THRUST CNTL #20101              6.00                  AC        011901190200
43.   COMMUNICATIONS                                                                          02000001
44.   B + W TV MONITOR #1            0101      20.00        CV        AC        020102010100
45.   B + W TV MONITOR #2            0101      20.00        CV        AC        020102010200
46.   TV REMOTE CONTROL              0101       5.00        CV        AC        020202020000
47.   TV CAMERA COLOR + MON          0101      20.00        CV        AC        020302030000
48.   TV CAMERA B+W #1+2             0202      12.50        CV        OT        020402040100
49.   TV CAMERA B+W #3+4             0202      12.50        CV        OT        020402040200
50.   PAN TILT ELECT #1              0101      10.00        CV        AC        020502050100
51.   PAN TILT ELECT #2              0101      10.00        CV        AC        020502050200
52.   PAN TILT MOUNT #1              0101       3.00        CV        OT        020602060100
53.   PAN TILT MOUNT #2              0101       3.00        CV        OT        020602060200
54.   VIDEO SWITCHING NETWORK        0101       5.00        CV        AC        020702070000
55.   NETWORK SIG PROCESSOR #10101             24.00        CD        W3        020702080100
56.   NETWORK SIG PROCESSOR #20101             24.00        CD        W3        020702080200
57.   CNTRL CNTL UNIT AUDIO #10101             34.00        CD        W1        021002100100
```

TABLE 7.2-1 (Continued)

```
                                                       L O A D S                                       DATE 110174

 58.   CNTRL CNTL UNIT AUDIO #2       0101        34.00        CD          W3     021002100200
 59.   S-BAND FM XMITTR #1            0101       100.00        S           A3     021102110100
 60.   S-BAND FM XMITTR #2            0101       100.00        C           W3     021102110200
 61.   S-BAND FM SIGNAL PROC          0101        10.00        C           A3     021202120000
 62.   S-BAND TRANSPONDER #1          0101        15.00        CD          W3     021302130100
 63.   S-BAND TRANSPONDRR #2          0101        15.00        C           W3     021302130200
 64.   S- BAND PWR AMP ASSY           0101       400.00        CD          W3         02140000
 65.   S-BAND PRE AMP ASSY            0101        25.0         CD          W3         02150000
 66.   S-BAND ANT SW ASSY             0101         0.60        CD          A3     [illegible]
 67.   TACAN #1                       0101       150.00        CV TBD      A1     021502170100
 68.   TACAN #2                       0101       150.00        CV TBD      A2     021502170200
 69.   TACAN #3                       0101       150.00        CV TBD      A3     021502170300
 70.   S-BAND SWITCH (COAXIAL)        0101         0.60        CD TBD      A1     021802140000
 71.   COMMUNICATIONS CONTINUED                                                       02[illegible]0001
 72.   MSBLS RF ASSY #1               0101        22.00        CD          A2     022002200100
 73.   MSBLS DCDR ASSY #1             0101        78.00        CD          A2     0220[illegible]0100
 74.   MSBLS RF ASSY #2               0101        22.00        CD          A2     0220[illegible]0200
 75.   MSBLS DCDR ASSY #2             0101        78.00        CD          A2     02200220[illegible]
 76.   MSBLS RF ASSY #3               0101        22.00        CD          A1     02200220[illegible]
 77.   MSBLS DCDR ASSY #3             0101        78.00        CD          A1     022002200300
 78.   RADAR ALTIMETER #1             0101        37.50        CV TBD      W1     022102210100
 79.   RADAR ALTIMETER #2             0101        37.50        CV TBD      W2     02210221[illegible]
 80.   COMSEC UNIT (AF) #1            0101        35.00        CD          W2     022802280100
 81.   COMSEC UNIT (AF) #2            0101        35.00        CD          W2     022802280200
 82.   COMSEC UNIT (AF) #3            0101        35.00        CD          W3     022802280300
 83.   COMSEC UNIT (AF) #4            0101        35.00        CD          W3     022802280400
 84.   P/L INTERG-(AF+NASA) #1        0101        30.00        CD          W3     023002300100
 85.   P/L INTERG-(AF+NASA) #2        0101        30.00        CD          W3     023002300200
 86.   PAYLOAD SIG PROCESSOR #1       0101        17.00        CD          W2     021602310100
 87.   PAYLOAD SIG PROCESSOR #2       0101        17.00        CD          W2     021602310200
 88.   UHF RCVR #1 MAIN/GUARD         0101        30.00        CD          W2     020902330100
 89.   UHF RCVR #2 MAIN/GUARD         0101        30.00        CD          W2     020902330200
 90.   UHF TRANSMITTER #1             0101        90.00        CD          A1     020902340100
 91.   UHF TRANSMITTER #2             0101        90.00        CD          A3     020902340200
 92.   UHF RF NETWORK CPLNG           0101        15.00        CD          A3     023502350000
 93.   DOPPLER EXTRACTOR #1           0101        15.00        CD          A3     023902390100
 94.   DOPPLER EXTRACTOR #2           0101        15.00        CD          A3     023902390200
 95.   EVA SIG PROCESSOR #1           0101        10.00        CD          A1     024002400100
 96.   EVA SIG PROCESSOR #2           0101        10.00        CD          A3     024002400200
 97.   COMMUNICATIONS CONTINUED                                                       02410001
 98.   AUDIO TERM UNIT - FWD          0202         5.00        CD          AC         02420100
 99.   AUDIO TERM UNIT - MSS          0101         5.00        CD          AC         02420200
100.   AUDIO TERM UNIT - PSS          0101         5.00        CD          AC         02420300
101.   AUDIO TERM UNIT - REAR         0202         5.00        CD          AC         02420400
102.   SPEAKER MIKE ASSY -RIGHT       0101         4.00        CD          AC         02470100
103.   SPEAKER MIKE ASSY -LEFT        0101         4.00        CD          AC         02470200
104.   S-BND FM XMITR (DFI)           0101       100.00        CD          DW         02480000
105.   S-BND MULTX (DFI)              0101         0.00        CD          DW         02490000
106.   RNDZ RADAR ELEC ASSY -DC       0101       160.00        CD          W3         02500000
107.   RNDZ RADAR ELEC ASSY -AC       0101        20.00        CD TBD      W3         02501000
108.   RNDZ RADAR ELEC ASSY -DC       0101        50.00        CD          DT         02510000
109.   RNDZ RADAR DPLY ASSY -AC       0101       395.00        CD TBD      OT         02511000
110.   KU-BAND EL ASSY - DC #1        0101       100.00        CD          W4         02520100
111.   KU-BAND EL ASSY - DC #2        0101       100.00        CD          W4         02520200
112.   KU-BAND EL ASSY - AC #1        0101        20.00        CD           W4        02521100
113.   KU-BAND EL ASSY - AC #2        0101        20.00        CD           W4        02521200
114.   KU-BAND COMM DPY ASSY #1       0101        85.00        CD          OT         02530100
```

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

TABLE 7.2-1 (Continued)

LOADS

DATE 110174

115.	KU-BAND COMM DPY ASSY #2	0101	85.00	CD	OT	02530200
116.	KU-BAND COMM DPY ASSY #1	0101	235.00	CD	OT	02531100
117.	KU-BAND COMM DPY ASSY #2	0101	235.00	CD	OT	02531200
118.	KU-BND SIG PROCESSOR	0101	15.00	CD	M3	02540000
119.	DISPLAYS + CONTROLS					03000001
120.	ATTITUDE DIR IND-FWD #1	0101	14.60	CD	AC	030103010100
121.	ATTITUDE DIR IND-FWD #2	0101	14.60	CD	AC	030103010200
122.	ATTITUDE DIR IND-AFT #3	0101	14.60	CD	AC	03010300
123.	HORZ SIT IND#1	0101	35.00	CD	AC	030303030100
124.	HORZ SIT IND#2	0101	35.00	CD	AC	030303030200
125.	AS/MACH IND(AMI) #1	0101	40.00	CD	AC	030403040100
126.	AS/MACH IND(AMI) #2	0101	40.00	CD	AC	030403040200
127.	ALT VER VEL IND #1	0101	40.00	CD	AC	030503050100
128.	ALT VER VEL IND #2	0101	40.00	CD	AC	030503050200
129.	TAPE METERS(HYD-APU-MPS)	0101	132.00	S	AC	03060000
130.	CROSS POINTER IND	0101	2.00	CD	AC	03120000
131.	SURF POSITION IND	0101	5.00	CD	AC	031303130000
132.	QTY IND OMS/RCS	0101	6.00	CD	AC	03140000
133.	CAUT + WARNING UNIT	0101	20.00	CD	AC	031503150000
134.	MISSION TIMER #1	0101	4.00	CD	AC	031703170100
135.	MISSION TIMER #2	0101	4.00	CD	AC	031703170200
136.	EVENT TIMER #1	0101	4.00	CD	AC	031803180100
137.	EVENT TIMER #2	0101	4.00	CD	AC	031803180200
138.	CRT DISPLAY UNIT #1	0101	90.00	CD	HX	031903190100
139.	CRT DISPLAY UNIT #2	0101	90.00	CD	HX	031903190200
140.	CRT DISPLAY UNIT #3	0101	90.00	CD	HX	031903190300
141.	CRT DISPLAY UNIT #4	0101	90.00	CD	HX	031903190400
142.	DISPLAY ELECT UNIT #1	0101	207.30	CD	HX	03210100
143.	DISPLAY ELECT UNIT #2	0101	207.30	CD	HX	03210200
144.	DISPLAY ELECT UNIT #3	0101	207.30	CD	HX	03210300
145.	DISPLAY ELECT UNIT #4	0101	007.30	CD	HX	03210400
146.	DISP DRVR UNIT-CRW FWD#1	0101	120.00	CD	HX	03220100
147.	DISP DRVR UNIT-CRW FWD#2	0101	120.00	CD	HX	03220200
148.	DISP DRVR UNIT-CRW AFT#3	0101	120.00	CD	HX	03220300
149.	MANIP HAND CONTROLLER	0101	8.00	CD	AC	032503250000
150.	D + C LIGHTING					03300001
151.	INTEGRAL LIGHTS-LEFT/CTR	0101	134.00	CDTBD	AC	033103310100
152.	INTEGRAL LIGHTS-OVHD	0101	134.00	CDTBD	AC	033103310200
153.	INTEGRAL LIGHTS-RIGHT	0101	134.00	CDTBD	AC	033103310300
154.	INTEGRAL LIGHTS-REAR	0101	134.00	CDTBD	AC	033103310400
155.	ANNUNCIATOR LTS-LEFT/CTR	0101	23.30	CD	AC	033303330100
156.	ANNUNCIATOR LTS-OVHD	0101	23.30	CD	AC	033303330200
157.	ANNUNCIATOR LTS-RIGHT	0101	23.30	CD	AC	033303330300
158.	MID DECK FLOOD LTS - 1	0101	19.40	CD	AC	033503350100
159.	MID DECK FLOOD LTS - 2/3	0202	19.40	CD	AC	033503350200
160.	MID DECK FLOOD LTS - 4/6	0202	19.40	CD	AC	033503350300
161.	MID DECK FLOOD LTS - 5	0101	19.40	CD	AC	033503350400
162.	MID DECK FLOOD LTS-PANEL	0202	19.40	CD	AC	033503350500
163.	LWR DECK SLEEP STA LTS	0404	18.50	CD	AC	033603360000
164.	LWR DECK WASTE MGMT LTS	0202	18.50	CD	AC	033803380000
165.	LWR DECK GALLEY LIGHT	0101	15.00	CD	AC	033903390000
166.	AIRLOCK LIGHTS	0404	103.50	CD	AC	034103410000
167.	CABIN FLOOD LIGHTS AFT	0202	29.80	CD	AC	034203420100
168.	GLARESHIELD FLDLTS -LEFT	0202	29.80	CD	AC	034203420200
169.	GLARESHIELD FLDLTS-RIGHT	0202	29.80	CD	AC	034203420300
170.	CENTER CONSOLE FLOODLTS	0101	29.80	CD	AC	034203420400
171.	PILOT CONSOLE FLDLTS-RHT	0101	29.80	CD	AC	034203420500

TABLE 7.2-1 (Continued)

LOADS DATE 110174

172.	PILOT CONSOLE FLDLTS-LFT	0101	29.80	CD	AC	034203420600
173.	REAR STA(P/L) LTS	0202	60.00	S	AC	034303430000
174.	EMERGENCY LIGHT - 1	0101	29.80	C	AC	034503450100
175.	EMERGENCY LIGHT - 2	0101	29.80	C(	AC	034503450200
176.	PAYLOAD BAY FLOOD LTS	0606	200.00	S	OT	034903490000
177.	MANIP SPOT LIGHT	0202	100.00	S	OT	035003500000
178.	RNDZ LIGHT	0101	30.00	S	OT	035103510000
179.	D+C - LIGHTING CONTINUED					03520001
180.	DOCKING SPOT LIGHTS	0202	150.00	S	OT	03540000
181.	C+W STATUS BOARD	0101	36.00	CD	AC	03550000
182.	C+W ANNUNCIATOR ASSY	0101	24.00	CD	AC	03560000
183.	C+W ANNUN ASSY - QUIESCT	0101	2.00	CD	AC	03560010
184.	OPERATIONAL FLT INST					04000001
185.	PCM MASTER UNIT(DACBU)#1	0101	60.00	CD	W2	040304030100
186.	PCM MASTER UNIT(DACBU)#2	0101	60.00	CD	W3	040304030200
187.	MAINT RECORDER	0101	40.00	CD	W2	040404040000
188.	SIG COND UNIT-FWD #1	0101	35.00	CV	W1	040504050100
189.	SIG COND UNIT-FWD #2	0101	35.00	CV	W2	040504050200
190.	SIG COND UNIT-FWD #3	0101	35.00	CV	W3	040504050300
191.	SIG COND UNIT #1 - AFT	0101	35.00	CV	F4	040604060100
192.	SIG COND UNIT #2 - AFT	0101	35.00	CV	F5	040604060200
193.	SIG COND UNIT #3 - AFT	0101	35.00	CV	F6	040604060300
194.	LOOP RECORDER	0101	40.00	CD	W2	040704070000
195.	MASTER TIMING UNIT-WMUP	0101	40.00	CV	W1	040904090000
196.	MASTER TIMING UNIT-OPR	0101	26.00	CV	W1	040904090010
197.	PAYLOAD DATA INTERLEAVER	0101	30.00	CD	W2	041104110000
198.	SIG COND UNIT-OMS/RCS #1	0101	35.00	CV	OT	04120100
199.	SIG COND UNIT-OMS/RCS #2	0101	35.00	CV	OT	04120200
200.	SIG COND UNIT-F/C AREA	0101	35.00	CV	OT	04130000
201.	SIG COND UNIT-FWD RCS	0101	35.00	CV	OT	04140000
202.	CURRENT SENSOR	1818	0.30	CV	AC	04150000
203.	DEVELOPMENT FLT INST					05000001
204.	PCM MASTER UNIT - #1	0101	60.00	CD	DW	040305030100
205.	PCM MASTER UNIT - #2	0101	60.00	CD	DW	040305030200
206.	PCM RECORDER	0101	40.00	CD	DW	040405040000
207.	SIG COND UNIT - FWD #1	0101	35.00	CV	DW	040505050100
208.	SIG COND UNIT - FWD #2	0101	35.00	CV	DW	040505050200
209.	SIG COND UNIT - FWD #3	0101	35.00	CV	DW	040505050300
210.	SIG COND UNIT - FWD #4	0101	35.00	CV	DW	040505050400
211.	SIG COND UNIT -MID #1-12	1212	35.00	CV	DF	040505060000
212.	WIDEBAND FDM UNIT-FWD	0101	50.00	CD	DW	050705070000
213.	WIDEBAND FDM UNIT-MID #1	0101	50.00	CD	DF	050705080100
214.	WIDEBAND FDM UNIT-MID #2	0101	50.00	CD	DF	050705080200
215.	WIDEBAND RECORDER	0101	40.00	CD	DW	050905090000
216.	WIDEBND SIG CND UNIT FWD	5050	0.60	CV	DW	051205120000
217.	WIDEBND SIG CND UNIT MID	5050	0.60	CV	DF	051305130100
218.	WIDEBND SIG CND UNIT MID	5050	0.60	CV	DF	051305130200
219.	STRAIN GAGE SIG CND FWD	0505	5.60	CV	DW	051505150000
220.	STRAIN GAGE SIG CND MID	5656	5.60	CV	DF	051605160100
221.	STRAIN GAGE SIG CND MID	5656	5.60	CV	DF	051605160200
222.	CURRENT SENSOR	0909	0.30	CV	AC	051805180000
223.	ELECT PWR DIST + CONTROL					06000001
224.	INVERTERS 1PH,750VA,80(	0303	0.00	CD	W1	060106010100
225.	INVERTERS 1PH,750VA,80(	0303	0.00	CD	W2	060106010200
226.	INVERTERS 1PH,750VA,80(	0303	0.00	CD	W3	060106010300
227.	PYRO EVENT CNTLR -FWD #1	0101	25.00	CD	W1	060206020100
228.	PYRO EVENT CNTLR -FWD #2	0101	25.00	CD	W4	060206020200

TABLE 7.2-1 (Continued)

```
                                              L O A D S                              DATE 110174
229.     MASTER EVENT CNTLR-AFT=10101        25.00       CD       F4       060306030100
230.     MASTER EVENT CNTLR-AFT=20101        25.00       CD       F5       060306030200
231.     LOAD CNTLR ASSY-FWD =1   0101       75.00       CD       W1       060406040100
232.     LOAD CNTLR ASSY-FWD =2   0101       75.00       CD       W2       060406040200
233.     LOAD CNTLR ASSY-FWD =3   0101       75.00       CD       W3       060406040300
234.     LOAD CNTLR ASSY-AFT =1   0101       90.00       CD       F4       060506050100
235.     LOAD CNTLR ASSY-AFT =2   0101       90.00       CD       F5       060506050200
236.     LOAD CNTLR ASSY-AFT =3   0101       90.00       CD       F6       060506050300
237.     DC PWR CNTLR ASSY-FWD =10101       200.00       CD       W1       060606060100
238.     DC PWR CNTLR ASSY-FWD =20101       200.00       CD       W2       060606060200
239.     DC PWR CNTLR ASSY-FWD =30101       200.00       CD       W3       060606060300
240.     DC PWR CNTLR ASSY-AFT =10101       100.00       CD       F4       060706070100
241.     DC PWR CNTLR ASSY-AFT =20101       100.00       CD       F5       060706070200
242.     DC PWR CNTLR ASSY-AFT =30101       100.00       CD       F6       060706070300
243.     MAIN DC DIST+CNTL ASSY=10101        20.00       CD       FM       060806080100
244.     MAIN DC DIST+CNTL ASSY=20101        20.00       CD       FM       060806080200
245.     MAIN DC DIST+CNTL ASSY=30101        20.00       CD       FM       060806080300
246.     INV DIST + CNTL ASSY =1  0101       20.00       CD       W1       061006100100
247.     INV DIST + CNTL ASSY =2  0101       20.00       CD       W2       061006100200
248.     INV DIST + CNTL ASSY =3  0101       20.00       CD       W3       061006100300
249.     ELEC PWR DST/CNTL CONT                                                06110001
250.     DC PWR CNTL ASSY-MID =1  0101       30.00       CD       FM       061206120100
251.     DC PWR CNTL ASSY-MID =2  0101       30.00       CD       FM       061206120200
252.     DC PWR CNTL ASSY-MID =3  0101       30.00       CD       FM       061206120300
253.     EVLSS BAT CHARGER        0101        5.00       CD       A3       061606160000
254.     EVLSS PWR SUPPLY         0101       75.00       CD       A3       061806180000
255.     PROXIMITY SWITCH =1      0101        8.00       CD       A1       061906190100
256.     PROXIMITY SWITCH =2      0101        8.00       CD       A3       061906190200
257.     PROXIMITY SWITCH =3      0101        8.00       CD       A3       061906190300
258.     DATA PROCESSING                                                       07000001
259.     COMPUTER =1              0101      600.00       CD       A1       070107010100
260.     COMPUTER =2              0101      600.00       CD       A1       070107010200
261.     COMPUTER =3              0101      600.00       CD       A2       070107010300
262.     COMPUTER =4              0101      600.00       CD       A2       070107010400
263.     COMPUTER =5              0101      600.00       CD       A3       070107010500
264.     MDM FF1                  0101       40.00       CD       W1       070307030100
265.     MDM FF2                  0101       40.00       CD       W2       070307030200
266.     MDM FF3                  0101       40.00       CD       W2       070307030300
267.     MDM FF4                  0101       40.00       CD       W3       070307030400
268.     MDM FA1                  0101       40.00       CD       F4       070307040100
269.     MDM FA2                  0101       40.00       CD       F5       070307040200
270.     MDM FA3                  0101       40.00       CD       F6       070307040300
271.     MDM FA4                  0101       40.00       CD       F6       070307040400
272.     MDM DFI - FWD            0202       40.00       CD       DW           07050000
273.     MDM DFI - MID            0606       40.00       CD       DF           07060000
274.     MASS MEM=1(TAPE) OPER    0101       53.00       CD       W1       070907090100
275.     MASS MEM=1(TAPE) STBY    0101        8.00       CD       W1       070907090110
276.     MASS MEM=2(TAPE) OPER    0101       53.00       CD       W2       070907090200
277.     MASS MEM=2(TAPE) STBY    0101        8.00       CD       W2       070907090210
278.     MDM OFI 1                0101       40.00       CD       W1           07100100
279.     MDM OFI 2                0101       40.00       CD       W2           07100200
280.     MDM OFI 3                0101       40.00       CD       W3           07100300
281.     MDM OFI 4                0101       40.00       CD       WC           07100400
282.     MDM OFI AFT 1            0101       40.00       CD       F4           07110100
283.     MDM OFI AFT 2            0101       40.00       CD       F5           07110200
284.     MDM OFI AFT 3            0101       40.00       CD       F6           07110300
285.     MDM LF-1                 0101       40.00       CD       W1       071207120000
```

TABLE 7.2-1 (Continued)

L O A D S DATE 110174

286.	MDM LA-1	0101	40.00	CD	F6	071307130000
287.	DATA PROCESSING CONIT					07140001
288.	ENG INTERFACE UNIT =1	0101	50.60	CD	F4	071507150100
289.	ENG INTERFACE UNIT =2	0101	50.60	CD	F5	071507150200
290.	ENG INTERFACE UNIT =3	0101	50.60	CD	F6	0715071503[illegible]
291.	DATA BUS ISO AMP =1 (GSE)	0101	20.00	CD	F4	071607160100
292.	DATA BUS ISO AMP =1 (ORB)	0101	10.00	CD	F4	071607160110
293.	DATA BUS ISO AMP =2 (GSE)	0101	20.00	CD	F5	071607160200
294.	DATA BUS ISO AMP =2 (ORB)	0101	10.00	CD	F	071607160210
295.	PAYLOAD MANAGEMENT					08000001
2 6.	MDM PAYLOAD FWD =1	0101	40.00	CD	W2	080108010100
297.	MDM PAYLOAD FWD =2	0101	40.00	CD	W[illegible]	080108010200
298.	WIDE BAND RECORDER (MSS)	0101	175.00	CV	W1	08020000
299.	PCM RECORDER (MSS)	0101	40.00	CV	W1	08030000
300.	P/L - ASCENT/ENTRY	0101	961.50	CD	OT	08040000
301.	P/L - SORTIE	0101	5769.20	CD	OT	08040100
302.	AUX C+W UNIT	0101	10.00	S	AC	08050000
303.	AUX C+W ANNUN ASSY	0101	15.00	S	AC	0[illegible]0000
304.	UNMANNED KIT					09000001
305.	SUBSYS SEQ CONTR UNIT=1	0101	370.00	CD	OT	09010000
306.	SUBSYS SEQ CONTR UNIT=2	0101	190.00	CD	OT	09020000
307.	EXTERNAL TANK					15000001
308.	MDM - DFI	0101	20.00	CD	OT	150115010000
309.	SOLID ROCKET BOOSTER					16000001
310.	RATE GYRO ASSY	0303	42.00	CD	OT	150116010100
311.	RATE GYRO ASSY	0303	42.00	CD	OT	150116010200
312.	MDM - SET 1	0202	15.00	CD	OT	150116020100
313.	MDM - SET 2	0202	15.00	CD	OT	150116020200
314.	MDM DFI =1	0101	35.00	CD	OT	16040100
315.	MDM DFI =2	0101	35.00	CD	OT	16040200
316.	PIC IGNITION - SET 1	0303	0.00	CD	OT	150316050100
317.	PIC IGNITION - SET 2	0303	0.00	CD	OT	150316050200
318.	PIC SEPARATION-SET 1	2121	0.00	CD	OT	150316060100
319.	PIC SEPARATION-SET 2	2121	0.00	CD	OT	150316060200
320.	SIG COND - SET 1	0202	20.00	CD	OT	150116070100
321.	SIG COND - SET 2	0202	20.00	CD	OT	150116070200
322.	TVC HYDR RECIRC SYS	0404	206.00	CD	OT	16080000
323.	SAFE + ARM DEVICE	0404	75.00	CD	OT	16090000
324.	MAIN PROPULSION SYS					20000001
325.	MAIN ENG CONTROLLER-1	0101	750.00	S	1.00T	200120010100
326.	MAIN ENG CONTROLLER-2	0101	750.00	S	1.00T	200120010200
327.	MAIN ENG CONTROLLER-3	0101	750.00	S	1.00T	200120010300
328.	MAIN ENG HTR =1	0101	300.00	S	OT	200220020100
329.	MAIN ENG HTR =2	0101	300.00	S	OT	200220020200
330.	MAIN ENG HTR =3	0101	300.00	S	OT	200220020300
331.	LO2 PREVALVE SOLENOID	0201	42.00	S	OT	200320030100
332.	LO2 PREVALVE SOLENOID	0201	42.00	S	OT	200320030200
333.	LO2 PREVALVE SOLONOID	0201	42.00	S	OT	200320030300
334.	LH2 PREVALVE SOLENOID	0201	42.00	S	OT	200420040100
335.	LH2 PREVALVE SOLENOID	0201	42.00	S	OT	200420040200
336.	LH2 PREVALVE SOLONOID	0201	42.00	S	OT	200420040300
337.	LO2 F+D VLV =1(O/B) SOL	0201	42.00	S	OT	20050000
338.	LO2 F+D VLV =2(O/B) SOL	0201	42.00	S	OT	20060000
339.	LH2 F+D VLV =1(O/B) SOL	0101	42.00	S	OT	20070100
340.	LH2 F+D VLV =1(O/B) SOL	0101	42.00	S	OT	20070200
341.	LH2 F+D VLV =2(O/B) SOL	0101	42.00	S	OT	20080100
342.	LH2 F+D VLV =2(O/B) SOL	0101	42.00	S	OT	20080200

TABLE 7.2-1 (Continued)

```
                                                              LOADS                                         DATE 110174
343.          LH2 TOPPING VLV OPEN SOL0101       42.00          S           OT           20090000
344.          LH2 RECRC VLV OPEN SOL=10101       42.00          S           OT           20100100
345.          LH2 RECRC VLV OPEN SOL=20101       42.00          S           OT           20100200
346.          LH2 RECRC VLV OPEN SOL=30101       42.00          S           OT           20100300
347.          ET/ORB LO2 FEED DISC S V0101       42.00          S           OT           20110100
348.          ET/ORB LO2 FEED DISC S V0101       42.00          S           OT           20110200
349.          ET/ORB LH2 FEED DISC S V0101       42.00          S           OT           20120100
350.          ET/ORB LH2 FEED DISC S V0101       42.00          S           OT           20120200
351.          ET/ORB RECIRC DISC S V  0101       42.00          S           OT           20130100
352.          ET/ORB RECIRC DISC S V  0101       42.00          S           OT           20130200
353.          LO2 FEEDLN RELF SHUTOFF 0101       42.00          S           OT           20140000
354.          LH2 FEEDLN RELF SHUTOFF 0101       42.00          S           OT           20150000
355.          MAIN PROP SYS-CONTINUED                                                    20150901
356.          LH2 PRESS:N DISC BYPASS 0101       42.00          S           OT           20160000
357.          ET VENT VLV ISO SOL VLV 0202       42.00          S           OT           20170000
3 8.          LO2 FEEDLN REPRESS VLV=10101       42.00          S           OT           20180100
359.          LO2 FEEDLN REPRESS VLV=20101       42.00          S           OT           20180200
360.          LH2 FEEDLN REPRESS VLV=10101       42.00          S           OT           20190100
361.          LH2 FEEDLN REPRESS VLV=20101       42.00          S           OT           20190200
362.          HE CROSSOVER VLV =1         0101   42.00          S           OT           20200100
363.          HE CROSSOVER VLV =2         0101   42.00          S           OT           20200200
364.          HE CROSSOVER VLV =3         0101   42.00          S           OT           20200300
3 5.          ENG HE SUPPLY ISO SOL =10202       42.00          S           OT           20210100
366.          ENG HE SUPPLY ISO SOL =20202       42.00          S           OT           20210200
367.          ENG HE SUPPLY ISO SOL =30202       42.00          S           OT           20210300
368.          VEH HE SUPPLY ISO SOL=1 0101       42.00          S           OT           20220100
369.          VEH HE SUPPLY ISO SOL=2 0101       42.00          S           OT           20220200
370.          HE BLOWDN SOL VLV =1        0101   42.00          S           OT           20230100
371.          HE BLOWDN SOL VLV =2        0101   42.00          S           OT           20230200
372.          LO2 PRESS:N FL CNTL SV1 0101       42.00          S           OT           20240100
373.          LO2 PRESS:N FL CNTL SV2 0101       42.00          S           OT           20240200
374.          LO2 PRESS:N FL CNTL SV3 0101       42.00          S           OT           20240300
375.          LH2 PRESS:N FL CNTL SV1 0101       42.00          S           OT           20250100
376.          LH2 PRESS:N FL CNTL SV2 0101       42.00          S           OT           20250200
377.          LH2 PRESS:N FL CNTL SV3 0101       42.00          S           OT           20250300
378.          ET ULLAGE SIG CND PKG =10101       33.33          CD          F5           20270100
379.          ET ULLAGE SIG CND PKG =20101       33.33          CD          F6           20270200
380.          ET ULLAGE SIG CND PKG =30101       33.33          CD          F6           20270300
381.          PROP LOW LEV SNSR SIGCND0808        7.00          CD          F5           20280000
382.          PROP LOADING SNSR SIGCND2020        7.00          CD          F5           20290000
383.          MPS DELTA P (GSE)           0101   14.00          CDTHD       F6       20322032000
384.          ORBITAL MANEUVERING SYS                                                    21000001
385.          ENGINE CONTROL VALVE =1 0101       56.00          CD          OT       21  121010100
386.          ENGINE CONTROL VALVE =2 0101       56.00          CD          OT       2101210100200
387.          ENGINE CONTROL VALVE =3 0101       56.00          CD          OT       2101210100300
388.          ENGINE CONTROL VALVE =4 0101       56.00          CD          OT       2101210100400
389.          HE ISOL VLVS-SET 1          0101   24.00          CD          OT       2102210200100
390.          HE ISOL VLVS-SET 2          0202   24.00          CD          OT       2102210200200
391.          HE ISOL VLVS-SET 3          0101   24.00          CD          OT       2102210200300
392.          VAPOR ISOL VLVS-SET 1       0101   24.00          CD          OT       2103210300100
393.          VAPOR ISOL VLVS-SET 2       0101   24.00          CD          OT       2103210300200
394.          VAPOR ISOL VLVS-SET 3       0101   24.00          CD          OT       2103210300300
395.          VAPOR ISOL VLVS-SET 4       0101   24.00          CD          OT       2103210300400
396.          QUANTITY GAGING PROBE =10101       67.00          CD          OT       2105210500100
397.          QUANTITY GAGING PROBE =20101       67.00          CD          OT       2105210500200
398.          QUANTITY GAGING PROBE =30101       67.00          CD          OT       2105210500300
399.          QUANTITY GAGING PROBE =40101       67.00          CD          OT       2105210500400
```

TABLE 7.2-1 (Continued)

```
                                        L O A D S                                      DATE 110174
400.      HE ISO VLV#1-AUX KIT     0101      24.00          CD        OT        210621060100
401.      HE ISO VLV#2-AUX KIT     0101      24.00          CD        OT        210621060200
402.      VAPOR ISO VLV#1-AUX KIT  0101      24.00          CD        OT            21070100
403.      VAPOR ISO VLV#2-AUX KIT  0101      24.00          CD        OT            21070200
404.      ENG GIMBAL ACTUATOR #1   0101     134.50          CD        OT        210921090100
405.      ENG GIMBAL ACTUATOR #2   0101     134.50          CD        OT        210921090200
406.      ENG GIMBAL ACTUATOR #3   0101     134.50          CD        OT        210921090300
407.      ENG GIMBAL ACTUATOR #4   0101     134.50          CD        OT        210921090400
408.      PROP TNK ISO VLVS        0808      32.00          CD        OT        211021100000
409.      CROSSFEED VLVS-SET 1     0303      32.00          CD        OT        211321130100
410.      CROSSFEED VLVS-SET 2     0303      32.00          CD        OT        211321130200
411.      CROSSFEED VLVS-SET 3     0202      32.00          CD        OT        211321130300
412.      THERMAL CNTL HTR #1      0101     700.00          CD        OT        211421140100
413.      THERMAL CNTL HTR #2      0101     700.00          CD        OT        211421140200
414.      ORBITAL MANEUV SYS -CONT                                                  21140901
415.      ENG ARMING SOL VALVE #1  0101      56.00          CD        OT        211521150100
416.      ENG ARMING SOL VALVE #2  0101      56.00          CD        OT        211521150200
417.      THERML CNTL HTRS-AUX KIT0101      700.00          CD        OT        211621160000
418.      PROP TNK ISO VLV-AUX KIT0808       32.00          CD        OT        211821180000
419.      CROSSFEED LINE HTRS      0101      50.00          CD        OT        211921190000
420.      ENGINE #1 HEATER         0101      50.00          CD        OT        212021200100
421.      ENGINE #2 HEATER         0101      50.00          CD        OT        212021200200
422.      VALVE POSITION IND       1616       0.40          CD        OT        212121210000
423.      VALVE POS IND-AUX KIT    0808       0.40          CD        OT        212221220000
424.      PROP LOW LEVEL SENSOR #10101       11.25          CD        OT        212321230100
425.      PROP LOW LEVEL SENSOR #20101       11.25          CD        OT        212321230200
426.      REACTION CONTROL SYS                                                      22000001
427.      THRUSTER - FWD           1402      56.00          CD        OT        220122010000
428.      THRUSTER - AFT           2804      56.00          CD        OT        220222020000
429.      THRUSTER-VERNIER (FWD)   0202      15.00          CD        OT        220322030000
430.      THRUSTER VERNIER (AFT)   0404      15.00          CD        OT        220422040000
431.      HP HELIUM ISOL VLV -FWD  0401      84.00          CD        OT        220622060000
432.      LP HEL ISOL VLV-FWD      0202      84.00          CD        OT        220722070000
433.      HP HELIUM ISOL VLV -AFT  0801      84.00          CD        OT        220822080000
434.      LP HELIUM ISOL VLV -AFT  0402      84.00          CD        OT        220922090000
435.      PROP MANIF ISOL VLV -FWD0801       84.00          CD        OT        221022100000
436.      PROP MANIF ISOL VLV -AFT1601       84.00          CD        OT        221122110000
437.      PROPELLANT ISOL VLV-VERN0401       56.00          CD        OT        221222120000
438.      TANK ISO THRST VLV- FWD  0401      84.00          CD        OT        221322130000
439.      TANK ISO THRST VLV-AFT   0801      84.00          CD        OT        221422140000
440.      TANK HEATERS-AFT LEFT    0404      55.00          CD        OT        221522150000
441.      TANK HEATERS-AFT RIGHT   0404      55.00          CD        OT        221622160000
442.      MAIN ENG HEATERS-FWD     1414      10.00          CD        OT        221722170000
443.      MAIN ENG HEATERS-AFT     2424      10.00          CD        OT        221822180000
444.      PROP FEED LINE HTRS-AFT  0808      16.00          CD        OT        221922190000
445.      PRESS PANEL HTRS         0404      20.00          CD        OT        222022200000
446.      FEED SYS HTRS-FWD        0404     160.00          CD        OT        222122210000
447.      VERNIER ENG HTRS-FWD     0202       5.00          CD        OT        222222220000
448.      VERNIER ENG HTRS-AFT     0404       5.00          CD        OT        222322230000
449.      POWER GENERATION SYS                                                      30000001
450.      GO2 PURGE VENT HTR #1    0101      33.00          CD        OT        300130010100
451.      GO2 PURGE VENT HTR #2    0101      33.00          CD        OT        300130010200
452.      GH2 PURGE VENT HTR #1    0101      61.00          CD        OT        300230020100
453.      GH2 PURGE VENT HTR #2    0101      61.00          CD        OT        300230020200
454.      H2O RELIEF VENT HTR #1   0101      16.00          CD        OT        300330030100
455.      H2O RELIEF VENT HTR #2   0101      16.00          CD        OT        300330030200
456.      FCP #1 CNTLS + FLOWMETRS0101       18.00          CV        OT        300430040100
```

TABLE 7.2-1 (Continued)

```
                                                L O A D 3                                          DATE 110174
457.        FCP =2 CNTLS + FLOWMETRS0101          15.00        CV          OT      300430040200
458.        FCP =3 CNTLS + FLOWMETRS0101          15.00        CV          OT      300430040300
459.        FCP =1 PUMP + H2O SENSOR0101         150.00        CV    =0.50OT      300530050100
460.        FCP =2 PUMP + H2O SENSOR0101         150.00        CV    =0.50OT      300530050200
461.        FCP =3 PUMP + H2O SENSOR0101         150.00        CV    =0.50OT      300530050300
462.        FCP =1 GO2 PURGE VALVE  0101          33.00        CV          OT      300630060100
463.        FCP =2 GO2 PURGE VALVE  0101          33.00        CV          OT      300630060200
464.        FCP =3 GO2 PURGE VALVE  0101          33.00        CV          OT      300630060300
465.        FCP =1 GH2 PURGE VALVE  0101          10.00        CV          OT      300630070100
466.        FCP =2 GH2 PURGE VALVE  0101          10.00        CV          OT      300630070200
467.        FCP =3 GH2 PURGE VALVE  0101          10.00        CV          OT      300630070300
468.        FCP =1 START + SUST HTR 0101        6000.00        CV          OT      300830080100
469.        FCP =2 START + SUST HTR 0101        6000.00        CV          OT      300830080200
470.        FCP =3 START + SUST HTR 0101        6000.00        CV          OT      300830080300
471.        H2O LINE HEATER-FCP =1  0101          15.00        CD          OT          30150100
472.        H2O LINE HEATER-FCP =2  0101          15.00        CD          OT          30150200
473.        H2O LINE HEATER-FCP =3  0101          15.00        CD          OT          30150300
474.        FCP =1 THERMAL CNTL HTR 0101         150.00        CV          OT          30170100
475.        FCP =2 THERMAL CNTL HTR 0101         150.00        CV          OT          30170200
476.        FCP =3 THERMAL CNTL HTR 0101         150.00        CV          OT          30170300
477.        CRYOGENICS SYS                                                             31000001
478.        VAC=ION PWR SUPL[GSE] =10101          10.00        CVTBD       OT      310131010100
479.        VAC=ION PWR SUPL[GSE] =20101          10.00        CVTBD       OT      310131010200
480.        VAC=ION PWR SUPL[GSE] =30101          10.00        CVTBD       OT      310131010300
481.        VAC=ION PWR SUPL[GSE] =40101          10.00        CVTBD       OT      310131010400
482.        SIG COND TEMP SNSR      1212           1.30        CD          OT      310231020000
483.        SIG COND QTY =1         0101           4.00        CV          OT      310331030100
484.        SIG COND QTY =2         0101           4.00        CV          OT      310331030200
485.        SIG COND QTY =3         0101           4.00        CV          OT      310331030300
486.        SIG COND QTY =4         0101           4.00        CV          OT      310331030400
487.        SIG COND PRESS =1       0101           0.30        CV          OT      310431040100
488.        SIG COND PRESS =2       0101           0.30        CV          OT      310431040200
489.        SIG COND PRESS =3       0101           0.30        CV          OT      310431040300
490.        SIG COND PRESS =4       0101           0.30        CV          OT      310431040400
491.        SIG COND PRESS CONT =1  0101           1.00        CV          OT      310531050100
492.        SIG COND PRESS CONT =2  0101           1.00        CV          OT      310531050200
493.        SIG COND PRESS CONT =3  0101           1.00        CV          OT      310531050300
494.        SIG COND PRESS CONT =4  0101           1.00        CV          OT      310531050400
495.        SWITCHING UNIT O2=ON    0303          26.00        CD          FM          31060000
496.        SWITCHING UNIT O2=OFF   0303           0.40        CD          FM          31060010
497.        SWITCHING UNIT H2=ON    0303           2.50        CD          FM          31070000
498.        SWITCHING UNIT H2=OFF   0303           0.20        CD          FM          31070010
499.        SOLENOID VLV FCP =1     0202          56.00        CD          OT      311131120100
500.        SOLENOID VLV FCP =2     0202          56.00        CD          OT      311131120200
501.        SOLENOID VLV FCP =3     0202          56.00        CD          OT      311131120300
502.        SOLENOID VALVE ECLSS =1 0101          56.00        CD          OT      311131130100
503.        SOLENOID VALVE ECLSS =2 0101          56.00        CD          OT      311131130200
504.        SOL VLV MANIFOLD =1     0101          56.00        CD          OT      311531150100
505.        SOL VLV MANIFOLD =2     0101          56.00        CD          OT      311531150200
506.        SOL VLV MANIFOLD =3     0101          56.00        CD          OT      311531150300
507.        SOL VLV MANIFOLD =4     0101          56.00        CD          OT      311531150400
508.        CRYOGENICS SYS CONTINUED                                                   31160001
509.        HEATERS [OXYGEN] SET 1  0202         394.50        CD          OT      311731170100
510.        HEATERS [OXYGEN] SET 2  0202         394.50        CD          OT      311731170200
511.        HEATERS [OXYGEN] SET 3  0202         394.50        CD          OT      311731170300
512.        HEATERS [HYDROGEN] SET 10202          81.00        CD          OT      311731180100
513.        HEATERS [HYDROGEN] SET 20202          81.00        CD          OT      311731180200
```

TABLE 7.2-1 (Continued)

```
                                                          L O A D S                                DATE 110174

514.    HEATERS (HYDROGEN) SET 30202        81.00      CD      OT     311731160300
515.    AUX POWER UNIT                                                    32000001
516.    FUEL ISOLATION VALVE =1  0101       40.00      S       OT     320232020100
517.    FUEL ISOLATION VALVE =2  0101       40.00      S       OT     320232020200
518.    FUEL ISOLATION VALVE =3  0101       40.00      S       OT     320232020300
519.    APU =1 CONTROLLER        0101      150.00      S       F4     320332030100
520.    APU =2 CONTROLLER        0101      150.00      S       F5     320332030200
521.    APU =3 CONTROLLER        0101      150.00      S       F6     320332030300
522.    TANK HTR =1 - LH SIDE    0201       50.00      S       OT     320532050100
523.    TANK HTR =2 - LH SIDE    0201       50.00      S       OT     320532050200
524.    TANK HTR =3 - RH SIDE    0201       50.00      S       OT     320532050300
525.    APU LINE HEATERS =1      0201       50.00      CD      OT     320732070100
526.    APU LINE HEATERS =2      0201       50.00      CD      OT     320732070200
527.    APU LINE HEATERS =3      0201       50.00      CD      OT     320732070300
528.    FUEL QTY GAGE =1         0101        1.00      CD      OT     320832080100
529.    FUEL QTY GAGE =2         0101        1.00      CD      OT     320832080200
530.    FUEL QTY GAGE =3         0101        1.00      CD      OT     320832080300
531.    APU OIL LINE HTR =1      0201      100.00      CD      OT     320932090100
532.    APU OIL LINE HTR =2      0201      100.00      CD      OT     320932090200
533.    APU OIL LINE HTR =3      0201      100.00      CD      OT     320932090300
534.    APU =1 TURB VLV HTR      0201       68.30      S       OT     321032100100
535.    APU =2 TURB VLV HTR      0201       68.30      S       OT     321032100200
536.    APU =3 TURB VLV HTR      0201       68.30      S       OT     321032100300
537.    APU =1 TURB GAS GEN HTR  0201       68.30      S       OT     321132110100
538.    APU =2 TURB GAS GEN HTR  0201       68.30      S       OT     321132110200
539.    APU =3 TURB GAS GEN HTR  0201       68.30      S       OT     321132110300
540.    SERVICE LINE HEATER =1   0201       50.00      CD      OT     321232120100
541.    SERVICE LINE HEATER =2   0201       50.00      CD      OT     321232120200
542.    SERVICE LINE HEATER =3   0201       50.00      CD      OT     321232120300
543.    ENVIR CONTROL + LIFE SUP                                          40000001
544.    CABIN FAN =1             0101      500.00      CD   -.75HX    400140010100
545.    CABIN FAN =2             0101      500.00      CD   -.75HX    400140010200
546.    CABIN FAN =3             0101      500.00      CD   -.75HX    400140010300
547.    WATER PUMP PKG PRI A     0101      270.00      CD   -.67WC    400240020100
548.    WATER PUMP PKG PRI B     0101      270.00      CD   -.67WC    400240020200
549.    WATER PUMP PKG SEC       0101      270.00      CD   -.67WC    400240020300
550.    CABIN PRESS CNTL SYSTEM  0101       84.00      CD       AC    400340030000
551.    CAB PRESS CNTL-AIRLK SP  0101       30.60      CD       AC    400340030010
552.    CAB PRESS CNTL-EMERG MD  0101       23.00      CD       AC    400340030020
553.    WATER SUBLIMATOR SYS =1  0101      101.00      CD       OT    400440040100
554.    WATER SUBLIMATOR SYS =2  0101      101.00      CD       OT    400440040200
555.    AVIONICS FANS-BAY 1 (A)  0101      180.00      CD   -.75A1    400540050100
556.    AVIONICS FANS-BAY 1 (B)  0101      180.00      CD   -.75A1    400540050200
557.    AVIONICS FANS-BAY 2 (A)  0101      180.00      CD   -.75A2    400540050300
558.    AVIONICS FANS-BAY 2 (B)  0101      180.00      CD   -.75A2    400540050400
559.    AVIONICS FANS-BAY 3 (A)  0101      180.00      CD   -.75A3    400540050500
560.    AVIONICS FANS-BAY 3 (B)  0101      180.00      CD   -.75A3    400540050600
561.    H2O SEPARATORS(ARS) - =10101        40.00      CD   -.30AC    400640060100
562.    H2O SEPARATORS(ARS) - =20101        40.00      CD   -.30AC    400640060200
563.    H2O SEPARATORS(ARS) - =30101        40.00      CD   -.30AC    400640060300
564.    CABIN HEATER =1          0101      333.33      CD       AC    400740070100
565.    CABIN HEATER =2          0101      333.33      CD       AC    400740070200
566.    CABIN HEATER =3          0101      333.33      CD       AC    400740070300
567.    INSTR + CONTROLS (ARS)   0101       47.00      CDTBD    HX    400840080000
568.    IMU HX ASSEMBLY FAN =1   0101       55.00      CD   -0.6WC    400940090100
569.    IMU HX ASSEMBLY FAN =2   0101       55.00      CD   -0.6WC    400940090200
570.    IMU HX ASSEMBLY FAN =3   0101       55.00      CD   -0.6WC    400940090300
```

TABLE 7.2-1 (Continued)

571.	OVEN HEATER #1	0101	150.00	CD	AC	401040100100
572.	OVEN HEATER #2	0101	150.00	CD	AC	401040100200
573.	ECLSS CONTINUED					40100901
574.	INST+CNTLS-OVEN FANS #1	0201	95.00	CDTBD	AC	401140110100
575.	INST+CNTLS-OVEN FANS #2	0201	95.00	CD 4011	AC	401140110200
576.	INST/CNTLS-OVEN FANS #1	0201	5.00	CD	AC	401140111100
577.	INST/CNTLS-OVEN FANS #2	0201	5.00	CD	AC	401140111200
578.	WATER HEATER #1	0101	455.00	CD	AC	401240120100
579.	WATER HEATER #2	0101	455.00	CD	AC	401240120200
580.	DUMP NOZZLE - WATER	0101	10.00	CD	OT	401340130000
581.	INSTR + CONTROLS (WATER)	0101	12.0	CDTBD	AC	401440140000
582.	INSTR + CONTROLS (WATER)	0101	10.00	CD	AC	401440141000
583.	SOLIDS COLLECTION SLINGR	0101	120.00	CDTBD	AC	401640160000
584.	WATER SEP -LIFE SUPPORT	0101	90.00	CDTBD	AC	401740170000
585.	DUMP NOZZLE-URINE	0101	10.00	CD	OT	401840180000
586.	INSTR + CONTROLS(WASTE)	0101	10.00	CD	AC	401940190000
587.	SMOKE DET SENR-FLT/MID	0202	4.00	CD	AC	402040200100
588.	SMOKE DET SESR-BAY A1	0202	4.00	CD	A1	402040200200
589.	SMOKE DET SNSR-BAY A2	0202	4.00	CD	A2	402040200300
590.	SMOKE DET SNSR-BAY A3	0202	4.00	CD	A3	402040200400
591.	SMOKE DETECTION ALARM	0101	8.0	CD	AC	40210000
592.	FLASH EVAPORATOR HTR #1	0101	310.00	CD	OT	40270100
593.	FLASH EVAPORATOR HTR #2	0101	310.00	CD	OT	40270200
594.	FLASH EVAPORATOR EL #1	0101	8.00	CD	OT	40280100
595.	FLASH EVAPORATOR EL #2	0101	8.00	CD	OT	40280200
596.	FREON PUMP LP 1-A/B ASC	0201	500.00	CDTBD	OT	40290100
597.	FREON PUMP LP 1-A/B 6 PL	0201	420.00	CDTBD	OT	40290110
598.	FREON PUMP LP 1-A/B 8 PL	0201	460.00	CDTBD	OT	40290120
599.	FREON PUMP LP 2-A/B ASC	0201	500.00	CDTBD	OT	40290200
600.	FREON PUMP LP 2-A/B 6 PL	0201	420.00	CDTBD	OT	40290210
601.	FREON PUMP LP 2-A/B 8 PL	0201	460.0	CDTBD	OT	40290220
602.	SPACE RADIATOR SYSTEM #1	0101	10.00	CD	OT	40300100
603.	SPACE RADIATOR SYSTEM #2	0101	10.00	CD	OT	40300200
604.	ECLSS CONTINUED					40300901
605.	AMMONIA BOILER SYSTEM #1	0101	12.50	CD	OT	40310100
606.	AMMONIA BOILER SYSTEM #2	0101	12.50	CD	OT	40310200
607.	FREON BYPASS CONTROL #1	0101	6.00	CDTBD	OT	40320100
608.	FREON BYPASS CONTROL #2	0101	6.00	CDTBD	OT	40320200
609.	DIVERTER VALVE #1	0101	19.50	CD	OT	40330100
610.	DIVERTER VALVE #2	0101	19.50	CD	OT	40330200
611.	LCG COOLANT PUMP #1	0101	0.00	CD	OT	40340100
612.	LCG COOLANT PUMP #2	0101	0.00	CD	OT	40340200
613.	FREON PROPOR VALVE #1	0101	67.00	CD	OT	40350100
614.	FREON PROPOR VALVE #2	0101	67.00	CD	OT	40350200
615.	HYDRAULICS POWER SYS					50000001
616.	LG EXTEND VALVE	0101	20.00	S	OT	500150010000
617.	MAIN LDG GEAR UPLK VL #1	0101	20.00	S	OT	50020100
618.	MAIN LDG GEAR UPLK VL #2	0101	20.00	S	OT	50020200
619.	MAIN LDG GEAR UPLK VL #3	0101	20.00	S	OT	50020300
620.	MAIN LDG GEAR UPLK VL #4	0101	20.00	S	OT	50020400
621.	LDG GEAR DUMP VLV #1	0101	20.00	S	OT	50030100
622.	LDG GEAR DUMP VLV #2	0101	20.00	S	OT	50030200
623.	LDG GEAR DUMP VLV #3	0101	20.00	S	OT	50030300
624.	LG RETRACT CIRC VLV	0101	20.00	S	OT	50040000
625.	REDUNDANT S/O VALVE #1	0101	20.00	S	OT	50050100
626.	REDUNDANT S/O VALVE #2	0101	20.00	S	OT	50050200
627.	MAIN PUMP #1 DEPRES VLV	0101	26.00	S	OT	50060100

TABLE 7.2-1 (Continued)

LOADS

DATE 110174

628.	MAIN PUMP =2 DEPRES VL	0101	26.00	S		OT	50060200
629.	MAIN PUMP =3 DEPRES VLV	0101	26.00	S		OT	50060300
630.	CIRC MOTOR PUMP =1	0101	1561.0	CD		OT	50070100
631.	CICR MOTOR PUMP =2	0101	1561.0	CD		OT	50070200
632.	CICR MOTOR PUMP =3	0101	1561.0	CD		OT	50070300
633.	RESVOIR =1 VOLUME SENSOR	0101	8.00	S	TBD	OT	50080100
634.	RESVOIR =2 VOLUME SENSOR	0101	8.00	S	TBD	OT	50080200
635.	RESVOIR =3 VOLUME SENSOR	0101	8.00	S	TBD	OT	50080300
636.	SSME =1 SYS S/O VALVE	0101	20.00	S		OT	50090100
637.	SSME =2 SYS S/O VALVE	0101	20.00	S		OT	50090200
638.	SSME =3 SYS S/O VALVE	0101	20.00	S		OT	50090300
639.	LI ELEVON HTR BKT =1/=2	0201	50.00	S		OT	50100100
640.	LO ELEVON HTR BKT =1/=2	0201	50.00	S		OT	50100200
641.	RI ELEVON HTR BKT =1/=2	0201	50.00	S		OT	50100300
642.	RO ELEVON HTR BKT =1/=2	0201	50.00	S		OT	50100400
643.	HYDRAULICS CONTINUED						50100901
644.	H20 BOILER =1 STM S/O VL	0101	20.00	CV	=0.8	OT	50110100
645.	H20 BOILER =2 STM S/O VL	0101	20.00	CV	=0.8	OT	50110200
646.	H20 BOILER =3 STM S/O VL	0101	20.00	CV	=0.8	OT	50110300
647.	H20 BOILER =1 XFER VLV	0101	50.00	CV		OT	50120100
648.	H20 BOILER =2 XFER VLV	0101	50.00	CV		OT	50120200
649.	H20 BOILER =3 XFER VLV	0101	50.00	CV		OT	50120300
650.	H20 BOLR =1 THRM CNTL VL	0101	20.00	CV	=0.8	OT	50130100
651.	H20 BOLR =2 THRM CNTL VL	0101	20.00	CV	=0.8	OT	50130200
652.	H20 BOLR =3 THRM CNTL VL	0101	20.00	CV	=0.8	OT	50130300
653.	H20 BOILER =1 ELECT CONT	0101	7.00	CV	1.0	OT	50140100
654.	H20 BOILER =2 ELECT CONT	0101	7.00	CV	1.0	OT	50140200
655.	H20 BOILER =3 ELECT CONT	0101	7.00	CV	1.0	OT	50140300
656.	H20 BOILER =1 HEATER	0101	100.00	CV		OT	50150100
657.	H20 BOILER =2 HEATER	0101	100.00	CV		OT	50150200
658.	H20 BOILER =3 HEATER	0101	100.00	CV		OT	50153300
659.	H20 BOILER =1 QTY GAGE	0101	5.0	CV	TBD	OT	50160100
660.	H20 BOILER =2 QTY GAGE	0101	5.0	CV	TBD	OT	50160200
661.	H20 BOILER =3 QTY GAGE	0101	5.0	CV	TBD	OT	50160300
662.	ELEVON ACT SW VLV POS	0808	1.00	S		OT	50170000
663.	RUD/SPDBRK ACT VL POS =1	0101	1.0	S		OT	50180100
664.	RUD/SPDBRK ACT VL POS =2	0101	1.0	S		OT	50180200
665.	TVC ACT SW VLV POS	1212	1.00	S		OT	50190000
666.	HYDRAULICS CONTINUED						50190901
667.	RESVR =1 LOW LEVEL IND	0101	2.0	S		OT	50200100
668.	RESVR =2 LOW LEVEL IND	0101	2.0	S		OT	50200200
669.	RESVR =3 LOW LEVEL IND	0101	2.0	S		OT	50200300
670.	BODYFLAP MTR 1 HTR =1/=2	0201	50.00	CD		OT	50220100
671.	BODYFLAP MTR 2 HTR =1/=2	0201	50.00	CD		OT	50220200
672.	BODYFLAP MTR 3 HTR =1/=2	0201	50.00	CD		OT	50220300
673.	MAIN PUMP =1 HTR - =1/=2	0201	25.00	CD		OT	50240100
674.	MAIN PUMP =2 HTR - =1/=2	0201	25.00	CD		OT	50240200
675.	MAIN PUMP =3 HTR - =1/=2	0201	25.00	CD		OT	50240300
676.	RUDDER SPDBRK MTR =1 HTR	0201	50.00	CD		OT	50250100
677.	RUDDER SPDBRK MTR =2 HTR	0201	50.00	CD		OT	50250200
678.	RUDDER SPDBRK MTR =3 HTR	0201	50.00	CD		OT	50250300
679.	RUDDER SPDBRK MTR =4 HTR	0201	50.00	CD		OT	50250400
680.	RUDDER SPDBRK MTR =5 HTR	0201	50.00	CD		OT	50250500
681.	RUDDER SPDBRK MTR =6 HTR	0201	50.00	CD		OT	50250600
682.	SSME =1 HYDR ISOL VALVE	0101	80.00	CD		OT	50260100
683.	SSME =2 HYDR ISOL VALVE	0101	80.00	CD		OT	50260200
684.	SSME =3 HYDR ISOL VALVE	0101	80.00	CD		OT	50260300

TABLE 7.2-1 (Continued)

```
                                                          L O A D S                                    DATE 110174
685.        DOCKING + CARGO HNDLG                                                                           51000001
686.        MANIPULATOR                    0101      1600.00          CD          OT                        51010000
687.        MANIP DEPLOY DRIVE             0806       150.00          CD      -0.70T                        51020000
688.        MANIP RETENT LATCH DRIVE0606               60.00          CD      -0.70T                        51030000
689.        PL BAY DOOR RET LCH DRVE3006               60.00          CD      -0.70T                        5[illegible]100
690.        XFER TUNNEL EXT/RET DR 10101              200.00          CD      -0.70T                        51[illegible]00
691.        XFER TUNNEL EXT/RET DR 20101              200.00          CD      -0.70T                        51060200
692.        XFER TUNNEL LTCH DRVE #10101              140.00          CD      -0.70T                        51070100
693.        XFER TUNNEL LTCH DRVE #20101              140.00          CD      -0.70T                        51070200
694.        PBD CIRCUM LATCH DRIVE  1206              140.00          CD      -0.70T                        51080000
695.        PBD CENTER LINE LTCH DR 1206              220.00          CD      -0.70T                        51090000
696.        RADIATOR RET LATCH DRIVE0808               60.00          CD      -0.70T                        51100000
697.        RADIATOR DEPLOY DRIVE   0606               15.00          CD      -0.70T                        51110000
698.        RENDZ SENSOR DEPL DR #1 0101              200.00          CD      -0.70T                        51120100
699.        RENDZ SENSOR DEPL DR #2 0101              200.00          CD      -0.70T                        51120200
700.        MANIP CNTL INTRFACE UNIT0101               11.00          CD          AC                    5114511140000
701.        E/T UMB (LH) DOOR DRIVE 0303              200.00          CD      -0.70T                        51150000
702.        E/T UMB (LH) DOOR LATCH 0303              200.00          CD      -0.70T                    5116511160000
703.        E/T UMB (RH) DOOR DRIVE 0303              200.00          CD      -0.70T                        51170000
704.        E/T UMB (RH) DOOR LATCH 0303              200.00          CD      -0.70T                        51180000
705.        MECHANICAL SYS + LNDG                                                                           5[illegible]000001
706.        RUD/SPD BRKE S/V (RUD )  0202              15.00          S           OT                        5[illegible]10000
707.        RUD/SPD BRKE S/V         0404              15.00          S           OT                        5[illegible]20000
708.        STARTRACKER DOOR DRIVE   0303             200.00          CD      -0.70T                        5[illegible]40000
709.        RCS TOP DOOR ACT         0303             200.00                  -0.70T                        5[illegible]50000
710.        RCS LH SIDE DOOR ACT     0303             200.00          CD      -0.70T                        5[illegible]60000
711.        RCS RH SIDE DOOR ACT     0303             200.00          CD      -0.70T                        [illegible]70000
712.        LAUNCH UMB (LH) DOOR DR  0303             200.00          CD      -0.70T                        52[illegible]80000
713.        LAUNCH UMB (RH) DOOR DR  0303             200.00          CD      -0.70T                        5[illegible]0000
714.        P/L BAY (RH) DR DRIVE    0303             400.00          CD      -0.70T                        52160000
715.        P/L BAY (LH) DR DRIVE    0303             400.00          CD      -0.70T                        52170000
716.        GN+C PROBE ACT LH-A-T    0202               5.00          CD      -0.70T                        52180000
717.        GN+C PROBE ACT RH-A-T    0202               5.00          CD      -0.70T                        52200000
718.        NOSE WHEEL STEERING UNIT0101               10.00          CD          A3                        52260000
719.        BRAKE/SKID POWER SYS     0101             140.00          CD          OT                        52270000
720.        GN+C PROBE HEATERS       0202            1100.00          S           OT                        523[illegible]000
721.        VENT DOOR MOTORS         0606              10.00          CDTBD       OT                    523252320[illegible]00
722.        VENT DOOR MOTORS         1212             100.00          CDTBD       OT                    523352330000
723.        VENT DOOR MOTORS         0606              20.00          CDTBD       OT                    523452340000
724.        VENT DOOR MTR PL BAY WNG0606              100.00          CDTBD       OT                    523552350000
725.
```

TABLE 7.2-2 SEPAP TOPOLOGY DEFINITION

SOURCE DEFINITION

(3-TOTAL)

SOURCE CODE NO.	CONNECTS* NODE	TO NODE	IDENTIFICATION
1	09	01	Fuel Cell 1
2	09	02	Fuel Cell 2
3	09	03	Fuel Cell 3

* NOTE: 09 is common ground.

TABLE 7.2-2 (Continued)

BUS/NODE DEFINITION

(40 NODES)

BUS/NODE NUMBER	IDENTIFICATION
01	Fuel Cell 1
02	Fuel Cell 2
03	Fuel Cell 3
09	Ground
10	Main dc Bus A
11	Main dc Bus A Loads
12	Fwd Local dc Bus A
13	Midbody Local dc Bus A
14	Aft Local dc Bus A
15	RH D&C Panels Bus A
16	LH D&C Panels Bus A
17	Essential Bus 3 AB
19	Inverter Bus A
20	Main dc Bus B
21	Main dc Bus B Loads
22	Fwd Local dc Bus B
33	Midbody Local dc Bus B
24	Aft Local dc Bus B
25	RH D&C Panels Bus B
26	LH D&C Panels Bus B

TABLE 7.2-2 (Continued)

BUSES/NODES DEFINITION

(40 NODES)

BUS/NODE NUMBER	IDENTIFICATION
27	Essential Bus 1 BC
29	Inverter Bus B
30	Main dc Bus C
31	Main dc Bus C Loads
32	Fwd dc Bus C
33	Midbody Local dc Bus C
34	Aft Local dc Bus C
35	RH D&C Panels Bus C
36	LH D&C Panels Bus C
37	Essential Bus 2 CA
39	Inverter Bus C
41	Fwd Sub-Bus AB
42	Fwd Sub-Bus BC
43	Fwd Sub-Bus CA
51	Aft Sub-Bus AB
52	Aft Sub-Bus BC
53	Aft Sub-Bus CA
60	Main Bus Tie - A, B, C
61	Fwd Sub-Bus ABC
62	Aft Sub-Bus ABC

TABLE 7.2-2 (Continued)

LOAD DEFINITION

(54 LOADS)

SEPAP LOAD NO.	R/SD NO.	IDENTIFICATION
111	D1O2	Main A On-Orbit c/b Panel
112	D1G2	Main A dc Loads (Bus Return)
113	D1G1	Main A dc Loads (Local Ground)
114	D1S2	Main A Mission Specialist c/b Panel
115	D1P2	Main A Payload Specialist c/b Panel
116	D1T2	Main A ALT c/b Panel
121	D1F2	Fwd Local A dc Loads (Bus Return)
122	D1F1	Fwd Local A dc Loads (Local Ground)
123	D1F3	Fwd Local A Inverter Loads
131	D1M1	Midbody Local A dc Loads (Local Ground)
141	D1A1	Aft Local A dc Local (Local Ground)
142	D1A4	Aft Local A Payload
151	D1R2	RHD&C Panel Bus A Loads
161	D1L2	LHD&C Panel Bus A Loads
171	D3E1,D1E1,D2E1	Essential Bus 3 AB Loads
211	D2O2	Main B On-Orbit c/b Panel
212	D2G2	Main B dc Loads (Bus Return)
213	D2G1	Main B dc Loads (Local Ground)
214	D2S2	Main B Mission Specialist c/b Panel
215	D2P2	Main B Payload Specialist c/b Panel
216	D2T2	Main B ALT c/b Panel

TABLE 7.2-2 (Continued)

LOAD DEFINITION

(54 LOADS)

SEPAP LOAD NO.	R/SD NO.	IDENTIFICATION
221	D2F2	Fwd Local B dc Loads (Bus Returns)
222	D2F1	Fwd Local B dc Loads (Local Ground)
223	D2F3	Fwd Local B Inverter Loads
231	D2M1	Midbody Local B dc Loads (Local Ground)
241	D2A1	Aft Local B dc Loads (Local Ground)
242	D2A4	Aft Local B Payload
251	D2R2	RH D&C Panel Bus B Loads
261	D2L2, D	LH D&C Panel Bus B Loads
271	D1E1,I2E1,D3E1	Essential Bus 1 BC Loads
302	D4W4	Main C Payload
311	D3O2	Main C On-Orbit c/b Panel
312	D3G2	Main C dc Loads (Bus Return)
313	D3G1	Main C dc Loads (Local Ground)
314	D3S2	Main C Mission Specialist c/b Panel
315	D3P2	Main C Payload Specialist c/b Panel
316	D3T2	Main C ALT c/b Panel
321	D3F2	Fwd Local C dc Loads (Bus Return)
322	D3F1	Fwd Local C dc Loads (Local Ground)
323	D3F3	Fwd Local C Inverter Loads
325	D3D2	Fwd Local C DFI
331	D3M1	Midbody Local C dc Loads (Local Ground)

TABLE 7.2-2 (Continued)

LOAD DEFINITION

(54 LOADS)

SEPAP LOAD NO.	R/SD NO.	IDENTIFICATION
341	D3A1	Aft Local C dc Loads (Local Ground)
351	D3R2	RH D&C Panel Bus C Loads
361	D3L2	LH D&C Panel Bus C Loads
371	D2E1,D3E1,D1E1	Essential Bus 2 CA Loads
412	D1F2,D2F2	Fwd Sub-Bus AB Loads
423	D2F2,D3F2	Fwd Sub-Bus BC Loads
431	D3F2,D1F2	Fwd Sub-Bus CA Loads
512	D1A2,D2A2	Aft Sub-Bus AB Loads
523	D2A2,D3A2	Aft Sub-Bus BC Loads
531	D3A2,D1A2	Aft Sub-Bus CA Loads
601	D1F2,D2F2,D3F2	Fwd Sub-Bus ABC Loads
602	D1A2,D2A2,D3A2	Aft Sub-Bus ABC Loads

TABLE 7.2-2 (Continued)

RESISTOR/SWITCH/DIODE

DEFINITION

(115-TOTAL)

RESISTOR AND SWITCH NO.	CONNECTS NODE	TO NODE	THRU LOAD NO.	THRU* DIODE NO.	RESISTOR VALUE (OHMS)	SWITCH POSITION
101	01	10	-	-	.00371	C
110	10	11	-	-	.00001	C
111	11	09	111	-	.02320	C
112	11	09	112	-	.02168	C
113	11	09	113	-	.04339	C
114	11	09	114	-	.02320	C
115	11	09	115	-	.00893	C
116	11	09	116	-	.00234	OP
120	10	12	-	-	.00419	C
121	12	09	121	-	.00243	C
122	12	09	122	-	.00487	C
123	19	09	123	-	.00908	C
124	12	19	-	-	.00001	C
130	10	13	-	-	.00605	C
131	13	09	131	-	.04339	C
140	10	14	-	-	.00946	C
141	14	09	141	-	.04339	C
142	14	09	142	-	.00447	OP
150	10	15	-	-	.00826	C
151	15	09	151	-	.00604	C
160	10	16	-	-	.00826	C

*Nodal connections as listed reflect diode current flow.

TABLE 7.2-2 (Continued)

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

RESISTOR/SWITCH/DIODE DEFINITION

(115-TOTAL)

RESISTOR AND SWITCH NO.	CONNECTS NODE	TO NODE	THRU LOAD NO.	THRU DIODE NO.	[illegible] VALUE [illegible]	SWITCH POSITION
161	16	09	161	-	.00845	C
170	10	17	-	170	.00001	C
171	17	09	171	-	.00447	C
172	17	15	-	-	.00001	OP
173	17	16		-	.00001	OP
174	20	17		174	.00001	C
175	03	17		175	.00001	C
180	10	60		-	.00001	OP
201	02	20		-	.00371	C
210	20	21	-	-	.00001	C
211	21	09	211	-	.02320	C
212	21	09	212	-	.02168	C
213	21	09	213	-	.00523	C
214	21	09	214	-	.01774	C
215	21	09	215	-	.01785	C
216	21	09	216	-	.00199	OP
217	21	09	217	-	.00199	OP
220	20	22	-	-	.00119	C
221	22	09	221	-	.00119	C
222	22	09	222	-	.00199	C
223	29	09	223	-	.00644	C

---

*Nodal connections as listed reflect diode current flow

TABLE 7.2-2 (Continued)

RESISTOR/SWITCH/DIODE DEFINITION

(115-TOTAL)

RESISTOR AND SWITCH NO.	CONNECTS NODE	TO NODE	THRU LOAD NO.	THRU* DIODE NO.	RESISTOR VALUE (OHMS)	SWITCH POSITION
224	22	29	-	-	.00001	C
230	20	23	-	-	.00605	C
231	23	09	231	-	.04339	C
240	20	24	-	-	.00946	C
241	24	09	241	-	.00572	C
242	24	09	242	-	.00447	OP
250	20	25	-	-	.00826	C
251	25	09	251	-	.01256	C
260	20	26	-	-	.00826	C
261	26	09	261	-	.01123	C
270	20	27	-	270	.00001	C
271	27	09	271	-	.00447	C
272	27	25	-	-	.00001	OP
273	27	26	-	-	.00001	OP
274	30	27	-	274	.00001	C
275	01	27	-	275	.00001	C
280	20	60	-	-	.00001	OP
301	03	30	-	-	.00371	C
302	03	09	302	-	.00447	OP
310	30	31	-	-	.00001	C
311	31	09	311	-	.02320	C
312	31	09	312	-	.00574	C

* Nodal connections as listed reflect diode current flow.

TABLE 7.2-2 (Continued)

RESISTOR/SWITCH/DIODE DEFINITION

(115-TOTAL)

RESISTOR AND SWITCH NO.	CONNECTS NODE	TO NODE	THRU LOAD NO.	THRU* DIODE NO.	RESISTOR VALUE (OHMS)	SWITCH POSITION
313	31	09	313	-	.24125	C
314	31	09	314		.01371	C
315	31	09	315		.01635	C
316	31	09	316	-	.00639	OP
320	30	32	-	-	.00419	C
321	32	09	321	-	.00243	C
322	32	09	322	-	.00734	C
323	39	09	323	-	.00756	C
324	32	39	-	-	.00001	C
325	32	09	325	-	.06361	OP
330	30	33	-	-	.00605	C
331	33	09	331	-	.04339	C
340	30	34	-	-	.00946	C
341	34	09	341	-	.00846	C
350	30	35	-	-	.00826	C
351	35	09	351	-	.02204	C
360	30	36	-	-	.00826	C
361	36	09	361	-	.01074	C
370	30	37	-	370	.00001	C
371	37	09	371	-	.00447	C
372	37	35	-	-	.00001	OP
373	37	36	-	-	[illegible]	[illegible]

* Nodal connections as listed reflect diode current flow.

TABLE 7.2-2 (Continued)

RESISTOR/SWITCH/DIODE

DEFINITION

(115-TOTAL)

RESISTOR AND SWITCH NO.	CONNECTS NODE	TO NODE	THRU LOAD NO.	THRU* DIODE NO.	RESISTOR VALUE (OHMS)	SWITCH POSITION
374	10	37	-	374	.00001	C
375	02	37	-	375	.00001	C
380	30	60	-	-	.00001	OP
401	12	41	-	401	.00001	C
402	12	61	-	402	.00001	C
403	12	43	-	403	.00001	C
404	22	42	-	404	.00001	C
405	22	61	-	405	.00001	C
406	22	41	-	406	.00001	C
407	32	43	-	407	.00001	C
408	32	61	-	408	.00001	C
409	32	42	-	409	.00001	C
412	41	09	412	-	.00447	C
423	42	09	423	-	.00447	C
431	43	09	431	-	.00447	C
501	14	51	-	501	.00001	C
502	14	62	-	502	.00001	C
503	14	53	-	503	.00001	C
504	24	52	-	504	.00001	C
505	24	62	-	505	.00001	C
506	24	51	-	506	.00001	C
507	34	53	-	507	.00001	C

* Nodal connections as listed reflect diode current flow.

TABLE 7.2-2 (Continued)

RESISTOR/SWITCH/DIODE
DEFINITION
(J15-TOTAL)

RESISTOR AND SWITCH NO.	CONNECTS NODE	TO NODE	THRU LOAD NO.	THRU* DIODE NO.	RESISTOR VALUE (OHMS)	SWITCH POSITION
508	34	62	-	508	.00001	C
509	34	52	-	509	.00001	C
512	51	09	512	-	.00447	C
523	52	09	523	-	.00447	C
531	53	09	531	-	.00447	C
601	61	09	601	-	.00447	C
602	62	09	602	-	.00447	C

* Nodal connections as listed reflect diode current flow.

APPENDIX 7.3

LISTING OF EPDC AND USER LOAD ELEMENTS BY SUBSYSTEM (FROM ROCKWELL PROFILE ANALYSIS DOCUMENT, DATED 13 AUGUST 1974 AND LEC MEMORANDA)

TABLE 7.3-1

EPDC USER SUBSYSTEM CODE NUMBER LISTING

01	GUIDANCE NAVIGATION & CONTROL
02	COMMUNICATIONS
03	DISPLAYS & CONTROLS
04	OPERATIONAL FLIGHT INSTRUMENTATION
05	DEVELOPMENT FLIGHT INSTRUMENTATION
06	ELECTRICAL POWER DISTRIBUTION & CONTROL
07	DATA PROCESSING
08	PAYLOAD MANAGEMENT
09	UNMANNED KIT
15	EXTERNAL TANK
16	SOLID ROCKET BOOSTER
20	MAIN PROPULSION
21	ORBIT MANEUVERING SYSTEM
22	REACTION CONTROL SYSTEM
30	POWER GENERATION SYSTEM
31	CRYOGENICS SYSTEM
32	AUXILLARY POWER UNIT
40	ENVIRONMENTAL CONTROL & LIFE SUPPORT
50	HYDRAULICS
51	DOCKING & CARGO HANDLING
52	MECHANICAL SYSTEM & LANDING

TABLE 7.3-2. SHUTTLE SUBSYSTEM ELEMENT CODE AND PRIME POWER LISTING

SUBSYSTEM: GUIDANCE AND NAVIGATION CODE 01

ELEMENT NAME	S/S WATTS	ELEMENT CODE
IMU =1 OPERATE	160.00	010101010100
IMU =1 STANDBY	55.00	010101010110
IMU =2 OPERATE	160.00	010101010200
IMU =2 STANDBY	55.00	010101010210
IMU =3 OPERATE	160.00	010101010300
IMU =3 STANDBY	55.00	010101010310
STAR TRKER + LT SHLD =1	20.00	010301030100
STAR TRKER + LT SHLD =2	20.00	010301030200
STAR TRKER + LT SHLD =3	20.00	010301030300
AIR DATA XDCR ASSY =1	45.00	010401040100
AIR DATA XDCR ASSY =2	45.00	010401040200
AIR DATA XDCR ASSY =3	45.00	010401040300
AIR DATA XDCR ASSY =4	45.00	010401040400
FLIGHT CONTROLS	—	01070001
ASCENT TVC DRVR =1 - AFT	94.50	010801080100
ASCENT TVC DRVR =2 - AFT	94.50	010801080200
ASCENT TVC DRVR =3 - AFT	94.50	010801080300
AERO SRF SRV AMP =1-AFT	107.77	010901090100
AERO SRF SRV AMP =2-AFT	107.77	010901090200
AERO SRF SRV AMP =3-AFT	107.77	010901090300
AERO SRF SRV AMP =4-AFT	107.77	010901090400
REACTION JET DRVR =1 FWD	59.20	011101110100
REACTION JET DRVR =2 FWD	59.20	011101110200
REACT JET OMS DRVR=1-AFT	152.70	011201120100
REACT JET OMS DRVR=2-AFT	152.70	011201120200
RATE GYRO ASSY-AFT =1	23.00	011301130100
RATE GYRO ASSY-AFT =2	23.00	011301130200
RATE GYRO ASSY-AFT =3	23.00	011301130300
ACCELEROMETER ASSY-FWD=1	2.90	011401140100
ACCELEROMETER ASSY-FWD=2	2.90	011401140200
ACCELEROMETER ASSY-FWD=3	2.90	011401140300
TRANS HAND CONTROL =1	4.00	011601160100
TRANS HAND CONTROL =2	4.00	011601160200
ROT HAND CONTROL =1	10.60	011701170100
ROT HAND CONTROL =2	10.60	011701170200
ROT HAND CONTROL =3	10.60	011701170300
RUDDER PEDAL XDCR ASY =1	3.30	011801180100
RUDDER PEDAL XDCR ASY =2	3.30	011801180200
SPEED BRK THRUST CNTL =1	6.00	011901190100
SPEED BRK THRUST CNTL =2	6.00	011901190200

TABLE 7.3-2 (Continued)

SHUTTLE SUBSYSTEM ELEMENT CODE AND PRIME POWER LISTING

SUBSYSTEM: COMMUNICATIONS

CODE 02

ELEMENT NAME	S/S WATTS	ELEMENT CODE
B + W TV MONITOR =1	20.00	020102010100
B + W TV MONITOR =2	20.00	020102010200
TV REMOTE CONTROL	5.00	020202020000
TV CAMERA COLOR + MON	20.00	020302030000
TV CAMERA B+W =1+2	12.50	020402040100
TV CAMERA B+W =3+4	12.50	020402040200
PAN TILT ELECT =1	10.00	020502050100
PAN TILT ELECT =2	10.00	020502050200
PAN TILT MOUNT =1	3.00	020602060100
PAN TILT MOUNT =2	3.00	020602060200
VIDEO SWITCHING NETWORK	5.00	020702070000
NETWORK SIG PROCESSOR =1	24.00	020702080100
NETWORK SIG PROCESSOR =2	24.00	020702080200
CNTRL CNTL UNIT AUDIO =1	34.00	021002100100
CNTRL CNTL UNIT AUDIO =2	34.00	021002100200
S-BAND FM XMITR =1	100.00	021102110100
S-BAND FM XMITR =2	100.00	021102110200
S-BAND FM SIGNAL PROC	10.00	021202120000
S-BAND TRANSPONDER =1	15.00	021302130100
S-BAND TRANSPONDRR =2	15.00	021302130200
S- BAND PWR AMP ASSY	400.00	02140000
S-BAND PRE AMP ASSY	25.0	02150000
S-BAND ANT SW ASSY	0.60	021402160000
TACAN =1	150.00	021502170100
TACAN =2	150.00	021502170200
TACAN =3	150.00	021502170300
S-BAND SWITCH COAXIAL	0.60	021802180000

TABLE 7.3-2 (Continued)

SHUTTLE SUBSYSTEM ELEMENT CODE AND PRIME POWER LISTING

SUBSYSTEM: COMMUNICATIONS (CONTINUED)

ELEMENT NAME	S/S WATTS	ELEMENT CODE
MSBLS RF ASSY =1	22.00	022002200100
MSBLS DCDR ASSY =1	78.00	022002200110
MSBLS RF ASSY =2	22.00	022002200200
MSBLS DCDR ASSY =2	78.00	022002200210
MSBLS RF ASSY =3	22.00	022002200300
MSBLS DCDR ASSY =3	78.00	022002200310
RADAR ALTIMETER =1	37.50	022102210100
RADAR ALTIMETER =2	37.50	022102210200
COMSEC UNIT AF =1	35.00	022802280100
COMSEC UNIT AF =2	35.00	022802280200
COMSEC UNIT AF =3	35.00	022802280300
COMSEC UNIT AF =4	35.00	022802280400
P/L INTERG- AF+NASA =1	30.00	023002300100
P/L INTERG- AF+NASA =2	30.00	023002300200
PAYLOAD SIG PROCESSOR =1	17.00	021602310100
PAYLOAD SIG PROCESSOR =2	17.00	021602310200
UHF RCVR =1 MAIN/GUARD	30.00	020902330100
UHF RCVR =2 MAIN/GUARD	30.00	020902330200
UHF TRANSMITTER =1	90.00	020902340100
UHF TRANSMITTER =2	90.00	020902340200
UHF RF NETWORK CPLNG	15.00	023502350000
DOPPLER EXTRACTOR =1	15.00	023902390100
DOPPLER EXTRACTOR =2	15.00	023902390200
EVA SIG PROCESSOR =1	10.00	024002400100
EVA SIG PROCESSOR =2	10.00	024002400200
AUDIO TERM UNIT - FWD	5.00	02410001
AUDIO TERM UNIT - MSS	5.00	02420100
AUDIO TERM UNIT - PSS	5.00	02420200
AUDIO TERM UNIT - REAR	5.00	02420300
SPEAKER MIKE ASSY -RIGHT	4.00	02420400
SPEAKER MIKE ASSY -LEFT	4.00	02470100
S-BND FM XMITR DFI	100.00	02470200
S-BND MULTX DFI	0.00	02480000
RNDZ RADAR ELEC ASSY -DC	160.00	02490000
RNDZ RADAR ELEC ASSY -AC	20.00	02500000
RNDZ RADAR ELEC ASSY -DC	50.00	02501000
RNDZ RADAR DPLY ASSY -AC	395.00	02510000
KU-BAND EL ASSY - DC =1	100.00	02511000
KU-BAND EL ASSY - DC =2	100.00	02520100
KU-BAND EL ASSY - AC =1	20.00	02520200
KU-BAND EL ASSY - AC =2	20.00	02521100
KU-BAND COMM DPY ASSY =1	85.00	02521200
KU-BAND COMM DPY ASSY =2	85.00	02530100
KU-BAND COMM DPY ASSY =1	235.00	02530200
KU-BAND COMM DPY ASSY =2	235.00	02531100
KU-BND SIG PROCESSOR	15.00	02531200
		02540000

TABLE 7.3-2 (Continued)

SHUTTLE SUBSYSTEM ELEMENT CODE AND PRIME POWER LISTING

SUBSYSTEM: DISPLAYS AND CONTROLS CODE 03

ELEMENT NAME	S/S WATTS	ELEMENT CODE
ATTITUDE DIR IND-FWD =1	14.60	030103010100
ATTITUDE DIR IND-FWD =2	14.60	030103010200
ATTITUDE DIR IND-AFT =3	14.60	03010300
HORZ SIT IND=1	35.00	030303030100
HORZ SIT IND=2	35.00	030303030200
AS/MACH IND AMI =1	40.00	030403040100
AS/MACH IND AMI =2	40.00	030403040200
ALT VER VEL IND =1	40.00	030503050100
ALT VER VEL IND =2	40.00	030503050200
TAPE METERS HYD-APU-MPS	132.00	03060000
CROSS POINTER IND	.00	03120000
SURF POSITION IND	5.00	031303130000
QTY IND OMS/RCS	6.00	03140000
CAUT + WARNING UNIT	20.00	031503150000
MISSION TIMER =1	4.00	031703170100
MISSION TIMER =2	4.00	031703170200
EVENT TIMER =1	4.00	031803180100
EVENT TIMER =2	4.00	031803180200
CRT DISPLAY UNIT =1	90.00	031903190100
CRT DISPLAY UNIT =2	90.00	031903190200
CRT DISPLAY UNIT =3	90.00	031903190300
CRT DISPLAY UNIT =4	90.00	031903190400
DISPLAY ELECT UNIT =1	207.30	03210100
DISPLAY ELECT UNIT =2	207.30	03210200
DISPLAY ELECT UNIT =3	207.30	03210300
DISPLAY ELECT UNIT =4	207.30	03210400
DISP DRVR UNIT-CRW FWD=1	120.00	03220100
DISP DRVR UNIT-CRW FWD=2	120.00	03220200
DISP DRVR UNIT-CRW AFT=3	120.00	03220300
MANIP HAND CONTROLLER	8.00	032503250000

TABLE 7.3-2 (Continued)

SHUTTLE SUBSYSTEM ELEMENT CODE AND PRIME POWER LISTING

SUBSYSTEM: DISPLAY AND CONTROL LIGHTING CODE 03

ELEMENT NAME	S/S WATTS	ELEMENT CODE
INTEGRAL LIGHTS-LEFT/CTR	134.00	033103310100
INTEGRAL LIGHTS-OVHD	134.00	033103310200
INTEGRAL LIGHTS-RIGHT	134.00	033103310300
INTEGRAL LIGHTS-REAR	134.00	033103310400
ANNUNCIATOR LTS-LEFT/CTR	23.30	033303330100
ANNUNCIATOR LTS-OVHD	23.30	033303330200
ANNUNCIATOR LTS-RIGHT	23.30	033303330300
MID DECK FLOOD LTS - 1	19.40	033503350100
MID DECK FLOOD LTS - 2/3	19.40	033503350200
MID DECK FLOOD LTS - 4/6	19.40	033503350300
MID DECK FLOOD LTS - 5	19.40	033503350400
MID DECK FLOOD LTS-PANEL	19.40	033503350500
LWR DECK SLEEP STA LTS	18.50	033603360000
LWR DECK WASTE MGMT LTS	18.50	033803380000
LWR DECK GALLEY LIGHT	15.00	033903390000
AIRLOCK LIGHTS	103.50	034103410000
CABIN FLOOD LIGHTS AFT	29.80	034203420100
GLARESHIELD FLDLTS -LEFT	29.80	034203420200
GLARESHIELD FLDLTS-RIGHT	29.80	034203420300
CENTER CONSOLE FLOODLTS	29.80	034203420400
PILOT CONSOLE FLDLTS-RHT	29.80	034203420500
PILOT CONSOLE FLDLTS-LFT	29.80	034203420600
REAR STA P/L LTS	60.00	034303430000
EMERGENCY LIGHT - 1	29.80	034503450100
EMERGENCY LIGHT - 2	29.80	034503450200
PAYLOAD BAY FLOOD LTS	200.00	034903490000
MANIP SPOT LIGHT	100.00	035003500000
RNDZ LIGHT	30.00	035103510000
DOCKING SPOT LIGHTS	150.00	03540000
C+W STATUS BOARD	36.00	03550000
C+W ANNUNCIATOR ASSY	24.00	03560000
C+W ANNUN ASSY - QUIESCT	2.00	03560010

TABLE 7.3-2 (Continued)

SHUTTLE SUBSYSTEM ELEMENT CODE AND PRIME POWER LISTING CODE 04

SUBSYSTEM: OPERATIONAL FLIGHT INSTRUMENTATION

ELEMENT NAME	S/S WATTS	ELEMENT CODE
PCM MASTER UNIT DACBU =1	60.00	040304030100
PCM MASTER UNIT DACBU =2	60.00	040304030200
MAINT RECORDER	40.00	040404040000
SIG COND UNIT-FWD =1	35.00	040504050100
SIG COND UNIT-FWD =2	35.00	040504050200
SIG COND UNIT-FWD =3	35.00	040504050300
SIG COND UNIT =1 - AFT	35.00	040604060100
SIG COND UNIT =2 - AFT	35.00	040604060200
SIG COND UNIT =3 - AFT	35.00	040604060300
LCOP RECORDER	40.00	040704070000
MASTER TIMING UNIT-WMUP	40.00	040904090000
MASTER TIMING UNIT-OPR	26.00	040904090010
PAYLOAD DATA INTERLEAVER	30.00	041104110000
SIG COND UNIT-CMS/RCS =1	35.00	04120100
SIG COND UNIT-CMS/RCS =2	35.00	04120200
SIG COND UNIT-F/C AREA	35.00	04130000
SIG COND UNIT-FWD RCS	35.00	04140000
	0.30	04150000

TABLE 7.3-2 (Continued)

SHUTTLE SUBSYSTEM ELEMENT CODE AND PRIME POWER LISTING

SUBSYSTEM: DEVELOPMENT FLIGHT INSTRUMENTATION CODE 05

ELEMENT NAME	S/S WATTS	ELEMENT CODE
PCM MASTER UNIT - =1	60.00	040305030100
PCM MASTER UNIT - =2	60.00	040305030200
PCM RECORDER	40.00	040405040000
SIG COND UNIT - FWD =1	35.00	040505050100
SIG COND UNIT - FWD =2	35.00	040505050200
SIG COND UNIT - FWD =3	35.00	040505050300
SIG COND UNIT - FWD =4	35.00	040505050400
SIG COND UNIT -MID =1-12	35.00	040505060000
WIDEBAND FDM UNIT-FWD	50.00	050705070000
WIDEBAND FDM UNIT-MID =1	50.00	050705080100
WIDEBAND FDM UNIT-MID =2	50.00	050705080200
WIDEBAND RECORDER	40.00	050905090000
WIDEBND SIG CND UNIT FWD	0.60	051205120000
WIDEBND SIG CND UNIT MID	0.60	051305130100
WIDEBND SIG CND UNIT MID	0.60	051305130200
STRAIN GAGE SIG CND FWD	5.60	051505150000
STRAIN GAGE SIG CND MID	5.60	051605160100
STRAIN GAGE SIG CND MID	5.60	051605160200
CURRENT SENSOR	0.30	051805180000

TABLE 7.3-2 (Continued)

SHUTTLE SUBSYSTEM ELEMENT CODE AND PRIME POWER LISTING

SUBSYSTEM: ELECTRICAL POWER DISTRIBUTION & CONTROL CODE 06

ELEMENT NAME	S/S WATTS	ELEMENT CODE
INVERTERS 1PH,750VA,80(	0.00	060106010100
INVERTERS 1PH,750VA,80(	0.00	060106010200
INVERTERS 1PH,750VA,80(	0.00	060106010300
PYRO EVENT CNTLR -FWD =1	25.00	060206020100
PYRO EVENT CNTLR -FWD =2	25.00	060206020200
MASTER EVENT CNTLR-AFT=1	25.00	060306030100
MASTER EVENT CNTLR-AFT=2	25.00	060306030200
LOAD CNTLR ASSY-FWD =1	75.00	060406040100
LOAD CNTLR ASSY-FWD =2	75.00	060406040200
LOAD CNTLR ASSY-FWD =3	75.00	060406040300
LOAD CNTLR ASSY-AFT =1	90.00	060506050100
LOAD CNTLR ASSY-AFT =2	90.00	060506050200
LOAD CNTLR ASSY-AFT =3	90.00	060506050300
DC PWR CNTLR ASSY-FWD =1	260.00	060606060100
DC PWR CNTLR ASSY-FWD =2	260.00	060606060200
DC PWR CNTLR ASSY-FWD =3	260.00	060606060300
DC PWR CNTLR ASSY-AFT =1	160.00	060706070100
DC PWR CNTLR ASSY-AFT =2	160.00	060706070200
DC PWR CNTLR ASSY-AFT =3	160.00	060706070300
MAIN DC DIST+CNTL ASSY=1	20.00	060806080100
MAIN DC DIST+CNTL ASSY=2	20.00	060806080200
MAIN DC DIST+CNTL ASSY=3	20.00	060806080300
INV DIST + CNTL ASSY =1	20.00	061006100100
INV DIST + CNTL ASSY =2	20.00	061006100200
INV DIST + CNTL ASSY =3	20.00	061006100300
ELEC PWR DST/CNTL CONT		06110001
DC PWR CNTL ASSY-MID =1	30.00	061206120100
DC PWR CNTL ASSY-MID =2	30.00	061206120200
DC PWR CNTL ASSY-MID =3	30.00	061206120300
EVLSS BAT CHARGER	5.00	061606160000
EVLSS PWR SUPPLY	75.00	061806180000
PROXIMITY SWITCH =1	8.00	061906190100
PROXIMITY SWITCH =2	8.00	061906190200
PROXIMITY SWITCH =3	8.00	061906190300

TABLE 7.3-2 (Continued)

SHUTTLE SUBSYSTEM ELEMENT CODE AND PRIME POWER LISTING

SUBSYSTEM: DATA PROCESSING CODE 07

ELEMENT NAME	S/S WATTS	ELEMENT CODE
COMPUTER =1	600.00	070107010100
COMPUTER =2	600.00	070107010200
COMPUTER =3	600.00	070107010300
COMPUTER =4	600.00	070107010400
COMPUTER =5	600.00	070107010500
MDM FF1	40.00	070307030100
MDM FF2	40.00	070307030200
MDM FF3	40.00	070307030300
MDM FF4	40.00	070307030400
MDM FA1	40.00	0703070401
MDM FA2	40.00	070307040200
MDM FA3	40.00	070307040300
MDM FA4	40.00	070307040400
MDM OFI - FWD	40.00	07050000
MDM OFI - MID	40.00	07060000
MASS MEM=1 TAPE OPER	53.00	070907090100
MASS MEM=1 TAPE STBY	8.00	070907090110
MASS MEM=2 TAPE OPER	53.00	070907090200
MASS MEM=2 TAPE STBY	8.00	070907090210
MDM OFI 1	40.00	07100100
MDM OFI 2	40.00	07100200
MDM OFI 3	40.00	07100300
MDM OFI 4	40.00	07100400
MDM OFI AFT 1	40.00	07110100
MDM OFI AFT 2	40.00	07110200
MDM OFI AFT 3	40.00	07110300
MDM LF-1	40.00	071207120000
MDM LA-1	40.00	071307130000
DATA PROCESSING CON T		07140001
ENG INTERFACE UNIT =1	50.60	071507150100
ENG INTERFACE UNIT =2	50.60	071507150200
ENG INTERFACE UNIT =3	50.60	071507150300
DATA BUS ISO AMP =1 GSE	20.00	071607160100
DATA BUS ISO AMP =1 ORB	10.00	071607160110
DATA BUS ISO AMP =2 GSE	20.00	071607160200
DATA BUS ISO AMP =2 ORB	10.00	071607160210

TABLE 7.3-2 (Continued)

SHUTTLE SUBSYSTEM ELEMENT CODE AND PRIME POWER LISTING

SUBSYSTEM: PAYLOAD MANAGEMENT CODE 08

ELEMENT NAME	S/S WATTS	ELEMENT CODE
MCM PAYLOAD FWD =1	40.00	080108010100
MCM PAYLOAD FWD =2	40.00	080108010200
WIDE BAND RECORDER MSS	175.00	08020000
PCM RECORDER MSS	40.00	08030000
P/L - ASCENT/ENTRY	961.50	08040000
P/L - SORTIE	5769.20	08040100
AUX C+W UNIT	10.00	08050000
AUX C+W ANNUN ASSY	15.00	08060000
UNMANNED KIT		09000001
SUBSYS SEQ CCNTR UNIT=1	370.00	09010000
SUBSYS SEQ CCNTR UNIT=2	190.00	09020000
EXTERNAL TANK		15000001
MLM - DFI	20.00	150115010000

TABLE 7.3-2 (Continued)

SHUTTLE SUBSYSTEM ELEMENT CODE AND PRIME POWER LISTING

SUBSYSTEM: SOLID ROCKET BOOSTER CODE 16

ELEMENT NAME	S/S WATTS	ELEMENT CODE
RATE GYRO ASSY	42.00	150116010100
RATE GYRO ASSY	42.00	150116010200
MDM - SET 1	15.00	150116020100
MDM - SET 2	15.00	150116020200
MDM DFI =1	35.00	16040100
MDM DFI =2	35.00	16040200
PIC IGNITION - SET 1	0.00	150316050100
PIC IGNITION - SET 2	0.00	150316050200
PIC SEPARATION-SET 1	0.00	150316060100
PIC SEPARATION-SET 2	0.00	150316060200
SIG COND - SET 1	20.00	150116070100
SIG COND - SET 2	20.00	150116070200
TVC HYDR RECIRC SYS	206.00	16080000
SAFE + ARM DEVICE	75.00	16090000

TABLE 7.3-2 (Continued)

SHUTTLE SUBSYSTEM ELEMENT CODE AND PRIME POWER LISTING

SUBSYSTEM: MAIN PROPULSION SYSTEM CODE 20

ELEMENT NAME	S/S WATTS	ELEMENT CODE
MAIN ENG CONTROLLER-1	750.00	200120010100
MAIN ENG CONTROLLER-2	750.00	200120010200
MAIN ENG CONTROLLER-3	750.00	200120010300
MAIN ENG HTR =1	300.00	200220020100
MAIN ENG HTR =2	300.00	200220020200
MAIN ENG HTR =3	300.00	200220020300
LO2 PREVALVE SOLENOID	42.00	200320030100
LO2 PREVALVE SOLENOID	42.00	200320030200
LO2 PREVALVE SOLENOID	42.00	200320030300
LH2 PREVALVE SOLENOID	42.00	200420040100
LH2 PREVALVE SOLENOID	42.00	200420040200
LH2 PREVALVE SOLENOID	42.00	200420040300
LO2 F+D VLV =1 C/B SOL	42.00	20050000
LO2 F+D VLV =2 C/B SOL	42.00	20060000
LH2 F+D VLV =1 C/B SOL	42.00	20070100
LH2 F+D VLV =1 C/B SOL	42.00	20070200
LH2 F+D VLV =2 C/B SOL	42.00	20080100
LH2 F+D VLV =2 C/B SOL	42.00	20080200
LH2 TOPPING VLV OPEN SOL	42.00	20090000
LH2 RECRC VLV OPEN SOL=1	42.00	20100100
LH2 RECRC VLV OPEN SOL=2	42.00	20100200
LH2 RECRC VLV OPEN SOL=3	42.00	20100300
ET/ORB LO2 FEED DISC S V	42.00	20110100
ET/ORB LO2 FEED DISC S V	42.00	20110200
ET/ORB LH2 FEED DISC S V	42.00	20120100
ET/ORB LH2 FEED DISC S V	42.00	20120200
ET/ORB RECIRC DISC S V	42.00	20130100
ET/ORB RECIRC DISC S V	42.00	20130200
LO2 FEEDLN RELF SHUTOFF	42.00	20140000
LH2 FEEDLN RELF SHUTOFF	42.00	20150000
MAIN PROP SYS-CONTINUED		20150901
LH2 PRESS N DISC BYPASS	42.00	20160000
ET VENT VLV ISO SOL VLV	42.00	20170000
LO2 FEEDLN REPRESS VLV=1	42.00	20180100
LO2 FEEDLN REPRESS VLV=2	42.00	20180200

TABLE 7.3-2 (Continued)

SHUTTLE SUBSYSTEM ELEMENT CODE AND PRIME POWER LISTING

SUBSYSTEM: MAIN PROPULSION SYSTEM (CONTINUED) CODE 20

ELEMENT NAME	S/S WATTS	ELEMENT CODE
LH2 FEEDLN REPRESS VLV=1	42.00	20190100
LH2 FEEDLN REPRESS VLV=2	42.00	20190200
HE CROSSOVER VLV =1	42.00	20200100
HE CROSSOVER VLV =2	42.00	20200200
HE CROSSOVER VLV =3	42.00	20200300
ENG HE SUPPLY ISO SOL =1	42.00	20210100
ENG HE SUPPLY ISO SOL =2	42.00	20210200
ENG HE SUPPLY ISO SOL =3	42.00	20210300
VEH HE SUPPLY ISO SOL=1	42.00	20220100
VEH HE SUPPLY ISO SOL=2	42.00	20220200
HE BLOWDN SOL VLV =1	42.00	20230100
HE BLOWDN SOL VLV =2	42.00	20230200
LO2 PRESS N FL CNTL SV1	42.00	20240100
LO2 PRESS N FL CNTL SV2	42.00	20240200
LO2 PRESS N FL CNTL SV3	42.00	20240300
LH2 PRESS N FL CNTL SV1	42.00	20250100
LH2 PRESS N FL CNTL SV2	42.00	20250200
LH2 PRESS N FL CNTL SV3	42.00	20250300
ET ULLAGE SIG CND PKG =1	33.33	20270100
ET ULLAGE SIG CND PKG =2	33.33	20270200
ET ULLAGE SIG CND PKG =3	33.33	20270300
PROP LOW LEV SNSR SIGCND	7.00	20280000
PROP LOADING SNSR SIGCND	7.00	20290000
MPS DELTA P GSE	14.00	203220320000

TABLE 7.3-2 (Continued)

SHUTTLE SUBSYSTEM ELEMENT CODE AND PRIME POWER LISTING

SUBSYSTEM: ORBITAL MANEUVERING SYSTEM CODE 21

ELEMENT NAME	S/S WATTS	ELEMENT CODE
ENGINE CONTROL VALVE =1	56.00	210121010100
ENGINE CONTROL VALVE =2	56.00	210121010200
ENGINE CONTROL VALVE =3	56.00	210121010300
ENGINE CONTROL VALVE =4	56.00	210121010400
HE ISOL VLVS-SET 1	24.00	210221020100
HE ISOL VLVS-SET 2	24.00	210221020200
HE ISOL VLVS-SET 3	24.00	210221020300
VAPOR ISOL VLVS-SET 1	24.00	210321030100
VAPOR ISOL VLVS-SET 2	24.00	210321030200
VAPOR ISOL VLVS-SET 3	24.00	210321030300
VAPOR ISOL VLVS-SET 4	24.00	210321030400
QUANTITY GAGING PROBE =1	67.00	210521050100
QUANTITY GAGING PROBE =2	67.00	210521050200
QUANTITY GAGING PROBE =3	67.00	210521050300
QUANTITY GAGING PROBE =4	67.00	210521050400
HE ISO VLV=1-AUX KIT	24.00	210621060100
HE ISO VLV=2-AUX KIT	24.00	210621060200
VAPOR ISO VLV=1-AUX KIT	24.00	21070100
VAPOR ISO VLV=2-AUX KIT	24.00	21070200
ENG GIMBAL ACTUATOR =1	134.50	210921090100
ENG GIMBAL ACTUATOR =2	134.50	210921090200
ENG GIMBAL ACTUATOR =3	134.50	210921090300
ENG GIMBAL ACTUATOR =4	134.50	210921090400
PROP TNK ISO VLVS	32.00	211021100000
CROSSFEED VLVS-SET 1	32.00	211321130100
CROSSFEED VLVS-SET 2	32.00	211321130200
CROSSFEED VLVS-SET 3	32.00	211321130300
THERMAL CNTL HTR =1	700.00	211421140100
THERMAL CNTL HTR =2	700.00	211421140200
ENG ARMING SOL VALVE =1	56.00	211521150100
ENG ARMING SOL VALVE =2	56.00	211521150200
THERML CNTL HTRS-AUX KIT	700.00	211621160000
PROP TNK ISO VLV-AUX KIT	32.00	211821180000
CROSSFEED LINE HTRS	50.00	211921190000
ENGINE =1 HEATER	50.00	212021200100
ENGINE =2 HEATER	50.00	212021200200
VALVE POSITION IND	0.40	212121210000
VALVE POS IND-AUX KIT	0.40	212221220000
PROP LOW LEVEL SENSOR =1	11.25	212321230100
PROP LOW LEVEL SENSOR =2	11.25	212321230200

TABLE 7.3-2 (Continued)

SHUTTLE SUBSYSTEM ELEMENT CODE AND PRIME POWER LISTING

SUBSYSTEM: REACTION CONTROL SYSTEM CODE 22

ELEMENT NAME		S/S WATTS	ELEMENT CODE
THRUSTER - FWD	14C2	56.00	220122010000
THRUSTER - AFT	24C4	56.00	220222020000
THRUSTER-VERNIER FWD	02C2	15.00	220322030000
THRUSTER VERNIER AFT	04C4	15.00	220422040000
HP HELIUM ISOL VLV -FWD	0401	84.00	220622060000
LP HEL.ISOL VLV-FWD	02C2	84.00	220722070000
HP HELIUM ISOL VLV -AFT	08C1	84.00	220822080000
LP HELIUM ISOL VLV -AFT	04C2	84.00	220922090000
PROP MANIF ISOL VLV -FWD	08C1	84.00	221022100000
PROP MANIF ISOL VLV -AFT	1601	84.00	221122110000
PROPELLANT ISOL VLV-VERN	04C1	56.00	221222120000
TANK ISO THRST VLV- FWD	0401	84.00	221322130000
TANK ISO THRST VLV-AFT	08C1	84.00	221422140000
TANK HEATERS-AFT LEFT	04C4	55.00	221522150000
TANK HEATERS-AFT RIGHT	0404	55.00	221622160000
MAIN ENG HEATERS-FWD	1414	10.00	221722170000
MAIN ENG HEATERS-AFT	2424	10.00	221822180000
PROP FEED LINE HTRS-AFT	08C8	16.00	221922190000
PRESS PANEL HTRS	0404	20.00	222022200000
FEED SYS HTRS-FWD	04C4	160.00	222122210000
VERNIER ENG HTRS-FWD	02C2	5.00	222222220000
VERNIER ENG HTRS-AFT	04C4	5.00	222322230000

TABLE 7.3-2 (Continued)

SHUTTLE SUBSYSTEM ELEMENT CODE AND PRIME POWER LISTING

SUBSYSTEM: POWER GENERATION SYSTEM CODE 30

ELEMENT NAME	S/S WATTS	ELEMENT CODE
GO2 PURGE VENT HTR =1	33.00	300130010100
GO2 PURGE VENT HTR =2	33.00	300130010200
GH2 PURGE VENT HTR =1	61.00	300230020100
GH2 PURGE VENT HTR =2	61.00	300230020200
H2O RELIEF VENT HTR =1	16.00	300330030100
H2O RELIEF VENT HTR =2	16.00	300330030200
FCP =1 CNTLS + FLOWMETRS	15.00	300430040100
FCP =2 CNTLS + FLOWMETRS	15.00	300430040200
FCP =3 CNTLS + FLOWMETRS	15.00	300430040300
FCP =1 PUMP + H2O SENSOR	150.00	300530050100
FCP =2 PUMP + H2O SENSOR	150.00	300530050200
FCP =3 PUMP + H2O SENSOR	150.00	300530050300
FCP =1 GO2 PURGE VALVE	33.00	300630060100
FCP =2 GO2 PURGE VALVE	33.00	300630060200
FCP =3 GO2 PURGE VALVE	33.00	300630060300
FCP =1 GH2 PURGE VALVE	10.00	300630070100
FCP =2 GH2 PURGE VALVE	10.00	300630070200
FCP =3 GH2 PURGE VALVE	10.00	300630070300
FCP =1 START + SUST HTR	6000.00	300830080100
FCP =2 START + SUST HTR	6000.00	300830080200
FCP =3 START + SUST HTR	6000.00	300830080300
H2O LINE HEATER-FCP =1	15.00	30150100
H2O LINE HEATER-FCP =2	15.00	30150200
H2O LINE HEATER-FCP =3	15.00	30150300
FCP =1 THERMAL CNTL HTR	150.00	30170100
FCP =2 THERMAL CNTL HTR	150.00	30170200
FCP =3 THERMAL CNTL HTR	150.00	30170300

TABLE 7.3-2 (Continued)

SHUTTLE SUBSYSTEM ELEMENT CODE AND PRIME POWER LISTING

SUBSYSTEM: CRYOGENICS SYSTEM CODE 31

ELEMENT NAME	S/S WATTS	ELEMENT CODE
VAC-ION PWR SUPL GSE =1	10.00	310131010100
VAC-ION PWR SUPL GSE =2	10.00	310131010200
VAC-ION PWR SUPL GSE =3	10.00	310131010300
VAC-ION PWR SUPL GSE =4	10.00	310131010400
SIG COND TEMP SNSR	1.30	310231020000
SIG COND QTY =1	4.00	310331030100
SIG COND QTY =2	4.00	310331030200
SIG COND QTY =3	4.00	310331030300
SIG COND QTY =4	4.00	310331030400
SIG COND PRESS =1	0.30	310431040100
SIG COND PRESS =2	0.30	310431040200
SIG COND PRESS =3	0.30	310431040300
SIG COND PRESS =4	0.30	310431040400
SIG COND PRESS CONT =1	1.00	310531050100
SIG COND PRESS CONT =2	1.00	310531050200
SIG COND PRESS CONT =3	1.00	310531050300
SIG COND PRESS CONT =4	1.00	310531050400
SWITCHING UNIT O2-ON	26.00	31060000
SWITCHING UNIT O2-OFF	0.40	31060010
SWITCHING UNIT H2-ON	2.50	31070000
SWITCHING UNIT H2-OFF	0.20	31070010
SOLENOID VLV FCP =1	56.00	311131120100
SOLENOID VLV FCP =2	56.00	311131120200
SOLENOID VLV FCP =3	56.00	311131120300
SOLENOID VALVE ECLSS =1	56.00	311131130100
SOLENOID VALVE ECLSS =2	56.00	311131130200
SOL VLV MANIFOLD =1	56.00	311531150100
SOL VLV MANIFOLD =2	56.00	311531150200
SOL VLV MANIFOLD =3	56.00	31153115030
SOL VLV MANIFOLD =4	56.00	311531150400
HEATERS OXYGEN SET 1	394.50	311731170100
HEATERS OXYGEN SET 2	394.50	311731170200
HEATERS OXYGEN SET 3	81.00	311731170300
HEATERS HYDROGEN SET 1	81.00	311731180100
HEATERS HYDROGEN SET 2	81.00	311731180200
HEATERS HYDROGEN SET 3		311731180300

TABLE 7.3-2 (Continued)

SHUTTLE SUBSYSTEM ELEMENT CODE AND PRIME POWER LISTING

SUBSYSTEM: AUXILIARY POWER UNIT CODE 32

ELEMENT NAME	S/S WATTS	ELEMENT CODE
FUEL ISOLATION VALVE =1	40.00	320232020100
FUEL ISOLATION VALVE =2	40.00	320232020200
FUEL ISOLATION VALVE =3	40.00	320232020300
APU =1 CONTROLLER	150.00	320332030100
APU =2 CONTROLLER	150.00	320332030200
APU =3 CONTROLLER	150.00	320332030300
TANK HTR =1 - LH SIDE	50.00	320532050100
TANK HTR =2 - LH SIDE	50.00	320532050200
TANK HTR =3 - RH SIDE	50.00	320532050300
APU LINE HEATERS =1	50.00	320732070100
APU LINE HEATERS =2	50.00	320732070200
APU LINE HEATERS =3	50.00	320732070300
FUEL QTY GAGE =1	1.00	320832080100
FUEL QTY GAGE =2	1.00	320832080200
FUEL QTY GAGE =3	1.00	320832080300
APU OIL LINE HTR =1	100.00	320932090100
APU OIL LINE HTR =2	100.00	320932090200
APU OIL LINE HTR =3	100.00	320932090300
APU =1 TURB VLV HTR	68.30	321032100100
APU =2 TURB VLV HTR	68.30	321032100200
APU =3 TURB VLV HTR	68.30	321032100300
APU =1 TURB GAS GEN HTR	68.30	321132110100
APU =2 TURB GAS GEN HTR	68.30	321132110200
APU =3 TURB GAS GEN HTR	68.30	321132110300
SERVICE LINE HEATER =1 02C1	50.00	321232120100
SERVICE LINE HEATER =2 02C1	50.00	321232120200
SERVICE LINE HEATER =3 02C1	50.00	321232120300

TABLE 7.3-2 (Continued)

SHUTTLE SUBSYSTEM ELEMENT CODE AND PRIME POWER LISTING

SUBSYSTEM: ENVIRONMENTAL CONTROL & LIFE SUPPORT CODE 40

ELEMENT NAME	S/S WATTS	ELEMENT CODE
CABIN FAN =1	500.00	400140010100
CABIN FAN =2	500.00	400140010200
CABIN FAN =3	500.00	400140010300
WATER PUMP PKG PRI A	270.00	400240020100
WATER PUMP PKG PRI B	270.00	400240020200
WATER PUMP PKG SEC	270.00	400240020300
CABIN PRESS CNTL SYSTEM	84.00	400340030000
CAB PRESS CNTL-AIRLK SP	30.60	400340030010
CAB PRESS CNTL-EMERG MD	23.00	400340030020
WATER SUBLIMATOR SYS =1	101.00	400440040100
WATER SUBLIMATOR SYS =2	101.00	400440040200
AVIONICS FANS-BAY 1 A	180.00	400540050100
AVIONICS FANS-BAY 1 B	180.00	400540050200
AVIONICS FANS-BAY 2 A	180.00	400540050300
AVIONICS FANS-BAY 2 B	180.00	400540050400
AVIONICS FANS-BAY 3 A	180.00	400540050500
AVIONICS FANS-BAY 3 B	180.00	400540050600
H2O SEPARATORS ARS - =1	40.00	400640060100
H2O SEPARATORS ARS - =2	40.00	400640060200
H2O SEPARATORS ARS - =3	40.00	400640060300
CABIN HEATER =1	333.33	400740070100
CABIN HEATER =2	333.33	400740070200
CABIN HEATER =3	333.33	400740070300
INSTR + CONTROLS ARS	47.00	4008400800[illegible]
IMU ASSEMBLY FAN =1	55.00	400940090100
IMU HX ASSEMBLY FAN =2	55.00	400940090200
IMU HX ASSEMBLY FAN =3	55.00	400940090300
OVEN HEATER =1	150.00	401040100100
OVEN HEATER =2	150.00	401040100200

TABLE 7.3-2 (Continued)

SHUTTLE SUBSYSTEM ELEMENT CODE AND PRIME POWER LISTING

SUBSYSTEM: ENVIRONMENTAL CONTROL & LIFE SUPPORT (CONTINUED) CODE 40

ELEMENT NAME	S/S WATTS	ELEMENT CODE
INST+CNTLS-OVEN FANS =1	95.00	401140110100
INST+CNTLS-OVEN FANS =2	95.00	401140110200
INST/CNTLS-OVEN FANS =1	5.00	401140111100
INST/CNTLS-OVEN FANS =2	5.00	401140111200
WATER HEATER =1	455.00	401240120100
WATER HEATER =2	455.00	401240120200
DUMP NOZZLE - WATER	10.00	401340130000
INSTR + CONTROLS WATER	12.0	401440140000
INSTR + CONTROLS WATER	10.00	401440141000
SOLIDS COLLECTION SLINGS	120.00	401640160000
WATER SEP -LIFE SUPPORT	90.00	401740170000
DUMP NOZZLE-URINE	10.00	401840180000
INSTR + CONTROLS WASTE	10.00	401940190000
SMOKE DET SENR-FLT/MIC	4.00	402040200100
SMOKE DET SESR-BAY A1	4.00	402040200200
SMOKE DET SNSR-BAY A2	4.00	402040200300
SMOKE DET SNSR-BAY A3	4.00	402040200400
SMOKE DETECTION ALARM	8.0	40210000
FLASH EVAPORATOR HTR =1	310.00	40270100
FLASH EVAPORATOR HTR =2	310.00	40270200
FLASH EVAPORATOR FL =1	8.00	40280100
FLASH EVAPORATOR FL =2	8.00	40280200
FREON PUMP LP 1-A/B ASC	500.00	40290100
FREON PUMP LP 1-A/B 6 PL	420.00	40290110
FREON PUMP LP 1-A/B 8 PL	460.00	40290120
FREON PUMP LP 2-A/B ASC	500.00	40290200
FREON PUMP LP 2-A/B 6 PL	420.00	40290210
FREON PUMP LP 2-A/B 8 PL	460.0	40290220
SPACE RADIATOR SYSTEM =1	10.00	40300100
SPACE RADIATOR SYSTEM =2	10.00	40300200
AMMONIA BOILER SYSTEM =1	12.50	40310100
AMMONIA BOILER SYSTEM =2	12.50	40310200
FREON BYPASS CONTROL =1	6.00	40320100
FREON BYPASS CONTROL =2	6.00	40320200
DIVERTER VALVE =1	19.50	40330100
DIVERTER VALVE =2	19.50	40330200
LCG COOLANT PUMP =1	0.00	40340100
LCG COOLANT PUMP =2	0.00	40340200
FREON PROPOR VALVE =1	67.00	40350100
FREON PROPOR VALVE =2	67.00	40350200

TABLE 7.3-2 (Continued)

SHUTTLE SUBSYSTEM ELEMENT CODE AND PRIME POWER LISTING

SUBSYSTEM: HYDRAULICS POWER SYSTEM CODE 50

ELEMENT NAME	S/S WATTS	ELEMENT CODE
LG EXTEND VALVE	20.00	500150010000
MAIN LDG GEAR UPLK VL =1	20.00	50020100
MAIN LDG GEAR UPLK VL =2	20.00	50020200
MAIN LDG GEAR UPLK VL =3	20.00	50020300
MAIN LDG GEAR UPLK VL =4	20.00	50020400
LDG GEAR DUMP VLV =1	20.00	50030100
LDG GEAR DUMP VLV =2	20.00	50030200
LDG GEAR DUMP VLV =3	20.00	50030300
LG RETRACT CIRC VLV	20.00	50040000
REDUNDANT S/O VALVE =1	20.00	50050100
REDUNDANT S/O VALVE =2	20.00	50050200
MAIN PUMP =1 DEPRES VLV	26.00	50060100
MAIN PUMP =2 DEPRES VLV	26.00	50060200
MAIN PUMP =3 DEPRES VLV	26.00	50060300
CIRC MOTOR PUMP =1	1561.0	50070100
CICR MOTOR PUMP =2	1561.0	50070200
CICR MOTOR PUMP =3	1561.0	50070300
RESVOIR =1 VOLUME SENSOR	8.00	50080100
RESVOIR =2 VOLUME SENSOR	8.00	50080200
RESVOIR =3 VOLUME SENSOR	8.00	50080300
SSME =1 SYS S/O VALVE	20.00	50090100
SSME =2 SYS S/O VALVE	20.00	50090200
SSME =3 SYS S/O VALVE	20.00	50090300
LI ELEVON HTR BKT =1/=2	50.00	50100100
LO ELEVON HTR BKT =1/=2	50.00	50100200
RI ELEVON HTR BKT =1/=2	50.00	50100300
RO ELEVON HTR BKT =1/=2	50.00	50100400
HYDRAULICS CONTINUED		50100901
H2O BOILER =1 STM S/O VL	20.00	50110100
H2O BOILER =2 STM S/O VL	20.00	50110200
H2O BOILER =3 STM S/O VL	20.00	50110300
H2O BOILER =1 XFER VLV	50.00	50120100
H2O BOILER =2 XFER VLV	50.00	50120200
H2O BOILER =3 XFER VLV	50.00	50120300
H2O BOLR =1 THRM CNTL VL	20.00	50130100
H2O BOLR =2 THRM CNTL VL	20.00	50130200
H2O BOLR =3 THRM CNTL VL	20.00	50130300
H2O BOILER =1 ELECT CONT	7.00	50140100
H2O BOILER =2 ELECT CONT	7.00	50140200
H2O BOILER =3 ELECT CONT	7.00	50140300
H2O BOILER =1 HEATER	100.00	50150100
H2O BOILER =2 HEATER	100.00	50150200
H2O BOILER =3 HEATER	100.00	50150300
H2O BOILER =1 QTY GAGE	5.0	50160100

TABLE 7.3-2 (Continued)

SHUTTLE SUBSYSTEM ELEMENT CODE AND PRIME POWER LISTING

SUBSYSTEM: HYDRAULICS POWER SYSTEM (CONTINUED) CODE 50

ELEMENT NAME	S/S WATTS	ELEMENT CODE
H2O BOILER =2 QTY GAGE	5.0	50160200
H2O BOILER =3 QTY GAGE	5.0	50160300
ELEVON ACT SW VLV POS	1.00	50170000
RUD/SPDBRK ACT VL POS =1	1.0	50180100
RUD/SPDBRK ACT VL POS =2	1.0	50180200
TVC ACT SW VLV POS	1.00	50190000
RESVR =1 LOW LEVEL IND	2.0	50190901
RESVR =2 LOW LEVEL IND	2.0	50200200
RESVR =3 LOW LEVEL IND	2.0	50200300
BODYFLAP MTR 1 HTR =1/=2	50.00	50220100
BODYFLAP MTR 2 HTR =1/=2	50.00	50220200
BODYFLAP MTR 3 HTR =1/=2	50.00	50220300
MAIN PUMP =1 HTR - =1/=2	25.00	50240100
MAIN PUMP =2 HTR - =1/=2	25.00	50240200
MAIN PUMP =3 HTR - =1/=2	25.00	50240300
RUDDER SPDBRK MTR =1 HTR	50.00	50250100
RUDDER SPDBRK MTR =2 HTR	50.00	50250200
RUDDER SPDBRK MTR =3 HTR	50.00	50250300
RUDDER SPDBRK MTR =4 HTR	50.00	50250400
RUDDER SPDBRK MTR =5 HTR	50.00	50250500
RUDDER SPDBRK MTR =6 HTR	50.00	50250600
SSME =1 HYDR ISOL VALVE	80.00	50260100
SSME =2 HYDR ISOL VALVE	80.00	50260200
SSME =3 HYDR ISOL VALVE	80.00	50260300

TABLE 7.3-2 (Continued)

SHUTTLE SUBSYSTEM ELEMENT CODE AND PRIME POWER LISTING

SUBSYSTEM: DOCKING AND CARGO HANDLING CODE 51

ELEMENT NAME	S/S WATTS	ELEMENT CODE
MANIPULATOR	1600.00	51010000
MANIP DEPLOY DRIVE	150.00	51020000
MANIP RETENT LATCH DRIVE	60.00	51030000
PL BAY DOOR RET LCH DRVE	60.00	51050000
XFER TUNNEL EXT/RET DR 1	200.00	51060100
XFER TUNNEL EXT/RET DR 2	200.00	51060200
XFER TUNNEL LTCH DRVE =1	140.00	51070100
XFER TUNNEL LTCH DRVE =2	140.00	51070200
PBD CIRCUM LATCH DRIVE	140.00	51080000
PBD CENTER LINE LTCH DR	220.00	51090000
RADIATOR RET LATCH DRIVE	60.00	51100000
RADIATOR DEPLOY DRIVE	15.00	51110000
RENDZ SENSOR DEPL DR =1	200.00	51120100
RENDZ SENSOR DEPL DR =2	200.00	51120200
MANIP CNTL INTRFACE UNIT	11.00	511451140000
F/T UMB LH DOOR DRIVE	200.00	51150000
F/T UMB LH DOOR LATCH	200.00	511651160000
F/T UMB RH DOOR DRIVE	200.00	51170000
F/T UMB RH DOOR LATCH	200.00	51180000

TABLE 7.3-2 (Continued)

SHUTTLE SUBSYSTEM ELEMENT CODE AND PRIME POWER LISTING

SUBSYSTEM: MECHANICAL SYSTEM AND LANDING CODE 52

ELEMENT NAME	S/S WATTS	ELEMENT CODE
RUD/SPD BRKE S/V RUD	15.00	52010000
RUD/SPD BRKE S/V	15.00	52020000
STARTRACKER DOOR DRIVE	200.00	52040000
RCS TOP DOOR ACT	200.00	52050000
RCS LH SIDE DOOR ACT	200.00	52060000
RCS RH SIDE DOOR ACT	200.00	52070000
LAUNCH UMB LH DOOR DR	200.00	52080000
LAUNCH UMB RH DOOR DR	200.00	52100000
P/L BAY RH DR DRIVE	400.00	52160000
P/L BAY LH DR DRIVE	400.00	52170000
GN+C PROBE ACT LH-A-T	5.00	52180000
GN+C PROBE ACT RH-A-T	5.00	52200000
NOSE WHEEL STEERING UNIT	10.00	52260000
BRAKE/SKID POWER SYS	140.00	52270000
GN+C PROBE HEATERS	1100.00	52300000
VENT DOOR MOTORS	10.00	523252320000
VENT DOOR MOTORS	100.00	523352330000
VENT DOOR MOTORS	20.00	523452340000
VENT DOOR MTR PL BAY WNG	100.00	523552350000

APPENDIX 7.4

SAMPLE SET OF USER LOAD ELEMENT DATA SHEETS

(GENERATED FROM VENDOR INFORMATION BY RI/JSC)

Subsystem GN+C

Equipment No. 010101

Equipment Title IMU

Power Requirements ①

DC Load

Nominal Power (Watts) 75

Mode of Operation Stand By

Number in System 3

Number Normally Opeating 3

Parameter		Calculated or Estimated Value	Spec. Value	Test Value	Remarks
AMPERES	Average (steady state) continuous duty	3.12			24 volts at load interface
		2.67			28 volts at load interface
		2.34			32 volts at load interface
	Peak transient and duration ②	0			Amps
		0			Time in miliseconds
	Load Range ③	120W / 28V = 4.29			Max
		12W / 32V .36			Min
Malfunction voltage limit (volts) ④		32 v			Max
		24 v			Min

Duty Cycle ⑤

Periodic ☐ Percent "on" ______ %

Aperiodic ☐ Period of Cycle ______

Indicate units if other than minutes

Input voltage Converter

Yes ☒

No ☐

Converted to 30 vdc 5 vdc

Volts 115 vdc

Frequency [illegible]

AC ☒ DC ☒

JSC Engineer Bill Swingle TABLE 1 Date 3-27-74

7.4-1

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

NF0004-002

PAGE

ENCLOSURE 4

RI 2/22 - 15 [illegible]

Subsystem EPDC
Equipment No. [illegible]
Equipment Title POWER CONTROL ASSY-FWD

Power Requirements (1)
DC Load

Nominal Power (Watts) 30
Mode of Operation [illegible]

Number in System 3

Number Normally Opeating 3

		Calculated or Estimated Value	Spec. Value	Test Value	Remarks
AMPERES	Average (steady state) continuous duty	1.3			24 volts at load interface
		1.7			28 volts at load interface
		.95			32 volts at load interface
	Peak transient and duration (2)	0			Amps
		0			Time in miliseconds
	Load Range (3)	NA			Max
		NA			Min
Malfunction voltage limit (volts) (4)		TBD			Max
		TBD			Min
Duty Cycle (5)		Periodic ☒ Aperiodic ☐	Percent "on" 100% Period of Cycle ____		Indicate units if other than minutes
Input voltage Converter		Yes ☐ No ☒	Converted to Volts ____ Frequency ____ AC ☐ DC ☐		

Note: Component used 50% [illegible] [illegible] period.

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

7.4.3

Subsystem OMS (2 PODS)

Equipment No. 12101

Equipment Title ENGINE CONTROL VALVES

Power Requirements ①

DC Load

Nominal Power (Watts) 32.0

Mode of Operation [illegible]

Number in System 8

Number Normally Operating 8

Parameter		Calculated or Estimated Value	Spec. Value	Test Value	Remarks
AMPERES	Average (steady state) continuous duty	1.15			24 volts at load interface 28 volts at load interface 32 volts at load interface
	Peak transient and duration ②	0.0			Amps
		0.0			Time in miliseconds
	Load Range ③	NA			Max
		NA			Min
Malfunction voltage limit (volts) ④		TBD			Max
		TBD			Min

Duty Cycle ⑤

Periodic ☑ Aperiodic ☐

Percent "on" 100 %

Period of Cycle ____

Indicate units if other than minutes

Input voltage Converter

Yes ☐ No ☒

Converted to Volts ____ Frequency ____ AC ☐ DC ☐

JSC Engineer

TABLE 1

From 4K

Date 4/23/74

Subsystem OMS (2 PODS)
Equipment No. 12103
Equipment Title HELIUM ISOLATION VALVES

Power Requirements (1)

DC Load

Nominal Power (Watts) 24.0
Mode of Operation OPERATE

Number in System
4

Number Normally Operating
4

Parameter		Calculated or Estimated Value	Spec. Value	Test Value	Remarks
AMPERES	Average (steady state) continuous duty				24 volts at load interface
		.86			28 volts at load interface
					32 volts at load interface
	Peak transient and duration (2)	0.0			Amps
		0.0			Time in miliseconds
	Load Range (3)	NA			Max
		NA			Min
Malfunction voltage limit (volts) (4)		TBD			Max
		TBD			Min

Duty Cycle (5)	Periodic ☑ Aperiodic ☐	Percent "on" 100 % Period of Cycle ____	Indicate units if other than minutes
Input voltage Converter	Yes ☐ No ☐	Converted to Volts ____ Frequency ____ AC ☐ DC ☐	

JSC Engineer
TABLE 1
Date 4-23-74

7.4-4

MF0004-002

PAGE

ENCLOSURE 4

Power Requirements ①

Subsystem
Equipment No. 12005
DC Load
Nominal Power (Watts) [illegible]
Equipment Title LH2 Recirc Valve solenoid
Mode of Operation [illegible]

Number in System
3

Number Normally Operating
3

Parameter		Calculated or Estimated Value	Spec. Value	Test Value	Remarks
AMPERES	Average (steady state) continuous duty				24 volts at load interface
		1.5			28 volts at load interface
					32 volts at load interface
	Peak transient and duration ②	0			Amps
		0			Time in miliseconds
	Load Range ③	NA			Max
		NA			Min
Malfunction voltage limit (volts) ④		TBD			Max
		TBD			Min
Duty Cycle ⑤		Periodic ☑ Aperiodic ☐	Percent "on" ____ % Period of Cycle ____		Indicate units if other than minutes
Input voltage Converter		Yes ☐ No ☑	Converted to Volts ____ Frequency ____ AC ☐ DC ☐		

JSC Engineer
TABLE 1
Date 5-13-74

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR.

Subsystem EC/LSS

Equipment No. 24020

Equipment Title [illegible]

Power Requirements ①

DC Load

Nominal Power (Watts) 5

Mode of Operation

Number in System
2

Number Normally Opeating
1

		Calculated or Estimated Value	Spec. Value	Test Value	Remarks
Parameter					
AMPERES	Average (steady state) continuous duty				24 volts at load interface
		0.17			28 volts at load interface
					32 volts at load interface
	Peak transient and duration ②	0			Amps
		0			Time in miliseconds
	Load Range ③	N/A			Max
		N/A			Min
Malfunction voltage limit (volts) ④		TBD			Max
		TBD			Min

Duty Cycle ⑤	Periodic ☐ Aperiodic ☐	Percent "on" 100 % Period of Cycle	Indicate units if other than minutes
Input voltage Converter	Yes ☐ No ☒	Converted to Volts Frequency AC ☐ DC ☐	

JSC Engineer D. W. Harris

TABLE 1

Date 4-18-74

7.4-6

MF0004-002

PAGE

ENCLOSURE 4

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR.

⑥

Subsystem Pwr GEN.

Equipment No. 13006

Equipment Title FCP SO2 Purge VLV

Power Requirements ①

DC Load

Nominal Power (Watts) 10

Mode of Operation In[illegible]
Normally Closed

Parameter		Calculated or Estimated Value	Spec. Value	Test Value	Remarks
AMPERES	Average (steady state) continuous duty				24 volts at load interface
		1.178	~~0.358~~		28 volts at load interface
					32 volts at load interface
	Peak transient and duration ②				Amps
					Time in miliseconds
	Load Range ③	NA			Max
		NA			Min
Malfunction voltage limit (volts) ④		TBD			Max
		TBD			Min
Duty Cycle ⑤		Periodic ☑ Aperiodic ☐	Percent "on" 100 % Period of Cycle ____		Indicate units if other than minutes
Input voltage Converter		Yes ☐ No ☑	~~Converted to~~ Volts ____ Frequency ____ AC ☐ DC ☑		CONTROL: MANUAL OR AUTO Source: MN DC Bus

Number in System 3

Number Normally Opeating 3

note:
On for
≈ 2 minutes
in 12 hours

JSC Engineer ____ TABLE I Date 4/25/75

7.4-7

MF0004-002

PAGE

ENCLOSURE 4

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR.

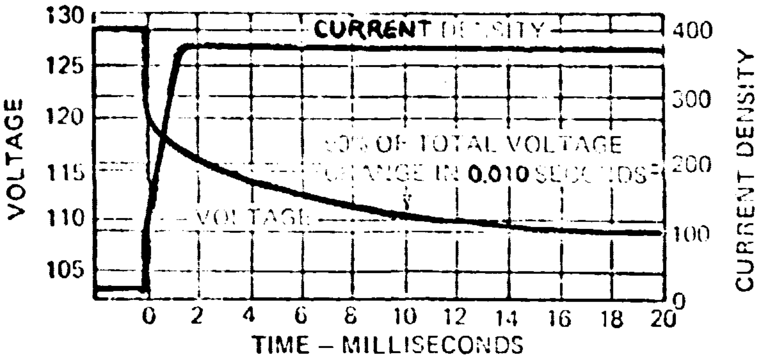


Figure A
PC15 Transient Response
to Step Load Change

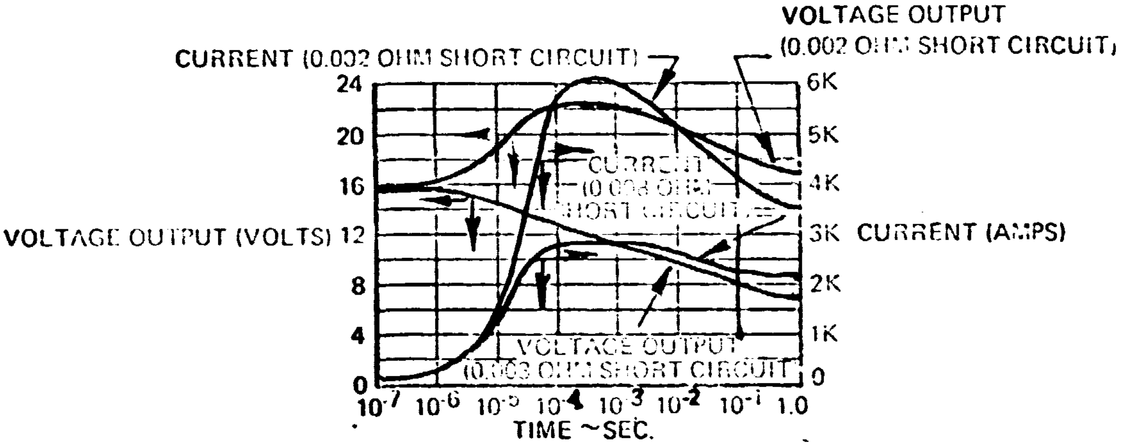


Figure B PC17 Powerplant Impedance

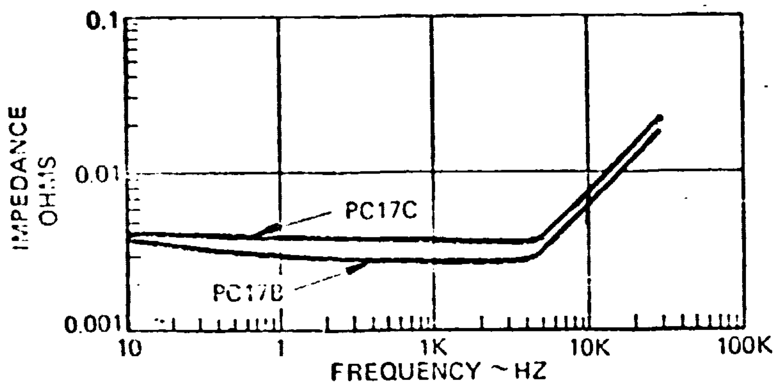


Figure C
PC17 Short Circuit
Capability

(REPRODUCED FROM PRATT AND WHITNEY AIRCRAFT DATA)

APPENDIX 7.5

PROCUREMENT SPECIFICATIONS FOR CRITICAL EPDC ELEMENTS

(DOCUMENTS GENERATED BY ROCKWELL INTERNATIONAL)

($)³ 74-042

PREPARED BY C. J. [illegible] APPROVALS 9-4-73 J. R. Hale 9-?-73	CODE IDENT. NO.: 03953 SPACE DIVISION NORTH AMERICAN ROCKWELL CORPORATION 12214 LAKEWOOD BOULEVARD • DOWNEY, CALIFORNIA 90241 **SPECIFICATION**	NUMBER MC495-0012 TYPE PROCUREMENT DATE August 30, 1973 SUPERSEDES SPEC. DATED: REV. LTR. NEW PAGE 1 of 49

TITLE

Total Pages 54

INVERTER, POWER STATIC, 115 VOLT,
SINGLE-PHASE, 400 HZ

Jim Pawlowski?
of.
Pawlowski

1. SCOPE

This specification establishes the performance, design, development and verification requirements for a single-phase modular inverter referred to herein as the inverter.

1.1 Seller's Equipment Internal Design. Except as otherwise specified the requirements of this specification are not intended to restrict inverter internal design except for those areas necessary for compatibility with the design requirements specified herein.

1.2 Sub-Tier Supplier Control. Where necessary to meet the requirements of this specification, the seller shall impose this specification on sub-tier suppliers with design responsibility.

2. APPLICABLE DOCUMENTS

The following documents of the exact issue shown form a part of this specification to the extent specified herein. In the event of a conflict between the documents referenced herein and the content of this specification, the content of this specification shall take precedence.

SPECIFICATIONS

Federal

Military

MIL-B-5087B(2) 31 August 1970	Bonding, Electrical and Lightning Protection, for Aerospace Systems
MIL-C-5541B(1) 30 June 1970	Chemical Conversion Coatings on Aluminum and Aluminum Alloy
MIL-C-7078B 5 December 1969	Cable, Electrical, Aerospace Vehicle, General Specification for
MIL-C-83723 26 March 1965	Connector, Electric, Circular, Environment Resisting, General Specification for
MIL-I-26860B 17 May 1972	Indicator, Humidity, Plug, Color Change
MIL-I-27273A(3) 3 June 1965	Inverter, Power, Static, General Specification for
MIL-W-81381 15 October 1966	Wire, Electric, Polyimide Insulation, Copper and Copper Alloy

NASA/JSC

MSC-Spec-Q-1A October 1967	Crimping of Electrical Connections, Requirements for

SPECIFICATIONS

Rockwell International/Space Division

MC414-0148C 25 March 1966	Connector, Receptacle, Electrical
MC999-0096B 6 July 1973	Materials and Processes Control and Verification System for Space Shuttle Program Suppliers and Subcontractors
MF0004-002A 13 July 1973	Electrical Design Requirements for Electrical Equipment Utilized on the Space Shuttle Vehicle
MF0004-006 27 July 1973	Instrumentation Requirements for Suppliers and Sub-contractors for the Space Shuttle Program
MF0004-100 31 July 1973	Mechanical Orbiter Project Parts List
MF0004-400 25 July 1973	Electrical, Electronic and Electromechanical (EEE) Orbiter Project Parts List

STANDARDS

Federal

FED-STD-101B(2) 8 October 1971	Preservation, Packaging, and Packing Materials: Test Procedures

Military

MIL-STD-12C(1) 1 February 1971	Abbreviations for Use on Drawings, Specifications, Standards and in Technical Documents
MIL-STD-129E(6) 10 April 1972	Marking for Shipment and Storage
MIL-STD-130D(1) 30 July 1971	Identification Marking of U. S. Military Property
MIL-STD-143B 12 November 1969	Standards and Specifications, Order of Precedence for Selection of

STANDARDS

MIL-STD-202D 14 April 1969	Test Methods for Electronic and Electrical Component Parts
MIL-STD-280 7 July 1969	Definitions of Item Levels, Items Exchange, Models and Related Items
MIL-STD-461A 1 August 1968 and Shuttle Amendment 4 June 1973	Electromagnetic Interference Characteristics, Requirements for Equipment
MIL-STD-740 6 July 1964	Noise Measurements of Shipboard Machinery and Equipment
MIL-STD-794C(1) 18 February 1972	Parts and Equipment, Procedure for Packaging and Packing of
MIL-STD-810B(4) 21 September 1970	Environmental Test Methods

<u>SAE Aerospace Standard</u>

AS1212 December 1971	Electrical Power, Aircraft, Characteristics and Utilization of

OTHER PUBLICATIONS

<u>Handbooks</u>

DODH4-1 Latest Revision	Federal Supply Code for Manufacturers' Name to Code
MHB5300.4(3A) May 1968	Requirements for Soldered Electrical Connections
MHB6000.1(1A) December 1969	Requirements for Packaging, Handling, and Transportation for Aeronautical and Space Systems Equipment and Associated Components

3. REQUIREMENTS

3.1 Item Definition

3.1.1 Item Diagram. Figure 1 is the schematic block diagram showing the function of the inverter assembled as a three-phase array in the electrical power distribution and control sub-system.

3.1.2 Interface Definition

3.1.2.1 Envelope. The inverter envelope and its attachment provisions shall not exceed the dimensions shown in Figure 2.

3.1.2.2 Mounting. The mounting provisions of the inverter shall be as shown in Figure 3 and in accordance with the requirements of paragraph 3.2.5.2.C.2.

3.1.2.3 Weight. The inverter shall have a maximum weight of (TBD) pounds.

3.1.2.4 Cooling

3.1.2.4.1 Coldplate Cooling. The inverter shall be designed for conduction cooling by contact with the mounting surface. An aluminum mounting surface will be provided in the spacecraft by the buyer. The mounting surface will have a contact area of not less than TBD square inches. The spacecraft mounting surface will maintain the inverter baseplate at the following temperatures by coolant flow for rated inverter loads:

Temperature Condition	Inverter Surface Temp. Above Inlet	Inv. Surface Temp. Above Outlet
(a) Maximum	120 F (Maximum)	140 ± 2 F
(b) Minimum	35 ± 2 F	55 ± 2 F

3.1.2.4.2 Heat Flux. Heat flux loading shall be arranged to take maximum advantage of the coldplate temperature distribution. The maximum heat flux in any local inverter surface area shall be shown by calculation not to exceed TBD watts per square inch. Thermal conductance between the inverter baseplate and the coldplate mounting surface shall be 500 BTU per hour per square foot per degree F, minimum.

3.1.2.4.3 Cooling Surface Finish. The inverter baseplate shall have a surface finish of 63 micro-inches RMS and a flatness deviation of not more than 0.010 inch total indicated run-out. The baseplate shall be measured for flatness when bolted to a test plate with 0.25-inch bolts torqued to 70 plus or minus 5 inch-pounds. Depth gage measurements shall indicate the flatness of the inverter baseplate through each of TBD holes in the test plate. The test plate used shall be mutually acceptable to the Seller and the Buyer.

3.1.2.5 Temperature Sensor. The inverter shall incorporate a transducer in accordance with specification MF0004-006 which shall provide an electrical signal proportional to the inverter internal temperature. The transducer shall consist of a resistance wire wound sensor with the following characteristics: 500 ohms ± 2 percent at 75 degrees F; 455 ohms ± 2 percent at 32 degrees F; and 650 ohms ±2 percent at 248 degrees F. The transducer shall be located within the inverter to indicate excessive inverter temperature in the event of impending failure due to a malfunction or overload.

3.1.2.6 Sealing. The inverter shall be designed to seal those portions of the circuit that will burn, spark or outgas because of electrical overload or short circuit.

3.1.2.7 Finish. All areas of the inverter exposed to external environments, except coldplate mating surfaces, nameplate and connectors shall be chem-filmed per MIL-C-5541, Class 1A.

3.1.2.8 Vibration Isolation. The inverter shall be designed so that external vibration isolators are not required.

3.1.2.9 Electrical Connectors. The electrical connectors used for the inverter outputs shall be mutually acceptable to the Buyer and the Seller and shall be governed by MF0004-400, Orbiter project parts list and the following:

a. Keyed cylindrical (preferably bayonet locking) configurations per MIL-C-83723 shall be utilized, if possible.

b. In applications where the MIL-C-83723 bayonet style cannot be used due to wire gauge limitations, threaded coupling designs may be employed. Buyer approval is required prior to usage.

c. Rectangular connectors shall be per Buyer specification MC414-0148 and may be employed in those applications where cylindrical connectors will not allow sufficient wire penetration. Buyer approval is required prior to usage.

d. The inverter connector shall be mounted on the front panel.

e. Socket contact arrangements shall be used as the "hot" or energized half when a connection is broken.

f. Connector keys shall be designed such that engagement of the keys occurs prior to engagement of the contacts.

3.1.2.9.1 Keyway Clocking. The connector(s) on the inverter shall be oriented so that the master (largest) key is located at the top-centerline position on the connector. The connector keyway clocking shall be shown on the Seller's drawing of the inverter envelope.

3.1.2.10 Connections. The design of input and output connections shall be mutually acceptable to the Buyer and the Seller. Electrical connectors shall be per paragraph 3.1.2.9. The connections required are as follows: D-C plus, D-C minus, A-C phase output, A-C neutral, two for the inverter temperature transducer output, overload grounding, local, phase synchronization signal output, phase synchronization signal input, and central timing signal input.

3.1.2.10.1 Negative and Neutral Connections. The direct-current input negative and the alternating current output neutral connections in the inverter shall be isolated from the inverter chassis and from each other.

3.1.2.11 Adjustment. The inverter shall require no external adjustment for voltage or frequency regulation. Provision shall be made for internal voltage adjustment of plus or minus 2 volts of the nominal line-to-neutral ac voltage by selection of fixed components. No provisions for adjustment of frequency shall be made. Potentiometers or sliding contacts of any type shall not be incorporated in the inverter design.

3.1.2.12 Electrical Power Characteristics. The electrical power characteristics of the inverter interface shall comply with the requirements of MF0004-002 and as follows:

3.1.2.12.1 Input Power. The input voltage shall be 28V dc nominal, two wire, structure ground. Steady state input voltage limits shall be 24 to 32 volts dc. Source dynamic impedance shall be 0.TBD ohms at TBD Hz. The dc transient limits shall be in accordance with MF0004-002. During steady-state DC operation the ripple voltage about the mean level of the D-C voltage shall be four volts peak-to-peak or less over the frequency range per AS-1212. The inverter shall switch off at an input voltage TBD volts or lower and shall turn on at TBD volts ±0.5 volts.

3.1.2.12.1.1 Voltage Spikes. Short duration spikes at the dc input terminals of the inverter shall not exceed the values specified in MIL-STD-461 paragraph 6.9.

3.1.2.12.1.2 Loss of Input Power. Instantaneous removal of input power while the inverter is operating shall cause no damage or degradation to the inverter.

3.1.2.12.2 Inverter Feedback

3.1.2.12.2.1 Ripple Current. The ripple current induced on the dc power bus by the inverter shall not exceed the limits of Space Shuttle Amendment "A" to MIL-STD-461 under any combination of load ranging from no load to 750 va; of input voltage ranging from 24 to 32 volts dc, or power factor ranging from 0.7 lagging to 0.9 leading including unity.

3.1.2.12.2.2 Voltage Spikes. Short duration voltage spikes induced on the dc bus by the inverter shall not exceed the values specified in MIL-STD-461, paragraph 6.9.

3.1.2.12.3 Inverter In-Rush Current. In-rush current at turn-on at 32 volts dc and under all combinations of line, load and environment shall not exceed TBD amperes at 0.TBD ohm source impedance in series with TBD microhenries and shall stabilize to within 10 percent of normal within 100 milliseconds.

3.1.2.12.4 Inverter Output. The inverter shall have a single-phase two-wire output with the output voltage and frequency in accordance with paragraphs 3.2.1.1.5 and 3.2.1.1.7 respectively. When the inverter is connected to two other inverters the combined output shall form a 115/200 volt, 400 Hz three-phase, 4-wire wye connected assembly rated at 2250 va at power factors ranging from 0.7 lagging to 0.9 leading including unity power factor.

3.1.2.12.5 Short Circuit Sensing. Current sensing and conditioning circuitry shall be incorporated in the inverter to complete a 28 volt dc circuit external to the inverter under the following conditions. When the inverter is subjected to an overload of 225 percent of rated current for 15 seconds ±1 second, and to 300 ± 30 percent of rated output current for a duration of 5 seconds plus or minus one second, the inverter shall cause a grounding signal (referenced to the dc negative terminal) to be applied to the overload signal output terminal of the inverter. The device used to complete the circuit must be capable of carrying a relay coil current of 0.2 amperes at 28.0 vdc and a light bulb load of 0.040 amperes at 28 vdc. A "push-to-test" switch shall be incorporated on the inverter to verify continuity from the inverter overload indication signal to the warning light in the cabin.

3.1.2.12.6 Single-Phase Half-Wave Load Capability. The inverter shall have a half-wave, single-phase load applied under the following conditions:

a. A resistive load of 70 ohms in series with a 1N1187 rectifier, or equivalent, while continuing to meet the performance requirements specified herein.

b. A resistive load of 2.5 ohms in series with a 1N1187 rectifier, or equivalent, shall activate the short-circuit sensing capability of the inverter. This rectifier-resistive load must be removed at the time the overload trip signal is activated. Upon removal of this load the output voltage shall stabilize to within 115 volts plus or minus 10 percent within 100 milliseconds and transient voltages in excess of 195 volts peak shall not appear.

3.1.2.12.7 Vehicle Interface. The inverter shall operate within its specification limits when connected to vehicle wiring which may have a resistance to ground or resistance between adjacent circuits of two megohms.

3.1.3 Item Identification. The identification of the inverter shall be as follows:

Nomenclature and Mfg. Code Ident. No.	Buyer's Control No.	Seller's Part No.	Traceability Classification
Inverter	MC495-0012-0001	TBS	T_S
Capacitor	N/A	TBS	T_L
Diode	N/A	TBS	T_L
Transistor	N/A	TBS	T_H
Resistor	N/A	TBS	T_L
Transformer	N/A	TBS	T_S
Connector	N/A	TBS	T_H
Temperature	N/A	TBS	T_H
Transducer	N/A	TBS	T_H
Push-to-Test Switch	N/A	TBS	T_S

3.2 CHARACTERISTICS

3.2.1 Performance

3.2.1.1 Inverter Performance

3.2.1.1.1 Insulation Resistance. The exterior configuration of the inverter shall have insulation properties to prevent electrical shock to personnel. Subsequent to assembly and any potting or sealing required, a minimum insulation resistance of 100 megohms is required between the dc input terminals and the inverter case and the ac output terminals and case at a potential of 100 volts minimum.

3.2.1.1.2 Input Power. The inverter shall meet all performance requirements of this specification when operated within the normal steady state dc voltage range specified in paragraph 3.1.2.12.1.

3.2.1.1.2.1 Input Susceptibility. No change in indication, malfunction, or degradation in performance shall be produced in the inverter when subjected to the dc input ripple specified in paragraph 3.1.2.12.1. The ripple energy placed on the dc bus by the inverter shall not be considered as part of the ripple energy for susceptibility.

3.2.1.1.2.2 Input Transients

3.2.1.1.2.2.1 Normal Electrical System Operation. The inverter shall operate within specification requirements without degradation when subjected to the normal condition dc voltage transients specified in paragraph 3.1.2.12.1.

3.2.1.1.2.2.2 Abnormal Electrical System Operation. The inverter shall not incur damage or degradation of reliability when subjected to the abnormal condition dc voltage transient limits in Paragraph 3.1.2.12.1 and shall return to operation within specification requirements when the D-C voltage returns to normal steady-state condition.

3.2.1.1.2.2.3 Voltage Spikes. The inverter shall operate and shall not incur degradation or damage when subjected to the voltage spikes specified in paragraph 3.1.2.12.1.1.

3.2.1.1.3 Warm-Up Time. The inverter shall stabilize to the performance requirements of this specification within one second after turn-on under all combinations of line, load and environment specified herein. Output line-to-neutral voltage shall be 115 volts, plus or minus 10 percent RMS within 200 milliseconds after turn on under all combinations of line, load and environment specified herein.

3.2.1.1.4 Dielectric Withstanding Voltage. The dielectric withstanding voltage of the inverter shall meet the following requirements:

a. Electrical parts and sub-assemblies prior to being wired shall be capable of withstanding an initial electrical potential of 1500 volts rms, 60 Hz between insulated points and case without electrical breakdown. Current flow in excess of 0.5 milliamperes or breakdown shall be considered a failure. Any exceptions such as EMI filters, etc., shall be subject to Buyer approval.

b. Prior to any sealing or potting, if required, and with RF suppression capacitors and similar components disconnected, no break down of the insulation or leakage current in excess of one milliampere shall occur during a one-minute test in which 1200 volts rms, 60 Hz is applied between the ac output terminals and the chassis and during a one-minute test in which 500 volts rms, 60 Hz is applied between the dc input power terminals and the chassis.

c. Subsequent to completion of assembly wiring and any sealing or potting, if required, no break down of insulation or leakage current in excess of one milliampere shall occur during a one-minute test in which 750 volts dc shall be applied between each output terminal and chassis and during a one-minute test in which 400 vdc is applied between each input power terminal and chassis.

3.2.1.1.5 Output Voltage Steady-State. The steady-state output voltage of the inverter shall be 115 plus 3 volts minus 1 volt rms from no load to 750 va rated load.

3.2.1.1.6 Output Voltage Transient. The inverter output voltage shall remain at 115 volts rms plus or minus 10 percent for any step load or input voltage change within the specified limits. Recovery to the steady-state value shall be within 0.005 seconds. Transient voltages in excess of 195 volts peak shall not appear at the output under any condition.

3.2.1.1.7 Output Frequency. Output frequency shall be 400 Hz plus or minus 2 Hz when the inverter is synchronized to an external TBD Hz plus or minus TBD Hz source supplied through a pair of twisted, shielded leads. The inverter shall present a matched TBD ohms plus or minus TBD ohms impedance to this signal through an isolation transformer. The synchronizing signal shall be 5.0 plus or minus 0.5 volts peak square wave with rise and/or fall time no greater than 1 microsecond. In the absence of this external signal, the inverter frequency shall be maintained at 400 plus or minus 7 Hz. The synchronizing source shall not receive reverse current from the inverter. The synchronizing signal shall have a duty cycle of 40 to 60 percent "on" time.

3.2.1.1.8 Output Power. The inverter shall perform as specified herein under any combination of loads varying from no load to 750 va and at power factor ranging from 0.7 lagging to 0.9 leading including unity power factor. When the inverter is connected into a three-phase assembly the combined output rating shall be 2250 va with the power factor range stated above and with the capability of meeting related performance requirements specified herein. Also, if anyone of the inverters fails the remaining two inverters shall continue to produce two-phase output with the proper phase displacement and phase sequence. Under this condition the output of each of the two remaining inverters shall be within specification limits.

3.2.1.1.8.1 Overload. With the input voltage set at 24 volts dc, the inverter shall be capable of delivering 150 percent of rated load at minimum power factor for five minutes while providing steady state output voltage in accordance with paragraph 3.2.1.1.5. No degradation in reliability shall be incurred by the inverter as a result of this overload.

3.2.1.1.8.2 Short Circuit Capacity. The inverter shall conform to short circuit capacity requirements of specification MIL-I-27273 except the input shall be 24 volts dc and the inverter shall automatically limit the maximum short circuit output current to [illegible] ± 20 percent of rated current.

3.2.1.1.8.3 Motor Starting. A combination of three inverters which forms a three-phase output shall be capable of starting a 590 watt minimum, three-phase induction motor with a starting power factor of no less than 0.25; and a 400 percent motor inrush current, and a 0.75 lagging running power factor while carrying a balanced three-phase 1465 va steady-state load.

3.2.1.1.9 Efficiency. With a dc input of 24 to 30 volts and power factor between 0.85 lagging and 1.0 unity, the inverter shall operate at a minimum of 80 percent efficiency from half-rated load to full-rated load.

3.2.1.1.10 Operating Position. The inverter shall be capable of operating in any position.

3.2.1.1.11 Phase Rotation. When the inverter is connected to two other inverters to form a three-phase output the phase rotation shall be A-B-C.

3.2.1.1.12 Phase Displacement. When the inverter is connected to two other inverters to form three-phase output, the displacement angle between adjacent phases shall be 120° plus or minus 1.5 degrees under conditions from no load to full load and power factors from 0.70 lagging to 0.9 leading including unity power factor with either balanced 3-phase load or with phase unbalance as specified in paragraph 3.2.1.1.13. The angle shall be the relative displacement between the zero voltage points on the wave forms of the three phases. A phase-lock signal shall be supplied from one inverter to the next inverter in the following sequence: phase A to phase B, phase B to phase C and phase C to phase A.

3.2.1.1.13 Phase Unbalance. When the inverter is connected with two other inverters to form a three-phase output, the assembly shall be capable of supplying unbalanced loads and meeting performance requirements in accordance with paragraph 3.6.8 of MIL-I-27273 and in addition, shall meet the requirements of paragraphs 3.2.1.1.5, 3.2.1.1.7 and 3.2.1.1.12 with no load on one phase and 750 va on each of the other two phases.

3.2.1.1.14 Output Voltage Modulation. The inverter output voltage modulation shall not exceed one percent while operating with input power conditions in accordance with paragraph 3.1.2.12.1.

3.2.1.1.15 Output Frequency Modulation. The inverter output frequency modulation shall not exceed 0.5 Hz under any load and power factor combination specified herein.

3.2.1.1.16 Waveform. The line-to-crest factor shall not exceed the limits of 1.414 ± 10 percent and the observed change in the crest factor from no load to full load at any input voltage shall not exceed 10 percent. The total harmonic content shall not exceed 4 percent and no individual harmonic shall exceed 3 percent of the fundamental.

3.2.1.1.17 Acoustic Noise Generated. When the inverter is operated in accordance with the performance requirements of paragraph 3.2.1, the audible noise shall not exceed the following:

a. Sound Power Level

Octave Band Center Frequency - Hz	63	125	250	500	1000	2000	4000	8000
Sound Power Level - L_W dB RE:10^{-12} Watt	61	60	59	57	54	52	54	50

b. Speech Interference Level: The speech interfenence level shall be 45 dB maximum from 300 Hz to 8000 Hz.

3.2.1.1.18 Operating Life. The inverter shall have an operating life of not less than 17,000 hours.

3.2.1.1.19 Useful Life. The inverter shall have a useful life of not less than 25,000 hours. Preventive maintenance, servicing, repair and replacement of parts shall be consistent with the requirements of this specification.

3.2.1.1.20 Shelf Life. The inverter shall be capable of operating in accordance with the requirements specified herein following storage for a ten-year period from date of delivery when exposed to the environments of paragraph 3.2.5 and protected by the requirements defined in Section 5.0.

3.2.2 Physical Characteristics

3.2.2.1 Inverter Physical Characteristics

3.2.2.1.1 Weight. The weight of the inverter shall be in accordance with paragraph 3.1.2.3.

3.2.2.1.2 Center of Gravity. The center of gravity of the inverter shall be determined in three axes from a defined reference datum.

3.2.2.1.3 Growth Potential. Seller shall, unless otherwise provided, allow for a 10 percent (minimum) growth potential in the total useable volume in electrical/electronic/electromechanical devices. A minimum of 10 percent spare pins/sockets shall be provided in all external connectors. All "spare-pin" cavities shall be filled with sealing plugs as appropriate.

3.2.3 Reliability

3.2.3.1 Redundant Circuit Separation. Redundant circuits within the inverter shall not be routed through the same connector. Also, redundant paths for electrical wiring shall be so located that an event which damages one path will not damage another.

3.2.3.2 Derating. Derating of inverter components shall be utilized to enhance its reliability.

3.2.3.3 Failure Deterrent. The inverter design shall incorporate the following:

a. Alternate or redundant means of performing a critical function shall be separated physically by the maximum practical distance, or otherwise protected, such that all functional paths will not be lost due to a single event.

b. Where similar connections are in close proximity the inverter design shall preclude the capability of cross connection.

3.2.3.4 Failure Protection. There shall be no failure in the inverter which can cause the failure of another inverter when operating as a three-phase assembly.

3.2.4 Maintainability

3.2.4.1 Design Allocations. The design shall incorporate the following maintainability allocations:

a. The inverter shall be designed to allow failed subassemblies to be replaced on the bench in TBS hours or less after failure identification.

b. The inverter shall be designed to allow bench verification of its electrical functions within TBS minutes using suitable support equipment in the maintenance area.

c. The inverter shall be capable of being repaired in the shop in accordance with the skill level of TBS.

d. The inverter removal/installation time shall not exceed TBD minutes.

3.2.4.2 Design Features. The inverter design shall incorporate the following maintainability features.

a. Subassembly and component installation within the inverter shall facilitate replacement. Where feasible, functional circuit groups shall be packaged as easily removable and replaceable modules.

b. Arrangement of subassemblies and components within the inverter shall be relative to failure rate and compatible with redundancy requirement.

c. The inverter shall require no scheduled maintenance, including physical inspection and parts replacement.

d. The inverter mounting provisions shall permit removal and replacement using standard installation/handling devices.

e. The inverter shall be designed to preclude the use of special tools and equipment for the on-site maintenance and repair.

f. The inverter shall not require pre-installation acceptance checkout prior to use.

g. Where feasible, the inverter test points shall be accessible and clearly marked.

h. The inverter design shall preclude the requirement for "inspect and repair as necessary" (Iran.)

3.2.5 Environmental Conditions

3.2.5.1 Transportation, Ground Handling and Storage. The inverter shall be capable of meeting the operating performance requirements specified herein after exposure to the following transportation, ground handling and storage conditions. Exposure to transportation, ground handling and storage environments shall be limited to periods when the inverter is non-operating.

a. Temperature (Air)

1. Air Transportation	Minimum ambient of minus 65F for six hours (35,000 feet). Maximum ambient of plus 115F (ground) for one hour; maximum compartment temperature while on the ground of plus 190F for one hour and plus 150F for six hours per 24-hour period.
2. Ground Transportation	Minimum ambient of minus 23F, maximum ambinet of plus 115F; maximum compartment of plus 190F for one hour and plus 150F for six hours per 24-hour period.
3. Storage	Plus 25F to plus 105F for a ten-year period.

b. Pressure. Maximum of 15.23 PSIA (sea level), minimum of 3.47 PSIA (35,000 feet).

c. Humidity	15 to 100 percent relative humidity, including conditions wherein condensation takes place in the form of water or frost for up to 30 days.
d. Sand and Dust	As encountered in desert and ocean beach areas, equivalent to 140-mesh silica flour with particle velocity up to 500 feet per minute and a particle density of 0.25 grams per cubic foot.
e. Fungus	As experienced in tropical climate. Materials shall not be used which will support or be damaged by fungi.

(d)³ 74-041.

SHUTTLE

PREPARED BY G. A. Marshall	CODE IDENT. NO.: 03953	NUMBER MC450-0017
APPROVALS	SPACE DIVISION NORTH AMERICAN ROCKWELL CORPORATION 12214 LAKEWOOD BOULEVARD • DOWNEY, CALIFORNIA 90241	TYPE Procurement
1/ /74		DATE 10 January 1974
1/ /74	SPECIFICATION	SUPERSEDES SPEC. DATED:
1/15/74		REV. LTR. New
		PAGE 1 of 57

ERS 11

TITLE

Total Pages 57

CONTROLLER, REMOTE POWER

▷ - INDICATES CHANGE

3. REQUIREMENTS

3.1 Item Definition. The RPC shall function as a remote power control device in one or more direct current (dc) electrical power systems. The RPC shall also provide short circuit/overload protection and a Trip Signal. The RPC function is illustrated by Figure 1.

Fig 1

App I, II, III

3.1.1 Item Diagram. Appendices I, II, and III illustrate the envelope and mounting dimensions of the specific RPC Type and Class.

3.1.2 Electrical Power Characteristics. The Electrical Power Characteristics, at the RPC terminals, shall be as specified herein and in accordance with MF0004-002.

Fig 2

3.1.2.1 Interface Diagram. Figure 2 is a schematic block diagram in which an RPC may be used. The diagram illustrates Shuttle Orbiter aerospace vehicle power systems and current flow. The diagram is intended to assist in determination of the sellers' detail requirements and shall not be construed as a constraint on design.

3.1.3 Item Identification. Identification of the RPC shall be as specified in the applicable Appendix.

3.2 Characteristics.

3.2.1 RPC Performance. The RPC shall be capable of operating, as specified, when subjected to one or any combination of the requirements of this specification.

3.2.1.1 Life Requirements. The RPC shall be designed to provide the most cost effective life capability, considering minimum maintenance and/or refurbishment as well as state-of-the-art hardware design. Upon completion of tradeoffs by the seller to establish the optimum relationship between hardware life capability, maintenance, and/or refurbishment, the RPC operating life objective will be changed to become a requirement.

3.2.1.1.1 Operating Life. The RPC shall be capable of performance, as specified herein, for a minimum of 100,000 RPC operating cycles.

3.2.1.1.2 Useful Life. As a design objective, the RPC shall have a minimum useful life of 72,000 hours which is equivalent to 100 Orbital Missions in a ten-year period from date of delivery.

3.2.1.1.3 Shelf Life. As a design objective, the RPC shall be capable of operating in accordance with the requirements specified herein any time within a period of ten years from date of delivery when exposed to the environments of 3.2.5.

3.2.1.2 Electrical Performance.

3.2.1.2.1 Operating Voltages. The RPC Operating Voltages shall be within the limits specified in Table I and as illustrated in Figure 3.

3.2.1.2.1.1 Turn On Voltage. The Turn On Voltage shall be 14.0 volts, direct current (vdc) maximum. Application of the Turn On Voltage shall initiate current [illegible] external load.

3.2.1.2.1.2 Turn Off Voltage. The Turn Off Voltage shall be 9.0 vdc, plus 0.0, minus 2.5 vdc. The Turn Off Voltage is defined as that voltage at which current flow to the external load is turned off.

3.2.1.2.2 Rated Current. The Rated Current shall be as specified in the applicable Appendix. The RPC shall not be adversely effected when subjected to the higher currents specified in the following subparagraphs.

Fig 4

3.2.1.2.2.1 Current Limiting/Overload. The RPC shall limit/inhibit current flow to the external load within the time/current limits specified in Figure 4.

3.2.1.2.2.2 Rupture Current. The RPC shall fail safe when interrupting the Rupture Current specified in the applicable Appendix. Fail safe operation may be provided by a fusible link.

3.2.1.2.2.3 DC Ripple Current. The dc ripple current during Current Limiting/Overload conditions shall not exceed two percent of the input supply current.

3.2.1.2.3 Trip Signal. The Trip Signal (TS) shall be a steady-state discrete plus 28 vdc, in accordance with Table I. The TS vdc shall be referenced to the control circuit minus voltage. Subsequent to Current Limiting/Overload and Rupture "trip" conditions, the RPC shall provide the TS continuously when 14.0 to 34.0 vdc is applied at the RPC control terminals.

3.2.1.2.4 Reset Capability. Subsequent to "trip" or interruption of current flow, the RPC may be reset within 0.020 seconds.

Fr Table I

3.2.1.2.5 Response Times. The RPC Response Times shall be within the limits specified in Table I and Figure 3.

3.2.1.2.6 Common Mode Rejection. The RPC shall incorporate Common Mode (CM) Rejection capability to prevent inadvertent operation when a CM plus 10.0 volts peak, dc to 100 KHz, is present at the control terminals.

3.2.1.2.7 Burn-in. The RPC Electrical Performance shall be demonstrated, as a condition of the Buyers' acceptance of each RPC, 5,000 minimum operating cycles at the rated resistive current specified in the applicable Appendix.

3.2.2 RPC Physical Characteristics.

3.2.2.1 Weight. The maximum weight of the RPC shall not exceed that specified in the applicable Appendix.

3.2.2.2 Envelope. The Envelope of the RPC shall conform to the requirements of the applicable Appendix.

3.2.2.2.1 Enclosure. The RPC Enclosure shall be of sufficient mechanical strength to withstand the normal transit, test, storage, and use (requirements of this specification), without causing malfunction or distortion of parts. The RPC Enclosure shall be all-welded construction and shall not electrically interface with the terminals or operating plus and minus voltages.

3.2.2.2.2 Terminals. The RPC shall incorporate solder Terminals. The RPC Terminals shall conform to the "Terminals" and "Strength of Terminals" requirements specified in MIL-R-6106, paragraph 3.4.8.2.

3.2.2.2.3 Hermetic Seal. The RPC shall incorporate a Hermetic Seal. The Hermetic Seal is defined as a gas tight fusion of the Enclosure and Terminals, utilizing metals, vitreous materials, or other metal to metal bonding. The Hermetic Seal leakage rate shall not exceed 1 x 10^{-8} standard cubic centimeters (cc) per second per cubic inch (in^3) of the sealed RPC volume. Prior to sealing, the RPC shall be purged of all gasses and then back-filled to a pressure of one atmosphere with dry nitrogen and sufficient quantity of helium for mass spectrometer leak detection. Each back-fill gas shall have a 98 percent purity and a dew point not above 85 F.

3.2.2.2.3 Mounting. The RPC shall incorporate integral flange type mounting provisions as illustrated in the applicable Appendix. The mounting surface shall confirm to the environmental requirements of this specification and MF0004-009. The mounting surface finish shall ensure the Enclosure Bond Resistance does not exceed 0.0025 ohm.

3.2.2.3 Attitude. The RPC shall operate in accordance with the requirements of this specification when mounted in any position.

3.2.3 Reliability.

3.2.3.1 Failure Rate. As a goal, the RPC flight mission reliability, when operated within the requirements of 3.2.1.1.2 and 3.2.5.4 shall be 150,000 hours mean time before failure.

3.2.3.2 Failure Deterrent. The RPC shall be designed such that transient out-of-tolerance conditions or component failures will not cause other component or subsystem failures.

3.2.4 Maintainability. The RPC is designated as a Shop Replaceable Unit (SRU) and shall not require maintenance.

3.2.5 Environments.

3.2.5.1 Transportation (Packaged). The RPC shall be capable of meeting the Electromagnetic Interference and Electrical Design requirements specified herein after exposure to the following Transportation conditions when packaged in accordance with Section 5.

a. Air

(1) Temperature	Minimum ambient of minus 65 Fahrenheit (F) for six hours at 35,000 feet (ft). Maximum ambient of plus 115 F (ground) for one hour; maximum compartment temperature while on ground of plus 190 F for one hour and plus 150 F for six hours.
(2) Pressure	Maximum of 15.23 pounds (lbs) per square (sq) inch (in) absolute (psia), sea level; minimum of 3.28 psia; 35,000 ft.

(3) Humidity	8 to 100 percent relative humidity, including conditions wherein condensation takes place in the form of water or frost.

b. Ground

(1) Temperature	Minimum ambient of minus 23 F, maximum ambient of plus 115 F, maximum compartment of plus 190 F for one hour and plus 150 F for six hours.
(2) Pressure	Maximum of 15.23 psia (sea level); minimum of 9.76 psia (10,000 ft).
(3) Humidity	8 to 100 percent relative humidity, including conditions wherein condensation takes place in the form of water or frost.

c. Shock	Capable of withstanding shock, as specified in 5.2.3.
d. Vibration	Capable of withstanding Vibration, Sinusoidal, as specified in 5.2.3.

3.2.5.2 Storage. The RPC shall be capable of meeting the Electromagnetic Interference and Electrical Design requirements specified herein after exposure to the following storage conditions.

a. Sheltered Environment (packaged or unpackaged)

(1) Temperature	Minus 23 F to plus 150 F.
(2) Humidity	8 to 100 percent relative humidity, including conditions wherein condensation takes place in the form of water or frost.
(3) Pressure	Maximum of 15.23 psia (sea level); minimum of 9.75 psia (10,000 ft).
(4) Ozone	Three years exposure including 72 hours at 0.50 parts per million (ppm), three months at 0.25 ppm, and remainder at 0.05 ppm.
(5) Fungus	As specified in MC999-0096.
(6) Sand and Dust	Suspended dust (as distinguished from blowing sand) is uniformly distributed in the protected atmosphere, with particle sizes ranging from the lower limit of sand (0.08 millimeter (mm) down to below 0.0001 mm. Ninety percent of the dust particles will be between 0.0001 mm and 0.002 mm in diameter.

b. Unsheltered Environment (packaged)

(1) Temperature	Minus 23 F to plus 115 F.

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

(2)	Pressure	Maximum of 15.23 psia (sea level); minimum of 9.76 psia (10,000 ft).
(3)	Humidity	8 to 100 percent relative humidity, including conditions wherein condensation takes place in the form of water or frost.
(4)	Sand and Dust	As encountered in desert and ocean beach areas, equivalent to 140-mesh silica flour with particle velocity up to 500 feet per minute and a particle desnity of 0.25 grams per cubic foot.
(5)	Salt Fog	Salt atmosphere as encountered in coastal areas, the effect of which is simulated by exposure to a 1.0 percent salt solution by weight for 30 days.
(6)	Rain	Maximum of 19 inches in 24-hour period including short period extremes of four inches for one hour.
(7)	Ozone	Three years exposure including 72 hours at 0.50 ppm, three months at 0.25 ppm, and remainder at 0.05 ppm.
(8)	Solar Radiation	Solar radiation of 363 British Thermal Unit (BTU)/ft^2/hour for six hours per day for two weeks.
(9)	Fungus	As specified in MC999-0096.

3.2.5.3 Ground Handling Loads (Unpackaged). The RPC shall be capable of meeting the operating performance requirements specified herein after exposure to the following ground handling conditions when unpackaged.

a.	Shock, Bench Handling	As specified in MIL-STD-810, Method 514.7, Procedure V
b.	Shock	As specified in MIL-STD-840, Method 516.1, Procedure I

3.2.5.4 Flight Environments. The RPC shall be capable of operating as specified herein during and after exposure to any combination of the following environmental extremes:

a.	Pressure	16.0 psia, maximum to 1 x 10^{-10} mm of Mercury (mmHg or torr).
b.	Atmosphere	Circulating Nitrogen/Oxygen at maximum pressure (Oxygen = 3.45 psia, maximum; 2.75 psia, minimum) to nominal at 3.78 psia (35,000 ft).
c.	Temperature	Minus 65 F to plus 160 F in specified atmosphere; to plus 130 F at 1 x 10^{-10} mmHg (when mounted on coldplate).
d.	Humidity	Dew point plus 39 F to plus 61 F; salinity one percent by weight; 0 percent relative humidity, including conditions wherein condensation takes place in the form of water or frost for up to 30 days.

e.	Lightning	The RPC shall not be adversely effected when exposed to cable core transients at each RPC Terminal. The transient shall be a composite of two triangular wave forms, each having a total energy of 10 millijoules. The first one shall crest at two microseconds after initiation with a total duration of 100 microseconds. The second one shall crest at 300 microseconds after initiation with a total duration of 600 microseconds.
f.	Vibration Random	Acceleration spectral density (g^2/Hz) increasing at the rate of plus six decibels (db) per octave (oct) from 25 to 80 Hertz (Hz), constant at 0.2 g^2/Hz from 80 to 400 Hz, decreasing at the rate of minus 3 db/oct from 400 to 2,000 Hz, in each axes.
g.	Acceleration	Plus and minus 5.0 g, 3 minutes in each direction of each of the three mutual axes.
h.	Shock	
	(1) Non-operating	Peak acceleration (sawtooth pulses), 40.0 g, 0.011 second minimum in each direction of the three mutual axes.
	(2) Operating	Peak acceleration (rectangular pulses), one time, 1.5 g, 0.260 second minimum, in each direction of each of the three mutual axes.

3.2.5.5 Checkout Environments (Installed). The RPC shall be capable of operating as specified herein during and after exposure to environments specified as follows:

a.	Pressure	18.0 psia, maximum, to 14.5 psia, minimum.
b.	Atmosphere	Standard; circulating at the pressure extremes specified herein.
c.	Temperature (Ambient)	Minus 23 F to plus 135 F.
d.	Humidity	8 to 100 percent relative humidity, including conditions wherein condensation takes place in the form of water or frost for up to 30 days.
e.	Salt Fog	Salt atmosphere as encountered in coastal areas, the effect of which is simulated by exposure to a 1.0 percent salt solution by weight for 30 days.

3.2.6 Transportability. The RPC shall be designed so as to be capable of being handled and transported to using facilities without damage or degradation, utilizing available methods of transport with the RPC prepared for shipment in accordance with Section 5 requirements.

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

3.3 Design and Construction. The RPC shall be of compact design and of sufficiently rugged construction to withstand all stresses and operational conditions specified herein.

3.3.1 Materials, Parts, and Processes.

3.3.1.1 Materials and Processes. Materials and Processes for the RPC shall be in accordance with MC999-0096, to the extent specified in the requirements table of the purchase order.

3.3.1.2 Parts Standardization. Parts utilization shall be based on selection of qualified parts, proper derating, application, and minimizing the number of part types. Parts utilized shall conform to MFC004-400.

3.3.1.3 Parts Attachment. Parts within the RPC Enclosure shall be secured (bonded) to the RPC assembly by mechanical means, except attachment may be effected utilizing approved fusible materials with melting points equal to or greater than 375 F, or structural adhesive bonding in accordance with MC999-0096.

3.3.1.4 Cleanliness. The internal surfaces of the RPC and external surfaces of integral RPC parts within the RPC, shall be cleaned to the cleanliness requirements of MC999-0096.

3.3.2 Selection of Specifications and Standards. Specifications and Standards for use in the design and construction of the RPC, other than those specified herein, shall be selected in the order of precedence specified in MIL-STD-143, except that NASA documents, when suitable for the purpose shall take precedence.

3.3.3 Electromagnetic Interference and Electrical Design.

3.3.3.1 Electromagnetic Interference. The RPC shall be designed in accordance with MF0004-002, Class I, Subclass B.

3.3.3.2 Electrical Design. The RPC Electrical Design shall conform to the requirements specified in MF0004-002, except as follows.

3.3.3.2.1 Power. The power consumed by the RPC shall be the minimum required, consistent with the requirements of the applicable Appendix.

3.3.3.2.2 Voltage Drop. The Voltage Drop shall not exceed 0.5 vdc for current values from zero to 100 percent of the rated resistive current specified in the applicable Appendix.

3.3.3.2.3 Isolation.

3.3.3.2.3.1 Insulation Resistance. The Insulation Resistance, measured at a potential of 500 vdc (minimum) shall be 1,000 megohms (minimum) when tested as specified in 4.2.2.3.1.

3.3.3.2.3.2 Dielectric Strength. The RPC shall be capable of withstanding 1,250 volts rms alternating current (ac), 60 Hz minimum potential, applied between the RPC Terminals and the Enclosure as specified in 4.2.2.3.1, for a period of 60 seconds minimum. During each test, the leakage current shall not exceed 1.0 milliampere for 10 milliseconds. Subsequent to Acceptance Tests, the test potential shall be 1,000 vac rms, 60 Hz maximum.

3.3.3.2.3.3 Impedance. The Impedance of the RPC, between the plus control terminal and the RPC Enclosure and all other Terminals, shall not be less than 2,100 ohms plus or minus 100 ohms.

3.3.3.2.3.4 Leakage Current. The RPC Leakage Current with plus 34.0 vdc applied between the load terminals shall not exceed the maximum specified in the applicable Appendix.

3.3.4 Identification and Marking.

3.3.4.1 Identification of Parts. Each part fabricated shall be identified with a part number. The same specification or part number shall be used to identify all like materials, processes, and parts. Seller shall assign a new part number to the part when authorized changes make the superseded part not interchangeable with respect to interface, reliability, safety, logistics, traceability or performance. For traceable items the part identification shall additionally include the manufacturer's identification code in accordance with DOD Handbook H4-1, and be lot/number numbered or serial numbered when required.

3.3.4.2 Identification of All Development/Qualification Test Specimens. Test specimens shall be permanently and obviously identified prior to testing with the words "ENG. TEST ONLY" in addition to the identification required by the Drawing/Specification to preclude their use on production items. The letters shall be indelible and provide a distinctive and vivid contrast with the color of the specimen. The lettering size and identification location shall be clearly visible to casual observation. Materials used for the identification shall be compatible with the test specimen and its operating environment. When the size or configuration of the test specimen is such, the identification cannot appear on the specimen, other suitable means such as attached metal tags shall be used.

3.3.4.5 Nameplates. Nameplates shall be marked in accordance with MIL-STD-130 and shall include (as applicable) item name; buyer's control number; Federal Stock Number/North Atlantic Treaty Organization (FSN/NATO); manufacturer; date of manufacture; and manufacturer's serial number, part number, lot number, and code identification number. Abbreviations, in accordance with MIL-STD-12, may be used.

3.3.4.4 Terminal Identification/Wiring Diagram. The RPC shall have permanently affixed to the Enclosure an indelible and legible Terminal Identification/Wiring Diagram, that identifies each RPC Terminal function as specified herein, and each RPC Terminal location.

3.3.5 Traceability.

Traceability shall be provided by assigning a traceability identification to each RPC identified in 3.1.3. Such identification shall provide the means of correlating each to its historical records. Conversely, the records must be traceable to each RPC.

3.3.5.1 Traceability Classification. For lower tier items, traceability classifications shall be established by classifying raw material, part, assembly, or end item for determining the marking and traceability records required (or excluded for exempt items) for that item. Seller/subordinate supplier engineering documentation (e.g., drawings and specifications) shall specify traceability or exception for items in accordance with the applicable classifications defined in 6.1.

3.3.5.2 Traceability Identification. Each item identified as traceable (refer to 6.1 for T_S, T_L, T_M) shall have a traceability identifier consisting of the manufacturer's code identification number as listed in DOD Handbook H4-1 and a serial, lot, or member number. The serial, lot, or member number shall be assigned by the manufacturer and shall not exceed ten characters (alphas, numerics, dashes, etc.).

3.3.6 Interchangeability. The RPC and integral parts of the RPC, identified in 3.1.3 shall be interchangeable in accordance with the definition of "Interchangeable Items" specified in MIL-STD-280. Interchangeability shall be provided at the attachments of these items to their next assembly.

3.3.6.1 Design Tolerances. Provisions shall be made for Design Tolerances such that each RPC having the dimensions and characteristics permitted by this specification or the applicable Appendix are interchangeable without selection or departure from the RPC performance specified herein.

3.3.6.2 Use of Standard Parts. When standard parts specified in 3.3.1.2 are not available and permission is granted for use of a non-standard part due to unavailability of the standard part, the equipment shall be designed so that the nonstandard part can be replaced by the standard part. Appropriate space, mounting holes, and other necessary provisions shall be provided for this purpose.

3.3.7 Safety. The RPC design and operation shall not impair crew or vehicle safety when operated at the temperature and pressure extremes specified in this specification.

3.3.8 Human Performance/Human Engineering. The RPC design shall be homogeneous with the capabilities and limitations of human operators whenever a man-machine interface exists, including torques, forces, and other characteristics relative to service use and work stations. The principal design guide for the man-machine interface shall be MIL-STD-1472.

[illegible] 3, Change as Follows: (Continued)

Response Times (second)

Turn-On Minimum, is: [0.0002]

was: [illegible]

Turn-Off Minimum, is: [0.001]

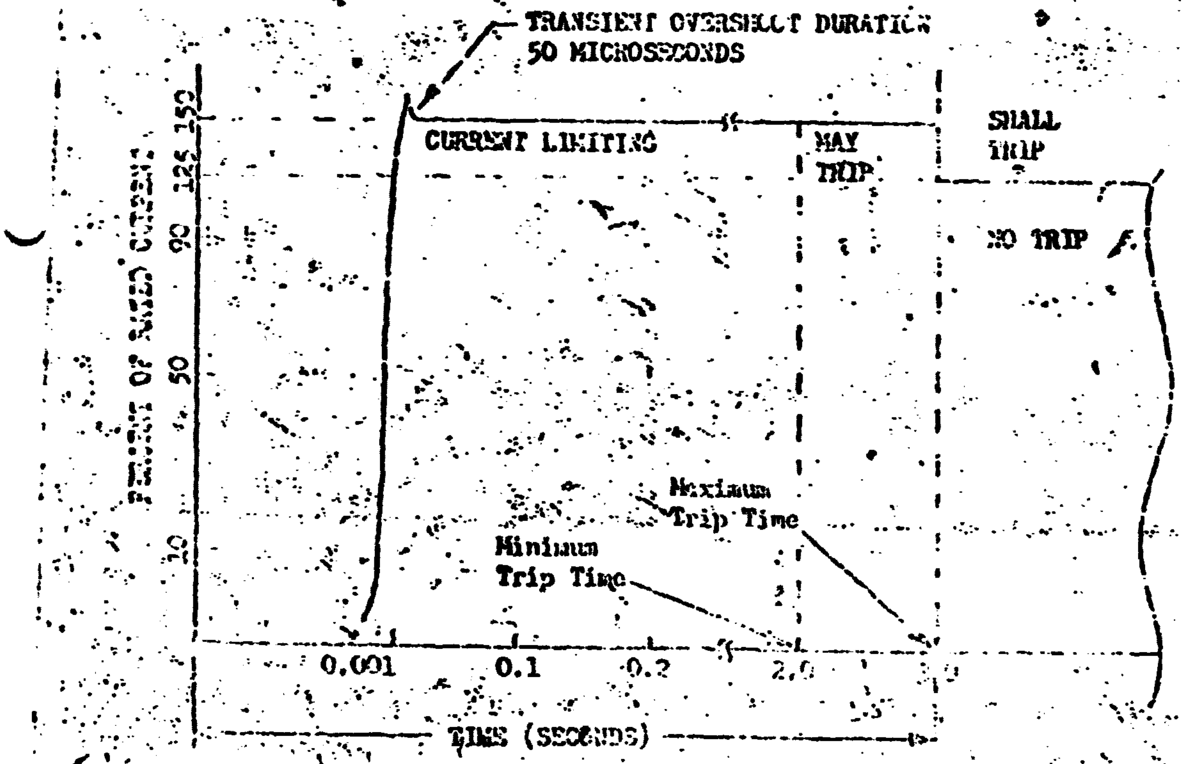
was: [illegible]

Delete: Trip Signal (Output)

Delete: Figure 2 RPC Power System Interface.

Delete: Figure 3 Operating Characteristics.

Figure 4, Replace With:



(Req) 321213 Current Limiting / Overload.
The RPC shall limit current flow to the external load at 150% of rated current for a duration of 2 sec. (min.) [illegible] at the [illegible] time [illegible] must be not greater than 10% of the rated current [illegible] RPC shall trip

RCCB

PRECEDING PAGE BLANK NOT FILMED

3. REQUIREMENTS

3.1 Item Definition. RCCB's built to this specification shall be capable of performing the following functions under all the environmental conditions and other requirements imposed by this specification:

a. Carry current in accordance with its rating as specified in Table I.

b. Automatically sense an overload and interrupt (trip) the circuit without damage under the conditions specified.

c. Provide the capability for closing and opening the circuit from a remote location during all conditions except overload.

This capability shall provide for closing (resetting) the RCCB following an automatic trip but only after the overload condition has been corrected. It shall not be possible to close and maintain the RCCB contacts closed while an overload condition is still present.

3.1.1 Item Diagram. Figure 1 is the block diagram for the RCCB external connections.

3.1.2 Interface Definition.

3.1.2.1 Electrical Power Characteristics. The electrical power characteristics at the RCCB interface shall be in accordance with MF0004-002.

3.1.2.2 Control Input. The RCCB shall be actuated (set) by application of a 24.0-32.0 Vdc signal applied through a 1300 ± 65 ohm, 1 watt resistance at the control input terminal as shown in Figure 1. Removal of the control input voltage shall open the RCCB. [illegible]

3.1.2.3 Backup Power. The RCCB shall be capable of operation using 28 Vdc backup power applied as shown in Figure 1 at times when line voltage is not available. There shall be no connection within the RCCB to allow the backup voltage to energize the main bus or the load, nor for the main bus to energize the backup voltage bus.

3.1.2.4 Electrical Connections. Connections to external circuits shall be as shown in Figure 1.

3.1.2.4.1 Line and Load Terminals. Terminal studs shall be used for main line and load connections as shown in Figure 2.

3.1.2.4.2 Control Terminals. The control terminals shall be contained in an integrated wire-termination module in accordance with MS27726 to accept pin contact MS39029/01-16-20 per MIL-C-39029/1 and as shown in Figure 2.

3.1.3 Item Identification. The identification of the RCCB shall be as follows:

PRECEDING PAGE BLANK NOT FILMED

Table I. Performance Requirements

Dash Number	Rated Current	Max Voltage Drop at 70°F (Rated Current)	Trip Time 30° to 140°F (Seconds)							
			Percent Rated Current							
			200		400		600		1000	
			min	max	min	max	min	max	min	max
-1015	15	0.25	13	45	1.7	7	0.7	3.4	0.35	1.2
-1020	20	0.25	14	47	2.2	8	0.9	3.5	0.35	1.2
-1025	25	0.25	15	49	2.5	9	1.0	3.7	0.35	1.3
-1035	35	0.25	16	52	2.8	10	1.2	4.1	0.4	1.4
-1050	50	0.25	16	56	2.9	11	1.3	4.6	0.4	1.6
-1075	75	0.25	16	61	3.3	12	1.4	5.2	0.4	1.8
-1100	100	0.25	17	63	3.5	13	1.4	5.4	0.4	1.9

Ultimate Trip	Percent Rated Current		
	30°	70°	140°F
Minimum-No Trip 1 hour	115	115	105
Maximum-Trip 1 Hour Max	145	140	140

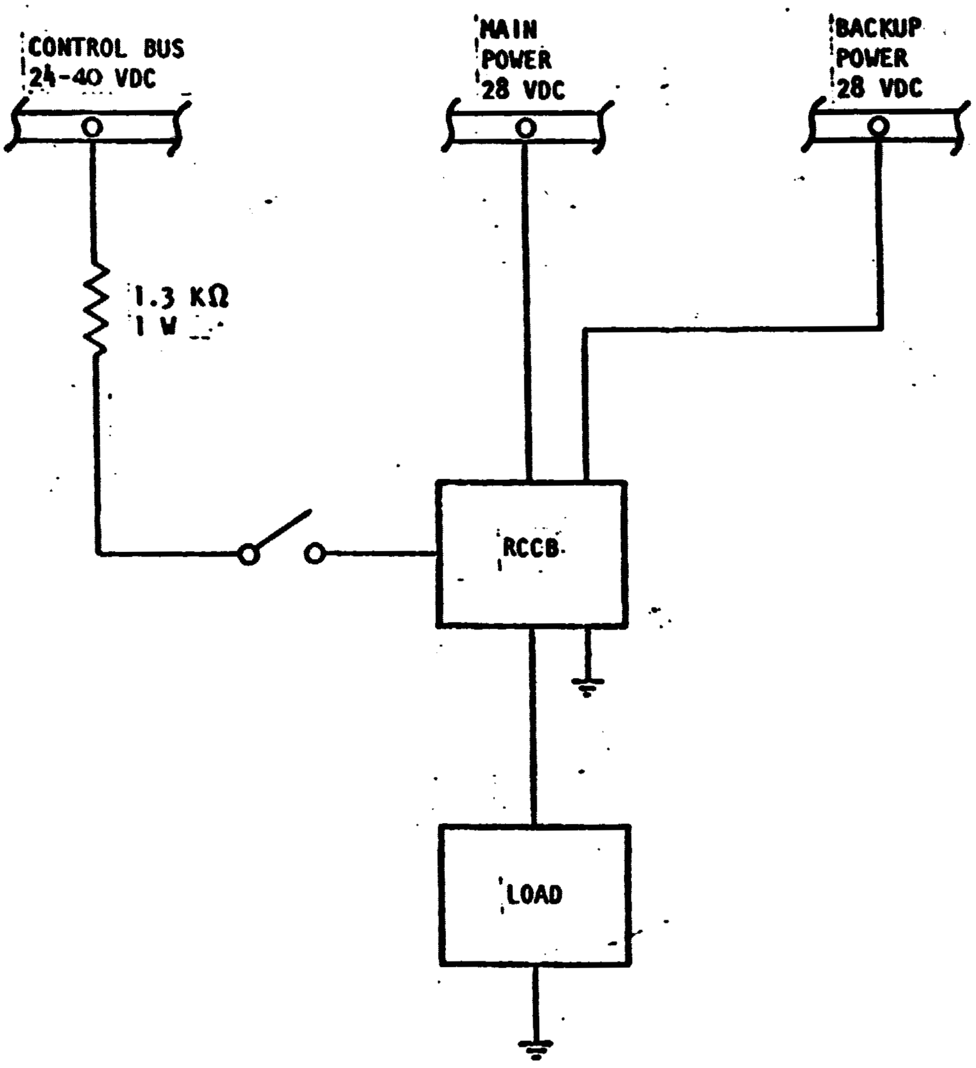
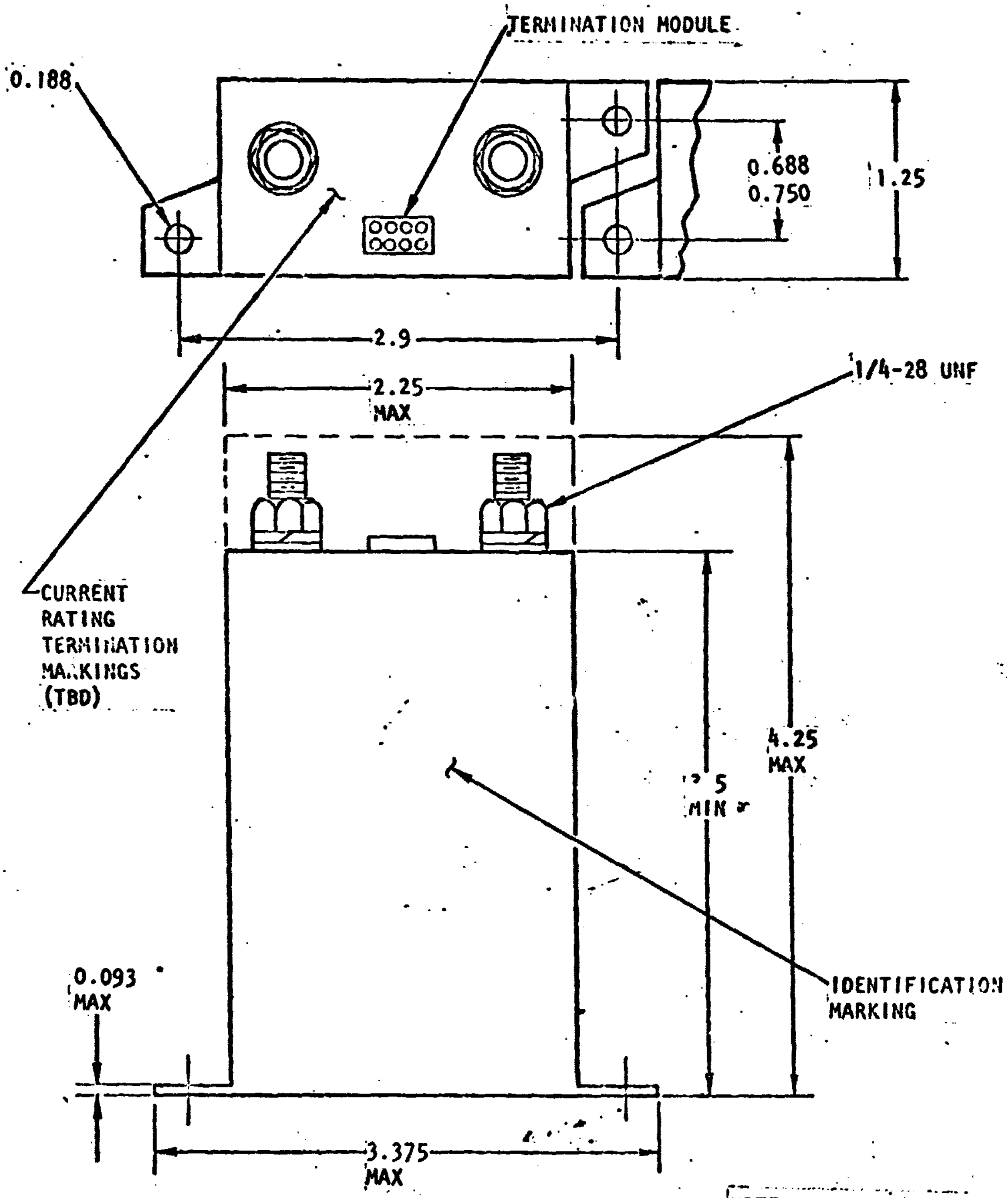


Figure 1. Block Diagram



NOTE:

DIMENSIONS IN INCHES
TOLERANCE: ± 0.005

Figure 2. Configuration

Nomenclature & Mfr Code Ident. No.	Buyer Control No.	Seller Part No.	Traceability Classification	LRU/ SRU
RCCB ( )	MC454-0027-1015	TBS	Serial	SRU
↓	1020	↓	↓	↓
↓	1025	↓	↓	↓
↓	1035	↓	↓	↓
↓	1050	↓	↓	↓
↓	1075	↓	↓	↓
RCCB ( )	MC454-0027-1100	TBS	Serial	SRU

3.2 Characteristics.

3.2.1 Performance.

3.2.1.1 Life Requirements. The RCCB shall be designed to provide the most cost effective life capability, considering state-of-the-art hardware design. Upon completion of tradeoffs by the Seller to establish the optimum relationship between hardware life capability and cost, the following life objectives will be changed to requirements.

3.2.1.1.1 Operating Life. As a design objective, the RCCB shall be capable of being remotely cycled "ON" and "OFF" for a minimum of 50,000 cycles at rated current. In addition, the RCCB shall be capable of withstanding 100 cycles of automatic trip at 200 percent rated current with remote reset.

3.2.1.1.2 Useful Life. As a design objective, the RCCB shall have a minimum useful life of 30,000 hours, which are equivalent to 100 orbital missions in a 10 year period from date of delivery.

3.2.1.1.3 Shelf Life. As a design objective, the RCCB shall be capable of operating in accordance with the requirements specified herein any time within a period of 10 years from date of delivery when exposed to the applicable environments of 3.2.3.

3.2.1.2 Electrical Characteristics.

3.2.1.2.1 Ampere Ratings. Ampere ratings shall be as specified in Table I.

3.2.1.2.2 Voltage Drop. With rated voltage and current applied the RCCB voltage drop from line to load terminals shall not exceed the value specified in Table I.

3.2.1.2.3 Interrupting Capacity. The RCCB shall be capable of interrupting currents as specified in Table II when tested in accordance with 4.2.4.1.16.

3.2.1.2.4 Power Requirements. The RCCB shall require a maximum current of 3.5 amperes at 32 Vdc to operate the main contacts and a maximum control current of 10 milliamperes at 40 Vdc.

3.2.1.2.5 Insulation Resistance. The insulation resistance between mutually insulated parts and mounting surfaces shall not be less than 100 megohms when measured with a test potential of 500 volts dc at ambient conditions.

3.2.1.2.6 Dielectric Withstanding Voltage. The RCCB shall withstand 1250 volts ac (rms) at 60 Hz for a period of 60 seconds and shall show no evidence of breakdown, flashover, or current flow in excess of 100 microamperes.

a. Between line and load terminals with the RCCB in the OFF or TRIPPED position.

b. Between terminals and parts normally grounded (such as frame, shell, mounting plate, etc.) with the main contacts in both CLOSED and OFF (or TRIPPED) positions.

3.2.1.3 Operation.

3.2.1.3.1 Control. With power applied to the line or backup power terminals, the RCCB shall be capable of being closed (set) by application of 28Vdc to the control input, and opened when the 28 Vdc signal is removed. If power is removed from both the line and backup power terminals, the RCCB contacts shall remain in the same state as they were before the power was removed. If power is again applied to the line or backup power terminals, the RCCB shall assume the state dictated by the status of the control input. With minimum voltage applied to the control input, the RCCB shall operate in a maximum time of 30 milliseconds.

3.2.1.3.2 Trip Performance. The RCCB shall interrupt the circuit (trip) within the limits specified in Table I.

3.2.1.3.3 Trip Mechanism. When an overload condition occurs, the RCCB trip mechanism shall open the main contacts. The trip mechanism shall not be capable of closing (re-setting) the main contacts until the remote control switch is moved to "OFF" and then to "ON".

3.2.1.3.4 Trip Free Operation. The RCCB shall be designed so that the circuit cannot be maintained closed when the contacts are carrying overload currents that would normally trip the RCCB to the open position.

3.2.2 Physical Characteristics.

3.2.2.1 Envelope. The envelope of the RCCB shall not exceed the dimensions shown in Figure 2.

Table II. Interrupting Capacity

Fault Description *	System Voltage	Open Circuit Voltage	Fault Current Amperes	Recovery Open Circuit Voltage Transient
1 OCO 1 CO Sea Level 1 OCO 1 CO 1 X 10^{-6} TORR	28 Vdc	30 ± 2 Vdc	6000 amperes in 0.01 to 0.03 seconds after fault initiation	28 V within 0.002 seconds 50 V maximum

*OCO - Test in which the circuit breaker is closed before initiation of the fault
CO - Test in which the circuit breaker is closed to complete the fault

3.2.2.2 Mounting. The mounting provisions of the RCCB shall be as shown in Figure 2.

3.2.2.3 Weight. The weight of the RCCB shall not exceed TBS pounds including terminal hardware.

3.2.2.4 Surface Wear. Interacting surfaces in the RCCB shall be sufficiently smooth and wear resistant such that particle generation will not preclude the normal functioning of the item as specified herein.

3.2.2.5 Terminal Nut Torque. The RCCB external terminal fastener torque shall be TBD.

3.2.2.6 Orientation. The RCCB shall be capable of operating in any position and at zero gravity where convection cooling is precluded.

3.2.3 Environments.

3.2.3.1 Operational. The RCCB shall be capable of meeting the operating performance requirements specified herein during and after exposure to any feasible combination of the following conditions:

a.	Temperature	Minimum: Plus 30 F Maximum: Plus 140 F
b.	Pressure	Minimum: 10^{-10} Torr Maximum: 18.0 psia
c.	Humidity	Minimum: 0 percent, relative Maximum: 100 percent, relative
d.	Salt Fog	Exposure to one percent salt solution by weight.
e.	Lightning	In accordance with MF0004-002.

f. Random Vibration

(a) Liftoff and Boost Vibration Spectra

10 -25 Hz	0.02 g^2/Hz
25 -80 Hz	+6 dB/octave
80 -400 Hz	0.2 g^2/Hz
400-2000 Hz	-3 dB/octave

Time duration - 1 hour per axis

(b) Main Engine Vibration Spectra

10 -30 Hz	0.012 g^2/Hz
30 -60 Hz	-3 dB/octave
60-2000 Hz	0.006 g^2/Hz

Time Duration - 12.5 hours per axis

g.	Acceleration	Plus and minus 5 g's in all axes
h.	Shock	Maintain structural integrity when subjected to a terminal peak sawtooth shock of 11 milliseconds duration and 40 g acceleration in any direction.
i.	Explosive Atmosphere	In accordance with MIL-STD-810, Method 511, Procedure I, using butane for fuel.

3.2.3.2 Non-Operational. The RCCB shall be capable of meeting the operating erformance requirements specified herein after exposure to the following transportaion and storage conditions when packaged in accordance with Section 5.

a.	Temperature (Packaged)	Minimum: Minus 65 F for six hours. Maximum: Plus 115 F for one hour, plus 150 F for six hours and plus 190 for one hour.
b.	Pressure	Minimum: 10^{-10} Torr Maximum: 18.00 psia
c.	Sand and Dust (Packaged)	(1) As encountered in desert and ocean beach areas, equivalent to 140-mesh silica flour with particle velocity up to 500 feet per minute and a particle density of 0.25 grams per cubic foot. (2) Suspended dust (as distinguished from blowing sand) is uniformly distributed in the protected atmosphere, with particle sizes ranging from the lower limit of sand (0.08 millimeter (MM)) down to below 0.0001 mm (0.01 micron). Ninety percent of the dust particles will be between 0.0001 mm and 0.002 mm in diameter.
d.	Solar Radiation (Packaged)	363 BTU/ft^2/hr for 6 hours per day for two weeks.
e.	Rain (Packaged only)	Maximum of 19 inches for a 24 hour period, including short period extremes of four inches per hour.
f.	Hail (packaged only)	Diameter of 0.30 inches with fall velocity of 66 ft/sec.
g.	Snow (packaged only)	10.2 lb/ft^2
h.	Shock (Bench Handling)	As specified in MIL-STD-810 Method 516.1, Procedure V.
i.	Ozone	Three years exposure, including 72 hours at 6.0 parts per hundred million (phm) and remainder at 3.0 phm.
j.	Fungus	As specified in MC999-C096
k.	Vibration & Shock (Packaged)	In accordance with 5.2.3

3.3 Design and Construction.

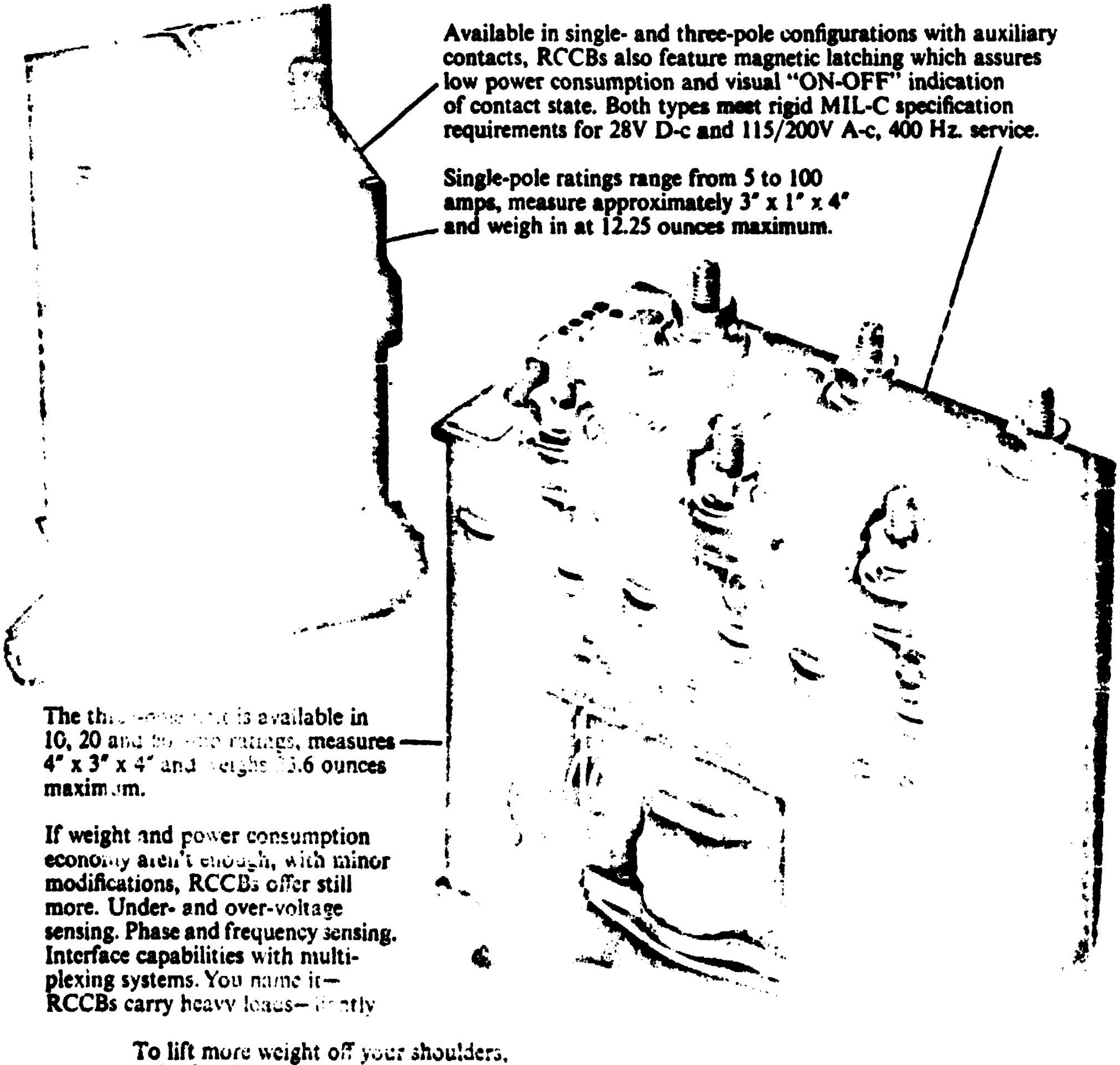
3.3.1 Materials, Processes, and Parts.

3.3.1.1 Materials and Processes. Materials and Processes for the RCCB shall be in accordance with MC999-0096 to the extent specified in the requirements table of the purchase order.

NEW FROM CUTLER-HAMMER

Remote load controllers carry heavy loads lightly.

New Remote Control Circuit Breakers (RCCB) combine the functions of a relay and a circuit breaker in one compact package. Heavyweight performers—they mount near the load or power source and are controlled and/or monitored from remote locations with 22 gauge control wiring. You save weight, simplify control circuitry and eliminate heavy cable runs—for lightweight results.



Available in single- and three-pole configurations with auxiliary contacts, RCCBs also feature magnetic latching which assures low power consumption and visual "ON-OFF" indication of contact state. Both types meet rigid MIL-C specification requirements for 28V D-c and 115/200V A-c, 400 Hz. service.

Single-pole ratings range from 5 to 100 amps, measure approximately 3" x 1" x 4" and weigh in at 12.25 ounces maximum.

The three-pole unit is available in 10, 20 and [illegible] amp ratings, measures 4" x 3" x 4" and weighs [illegible].6 ounces maximum.

If weight and power consumption economy aren't enough, with minor modifications, RCCBs offer still more. Under- and over-voltage sensing. Phase and frequency sensing. Interface capabilities with multiplexing systems. You name it—RCCBs carry heavy loads—lightly

To lift more weight off your shoulders, write for the RCCB Data Kit or call your Cutler-Hammer Sales Office.

7.5-37

RPC

PRECEDING PAGE BLANK NOT FILMED

APPENDIX 7.6

THEORETICAL BASIS FOR SYSTID

APPENDIX 7.6

THEORETICAL BASIS FOR SYSTID

THEORETICAL INTRODUCTION

Direct representation of systems on the digital computer by sample data simulation is a powerful systems analysis technique. Such simulation requires transformation by the computer of continuous system input functions in a manner which characterizes system behavior. The digital computation/process by which this transformation is accomplished is known as a digital filter. This is an algorithm by which sample values of a continuous input function are transformed into sample values of the continuous output function which would result from operating on the input with a given continuous transfer characteristic. The central problem in sample data simulation is obtaining the digital filter algorithm which effects this transformation in the most accurate and efficient manner.

Digital filters may be classified into two major categories as recursive or non-recursive. Non-recursive digital filter outputs depend only on present and previous input samples; recursive filter outputs depend on previous output values as well. The design methods for these two filter types are distinctly different as are their properties. The non-recursive filter has finite memory and excellent phase response characteristics but may require a large number of terms to obtain sharp cutoff properties. The recursive filter has infinite memory but rather poor characteristics. Recursive filters have fewer terms and lend themselves more efficiently to applications requiring sharp cutoff properties. The recursive filter is the digital counterpart of the linear lumped parameter continuous filter. For these reasons, recursive filters are of greater interest in systems analysis by sample data simulation and will be summarized briefly.

If it is assumed that the linear system for which a digital approximation is sought has a transfer characteristic of the form

$$H(s) = \frac{\sum_{m=0}^{M} C_m s^m}{\sum_{n=0}^{N} d_n s^n} \qquad (7.6\text{-}1)$$

where $s = j\omega$, then the corresponding digital transfer characteristic has the form

$$H^*(z) = \frac{\sum_{j=0}^{N-1} a_j z^{-j}}{1+\sum_{j=1}^{N} b_j z^{-j}} \qquad (7.6\text{-}2)$$

where z^{-1} is the unit delay operator. It is assumed that the continuous function H(s) is known or can be determined by established design procedures. The digital filter design problem is thus reduced to determining the coefficients a_j and b_j in $H^*(z)$ such that the continuous filter characteristic H(s) is best approximated for a given number of terms.

One digital filter design technique is based on the standard z-transform, defined so that the impulse response of the digital filter is identical to the sampled impulse response of the corresponding continuous filter. The standard z-transform of H(s) is given by

$$H^*(s) = \sum_{m=-\infty}^{\infty} H(s+jm\,\omega s) \qquad (7.6\text{-}3)$$

or in terms of the filter impulse response h(t) ,

$$H^*(z) = T \sum_{\ell=0}^{\infty} h(\ell T) z^{-1} \qquad (7.6\text{-}4)$$

where

s = $\sigma + j\omega$

$H(s)$ = Laplace transform of h(t)

ω_s = $\frac{2\pi}{T}$, radian sampling frequency

$H^*(s)$ = Laplace transform of sampled filter impulse response

z^{-1} = e^{-st}, unit delay operator

$H(z)$ = $H^*(s)\big|\, s = \ln(z)/T$, z-transform of h(t)

For s greater than some critical frequency ω_c, H(s) is assumed to have the form

$$H(s)|_{s > j\omega_c} = K/s^n \qquad (7.6\text{-}5)$$

where $n > 0$ and K is a constant.

Equations 7.6-3 and 7.6-4 are the digital filter transfer functions which approximate that of the continuous filter.

The disagreement between the digital filter characteristics provided by the standard z-transform and the continuous filter characteristic in the baseband ($-\omega s/2 \le \omega \le \omega s/2$) is known as frequency aliasing error and results from terms of the form $H(s + jm\omega_s)$, $m \neq 0$. This disagreement is present whenever the continuous filter characteristic is not bandlimited to the baseband. Unfortunately this is the case for most lumped parameter systems, for which H(s) is a rational function of s. Thus, for physical systems of interest, the standard z-transform yields $H^*(s) \neq H(s)$ in the baseband and aliasing error is present to some degree.

For higher order continuous filter transfer functions (n in Equation 7.6-5 is large) having a critical frequency ω_c much less than the sample frequency ω_s, aliasing error is sufficiently small that the standard z-transform yields useful results. In many practical situations, however, neither of these conditions are met. In these cases, the standard z-transform results in prohibitive aliasing errors in the digital filter frequency characteristic.

Frequency aliasing error may be avoided if digital filters are designed by means of an artifice known as the bi-linear z-transform. The bi-linear z-transform maps the entire complex s plane into an s_1 plane bounded by the lines $s_1 = j\omega_s/2$ and $s_1 = -j\omega_s/2$. The bi-linear z-transform is defined by

$$s = \frac{2}{T} \tanh \frac{s_1 T}{2} \qquad (7.6\text{-}6)$$

where $s_1 = j\omega_s/2$ and T is the sample interval. This becomes upon substitution of the unit delay operator $z^{-1} = e^{-s_1 T}$,

$$s = \frac{2}{T}\left(\frac{1 - z^{-1}}{1 + z^{-1}}\right) \qquad (7.6\text{-}7)$$

The digital filter transfer function, $H^*(z)$ is determined by substituting the bi-linear z-transform into the continuous filter transfer function H(s),

$$H^*(z) = H(s)\Big|_{s = \frac{2}{T}\left(\frac{1 - z^{-1}}{1 + z^{-1}}\right)} \qquad (7.6\text{-}8)$$

One aspect of the digital filter so obtained is that a non-linear warping is imparted to its frequency scale in accord with the transformation

$$\frac{\omega T}{2} = \tan \frac{\omega_1 T}{2} \tag{7.6-9}$$

This transformation is depicted in Figure 7.6-1 which plots normalized warped frequency ω, versus normalized unwarped frequency ω. Frequency warping is not a significant constraint on the versatility of the bi-linear z-transform. The warping may be arbitrarily reduced by making the sample frequency ω_s high compared to the critical frequency ω_c of the continuous filter. Furthermore, frequency warping may be compensated for by prewarping the critical frequencies of the continuous filter so that transformed frequencies will be shifted back to the desired ones. Because it obviates inaccuracies due to aliasing error, the bi-linear z-transform is

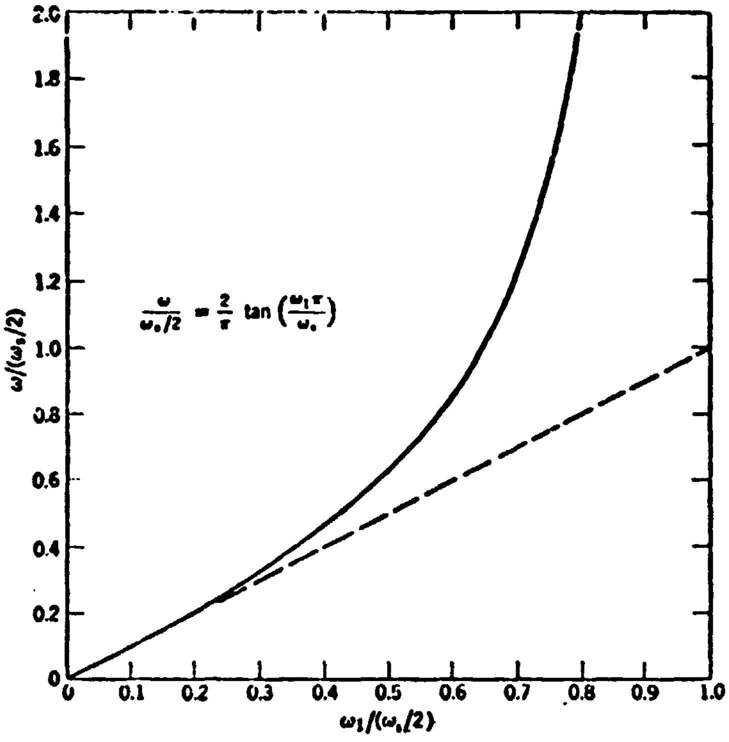


Figure 7.6-1. Non-Linear Warping of the Frequency Scale in the Bi-Linear z-Transformation

a most appealing digital filter design technique. It is applicable to low-pass, band-pass, band-stop, and other continuous filters whose magnitude characteristics are essentially constant within successive pass and stop bands.