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ADVANCED COMPOSITE COST ESTIMATING MANUAL

NORTHROP CORPORATION
AIRCRAFT DIVISION
HAWTHORNE, CALIFORNIA 90250

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TECHNICAL REPORT AFFDL-TR-76-87
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AIR FORCE FLIGHT DYNAMICS LABORATORY
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

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This technical report has been reviewed and is approved.

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FOR THE COMMANDER

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This program concentrated on the development of a computerized system that estimates the recurring costs associated with the fabrication of advanced composite detail parts and components. The system employs Industrial Engineering Standard equations developed in the program to calculate standard hours for the detail composite fabrication operations of layup, core preparation, part consolidation and finishing. With these standards as base, recurring costs are derived through the application of variance factors, improvement curve slopes and labor rates.

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PREFACE

This Technical Report was prepared by the Aircraft Division of Northrop Corporation under Contract No. F33615-75-C-3103 for the Air Force Flight Dynamics Laboratory, Air Force Wright Aeronautical Laboratories, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio. Mr. Richard J. Hirt, AFFDL was the Air Force Program Manager. This report covers the period from 1 April 1975 to 31 March 1976.

The work described in the report was carried out by Northrop Corporation, Aircraft Division, D. J. LeBlanc, Program Director. Principal contributors to the Northrop activities described in this report and their areas of responsibility are listed below:

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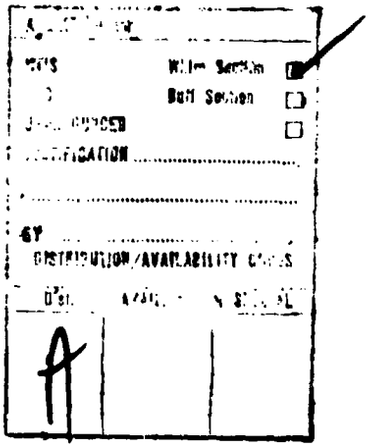

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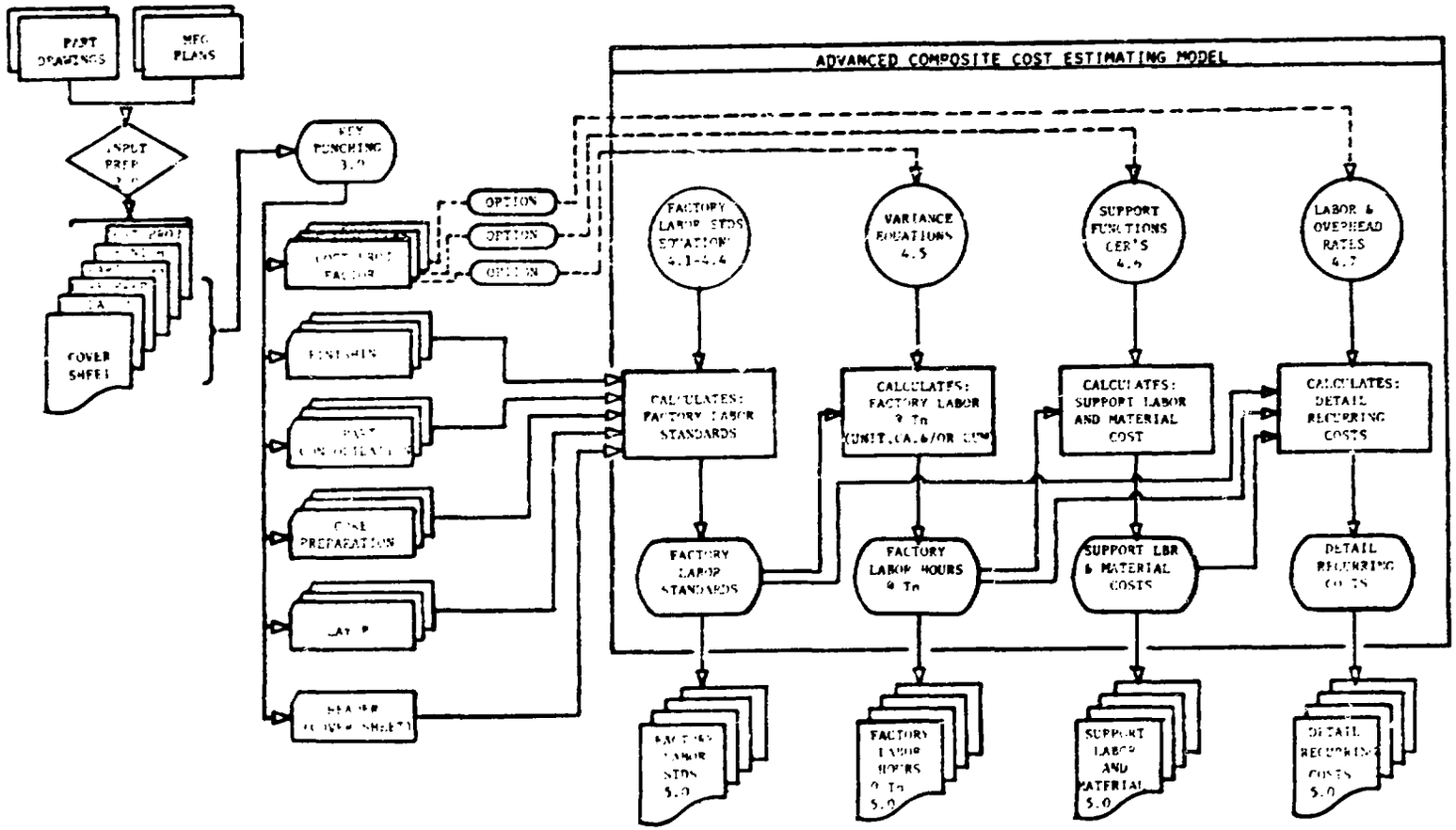
1.0 INTRODUCTION

The objective of the "Advanced Composite Cost Estimating Manual Program," Contract No. F33615-75-C-3103 was to develop a computerized methodology for estimating the recurring costs associated with the fabrication for advanced composite parts, and to fully document this methodology for use by Government and Industry. This program was conducted by Northrop Corporation, Aircraft Division, from April 1975 to 31 March 1976. A comprehensive description of the development of the computerized methodology is provided in Volume I of this report.

The User's Manual describes the implementation of the computerized estimating system developed in the "Advanced Composites Cost Estimating Manual Program." This volume contains instructions for completion of the input forms, instructions for keypunching data cards, estimating equations, and description of the outputs. This constitutes a complete explanation of the procedures to be followed in using the system.

The master diagram on the next page illustrates the flow of the estimating process. It identifies the various input and output documents prepared and generated as well as the operations, processing, and calculations performed to arrive at the desired cost estimates. Detailed discussions of the subject areas of this diagram are contained in the denoted sections of this volume.



MASTER DIAGRAM OF COMPUTERIZED COST ESTIMATING SYSTEM

2.0 INPUT FORMS

Six (6) Input Forms have been designed for this system. ACCEM-0 gives general information about the user and the part to be estimated. In addition, this form serves as a checklist that the computer uses to determine the type and quantity of the subsequent input forms submitted by the user. ACCEM-1 (Layup) provides detail information on the part or parts layed up, specifying the layup methods and techniques used and the type and form of advanced composite material layed up. It also provides information on supplementary layup operations such as debulking and trimming as required. ACCEM-2 (Core Operations) describes the processes performed to prepare aluminum honeycomb core according to specifications. ACCEM-3 (Part Consolidation) defines the processes performed in joining and/or curing composite and detail parts. When co-curing, this form identifies the various composite and core elements that are to be cured simultaneously. In addition, this form covers the splicing and bonding of core. More than one curing/joining cycle is available via this form, thereby accomodating pre-curing and secondary bonding operations. ACCEM-4 (finishing) identifies and provides detail information on the various trimming and drilling operations that are performed on cured composite parts. ACCEM-5 (Cost Projection) specifies the factors and rates that are used in calculating final cost estimates.

To aid the user in filling out the ACCEM input forms, descriptions/instructions have been provided. Examples of completed input forms for sample estimates are contained in the Appendix.

GENERAL INSTRUCTIONS

1. The user must follow a specific format when filling the data in the proper fields. Particular care should be exercised in positioning integers. In order to avoid confusion, all the spaces of the data field for the element must be filled in. For example, "1" is written "001," as illustrated below;

1 → 0,0,1,
10 → 0,1,0,
100 → 1,0,0,

The input elements for which this rule applies are identified in the description/instructions for each form.

2. The computer program has been designed with four levels of data requirements. Some of the data must be inputted by the user for program execution; some is computer generated; and some is for documentation purposes only. The data requirement for each input element is identified in the description/instructions for each ACCEM form. The definitions of the data requirements are as follows:

UNCONDITIONAL REQUIREMENT - Absolutely necessary for program execution.

CONDITIONAL REQUIREMENT - Necessity dependent upon other conditions being present. (For example, if an operation is performed, then the accompanying parameters must be filled in)

SYSTEM GENERATED - If data is not inputted by the user, then specified default values will be supplied.

DOCUMENTATION - Data input is voluntary and is generic to the user only.

ACCEM-0 INPUT CHECKLIST

OBJECTIVE

ACCEM-0 identifies the types and quantities of data contained in the Input Package. This information is used by the computer in determining the processing sequence.

ACCEM-0 is unconditionally required for computer program operation.

DESCRIPTION OF ELEMENTS		DATA REQ.
ESTIMATE NUMBER -	Name of person supply data	D
ESTIMATE NUMBER -	Identification number of estimate	D
PART NAME -	Name of part	D
PART NUMBER -	Identification number of part	D
INPUT FORMS -	List of form names	
QUANTITY USED -	Amount of each form included in Input Package (INTEGER)	
ACCEM - 1	LAYUP	U
ACCEM - 2	HONEYCOMB CORE PREPARATION	U
ACCEM - 3	PART CONSOLIDATION	U
ACCEM - 4	FINISHING OPERATIONS	U
ACCEM - 5	COST PROJECTIONS	U

LEGEND

DATA REQUIREMENT:
- U = Unconditional Requirement
- C = Conditional Requirement
- S = System Generated (Value Specified)
- D = Documentation

ACCEM-0 INPUT CHECKLIST

CARD 1

ESTIMATOR NAME	1
ESTIMATE NUMBER	21
PART NAME	41
PART NUMBER	61

CARD 2

INPUT FORMS		QUANTITY USED
ACCEM-1	LAYUP	1
ACCEM-2	HONEYCOMB CORE PREPARATION	3
ACCEM-3	PART CONSOLIDATION	5
ACCEM-4	FINISHING OPERATIONS	7
ACCEM-5	COST PROJECTION	9

ACCEM - 1 LAYUP

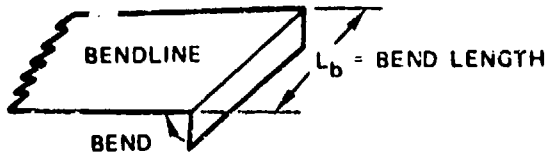
OBJECTIVE

ACCEM - 1 provides the information for the description of the material and the processes used in the layup operation. Data supplied in this form will be used in calculating the standard hours and material costs for the layup operation, as well as part weight. Codes are provided for some of the inputs. It is necessary to have one Layup Form for each non-identical layup.

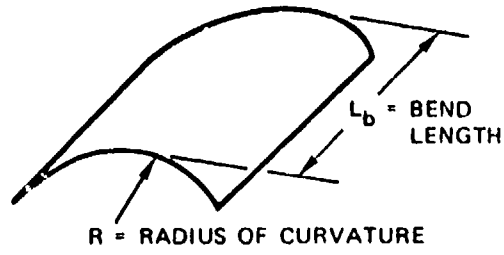
It is an unconditional requirement that either ACCEM - 1 or ACCEM - 2 be included in the Input Package for computer program operation.

DESCRIPTION OF ELEMENTS		DATA REQ.
PART NAME -	Name of part layed up	D
PART NUMBER -	Identification number of part layed up	U
QUANTITY -	Amount of identical parts layed up (INTEGER)	U
TRIM ALLOWANCE -	Unit of excess added to part dimensions to provide for trim, in inches	S = 1.00
LAYUP TOOL SAME AS CURING TOOL -	A layup may be layed up and cured on the same tool, or it may be transferred to another tool for curing.	S = 0
DEBULKING -	Process of densifying plies	
NO. OF OCCURRENCES -	Amount of debulking operations performed (INTEGER)	S = 0
TYPE OF BAG -	Category of material used in debulking	C
COST -	Cost of material in dollars per pound	
GRAPHITE - TAPE		S = 37.00
- WOVEN		S = 93.00
FIBERGLASS - TAPE		S = 8.70
- WOVEN		S = 9.30
DENSITY -	Weight of material for a given unit of surface area, in pounds per square inch	
GRAPHITE - TAPE		S = 0.0004
- WOVEN		S = 0.00089
FIBERGLASS - TAPE		S = 0.00054
- WOVEN		S = 0.00104

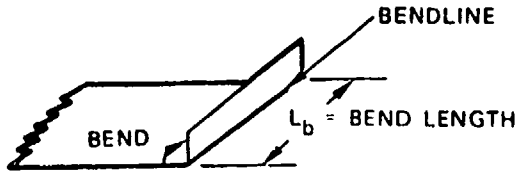
DESCRIPTION OF ELEMENTS		DATA REQ.
METHOD -	Procedures and techniques used to deposite composite material or tool (If HANDLING METHOD = 1, then information must be filled out for first line of preply. If HANDLING METHOD = 2, then information must be filled out for each ply)	
HANDLING METHOD		S = 2
PREPLY -	Stack of plies which are layed upon a flat surface and ther transferred to the layup tool.	
DIRECT-ON-TOOL -	Deposition of composite material one ply at a time on layup tool	
QUANTITY OF PREPLIES -	Amount of identical stacks of plies (INTEGER)	C
LAYUP METHOD -		S = 1
DEPOSITION TECHNIQUE -		S = 1
PLY-ON-PLY -	Layup directly on previously layed up ply	
PLY-ON-MYLAR -	Each ply is layed up on a template (mylar) and then transferred to the stack or layup tool.	
BEND DESCRIPTION -	Parameters which define layup complexity of non-flat parts. (If HANDLING METHOD = 1, then a separate entry for each type of bend must begin on the first line of the preply description. If HANDLING METHOD = 2, then a separate entry for each type of bend must begin on the line of the ply description)	
TYPE OF BEND -	A bend is characterized by a combination of factors. The surface along which the bend extends may be straight or curved. The change in the surface of the part which determines the bend is defined by the radius of curvature. If the radius is less than or equal to two inches, the bend is sharp. The bend is radial if the measurement is greater than two inches. A male bend is external to the tool surface; a femal bend is internal. Curved bends may be classified according to flange type. A stretch flange is one in which the outer edge expands away from the center of curvature. A shrink flange is one in which the outer edge contracts toward the center of curvature (See illustrations on next page.)	C
LENGTH OF BEND -	Length of the bent surface perpendicular to the bend angle	C



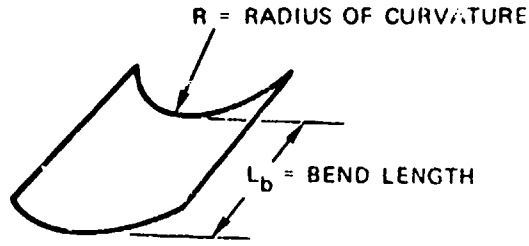
SHARP, MALE



RADIAL, MALE

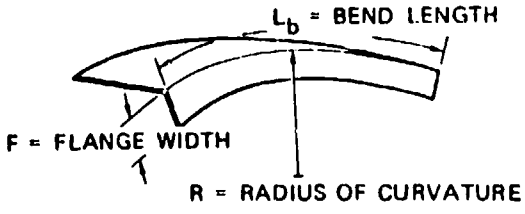


SHARP, FEMALE

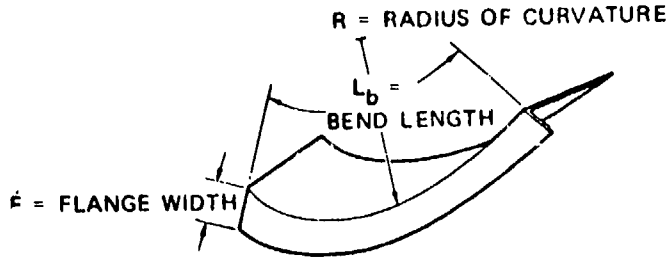


RADIAL, FEMALE

STRAIGHT BENDS



SHRINK FLANGE



STRETCH FLANGE

CURVED BENDS

DESCRIPTION OF ELEMENTS		DATA REQ.
RADIUS OF CURVATURE		C
For Bend Codes 3-4:	Radius of circle perpendicular to bend length	
For Bend Codes 5-7:	Radius of the circle formed by the bend length	
FLANGE WIDTH		C
For Bend Codes 5-6:	Distance from the bend angle to the edge of the flange	
PLY DESCRIPTION -	Defines each ply that composes the part. (If HANDLING METHOD = 1, then a separate entry for each ply type of the preplied stack must be filled out. If HANDLING METHOD = 2, then a new entry must be supplied for each ply having a unique Layup Method, Bend Description, or Ply Description.)	
ORIENTATION -	Angle which material is layed up. The 0 ply orientation is always in the length direction. (INTEGER)	U
COUNT -	Number of plies (INTEGER)	U
DIMENSION	(Where the part to be layed up has a curved bend, dimension can be measured by taking the flat equivalent of the layup. To do this, extend the web width to cover the flange width.) For a rectangular part, the dimensions are length and width. For non-rectangular parts the necessary dimensions are area and distance (greatest length across the part perpendicular to orientation). NOTE: Dimensions must be filled in for either the rectangular or non-rectangular category.	U
MATERIAL -	Defines the composite material used in layup	
FORM -		S = 1
TYPE -		S = 1
WIDTH -	(In inches)	S = 3.0

NOTE: AFTER FILLING THE LAST LINE OF DATA, THE USER MUST ENTER "9999" IN THE FIRST FOUR COLUMNS OF CARD 4, AND "000" IN THE FIRST THREE COLUMNS OF CARD 5.

LEGEND

DATA REQUIREMENT:
U = Unconditional Requirement
C = Conditional Requirement
S = System Generated (Value Specified)
D = Documentation

ACCEM-1 LAYUP

CARD 1

PART NAME (1) — PART NUMBER (21) — QTY (41)

TRIM ALLOWANCE (51) _____ IN

LAYUP TOOL SAME AS CURING TOOL (CIRCLE ONE) YES 1 NO 0 (61)

DEBULKING NUMBER OF OCCURRENCES (62)

TYPE OF BAG (CIRCLE ONE) DISPOSABLE 1 REUSABLE 2 (64)

CARD 2 (BLANK)

CARD 2

	GRAPHITE TAPE	GRAPHITE WOVEN	FIBERGLASS TAPE	FIBERGLASS WOVEN
COST ($/LB)	1	11	21	31
DENSITY (LB/SQ.IN.)	41	51	61	71

KEYPUNCH CARD 4 AND CARD 5 ALTERNATELY

CARD 4

METHOD | BEND DESCRIPTION

HANDLING METHOD (1) | QUANTITY OF PREPLIES (2) | DEPOSITION TECHNIQUE (4) | LAYUP METHOD (5) | TYPE OF BEND (6) | BEND LENGTH (IN.) (11) | RADIUS OF CURVATURE (21) | FLANGE WIDTH (IN.) (31)

CARD 5

PLY DESCRIPTION

ORIENTATION (DEG.) (1) | COUNT (11) | DIMENSIONS: RECTANGULAR — LENGTH (IN.) (21) | WIDTH (IN.) (31); NONRECTANGULAR — AREA (SQ.IN.) (41) | DISTANCE (IN.) (51) | MATERIAL: TYPE (61) | FORM (71) | WIDTH (27)

LAST ENTRY ON CARD 4 IS "9999"; LAST ENTRY ON CARD 5 IS "000"

LEGEND:

HANDLING METHOD: 1 = PREPLY, 2 = DIRECT-ON-TOOL

LAYUP METHOD: 1 = MANUAL, 2 = HAND-ASSIST, 4 = CONRAC AUTOMATIC (720 IPM), 5 = CONRAC AUTOMATIC (360 IPM)

DEPOSITION TECHNIQUE: 1 = PLY-ON-PLY, 2 = PLY ON MYLAR

TYPE OF BEND: 1 = STRAIGHT, SHARP, MALE, 2 = STRAIGHT, SHARP, FEMALE; 3 = STRAIGHT, RADIAL MALE; 4 = STRAIGHT, RADIAL, FEMALE; 5 = CURVED, STRETCH FLANGE (TAPE); 6 = CURVED, SHRINK FLANGE (TAPE), 7 = CURVED (WOVEN MATERIAL)

MATERIAL FORM: 1 = UNIDIRECTIONAL TAPE, 2 = WOVEN

MATERIAL TYPE: 1 = GRAPHITE/EPOXY, 2 = FIBERGLASS/EPOXY

ACCEM - 2 HONEYCOMB CORE PREPARATION

OBJECTIVE

ACCEM - 2 provides the description of the part, material, and processes used in aluminum core preparation operations. Data supplied in this form will be used in calculating the standard horus and material cost for core preparation as well as part weight. It is necessary to submit one form for each non-identical piece of core.

It is an unconditional requirement that either ACCEM - 1 or ACCEM -2 be included in the Input Package for computer program operation.

DESCRIPTION OF ELEMENTS		DATA REQ.
PART NAME -	Name of part	D
PART NUMBER -	Number of part	U
QUANTITY -	Amount of identical parts involved in operations (INTEGER)	U
MATERIAL DATA -	Characteristics of core material	
CELL SIZE -	Width of one cell, in inches	U
DENSITY -	Weight of material for a given unit of volume, in pounds per cubic foot	U
AREA -	Surface area of core piece, in square inches	U
CORE THICKNESS -	Depth of core, in inches	U
COST OF MATERIAL -	Cost of core in dollars per square foot	U
OPERATIONS -	Techniques used to alter the surface or shape of core	
SAWING -	Cutting the periphery of the core	
LENGTH OF CUT -	Total distance that is sawed	C
MACHINING -	Altering shape and dimensions of core	
FLAT -	Cut made perpendicular to the cells across the core surface	
LENGTH OF CUT -		C
WIDTH OF CUT -		C

DESCRIPTION OF ELEMENTS		DATA REQ.
CONTOUR -	Curved or angular cut across core surface	
LENGTH OF CUT -		C
WIDTH OF CUT -		C
STEP -	Removal of section perpendicular to cells along side of core	
LENGTH OF CUT -		C
WIDTH OF CUT -		C
SCARF -	Removal of angular section along side of core	
LENGTH OF CUT -		C
WIDHT OF CUT -		C
BLEND -	Removal of surface material to match structural element to which core is bonded	
LENGTH OF CUT -		C
WIDTH OF CUT -		C
CUTOUT -	Hole cut in core	
QUANTITY -	Amount of cutouts made in core	C
HAND FORMING -	Manual bending or shaping of core	C
BRAKE FORMING -	Machine assisted bending or shaping of core	
RADIUS OF CURVATURE -	Radius of circle to which core is formed	C
DIE LENGTH -	Size of initial die used in forming core	C
NO. OF DIE CHANGES -	Amount of times different dies is installed in machine	C
NO. OF REPOSITIONS -	Amount of times a particular die is shifted	C
LIQUID POTTING -	Strengthening core by filling cells with mixture which is hardened by application of heat	
VOLUME -	Measurement of area to be filled, in cubic inches	C
TAPE FOAMING -	Strengthening core by applying tape which expands when heated to fill cells	
VOLUME -	Measurement of area to be foamed, in cubic inches	C

LEGEND

DATA REQUIREMENT:
U = Unconditional Requirement
C = Conditional Requirement
S = System Generated (Value Specified)
D = Documentation

ACCEM-2 HONEYCOMB CORE PREPARATION

CARD 1 PART NAME (1) PART NUMBER (21) QTY. (41)

CARD 2 MATERIAL DESCRIPTION

CELL SIZE:	1	IN.
DENSITY:	11	LB./CU. FT.
THICKNESS:	21	IN.
AREA:	31	SQ. IN.
COST:	41	$/SQ. FT.

OPERATIONS

SAWING — LENGTH OF CUT:	51	IN.

CARD 3 MACHINING

FLAT — LENGTH OF CUT:	1	IN.
MAXIMUM WIDTH:	11	IN.
CONTOUR — LENGTH OF CUT:	21	IN.
MAXIMUM WIDTH:	31	IN.
STEP — LENGTH OF CUT:	41	IN.
WIDTH OF CUT:	51	IN.
SCARF — LENGTH OF CUT:	61	IN.
WIDTH OF CUT:	71	IN.

CARD 4

BLEND CUTOUTS — LENGTH OF CUT:	1	IN.
QUANTITY:	11	
HANDFORMING (CIRCLE ONE) — YES: (21) 1 NO: (21) 0		
BRAKEFORMING (CIRCLE ONE) — RADIUS OF CURVATURE:	31	IN.
DIE LENGTH ≤ 5 FT: (41) 1 > 5 (42) 2		
NO. DIE CHANGES:	43	
NO. DIE REPOSITIONS:	46	
LIQUID POTTING — VOLUME FILLED:	51	CU. IN.
TAPE FOAMING — VOLUME FILLED:	61	CU. IN.

ACCEM - 3 PART CONSOLIDATION

OBJECTIVE

ACCEM - 3 describes the methods and processes of joining and curing elements. Data supplied in this form will be used in calculating the standard hours for part consolidation. It is necessary to submit one form for each joining/curing cycle.

It is an unconditional requirement that either ACCEM - 1 or ACCEM -2 must be included in the Input Package if ACCEM -3 is to be used.

DESCRIPTION OF ELEMENTS		DATA REQ.
CYCLE NUMBER -	Identifies the sequence of consolidation	D
PART NUMBER -	Name of the part resulting from consolidation	D
PART NUMBER -	Number of the part resulting from consolidation	D
QUANTITY -	Amount of identical parts (INTEGER)	U
COMPONENT DETAIL PARTS-	Identification of elements to be consolidated (Elements must have been previously identified in ACCEM - 1 or ACCEM - 2)	
NO. OF DETAILS -	Quantity of line items (INTEGER)	U
PART NAME -	Name of element	D
PART NUMBER -	Number of element	U
QUANTITY -	Amount of elements (INTEGER)	U
CONSOLIDATION OF DETAILS -	Information identifying processes and methods used in joining elements (either bonding or splicing, and/or a curing process msut be selected for consolidation of details)	
ADHESIVE -	Chemical agent used to adhere elements	C
APPLICATION AREA -	Surface area in inches on which adhesive is applied	C
ADDITIONAL OPERATIONS		
BONDING -	Joining surfaces of detail elements	C
SPLICING -	Joining edges of detail elements	C

DESCRIPTION OF ELEMENTS		DATA REQ.
CURING PROCESS -	Application of pressure and heat (either vacuum bagging or thermal expansion mold, and one of the curing tools must be selected for the curing process)	
VACUUM BAGGING -	Application of vacuum pressure to advanced composite material.	
BAG MATERIAL -	Type of material used	C
RESIN BLEED -	Removal of excess resin from composite material	C
PLY-TO-BLEEDER RATIO -	Proportional relationship of composite plies to bleeder plies	S=3.0
BAGGING AREA -	Surface area covered by bag material, in square inches	C
SEALING/CLAMPING PERIMETER -	Distance around bag that is sealed or clamped, in inches	C
THERMAL EXPANSION MOLD -	Elastomeric tool in which composite material is contained	
MOLD CAGE DIMENSIONS (EXTERNAL)-	Outer surface dimensions of mold cage, in inches	C
CURING TOOL -	Method of applying heat and additional pressure for curing.	U
AUTOCLAVE -	Chamber which supplies additional pressure as well as heat to vacuum bagged material	
OVEN -	Chamber which supplies heat by convection to material enclosed in either a vacuum bag or thermal expansion mold	
HEATING ELEMENT -	Tool which transfers heat by conduction to material enclosed in thermal expansion mold	

LEGEND

DATA REQUIREMENT:
- U = Unconditional Requirement
- C = Conditional Requirement
- S = System Generated (Value Specified)
- D = Documentation

ACCEM-3 PART CONSOLIDATION

CYCLE NUMBER _____

CARD 1 — PART NAME (1) | PART NUMBER (21) | QUANTITY (41)

COMPONENT DETAIL PARTS
NUMBER OF LINES USED (51) ____ (MAXIMUM 10)

CARD 2 — PART NAME (1) | PART NUMBER (21) | QUANTITY (41)

CARD 3

CONSOLIDATION OF DETAILS

ADHESIVE (CIRCLE ONE) — NO: (1) 0 YES: (1) 1

APPLICATION AREA: (2) _____ SQ. IN.

ADDITIONAL OPERATIONS (CIRCLE IF APPLICABLE) — BONDING: (11) 1 SPLICING: (11) 2

CURING PROCESS

VACUUM BAGGING

TYPE OF BAG: (CIRCLE ONE) — DISPOSABLE: (12) 1 REUSABLE: (12) 2

RESIN BLEED: (CIRCLE ONE) — NO: (13) 0 YES: (13) 1

PLY-TO-BLEEDER RATIO: (14) _____ -TO-1

BAGGING AREA: (21) _____ SQ. IN.

SEALING/CLAMPING PERIMETER: (31) _____ IN.

THERMAL EXPANSION MOLDING

EXTERNAL MOLD CAGE DIMENSIONS:

LENGTH: (41) _____ IN.

WIDTH: (51) _____ IN.

DEPTH: (61) _____ IN.

CURING TOOL: (CIRCLE ONE) (71)

AUTOCLAVE: 1

OVEN: 2

HEATING ELEMENT: 3

ACCEM - 4 FINISHING OPERATIONS

OBJECTIVE

ACCEM - 4 provides the part description and process identification for the finishing operations performed on a cured composite part. Data supplied in this form will be used in calculating the standard hours for finishing. Codes are provided for identifying each operation. It is necessary to submit one form for each non-identical part.

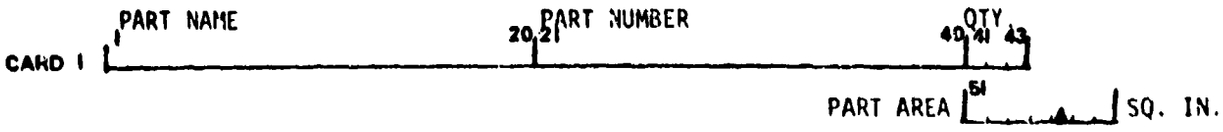
It is an unconditional requirement that either ACCEM - 1, or ACCEM - 2, and ACCEM - 3 be included in the Input Package if ACCEM - 4 is used.

DESCRIPTION OF ELEMENTS		DATA REQ.
PART NAME -	Name of part finished	D
PART NUMBER -	Number of part finished	D
QUANTITY -	Amount of identical parts (INTEGER)	D
PART AREA -	Surface area of part, in square inches	U
NET TRIM OPERATIONS -	Processes in which material is removed from the edges of the cured part.	
TYPE OF OPERATION -	Identification of net trim operation	C
AVERAGE THICKNESS -	Mean depth of area to be trimmed, in inches	C
TRIM LENGTH -	Total distance trimmed, in inches	C
FIXTURE -	Stationary tool on which operation is performed	C
TEMPLATE -	Guide tool for trimming	C
HOLE OPERATIONS -	Processes used to cut holes in cured parts	
OPERATION CODE -	Identification of hole cutting operation	C
QUANTITY -	Amount of identical holes cut in part (INTEGER)	C
HOLE DIAMETER -	Mean width of holes, in inches	
HOLE DEPTH -	Mean depth of holes, in inches	
FIXTURE -	Stationary tool on which operation is performed	C
TEMPLATE -	Guide tool for cutting holes	C
INSERTS -	Removable bushing used to guide hole operations	C

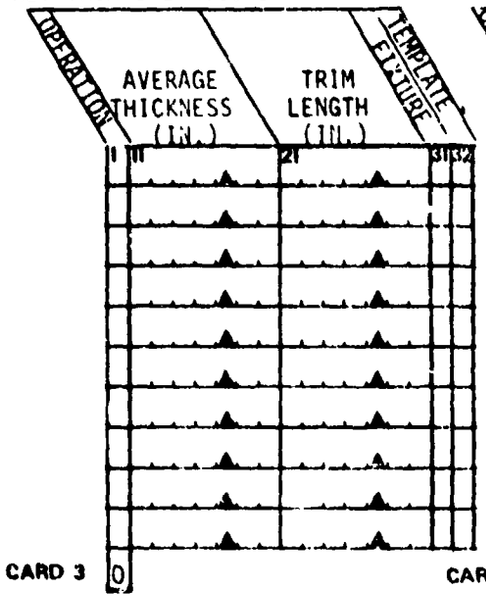
LEGEND

DATA REQUIREMENT: U = Unconditional Requirement
C = Conditional Requirement
S = System Generated (Value Specified)
D = Documentation

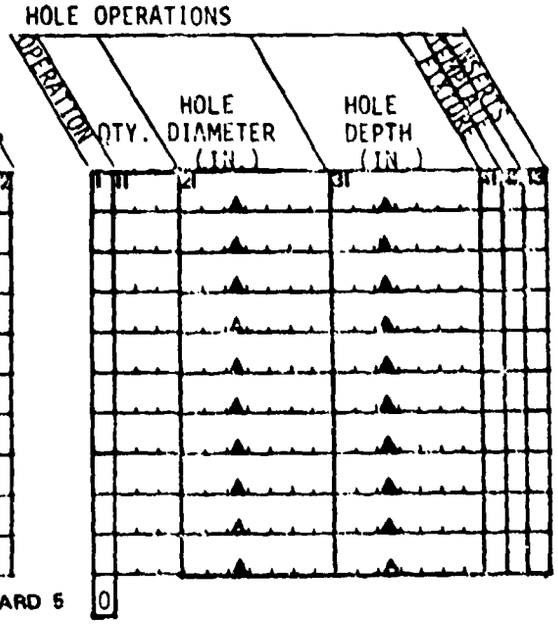
ACCEM-4 FINISHING OPERATIONS



CARD 2 (OMIT IF LEFT BLANK)
NET TRIM OPERATIONS



CARD 4 (OMIT IF LEFT BLANK)
HOLE OPERATIONS



LEGEND

OPERATION:	1 = HAND ROUTING
	2 = MACHINE ROUTING
	3 = HAND SAWING
	4 = MACHINE SAWING
	5 = HAND SANDING
	6 = PORTABLE TOOL SANDING
	7 = MACHINE SANDING
FIXTURE:	0 = NO,
	1 = YES
TEMPLATE:	0 = NO
	1 = YES

LEGEND

OPERATION:	1 = DRILLING
	2 = COUNTERBORING
	3 = REAMING
	4 = COUNTERSINKING
	5 = HOLE SAWING
	6 = HOLE PUNCHING
FIXTURE:	0 = NO
	1 = EXTERNAL
	2 = INTERNAL
TEMPLATE:	0 = NO
	1 = YES
INSERTS:	0 = NO
	1 = YES

ACCEM - 5 COST PROJECTIONS

OBJECTIVE

ACCEM - 5 provides the rates and factors to be used in Support Function Estimating and Cost Projection. Data supplied in this form will be applied to the results of Factory Labor Standards Estimating in order to arrive at total component costs in hours and dollars. Codes are provided to identify certain data input options which allow maximum flexibility.

It is an unconditional requirement that either ACCEM - 1 or ACCEM - 2 must be included in the Input Package if ACCEM - 5 is to be used. ACCEM - 3 and ACCEM -4 are not necessarily required if they are not applicable to the estimate.

DESCRIPTION OF ELEMENTS		DATA REQ.
UNIT NUMBER -	Number of production unit at which cost is estimated. (INTEGER)	U
AVERAGE LOT SIZE -	Mean number of units in each production lot.	U
TYPE OF ESTIMATE -	Unit Cost is estimated for the specified unit number. Cumulative Average Cost is the mean cost per unit. Cumulative Total Cost is the sum of the unit costs.	U
PROJECTION FACTORS -	Factors which are applied to the standards to compute component total factory labor hours.	
DATA INPUT OPTIONS -	Codes are provided to indicate whether factors in the program are to be applied, or whether data which have been entered (either in detail or in total) will override these values. The input requirement for this Section is dependent upon the option that is selected.	U
LEARNING CURVE -	Indicates type of learning curve slope	S = 0
T_1 VARIANCE -	Multiplicative factor applied to standards to arrive at total hours for first unit.	C
LEARNING CURVE SLOPE -	Progressive relationship of values expressed as a percentage.	C

DESCRIPTION OF ELEMENTS — DATA REQ.

IF DATA INPUT OPTION = 0, THEN THE FOLLOWING BASIC RELATIONSHIPS ARE APPLIED: LEARNING CURVE= 0

FOR N ≤ 5,

	T_1 VAR.	SLOPE	UNIT VAR. EQ'N
LAYUP	34.03	65.80%	$34.03N^{-.6037}$
CORE PREP	16.83	--	$1.397 + \frac{15.4359}{N}$
PART CONS	36.48	65.77%	$36.48N^{-.6044}$
FINISHING	35.19	65.82%	$35.19N^{-.6035}$

FOR N ≥ 6,

LAYUP	23.24	76.63%	$23.24N^{-.3840}$
CORE PREP	16.83	--	$1.397 + \frac{15.4359}{N}$
PART CONS	25.06	76.52%	$25.06N^{-.3860}$
FINISHING	23.84	76.77%	$23.84N^{-.3813}$

SUPPORT FUNCTION

ESTIMATES - Calculation of costs of support labor and material

DATA INPUT OPTIONS - Codes are provided to indicate whether relationships in the program are to be applied, or whether data which have been entered (either as a multiplicative relationship or as a direct input) will override these values. The input requirement for this Section is dependent upon the option selected. — U

BASE - Cost element which is the basis of the estimating relationship — C

BASE UNIT - Category of value of the cost element — C

FACTOR - Multiplier which is applied to base cost element value. — C

LABOR HRS/MAT'L $'s - Direct estimate of support function cost — C

IF DATA INPUT OPTION = 0, THEN THE FOLLOWING BASIC RELATIONSHIPS ARE APPLIED:

	BASE	BASE UNIT	FACTOR *	FACTOR **
QUAL. CONT.	1	1	$0.4243N^{-0.1737}$	$0.3542N^{-0.2285}$
TOOLING	1	1	$0.7030N^{-.0.2594}$	$0.6313N^{-0.4196}$
MFG. ENG.	1	1	$0.7227N^{-0.1826}$	$1.0062N^{-0.4256}$
ENG.	1	1	$0.3540N^{-0.2223}$	$0.3524N^{-0.3713}$
GR. SERV.	1	1	$0.0824N^{-0.2298}$	$0.0432N^{-0.1840}$
SUP. MAT'L	7	2	0.30	0.30

*Applicable if Learning Curve = 1
**Applicable if Learning Curve = 0

DESCRIPTION OF ELEMENTS		DATA REQ.
LABOR RATES -	Factors applied to labor hours to calculate labor cost in dollars.	
DATA INPUT OPTIONS -	Codes are provided to indicate whether rates in the program are to be applied, or whether data which have been entered will override these values. The input requirement is dependent upon the option that is selected.	U
RATES -	Cost of unit of labor in dollars per hour	C

IF DATA INPUT OPTION = 0, THEN THE FOLLOWING VALUES ARE APPLIED:

FACTORY LABOR	$10.00
QUALITY CONTROL	$10.00
TOOLING	$10.00
MFG. ENG.	$10.00
ENGINEERING	$10.00
GRAPHIC SERVICES	$10.00

OVERHEAD -	Costs incurred in doing business, regardless of particular goods produced, which are allocated to cost categories.	
DATA INPUT OPTIONS -	Codes are provided to indicate whether rates in the program are to be applied or whether data which have been entered (either in detail or in total) will override these values. The input requirement for this Section is dependent upon the option selected.	U
RATE -	Factors which are applied to cost category dollars to generate overhead costs.	C

IF DATA INPUT OPTION = 0, THEN THE FOLLOWING VALUES ARE APPLIED:

FACTORY FAB.	1.50
QUAL. CONT.	1.50
TOOLING	1.50
MFG. ENG.	1.50
ENG.	1.70
GR. SERV.	1.70
MATERIAL	0.20
ADMIN.	0.15

LEGEND

DATA REQUIREMENT:
- U = Unconditional Requirement
- C = Conditional Requirement
- S = System Generated (Value Specified)
- D = Documentation

ACCE'1-5 COST PROJECTION

CARD 1

UNIT NUMBER 1
AVE. LOT SIZE 11

TYPE OF ESTIMATE

UNIT COST	COL. 21 NO 0	YES 1	(CIRCLE ONE)
CUMULATIVE AVERAGE COST	COL. 22 NO 0	YES 1	(CIRCLE ONE)
CUMULATIVE TOTAL COST	COL 23 NO 0	YES 1	(CIRCLE ONE)

CARD 2

FACTORY LABOR PROJECTION FACTORS

LEARNING CURVE: LOG-LINEAR UNIT 24 0 CUM. AVE. 24 1 (CIRCLE ONE)

DATA INPUT OPTIONS (CIRCLE ONE) COL. 1

NONE 0
ITEM (a) - (d) 1
ITEM (e) 2

CARD 3 — T_1 VARIANCE

CARD 4 — LEARNING CURVE SLOPE

(a) LAYUP
(b) CORE PREPARATION
(c) PART CONSOLIDATION
(d) FINISHING OPERATIONS
(e) TOTAL FACTORY LABOR

DATA INPUT OPTIONS (CIRCLE ONE) 2

NONE 0
ITEMS (a) - (f) 1

CARD 5

LABOR RATES

(a) FACTORY LABOR $/HR
(b) QUALITY CONTROL $/HR
(c) TOOLING $/HR
(d) MFG. ENG. $/HR
(e) ENGINEERING $/HR
(f) GRAPHIC SERVICES $/HR

DATA INPUT OPTIONS (CIRCLE ONE) 3

NONE 0
CARDS (6) - (8) 1
CARD (9) 2

SUPPORT FUNCTIONS

	CARD 6 BASE	CARD 7 BASE UNIT
QUALITY CONTROL	2	2
TOOLING	3	3
MFG. ENG.	4	4
ENGINEERING	5	5
GRAPHIC SERVICES	6	6
SUPPORT MATERIAL		

CARD 8 — FACTOR

CARD 9 — LABOR HRS/MAT'L $'S

LEGEND

BASE: 1 = FACTORY FABRICATION, 2 = QUALITY CONTROL, 3 = TOOLING, 4 = MFG. ENG. 5 = ENGINEERING, 6 = GRAPHIC SERVICES, 7 = PRODUCTION MAT'L

BASE UNIT: 1 = HOURS, 2 = DOLLARS

DATA INPUT OPTIONS (CIRCLE ONE) 4

NONE 0
ITEMS (a) - (f), (2),(3) 1
ITEMS (1), (2), (3) 2

CARD 10

OVERHEAD RATES

(a) FACTORY FABRICATION
(b) QUALITY CONTROL
(c) TOOLING
(d) MFG. ENG.
(e) ENGINEERING
(f) GRAPHIC SERVICES
  (1) TOTAL LABOR
  (2) MATERIAL
  (3) ADMINISTRATIVE

CARD 11

3.0 KEYPUNCHING DATA CARDS

The ACCEM Input Forms have been designed so that the data can be keypunched directly from the forms. General instructions, as well as additional notes, by card, for each ACCEM Input Form have been provided. This information has been described in sufficient detail to serve as a guide for the user to keypunch data.

GENERAL INSTRUCTIONS

1) The card and column number where input data is to be keypunched has been identified on each input form. For each data field, inputs should be left justified.
2) All of the data inputs start in Columns 1, 11, 21, 31, 41, 51, 61, and 71. For convenience in keypunching, keypunch program cards (IBM 029) can be set to these columns.
3) Skip those items where data has not been entered..

ACCEM-0 INPUT CHECKLIST

Card 1 - one per page

Card 2 - one per page

ACCEM-1 LAYUP

Card 1 - one per page (except as noted below)

Card 2 - one per page (except as noted below)

Card 3 - one per page (except as noted below)

Card 4 }
Card 5 } Keypunch alternately, i.e., two cards per line. Continue sequence to the end of this data. The last entries should be:

Card 4 9999 (Col. 1-4)

Card 5 000 (Col. 1-3)

NOTE: More than one page of ACCEM-1 may be used to continue data on Card 4 and Card 5 for a non-identical layup. For these continuation pages skip Card 1, Card 2, and Card 3, and resume sequence for Card 4 and Card 5.

ACCEM-2 HONEYCOMB CORE PREPARATION

Card 1 - one per page

Card 2 - one per page

Card 3 - one per page

Card 4 - one per page

ACCEM-3 PART CONSOLIDATION

Card 1 - one per page

Card 2 - one per line of input (maximum 10 lines)

Card 3 - one per page

ACCEM-4 FINISHING OPERATIONS

Card 1 - one per page

Card 2 - one per line of input. Omit this card if lines are blank.

Card 3 - one per page

Card 4 - one per line of input. Omit this card if lines are blank.

Card 5 - one per page

ACCEM-5 COST PROJECTION

Card 1 - one per page

Card 2 - one per page

Card 3 - one per page

Card 4 - one per page

Card 5 - one per page

Card 6 - one per page

Card 7 - one per page

Card 8 - one per page

Card 9 - one per page

Card 10 - one per page

4.0 ESTIMATING EQUATIONS

The computerized estimating system is composed of equations which are used to calculate the elements of total recurring cost. These equations are provided in this section for the user's reference. In addition, manual cost estimates can be made by solving the appropriate equations.

The standards estimating relationships (Sections 4.1-4.4) form the core of the ACCEM computerized system. They are used to calculate the basic work element of factory labor.

To develop estimates of total recurring cost, the user has the option of either entering his own relationships and factors or using those supplied. The variance equations (Section 4.5), support function estimating relationships (Section 4.6), and labor and overhead rates (Section 4.7) which are generated by the computer are summarized herein.

4.1 LAYUP STANDARDS ESTIMATING RELATIONSHIPS

BASIC DEPOSITION

DETAIL ELEMENTS	SETUP	RUNTIME	
CLEAN LAYUP TOOL SURFACE		$0.000006A$	(L1)
APPLY RELEASE AGENT TO LAYUP TOOL SURFACE		$0.000009A$	(L2)
POSITION TEMPLATE (MYLAR) ON TABLE AND TAPE DOWN		$0.000107A^{0.77006}$	(L3)
PLY DEPOSITION			
MANUAL - 3" TAPE	0.05	$0.00140L^{0.6018}$	(L4)
- 12" TAPE	0.05	$0.001454L^{0.8245}$	(L5)
- WOVEN MATERIAL	0.05	$0.000751A^{0.6295}$	(L6)
HAND-ASSIST - 3" TAPE	0.10	$0.000368L^{0.8446}$	(L7)
- 12" TAPE	0.10	$0.001585L^{0.5580}$	(L8)
CONRAC AUTO. (720 IPM)	0.15	$0.00063L^{0.4942}$	(L9)
(360 IPM)	0.15	$0.00058L^{0.5716}$	(L10)
TRANSFER PLY FROM TEMPLATE TO STACK OR LAYUP TOOL		$0.000145A^{0.6711}$	(L11)
TRANSFER STACK TO LAYUP TOOL		$0.000145A^{0.6711}$	(L12)
CLEAN CURING TOOL SURFACE		$0.000006A$	(L13)
APPLY RELEASE AGENT TO CURING TOOL SURFACE		$0.000009A$	(L14)
TRANSFER LAYUP TO CURING TOOL		$0.000145A^{0.6711}$	(L15)

WHERE:

A = Area of ply, or greatest ply area of stack or layup, in square inches

L = Length of ply strip, in inches

LAYUP COMPLEXITY INCREMENTS

BEND TYPE	BEND FACTORS	NOTES	
STRAIGHT BENDS			
SHARP, MALE	$0.00007L_b$		(B1)
SHARP, FEMALE	$0.00016L_b$		(B2)
RADIAL, MALE	$0.00007L_b$	WHEN $R \leq 2"$	(B3a)
	NO FACTOR APPLIED	WHEN $R > 2"$	(B3b)
RADIAL, FEMALE	$0.00016L_b$	WHEN $R \leq 2"$	(B4a)
	$[0.00047R^{-1.3585}]L_b$	When $R > 2"$	(B4b)
CURVED BENDS			
TAPE			
STRETCH FLANGE	$[0.015R^{-.5532}{}_F{}^{.7456}]L_b$		(B5)
SHRINK FLANGE	$[0.0064R^{-.5379}{}_F{}^{.5178}]L_b$		(B6)
WOVEN	$[0.00444R^{-0.5958} + 0.0007]L_b$		(B7)

WHERE: L_b = Length of bendline
R = Radius of curvature
F = Flange Width

NOTE: The additional increment of runtime is added as follows:

Ply-On-Ply/Direct-On-Tool	(L4) - (L6) Ply Deposition
Ply-On-Ply/Pre-Plying	(L12) Transfer Stack to Layup Tool
Ply-On-Mylar/Direct-On-Tool	(L11) Transfer Ply to Layup Tool
Ply-On-Mylar/Pre-Plying	(L2) Transfer stack to Layup Tool

SUPPLEMENTARY LAYUP OPERATIONS

DETAIL ELEMENTS	SETUP	RUNTIME	
DEBULKING			
DISPOSABLE BAG	0.02	$0.00175A^{0.6911}$	(L16)
REUSABLE BAG	0.02	$0.000557A^{0.8159}$	(L17)
TRIMMING		0.00011P	(L18)

WHERE:

A = Area of layup, in square inches

P = Perimeter of layup, in inches

4.2 CORE PREPARATION STANDARDS ESTIMATING RELATIONSHIPS

DETAIL ELEMENT	SETUP	RUNTIME	
SAWING			
HANDLING		$H = 0.000453A^{0.3810}$	(H1)
SAWING	0.05	$H = (0.000663T^{0.4230})L$	(H2)
MACHINING			
POLYGLYCOL	0.02	$H = 0.00257A^{0.6175}$	(H3)
HANDLING		$H = 0.002657A^{0.5051}$	(H4)
FLAT	0.50	$H = 0.0002(W/1.5)(L + 6)$	(H5)
CONTOUR	0.60	$H = 0.00005(4W)(L + 6)$	(H6)
END MILL STEP	0.11	$H = 0.0006WL$	(H7)
END MILL SCARF	0.11	$H = 0.0006WL$	(H8)
END MILL BLEND	0.11	$H = 0.0009L$	(H9)
CUTOUT	0.01	$H = 0.0120(N)$	(H10)
FORMING			
HAND	0.05	$H = 0.000008A^{1.208}$	(H11)
POWER BRAKE		$H = 0.0008L^{0.5268}$	(H12)
SETUP			
IF DIE LENGTH $\leq$ 6 FT.	0.15		
IF DIE LENGTH > 6 FT.	0.19		
PER DIE CHANGE	0.12		
PER DIE REPOSITION	0.03		
INCREMENTS			
IF C = 0.1250 IN.		$H = 0.0091R$	(H12a)
IF C = 0.1875 IN.		$H = 0.0065R$	(H12b)
IF C = 0.2500 IN.		$H = 0.0052R$	(H12c)
IF C $\leq$ 0.3125 IN.		$H = 0.0039R$	(H12d)
LIQUID POTTING	0.05	$H = 0.0105V$	(H13)
TAPE FOAMING	0.05	$H = 0.0257V$	(H14)
CLEANING	0.05	$H = 0.00046V^{0.4257}$	(H15)

WHERE:

A = Core area in square inches
T = Core thickness, in inches
L = Length of cut, in inches
W = Maximum width of cut, in inches
N = Number of cutouts
R = Radius of curvature to be formed, in inches
C = Cell size, in inches
V = Volume to be potted or foamed, in inches

4.3 PART CONSOLIDATION STANDARDS ESTIMATING RELATIONSHIPS

SPLICING/BONDING

DETAIL ELEMENT	SETUP	RUNTIME	
APPLY ADHESIVE	0.05	$0.000055A_a$	(C1)
HANDLING		$0.0015A^{0.6311}$	(C2)

WHERE:

A_a = Adhesive application area, in square inches

A = Part area, in square inches

NOTE: These standards are applicable only if the adhesive which joins the detail elements is cured by applying heat with a hand gun.

VACUUM BAG/AUTOCLAVE CURE

DETAIL ELEMENT	SETUP	RUNTIME	APPLICATION DISP.	APPLICATION REUS.	
SETUP	0.07				
GATHER DETAILS, PREFIT, DISASSEMBLE AND CLEAN		$0.001326 \quad (A^{0.5252})$	X	X	(V1)
APPLY ADHESIVE		$0.000055[A_a]$	X	X	(V2)
ASSEMBLE DETAIL PARTS		$0.000145 \quad (A^{0.6711})$	X	X	(V3)
APPLY POROUS SEPARATOR FILM		$0.000009A_b$	X	X	(V4)
APPLY BLEEDER PLIES		$0.00002A_r$	X	X	(V5)
APPLY NON-POROUS SEPARATOR FILM		$0.000009A_b$	X	X	(V6)
APPLY VENT CLOTH		$0.00002A_b$	X	X	(V7)
INSTALL VACUUM FITTINGS		$0.0062N_f$	X		(V8)
INSTALL THERMOCOUPLES		$0.0162N_f$	X	X	(V9)
APPLY SEAL STRIPS		$0.00016P_b$	X		(V10
APPLY DISPOSABLE BAG		$0.000006A_b$	X		(V11
APPLY RUBBER BAG		$0.000015A_b$		X	(V12
SEAL EDGES		$0.00054P_b$	X		(V13
CLAMP EDGES		$0.00023P_b$		X	(V14
CONNECT VACUUM LINES & APPLY VACUUM		0.0061	X	X	(V15
SMOOTH DOWN		$0.000006A_b$	X	X	(V16
CHECK SEALS		$0.000017P_b$	X	X	(V17
DISCONNECT VACUUM LINES		0.0031	X	X	(V18
CHECK AUTOCLAVE INTERIOR		0.0300			(A1)
LOAD LAYUP IN TRAY		$0.000145A^{0.6711}$			(A2)
ROLL TRAY IN		0.0250			(A3)
CONNECT THERMOCOUPLE LEADS		$0.0092N_f$			(A4)
CONNECT VACUUM LINES AND APPLY VACCUM PRESSURE		$0.0061N_f$			(A5)
CHECK BAG, SEAL & FITTINGS		$[0.000006A_b + 0.00027P_b + 0.0088N_f]$			(A6)
CLOSE AUTOCLAVE		0.0192			(A7)
SET RECORDERS		0.0560			(A8)
START CURE CYCLE					

DETAIL ELEMENT	SETUP	RUNTIME	APPLICATION DISP.	APPLICATION REUS.	
CYCLE CHECK		0.0800			(A9)
SHUT DOWN		0.00332			(A10)
REMOVE CHARTS		0.00332			(A11)
OPEN AUTOCLAVE DOOR		0.0192			(A12)
DISCONNECT THERMOCOUPLE LEADS		$0.0035N_f$			(A13)
DISCONNECT VACUUM LINES		$0.0031N_f$			(A14)
ROLL TRAY OUT OF AUTOCLAVE		0.0120			(A15)
REMOVE LAYUP FROM TRAY		$0.000145A^{0.6711}$			(A16)
RELEASE CLAMPS		$0.00007P_b$		X	(V19)
REMOVE DISPOSABLE BAG		$0.000008A_b$	X		(V20
REMOVE REUSABLE BAG		$0.000003A_b$		X	(V21)
REMOVE THERMOCOUPLES		$0.0095N_f$	X	X	(V22)
REMOVE VACUUM FITTINGS		$0.0029N_f$	X		(V23)
REMOVE VENT CLOTH		$0.000007A_b$	X	X	(V24)
REMOVE NON-POROUS SEPARATOR FILM		$0.000007A_b$	X	X	(V25)
REMOVE BLEEDER PLIES		$0.000007A_b$	X	X	(V26)
REMOVE POROUS SEPARATOR FILM		$0.000007A_b$	X	X	(V27)
ASIDE USED MATERIAL		$0.000005A_b$	X	X	(V28)
REMOVE LAYUP & ASIDE		$0.000006A_b$	X	X	(V29)
CLEAN TOOL		$0.000006A_b$	X	X	(V30)

WHERE:

A = Area of detail part to be consolidated, in square inches
A_a = Area of surface where adhesive is applied, in square inches
A_b = Bagging area, in square inches
A_r = Area of resin bleeder plies
= Area of composite material used divided by ply to bleeder ratio, in square inches
N_f = Number of vacuum fittings = 1, if A_b - 432 square inches
= 2, if A_b - 432 square inches
P_b = Perimeter of bag to be sealed or clamped, in inches

NOTES:
1. (V1) - (V3) are applicable if two or more component detail parts are to be joined together in one cure cycle
2. (V4) - (V5) and (V26) - (V27) are applicable if resin bleeding.

VACUUM BAG/OVEN CURE

DETAIL ELEMENT	SETUP	RUNTIME	
SETUP	0.05		
SEE VACUUM BAG/AUTOCLAVE CURE FOR ELEMENTS (V1) - (V18)			
CHECK OVEN INTERIOR		0.0300	(01)
LOAD LAYUP INTO OVEN		$0.000114A_b^{0.8586}$	(02)
CONNECT VACUUM LINES AND APPLY VACUUM PRESSURE		$0.0061N_f$	(03)
CONNECT THERMOCOUPLE LEADS		$0.0092N_f$	(04)
CHECK FOR LEAKS		$[0.000006A_b + .00044P_b + 0.0088N_v]$	(05)
CLOSE OVEN		0.0192	(06)
SET RECORDER		0.0140	(07)
START CYCLE			
CYCLE CHECK		0.0800	(08)
SHUT DOWN AFTER CURE		0.00083	(09)
REMOVE CHARTS		0.00083	(010)
OPEN OVEN		0.0192	(011)
DISCONNECT THERMOCOUPLE LEADER		$0.0035N_f$	(012)
DISCONNECT VACUUM LINES		$0.0031N_f$	(013)
REMOVE PART FROM OVEN		$0.000114A_b^{0.8586}$	(014)
SEE VACUUM BAG/AUTOCLAVE CURE FOR ELEMENTS (V19) - (V30)			

WHERE:

A_b = Bagging area, in square inches

N_f = Number of vacuum fittings

P_b = Sealing/clamping perimeter, in inches

THERMAL EXPANSION MOLDING

DETAIL ELEMENT	SETUP	RUNTIME	
SETUP	0.02		
CLEAN MOLD CAGE		$0.0008A_m$	(X1)
APPLY RELEASE AGENT		$0.0013A_m$	(X2)
ASSEMBLE LAYUPS INTO CAGE		$[0.0237 \quad (A^{0.6083})] + 0.0016$	(X3)
APPLY HEAT:			
a. OVEN:	0.05	SEE VACUUM BAG/OVEN CURE ELEMENTS (01) - (014)	
b. HEATING ELEMENT:	0.43	$0.00264 \quad (A^{0.3207})$	(X4)
REMOVE PART FROM TOOL		$[0.000145 \quad (A^{0.6711})] + 0.000253$	(X5)
ASIDE PARTS		$0.000043 \quad A^{0.5985})$	

WHERE:

A_m = External surface area of mold cage, in square inches

A = Area of component detail part to be consolidated, in square inches

4.4 FINISHING STANDARDS ESTIMATING RELATIONSHIPS

DETAIL ELEMENT	SETUP	RUNTIME	
NET TRIM OPERATIONS			
HAND ROUTING	0.05	$(0.00666T^{0.9219})L$	(F1)
MACHINE ROUTING	0.20	$0.0015L$	(F2)
HAND SAWING	0.02	$(0.0046T^{0.6624})L$	(F3)
MACHINE SAWING	0.05	$(0.0022T^{0.6749})L$	(F4)
HAND SANDING	0.02	$0.0005L$	(F5)
PORTABLE TOOL SANDING	0.02	$(0.0012T)L$	(F6)
MACHINE SANDING	0.25	$(0.00046L)P$	(F7)
HOLE OPERATIONS			
DRILLING	0.05	$(0.01693D^{0.3370}\ Z^{0.4562} + 0.0006)Q$	(F8)
COUNTERBORING	0.05	$(0.00514D^{0.5966}\ Z^{0.2756} + 0.0006)Q$	(F9)
REAMING	0.05	$(0.01218D^{0.2747}\ Z^{0.8338} + 0.0006)Q$	(F10)
COUNTERSINKING	0.05	$(0.00450D^{0.7250} + 0.0006)Q$	(F11)
HOLE PUNCHING	0.05	$(0.0036)Q$	(F12)
HOLE SAWING	0.05	$(0.01293\ Z^{1.10151} + 0.0006)Q$	(F13)
HANDLING TIME			
PART HANDLING		$0.000145A^{0.6711}$	(F14)
FIXTURE - INTERNAL		$0.00414A^{0.3264}$	(F15)
- EXTERNAL		$0.00777A^{0.2894}$	(F16)
TEMPLATE		$0.000107A^{0.77006}$	(F17)
CLAMPS		$0.000322C$	(F18)
INSERTS		$0.0007Q$	(F19)

WHERE:

T = Average material thickness, in inches
L = Trim length, in inches
P = Number of passes
D = Hole diameter, in inches
Z = Hole depth, in inches
Q = Quantity of holes per part
A = Part area, in square inches
C = Part perimeter, in inches

4.5 FACTORY LABOR VARIANCE EQUATIONS

Factory labor hours at a specified production unit are calculated by applying the solution of the appropriate variance equation as follows:

$$(\text{Factory Labor Hours})_N = [(\text{Variance})_N \cdot (\text{Factory Labor Standards})],$$

where (Factory Labor Standards) = (Set Up/Lot Size) + Run

LAYUP

Unit Variance

$$V_{UL} = 34.03\, N^{-.6037}, \text{ for } N \leq 5$$

$$V_{UL} = 23.24\, N^{-.3840}, \text{ for } N \geq 6$$

Cumulative Variance

$$V_{CL} = [34.03 \sum_{1}^{N} (i^{-.6037})], \text{ for } N \leq 5$$

$$V_{CL} = [34.03 \sum_{i=1}^{5} (i^{-.6037})] + [23.24 \sum_{6}^{N} (i^{-.3840})], \text{ for } N \geq 6$$

Cumulative Average Variance

$$V_{CAL} = \frac{V_{CL}}{N}$$

HONEYCOMB CORE PREPARATION

Unit Variance

$$V_{UHC} = 1.3970 + \frac{15.4359}{N}$$

Cumulative Variance

$$V_{CHC} = 1.397N + 15.4359 \sum_{1}^{N} \frac{1}{i}$$

Cumulative Average Variance

$$V_{CAHC} = \frac{V_{CHC}}{N}$$

PART CONSOLIDATION

Unit Variance

$$V_{UPC} = [36.48N^{-.6044}], \text{ for } N \leq 5$$

$$V_{UPC} = [25.06N^{-.3860}], \text{ for } N \geq 6$$

Cumulative Variance

$$V_{CPC} = [36.48 \sum_{1}^{N} (i^{-.6044})], \text{ for } N \leq 5$$

$$V_{CPC} = [36.48 \sum_{i=1}^{5} (i^{-.6044})] + [25.06 \sum_{6}^{N} (i^{-.3860})], \text{ for } N \geq 6$$

Cumulative Average Variance

$$V_{CAPC} = \frac{V_{CPC}}{N}$$

FINISHING

Unit Variance

$$V_{UF} = [35.19N^{-.6035}], \text{ for } N \leq 5$$

$$V_{UF} = [23.84N^{-.3813}], \text{ for } N \geq 6$$

Cumulative Variance

$$V_{CF} = [35.19\sum_{I}^{N}(i^{-.6035})], \text{ for } N \leq 5$$

$$V_{CF} = [35.19\sum_{i=1}^{5}(i^{-.6035})] + [23.84\sum_{6}^{N}(i^{-.3813})], \text{ for } N \geq 6$$

Cumulative Average Variance

$$V_{CAF} = \frac{V_{CF}}{N}$$

4.6 SUPPORT FUNCTIONS ESTIMATING EQUATIONS

QUALITY CONTROL

Log- Linear Unit Improvement Curve

Unit Quality Control Labor Hours

$$QCLH_{N\text{-}Unit} = (0.3542N^{-0.2285}) \ (FLH_{N\text{-}Unit})$$

Cumulative Quality Control Control Labor Hours

$$QCLH_{N\text{-}Cum} = (0.3542\sum_{i=1}^{N} i^{-0.2285}) \ (FLH_{N\text{-}Cum})$$

Cumulative Average Quality Control Labor Hours

$$QCLH_{N\text{-}Cum\ Ave} = (QCLH_{N\text{-}Cum}) \ /N$$

Log-Linear Cumulative Average Improvement Curve

Cumulative Average Quality Control Labor Hours

$$QCLH_{N\text{-}Cum\ Ave} = (0.4243N^{-0.1737}) \ (FLH_{N\text{-}Cum\ Ave})$$

Cumulative Quality Control Labor Hours

$$QCLH_{N\text{-}Cum} = (0.4243N^{-0.1737}) \ (FLH_{N\text{-}Cum})$$

Unit Quality Control Hours

$$QCLH_{N\text{-}Unit} = (QCLH_{N\text{-}Cum}) - (QCLH_{(N-1)\text{-}Cum})$$

TOOLING

Log-Linear Unit Improvement Curve

Unit Tooling Labor Hours

$$TLH_{N\text{-}Unit} = (0.6313N^{-0.4196}) \ (FLH_{N\text{-}Unit})$$

Cumulative Tooling Labor Hours

$$TLH_{N\text{-}Cum} = (0.6313\sum_{i=1}^{N} i^{-0.4196}) \ (FLH_{N\text{-}Cum})$$

Cumulative Average Tooling Labor Hours

$$TLH_{N\text{-}Cum\ Ave} = (TLH_{N\text{-}Cum}) \ /N$$

Log-Linear Cumulative Average Improvement Curve

Cumulative Average Tooling Labor Hours

$$TLH_{N\text{-}Cum\ Ave} = (0.7030N^{-0.2594}) \ (FLH_{N\text{-}Cum\ Ave})$$

Cumulative Tooling Labor Hours

$$TLH_{N\text{-}Cum} = (0.7030N^{-0.2594}) \ (FLH_{N\text{-}Cum})$$

Unit Tooling Labor Hours

$$TLH_{N\text{-}Unit} = (TLH_{N\text{-}Cum}) - (TLH_{(N-1)\text{-}Cum})$$

MANUFACTURING ENGINEERING

Log-Linear Unit Improvement Curve

Unit Manufacturing Engineering Labor Hours

$$MELH_{N\text{-}Unit} = (1.0062N^{-0.4256}) \ (FLH_{N\text{-}Unit})$$

Cumulative Manufacturing Engineering Labor Hours

$$MELH_{N\text{-}Cum} = (1.0062\sum_{i-1}^{N} i^{-0.4256}) \ (FLH_{N\text{-}Cum})$$

Cumulative Average Manufacturing Engineering Labor Hours

$$MELH_{N\text{-}Cum\ Ave} = (MELH_{N\text{-}Cum}) \ /N$$

Log-Linear Cumulative Average Improvement Curve

Cumulative Average Manufacturing Engineering Labor Hours

$$MELH_{N\text{-}Cum\ Ave} = (0.7227N^{-0.1826}) \ (FLH_{N\text{-}Cum\ Ave})$$

Cumulative Manufacturing Engineering Labor Hours

$$MELH_{N\text{-}Cum} = (0.7227N^{-0.1826}) \ (FLH_{N\text{-}Cum})$$

Unit Manufacturing Engineering Labor Hours

$$MELH_{N\text{-}Unit} = (MELH_{N\text{-}Cum}) - (MELH_{(N-1)\text{-}Cum})$$

ENGINEERING

Log-Linear Unit Improvement Curve

Unit Engineering Labor Hours

$$ELH_{N\text{-Unit}} = (0.3524N^{-0.3713}) \ (FLH_{N\text{-Unit}})$$

Cumulative Engineering Labor Hours

$$ELH_{N\text{-Cum}} = (0.3524\sum_{i=1}^{N} i^{-0.3713}) \ (FLH_{N\text{-Cum}})$$

Cumulative Average Engineering Labor Hours

$$ELH_{N\text{-Cum Ave}} = (ELH_{N\text{-Cum}}) \ /N$$

Log-Linear Cumulative Average Improvement Curve

Cumulative Average Engineering Labor Hours

$$ELH_{N\text{-Cum Ave}} = (0.3540N^{-0.2223})(FLH_{N\text{-Cum Ave}})$$

Cumulative Engineering Labor Hours

$$ELH_{N\text{-Cum}} = (0.3540N^{-0.2223}) \ (FLH_{N\text{-Cum}})$$

Unit Engineering Labor Hours

$$ELH_{N\text{-Unit}} = (ELH_{N\text{-Cum}}) - (ELH_{(N-1)\text{-Cum}})$$

GRAPHIC SERVICES

Log-Linear Unit Improvement Curve

Unit Graphic Services Labor Hours

$$GSLH_{N\text{-}Unit} = (0.0432N^{-0.1840}) \ (FLH_{N\text{-}Unit})$$

Cumulative Graphic Services Labor Hours

$$GSLH_{N\text{-}Cum} = \left(0.0432 \sum_{i=1}^{N} i^{-0.1840}\right) \ (FLH_{N\text{-}Cum})$$

Cumulative Average Graphic Services Labor Hours

$$GSLH_{N\text{-}Cum\ Ave} = (GSLH_{N\text{-}Cum}) \ /N$$

Log-Linear Cumulative Average Improvement Curve

Cumulative Average Graphic Services Labor Hours

$$GSLH_{N\text{-}Cum\ Ave} = (0.0824N^{-0.2298}) \ (FLH_{N\text{-}Cum\ Ave})$$

Cumulative Graphic Services Labor Hours

$$GSLH_{N\text{-}Cum} = (0.0824N^{-0.2298}) \ (FLH_{N\text{-}Cum})$$

Unit Graphic Services Labor Hours

$$GSLH_{N\text{-}Unit} = (GSLH_{N\text{-}Cum}) - (GSLH_{(N-1)\text{-}Cum})$$

4.7 LABOR AND OVERHEAD RATES

LABOR RATES

FACTORY LABOR	$10.00/HOUR
QUALITY CONTROL	$10.00/HOUR
TOOLING	$10.00/HOUR
MFG. ENG.	$10.00/HOUR
ENGINEERING	$10.00/HOUR
GRAPHIC SERVICES	$10.00/HOUR

OVERHEAD RATES

FACTORY LABOR	1.50
QUALITY CONTROL	1.50
TOOLING	1.50
MFG. ENG.	1.50
ENGINEERING	1.70
GRAPHIC SERVICES	1.70
MATERIAL	0.20
ADMINISTRATIVE	0.15

SUPPORT MATERIAL

(Support Material $) = 0.30 (Production Material $)

Manufacturing Allowance

(Mfg. Allow. $) = [0.02 (Factory Labor $) + (Scrap Material $)]

5.0 OUTPUTS

The computerized cost estimating system generates a printing of the input data in coded form and of the calculated costs of advanced composite part fabrication. These outputs may be outlined as follows:

- GENERAL
  - IDENTIFICATION OF ESTIMATOR AND PART THAT IS ESTIMATED
  - QUANTITY OF EACH INPUT FORM
- LAYUP
  - CODED FORM OF INPUT DATA
  - STANDARD SETUP AND RUNTIME HOURS FOR DETAIL LABOR ELEMENTS
  - MATERIAL USAGE AND SCRAP
  - WEIGHT AND COST OF NET COMPOSITE MATERIAL
- HONEYCOMB CORE PREPARATION
  - CODED FORM OF INPUT DATA
  - STANDARD SETUP AND RUNTIME HOURS FOR DETAIL LABOR ELEMENTS
  - WEIGHT AND COST OF CORE MATERIAL
- PART CONSOLIDATION
  - CODED FORM OF INPUT DATA
  - STANDARD SETUP AND RUNTIME HOURS FOR DETAIL LABOR ELEMENTS
- FINISHING
  - CODED FORM OF INPUT DATA
  - STANDARD SETUP AND RUNTIME HOURS FOR DETAIL LABOR ELEMENTS
- SUMMARY OF TOTAL FACTORY LABOR STANDARD HOURS

- COST PROJECTIONS
  - CODED FORM OF INPUT DATA
  - UNIT COST ESTIMATE AT SPECIFIED UNIT NUMBER
  - CUMULATIVE COST ESTIMATE AT SPECIFIED UNIT NUMBER
  - CUMULATIVE AVERAGE COST ESTIMATE AT SPECIFIED UNIT NUMBER
  - WEIGHT ESTIMATE OF COMPOSITE AND CORE MATERIAL

Outputs of sample estimates which illustrate the contents of the above categories are contained in the Appendix.

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