DOE/JPL-1012-22
Distribution Category UC-63b

Low-Cost Solar
Array Project

5101-44
Revision A

SAMICS
Input Data Preparation

March 1, 1979

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California 91103

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SAMICS
Input Data Preparation

Robert G. Chamberlain

Robert W. Aster

March 1, 1979

Prepared for
U.S. Department of Energy
by
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California 91103

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PREFACE

The Solar Array Manufacturing Industry Costing Standards (SAMICS) were originally developed by the LSA Project Analysis and Integration Area. They are intended to provide a standard procedure and data base for estimating, from descriptions of the manufacturing processes, the price at which solar modules would have to be sold to realize a specified after-tax rate of return on equity.

COMPANION DOCUMENTS

This description of input data formats is intended for use in preparing data for use in

> "Solar Array Manufacturing Industry Costing Standards -- SAMICS Workbook," R. G. Chamberlain, JPL Document 5101-15, September 30, 1977,

which uses

> "Interim Price Estimation Guidelines," R. W. Aster and R. G. Chamberlain, JPL Document 5101-33, September 10, 1977,

or in the SAMIS III computer program, relying upon expense item descriptions contained in

> "SAMICS Support Study Final Report, Volume 1, Cost Account Catalog," Theodore Barry and Associates, ERDA/JPL-954800-77/2.1, September 1977

which is available from the LSA Data Center at JPL. A more recent version of the Cost Account Catalog with all expense items expressed in metric units of measure will be available soon. In any case, it is recommended that the user obtain a printout of the Cost Account Catalog computer data file, which will always contain the latest updates.

ABSTRACT

The Solar Array Manufacturing Industry Costing Standards (SAMICS) provide standard formats, data, assumptions, and procedures for estimating the price that a manufacturer would have to charge for the product of a specified manufacturing process sequence. This document gives a line-by-line explanation of those standard formats which describe the economically important characteristics of the manufacturing processes and the technological structure of the companies and the industry.

This revision provides an updated presentation of Format A - Process Description, consistent with the October 1978 version of that form (JPL 3037-S R 10/78). Also included is a checklist of items which should be entered on Format A as direct expenses.

CONTENTS

FIGURES

SECTION I

INTRODUCTION

This document provides a line-by-line explanation of the standard Process Description Format, Format A, which is a key element in the Solar Array Manufacturing Industry Costing Standards (SAMICS). The manufacturing technology, as described by a Format A for each process, is a major part of the input to the model of the manufacturing industry that is used in SAMICS to estimate the prices of the products of that technology. The section entitled "The Format A Appendix" contains an example of additional descriptive information that might accompany Format A, and includes an exemplary completed version of Format A.

Line-by-line explanations of the standard Company Description Format, Format B, and of the standard Industry Description Format, Format C, are also provided to permit delineation of the structure of the modeled industry. When SAMICS is used to compare the economic viability of alternative manufacturing processes, much of the structure is prespecified. (See, for example, the SAMICS Workbook, JPL Document 5101-15.)

SECTION II

PROCESS DESCRIPTION - FORMAT A

Fabrication of a company's product(s) generally requires the performance of a sequence of operations or processes. The purpose of Format A (page 2-3) is to describe the economically important characteristics of one of these processes.

Segregation of the process sequence into separate processes is, at least in some cases, somewhat arbitrary. In those cases, the guideline to follow is to distinguish between separate machines or separate pieces of apparatus. Usually Format A will describe a particular kind of equipment, such a a distillation tower or a diffusion furnace. Sometimes Format A will describe a collection of equipment, such as a quality control inspection station or part of a materials handling system. Other times Format A might describe a processing step performed by special facilities, such as storage between manufacuring operations or a chemical reaction in a high-pressure tank.

A1. Process Referent. This is a unique and conveniently short identifier (no more than 9 characters with no embedded blanks) which will be used to refer to this process.

A2. Descriptive Name. This provides an opportunity to identify or describe the process without the 9 character limitation imposed on the process referent (line A1).

PART 1 - PRODUCT DESCRIPTION

Every process produces a product, although it may be an intermediate product which the company uses in a subsequent process but does not sell. Almost every process requires one or more products as input. (Required products will be identified in Part 6). The process sequence can be deduced by consideration of the produced product - process - required product specifications. Part 1 of Format A describes the product produced by the process.

A3. Product Referent. This is a unique and conveniently short identifier (no more than 9 characters with no embedded blanks) which will be used to refer to the product produced by this process.

A4. Descriptive Name. This provides an opportunity to give more information about the product than can be provided within the 9 character limit for product referent (line A3).

A5. Unit of Measure. Product quantities are among the numbers that will be calculated when applying SAMICS. Consequently, the units in which those quantites are measured must be identified.

PART 2 - PROCESS CHARACTERISTICS

Format A can be thought of as a template or pattern of the "machine" that performs the process being described. Thus, Process Characteristics specify the operating parameters of a single machine.

A6. Output Rate. This is the average rate at which the product described in Part 1 is produced by this process, expressed in terms of product units (line A5) per minute of machine operation. Thus, a continuous process that produces 150 units of product every hour when operating, or a batch process that produces 50 units of product every 20 minutes, would have an output rate of 2.5 units per operating minute. Only usable product should be included; any resulting scrap or "reworkable" output product does not contribute to the output rate.

A7. Average Time at Station. This is the average time required at the process, including any waiting time in the input or output "hopper", and is not necessarily the reciprocal of the output rate given on line A6. For a batch process, this is the time interval between successive batches. For a continuous process, this is the time that the average unit spends at this processing step. This time quantity is used only in the calculation of in-process working capital requirements.

A8. Machine "Up" Time Fraction. This is the average ratio of machine operating time to factory open time, assuming round-the-clock (3 shifts per day) operation, expressed as a decimal fraction between 0.00 and 1.00. It includes consideration of down time due to machine failure, warm-up, or cool-down, and any time required for replacement of expendable parts (dies, screens, filters, etc.) or for employee preparation. This number may be thought of as the "duty cycle that would occur if the machine were operating at capacity".

PART 3 - EQUIPMENT COST FACTORS

Format A is a description of the characteristics of a machine or of a machine-like collection of apparatus. Parts of this machine (or machine-like collection) may have different expected useful lifetimes. Such differences can affect the calculation of depreciation, and must therefore be identified.

When different components of the "machine" have different lifetimes, equipment cost factors must be provided for each component, though pieces of equipment with the same lifetimes may be treated as a single component. Three columns are provided in Part 3, lines A9 through A14, for entering the data for (up to) three components. (If more columns are needed, use additional sheets.)

A9. Component (Referent). If there is only one component, which will usually be the case, this may be omitted (when entering the process description into the SAMIS program, a blank will not be accepted: a comma is recommended), and only one of the three columns will be used. Otherwise, this line is a unique and conveniently short identifier (no more than 9 characters with no embedded blanks) which can be used to refer to the particular component.

SOLAR ARRAY MANUFACTURING INDUSTRY COSTING STANDARDS

FORMAT A

JET PROPULSION LABORATORY
California Institute of Technology
4800 Oak Grove Dr / Pasadena, Calif 91103

PROCESS DESCRIPTION

Note: Names given in brackets [ ] are the names of process attributes requested by the SAMIS III computer program.

A1 Process [Referent] _____

A2 [Descriptive Name] _____

_____

PART 1 – PRODUCT DESCRIPTION

A3 [Product Referent] _____

A4 Descriptive Name [Product Name] _____

_____

A5 Unit Of Measure [Product Units] _____

PART 2 – PROCESS CHARACTERISTICS

A6 [Output Rate] (Not Thruput) _____ Units (given on line A5) Per Operating Minute

A7 Average Time at Station [Processing Time] _____ Calendar Minutes (Used only to compute in-process inventory)

A8 Machine "Up" Time Fraction [Usage Fraction] _____ Operating Minutes Per Minute

PART 3 – EQUIPMENT COST FACTORS [Machine Description]

A9	Component [Referent]	_____	_____	_____
A9a	Component [Descriptive Name] (Optional)	_____	_____	_____
		_____	_____	_____
		_____	_____	_____
A10	Base Year For Equipment Prices [Price Year]	_____	_____	_____
A11	Purchase Price ($ Per Component) [Purchase Cost]	_____	_____	_____
A12	Anticipated Useful Life (Years) [Useful Life]	_____	_____	_____
A13	[Salvage Value] ($ Per Component)	_____	_____	_____
A14	[Removal and Installation Cost] ($/Component)	_____	_____	_____

Note: The SAMIS III computer program also prompts for the [payment float interval], the [inflation rate table], the [equipment tax depreciation method], and the [equipment book depreciation method]. In the LSA SAMICS context, use 0.0, (1975, 6.0), DDB, and SL.

Format A: Process Description (Continued)

A15 Process Referent (From Page 1 Line A1) _____

PART 4 – DIRECT REQUIREMENTS PER MACHINE (Facilities) **OR PER MACHINE PER SHIFT** (Personnel)
[Facilities and Personnel Requirements]

A16 Catalog Number [Expense Item Referent]	A18 Amount Required Per Machine (Per Shift) [Amount per Machine]	A19 Units	A17 Requirement Description

PART 5 – DIRECT REQUIREMENTS PER MACHINE PER MINUTE
[Byproduct Outputs] and [Utilities and Commodities Requirements]

A20 Catalog Number [Expense Item Referent]	A22 Amount Required Per Machine Per Minute [Amount per Cycle]	A23 Units	A21 Requirement Description

PART 6 – INTRA-INDUSTRY PRODUCT(S) REQUIRED [Required Products]

A24 [Product Reference]	A28 [Yield]* (%)	A26 [Ideal Ratio]** Of Units Out/Units In	A27 Units Of A26***	A25 Product Name
			/	
			/	
			/	

Prepared by _____ **Date** _____

* 100% minus percentage of required product lost.
** Assume 100% yield here.
*** Examples: Modules/Cell or Cells/Wafer.

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A9a. Component Descriptive Name. This provides an opportunity to describe the component without the 9 character constraint of the component referent. Enough information should be given that an experienced engineer can judge for himself whether the cost data given below is reasonable.

A10. Base Year for Equipment Prices. Due to inflation, all cost and price statements must be related to a specific year. It will be assumed that the price on line A11, the value on line A13, and the cost on line A14 are valid as of the start of the year entered on line A10.

A11. Purchase Price ($ per Component). This is the price that must be paid to purchase this component outright, expressed in base price year (line A10) dollars. If the machine is to be leased or rented, rather than purchased, the entry on this line may be zero, but then Part 4, the direct requirements per machine, must include Item A2288D, "Leased or rented equipment". A zero may also be entered on line A11 in the unusual circumstance that the process is performed entirely with special facilities, rather than with equipment.

A12. Anticipated Useful Life (Years). This is the expected time interval, expressed in calendar years, between the installation of this component and the installation of its replacement, taking into consideration the usage data supplied in Part 2. This lifetime does not have to be an integer.

A13. Salvage Value ($ per Component) This is an estimate of the amount that could be obtained for this component as salvage, after it has been used for the number of years given on line A12, expressed in base price year (line A10) dollars.

A14. Cost of Removal and Installation ($ per Component). This is the cost of disconnecting and removing an old component plus the cost of installing and connecting its replacement, assuming that all of the utility services (gas, steam, electrical power, etc.) that are required are still in place. It will also be used to approximate the cost of installing the first component when minor modifications of the utility services may have to be performed. These costs, incidentally, will be capitalized, not expensed, in the financial model of the company.

FORMAT A REVERSE SIDE - DIRECT REQUIREMENTS

The face side of Format A describes the output of the process and its economically relevant characteristics. The reverse side describes what is put directly into the process to produce that output.

Only direct requirements: the personnel that tend the machine, the facilities and utilities services used by the machine, the byproducts produced by the machine, and the commodities which are fed into the machine, are to be included in the process description. All indirect requirements: the personnel who supervise the direct personnel and those who make the factory function (as distinguished from those who perform the processes), the facilities and utilities services that

support the people, the furniture and office supplies used to operate the factory, and so on, will be supplied in a standardized fashion by SAMICS. Inclusion of any indirect requirements on the reverse side of Format A will cause the expenses due to these indirect requirements to be counted twice.

A15. Process Referent (from page 1). This is simply a repeat of the referent supplied on line A1. Its importance becomes apparent if the reverse side of Format A is duplicated and therefore appears as a separate sheet.

PART 4 - DIRECT REQUIREMENTS PER MACHINE (Facilities) or PER MACHINE PER SHIFT (Personnel)

Some of the direct requirements of the process depend not on the operation of the machine, but on the existence of the machine in the production area. The best example of this is the floor space requirement, which clearly exists even if the machine is completely idle. Other facilities parameters and direct personnel requirements also depend on the number of machines assumed to be in continuous operation.

Use a separate line for each required item. Add additional sheets if necessary. (The non-sequential numbering of columns in Parts 4-6 of Format A is a result of rearrangement from its original structure; column numbers were kept unchanged when the columns were rearranged.)

A16. Catalog Number. This is the catalog number of the required item, obtained from referents in the SAMICS Cost Account Catalog (see "Companion Documents" in the front of this document). If a required item cannot be found in the Cost Account Catalog, try to find a suitable substitute in the catalog. If there is no suitable substitute, it will be necessary to create* an item for the "Temporary" account.

A17. Requirement Description. This is the name of the item identified by the catalog number in column A16.

A18. Amount Required per Machine or per Machine per Shift. This is the amount of the required item used by one machine. Be sure the amount is consistent with the units to be given in column A19 (which must be the units specified in the Cost Account Catalog). Do not arbitrarily round any amounts to integers.

---

*Referents for "Temporary" items consist of a letter (A, B, C, D, or E) to identify the account in which it belongs, followed by a letter (to "flag" the fact that this is a temporary item and to ensure that temporary item referents are unique with respect to the Cost Account Catalog), then by a number with no more than 7 digits. All temporary item referents must be unique.

A19. Units. This entry is the type of units in which the amount specified in column A18 is expressed. It must be the same as is given in the Cost Account Catalog, so that multiplication by the standard price per unit will give a valid result. "Per machine" is implicit. (The user should be aware of the fact that there will be two versions of the Cost Account Catalog, one with English units and one with metric, available for a few months. Referents in the English unit catalog end in "D", "I", or "B". Eventually, only the metric unit catalog will be supported.)

PART 5 - DIRECT REQUIREMENTS PER BATCH

Some of the direct requirements of the process do depend upon the extent to which the machine is operated, especially utilities, by-products, and commodities.

Use a separate line for each required item. Add additional sheets if necessary.

A20. Catalog Number. As with column A16, this is the catalog number of the required item, obtained from the SAMICS Cost Account Catalog.

A21. Requirement Description. As with column A17, this is the name of the item identified by the catalog number in colum A20.

A22. Amount Required Per Machine Per Minute. This is the average amount of the required item (including any wastage) required by one machine each operating minute. Be sure the amount is consistent with the units to be given in column A23 (which must be the units specified in the Cost Account Catalog). Do not arbitrarily round any amounts to integers.

A23. Units. This entry is the type of units in which the amount specified in column A22 is expressed, and must be the same as is given in the Cost Account Catalog. "Per minute" is implicit.

PART 6 - INTRA-INDUSTRY PRODUCT(S) REQUIRED

Products are distinguished from commodities by the fact that products are produced by processes within the modeled industry, while commodities are produced outside the modeled industry. While this distinction is rather artificial, it is an important one, since it facilitates the description of company and industry structure. Part 6 of Format A provides a reference to the input product(s) processed by the process being described. Since it is the products which are used to determine the technological sequence of processes within a firm, the referents assigned to the products of different processes must be different (i.e., mutually unique).

A24. Product Reference.* This is the identifier (a maximum of 9 characters with no embedded blanks) of a product which is processed by the process being described. The products identified in column A24 go into the process; the product described in Part 1 comes out.

A25. Product Name. This is the descriptive name (from line A4) of the product referred to in column A24.

A26. Ideal Ratio of Units Out/Units In. This is the ratio of the amount of the product (described in Part 1) that would be produced for each unit of the required product referred to in column A24 if there were no yield losses. For example, if the line A3 product were "solar modules," the column A24 required product were "solar cells," and 224 cells were used in each module, then the entry in column A26 would be 0.00446 (which is 1/224), and the units entered in column A27 would be "modules/cell."

A27. Units. This is the type of units in which the ideal ratio (column A26) is expressed. It is simply the ratio of the "units of measure" of the output product (from line A5) to those of the required product. (See example in A26 above.)

A28. Yield (%). This is the percentage of the (input) required product that remains as usable output product. For example, if the process produces 100 cells per minute, of which, on the average, 1 is defective (so that line A6 is 99 cells per minute), and it uses 101 wafers per minute (one wafer per minute is broken during processing) to produce those 99 usable cells, the yield would be 98.02 (which is 99/101 of 100%).

THE FORMAT A APPENDIX

The contents of Format A typically represent some combination of measured data and assumptions. The value and usefulness of this Format are greatly enhanced by describing those measurements and assumptions in a brief appendix to be attached to each Format A. A good example of this is shown in the following material, which was submitted by R. J. Casey of LMSC.

The completed Format A is shown on pages 2-9 and 2-10. Pages 2-11 through 2-13 contain a general description and a schematic diagram of the process under consideration. The subsequent pages consist of notes explaining each of the numbers used in the Format A. The work carried out on these pages was required to produce those numbers in the first place, and the extra effort of presenting these extremely valuable notes is well worthwhile.

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*The term reference is used where an identifier is cited; the term referent is used where an identifier is established. Thus, a product reference in column A24 of Format A can be used to find a process that must be performed earlier by seeking that process with a matching product referent on line A3.

SOLAR ARRAY MANUFACTURING INDUSTRY COSTING STANDARDS

FORMAT A

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PROCESS DESCRIPTION

Note: Names given in brackets [ ] are the names of process attributes requested by the SAMIS III computer program.

A1 Process [Referent] TEXETCH - A Revision A 6/29/78

A2 [Descriptive Name] Texturize Etch, Rinse and Dry

PART 1 – PRODUCT DESCRIPTION

A3 [Product Referent] TE Wafer

A4 Descriptive Name [Product Name] Texture Etched Wafers

A5 Unit Of Measure [Product Units] Wafers

PART 2 – PROCESS CHARACTERISTICS

A6 [Output Rate] (Not Thruput) 200 Units (given on line A5) Per Operating Minute

A7 Average Time at Station [Processing Time] 40 Calendar Minutes (Used only to compute in-process inventory)

A8 Machine "Up" Time Fraction [Usage Fraction] .976 Operating Minutes Per Minute

PART 3 – EQUIPMENT COST FACTORS [Machine Description]

A9	Component [Referent]	ETCHER		
A9a	Component [Descriptive Name] (Optional)			
A10	Base Year For Equipment Prices [Price Year]	1977		
A11	Purchase Price ($ Per Component) [Purchase Cost]	* $634,000		
A12	Anticipated Useful Life (Years) [Useful Life]	7		
A13	[Salvage Value] ($ Per Component)	$ 30,000		
A14	[Removal and Installation Cost] ($/Component)	** $ 83,000		

*A-11 includes on-site assembly and installation costs of $83,000 due to the configuration of this wet process equipment.

**A-14 Removal and installation taken at same level as original installation. Cost of removal assumed to be offset by reuse of some portion of installation, e.g., roof penetrations, safety sumps, electrical plumbing, etc.

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Note: See also Appendix to Format A - Texture Etch for additional information.

Format A: Process Description (Continued)

A15 Process Referent (From Page 1 Line A1) TEXETCH-A

PART 4 – DIRECT REQUIREMENTS PER MACHINE (Facilities) OR PER MACHINE PER SHIFT (Personnel)
[Facilities and Personnel Requirements]

A16 Catalog Number [Expense Item Referent]	A18 Amount Required Per Machine (Per Shift) [Amount per Machine]	A19 Units	A17 Requirement Description
A2064D	1000	Sq ft	Manufacturing Space (Type A)
B3672D	0.5	Persons/shift	Chemical Operator II 558885

PART 5 – DIRECT REQUIREMENTS PER MACHINE PER MINUTE
[Byproduct Outputs] and [Utilities and Commodities Requirements]

A20 Catalog Number [Expense Item Referent]	A22 Amount Required Per Machine Per Minute [Amount per Cycle]	A23 Units	A21 Requirement Description
	.069526	Gal/min	Alcohol
	.00925	Lbs/min	NaOH
C 1016B	.090454	Gal/min	Tap Water
	.779605 (A)	Lbs/min	H_2S_{04} Acid
C 1144D	.090454	Cu/ft	DI Water
	.01667	Gal/min	Freon
C 1032B	.376888	kWh/min	Electricity

PART 6 – INTRA-INDUSTRY PRODUCT(S) REQUIRED [Required Products]

A24 [Product Reference]	A28 [Yield]* (%)	A26 [Ideal Ratio]** Of Units Out/Units In	A27 Units Of A26*** TE / AS	A25 Product Name
AS Wafer	†99.2	1.0	Wafers/Wafer	As Sawn Wafer
			/	
			/	

Prepared by ††R. Casey LMSC Date 6/29/78

* 100% minus percentage of required product lost.
** Assume 100% yield here.
*** Examples: Modules/Cell or Cells/Wafer.

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(A) See also Appendix to Format A - Texture Etch for additional information.
†No inspection is planned at completion of this operation - Figure represents average yield for each of seven process stops with final inspection yield of 95%.
††Paraphrased to fit the revised form by R. Chamberlain 3/1/79.

APPENDIX TO FORMAT A - TEXTURE ETCH

Prepared by R. J. Casey, LMSC, 6/29/78

This material was provided as back-up to SAMICS input as part of JPL contract 954898 and includes the following:

- A description of the texture etch process (excerpted from Monthly Report No. 6)
- Explanation of the Format A inputs by part and item
- Equipment cost estimating sheets (by LMSC Plant Engineering)

HIGH VOLUME PRODUCTION

Texture Etch Process

The basic process specification for texture etching of silicon wafers was provided to LMSC (IR) by JPL. Some adjustments to procedural details were made to improve our results in processing of wafers during the early portion of this contract. This modified process has been extrapolated to a large scale automatic etching system as would be required for 1986 production quantities.

The hydrogen peroxide neutralizing rinse has been eliminated in our projected process, as we believe that the simpler acid rinse will suffice if followed by multiple DI water sprays. The system defined here is configured for pilot evaluation. In this regard, it provides for excess capability in terms of sodium hydroxide concentration, immersion time and/or processing temperature. Optimum process parameters for an automated system must necessarily be established during a period of trial operation of the actual system. It will be simpler at that time to reduce the value of one or more of the variables than to effect an increase. Impact of this approach on overall cost estimates is minimal. Provisions necessary to minimize downtime and maintain real time process control have been considered.

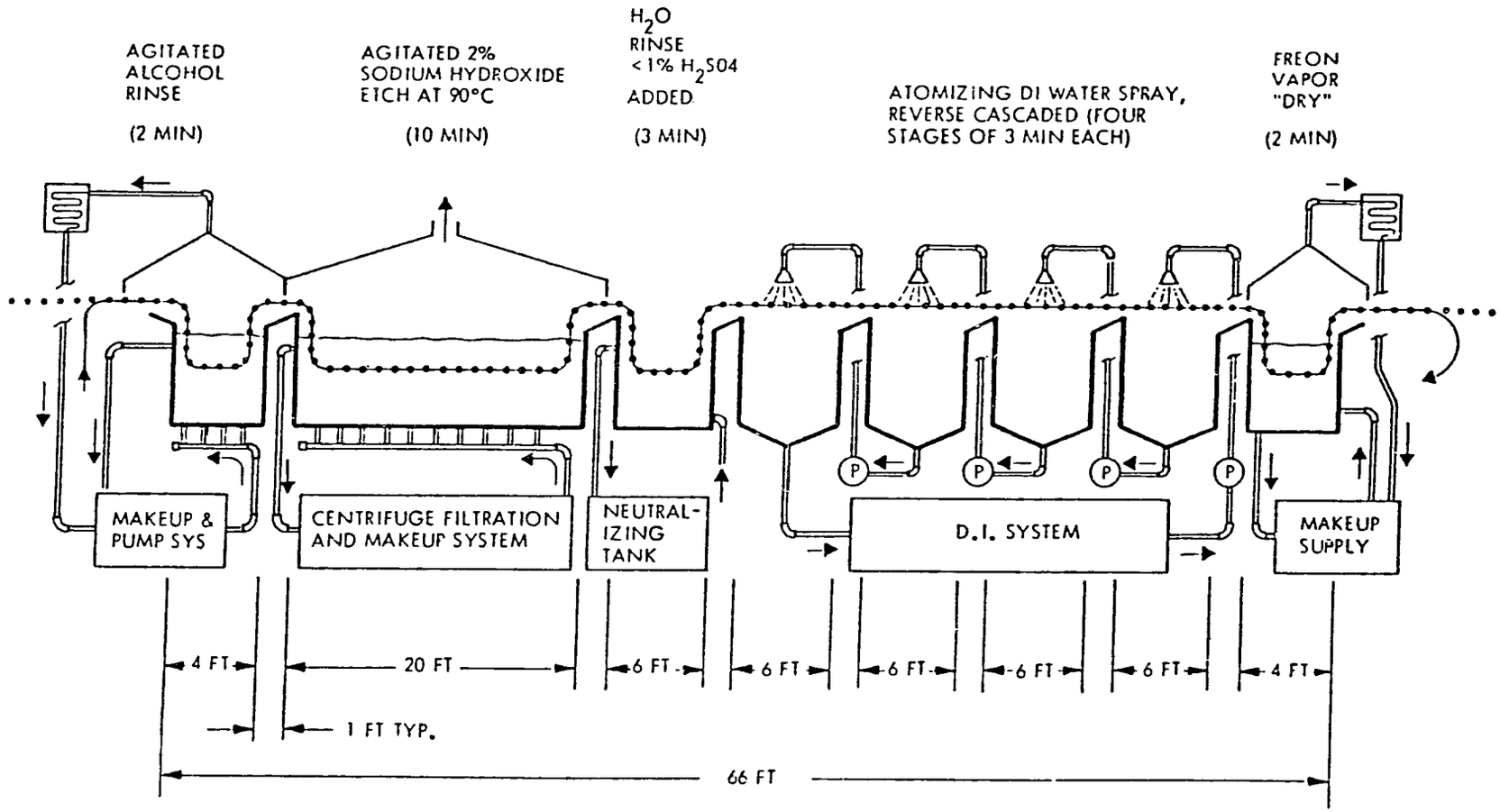
The large number of wafers to be run through a wet system argues convincingly for processing of the work pieces while they are held in cassettes. Accordingly, we have defined a special open frame cassette configuration for wet processing. The 3/16-inch wafer spacing is retained but the length is increased to approximately twelve inches to hold a quantity of 50 wafers. The cassettes are assumed to be loaded by Waferco and entered directly into the Cellco production sequence at this texture etch station. They are automatically clamped to holding devices attached on 6-inch centers to dual conveyor chains which carry the cassettes through the etching steps. Conveyor speed is assumed at 2 feet per minute. Masking of the wafers by the cassette retaining slots is avoided by a technique proven by the Siltec Corporation, Cassette Etch Station, Model 2001, where the cassette is slowly rotated on an eccentric longitudinal centerline. This causes the wafers to move back and forth in their retaining slots, exposing the entire surface to the

processing liquids. In this application, the rotation is achieved by spur gears on the end(s) of the cassette holders. The gears engage stationary gear racks as the conveyor chain moves. The conveyor path and the several process steps are shown schematically on the following page.

The first step in the etching process is an alcohol rinse, agitated by submerged jets to direct the flow between the wafers. Vapors are recondensed and returned to a reservoir which provides makeup alcohol. Cassettes are then carried directly into the etchant tank and through the hot, two percent sodium hydroxide solution. Agitation is similarly provided. Level, pH, temperature and specific gravity sensors control the makeup system. The solution is circulated in reverse flow direction and filtration is accomplished by De-Laval centrifuges which do not require consumable filters or labor intensive servicing. Vapors may be allowed to vent to the atmosphere carrying sodium carbonate salts, which are slightly basic. The next step is a tap water rinse with sufficient acid added to neutralize the drag-out from etching tank. Ten percent of the outflow is brought to neutral pH and discarded to control the salt concentration. Makeup acid and water are added to the remainder which is recirculated. The wafers are then carried through a series of four atomizing spray chambers where they are washed with reverse cascaded DI water. Waste water from the rinse may be used to heat the first spray station through a heat exchanger. This wash water is also reprocessed through filtration and deionizing steps. Finally, the wafers are dried by passing through Freon vapor where surface water on the wafers is displaced. As the wafers emerge, the Freon evaporates. Vapors rising into the hood are recondensed and returned to the system. Displaced water is removed from the Freon to maintain system balance. The cassettes are then fixed in an upright position and disengaged from their holders for transfer to the next operation.

The system will require computer control to maintain the several variables within pre-established limits. Quality of the etch will be sensed by test of the reflectivity of wafers leaving the station with automatic corrective action programmed. It has been suggested by IR that laser induced fluorescent spectroscopy may also be employed to check for contamination levels with automatic correction or shutdown procedures incorporated in the control system.

This texture etch station will process 4 cassettes or 200 wafers per minute. Four parallel stations will be required. Recycling subsystems will be cross-manifolded between stations to minimize downtime. All tanks will be castored and configured for quick-disconnect to allow rapid replacement and offline cleaning and/or refurbishment.



Schematic - Texture Etch Process

EXPLANATION OF FORMAT A INPUTS

PART 2 - TEXTURE ETCH

A-6 Output Rate = 200 wafers per minute

Determined by assumed conveyor speed of texture etch equipment at 2 ft/min and spacing of 50 wafer cassettes at 6" apart.

A-7 Average Time at Station = 38 minutes

Determined by assumed conveyor speed of texture etch equipment at 2 ft/min x length of conveyor chain in the processing area.
79 ft 2 ft/min = 39-1/2 40 minutes

A-8 Process Usage Time Fraction = .976

Determined on basis of assumed downtime under the following conditions:

- All tanks fitted with castors and quick disconnect plumbing to allow rapid replacement and off-line cleaning

- Centrifuge filters and other stationary subsystems cross-manifolded to permit rapid changeover, making individual units available for cleaning or service during idle time

- Continuous computer control with feedback loops to eliminate batch operations and allow continuous operation. Downtime assumed to be 4 hrs/wk for mechanical maintenance. 24 hrs/day x 7 days = 168 hrs
  168 hrs - 4 hrs downtime = 164 hrs
  164 operating hours 168 hrs = .976

PART 3 - TEXTURE ETCH

A-9 Component Referent = ETCHER

A-10 Base Price Year for Purchase Price = 1977

A-11 Purchase Price per Component = $634,000

Direct estimate from schematic diagram and written description in LMSC Monthly Report No. 6, supplemented by verbal descriptions and process notes. Estimate made by LMSC Plant Engineering organization (attached).

A-12 Anticipated Useful Life (Years) = 7

From 5101-33 Interim Price Estimation Guidelines p. 2-1

A-13 Salvage Value $/Component = $30,000

Arbitrary assumption

A-14 Cost of Removal and Installation = $83,000

Taken at same level as original installation, which is included in A-11 purchase price. Cost of removal is assumed to be offset by reuse of some portion of original installation, e.g., roof penetrations, safety sumps, electrical plumbing, etc.

PART 4 - TEXTURE ETCH: DIRECT REQUIREMENTS PER MACHINE

A-16 Catalog Number	A-17 Requirement Description	A-18 Amt. Req'd. per Machine	A-19 Units
A-2064-D	Manufacturing Space	1000 66' length of tank line plus 34' of service area = 100' length total 2' width of tanks + 2' for plumbing, etc. = 4' plus clearance for tank removal at 6' = 10 ft total 100' x 10' = 1000 sq ft	Sq Ft
B-3672-D	Chemical Operator II	0.5 Assumes 2 operators tending 4 etchant systems = .5	Person/shift

PART 5 - TEXTURE ETCH: DIRECT REQUIREMENTS PER BATCH

A-20 Catalog Number	A-21 Requirement Description	A-22 Amt. Req'd. per Batch	A-23 Units
C1032B	Electricity		KW hr/min
	a. Make up heating of NaOH sol'n to compensate for cooling effect of wafers	@ 90°C process temp - temp rise of wafer is 73°C Specific heat of Si is .15 cal/g - Wafer weight is 4.8g .15 x 4.8 = .72 cal/deg C x 73°C = 52.56 cal/wafer 4.1868 J/cal x 52.56 = 220.0582 J req'd. to reach 90°C or .00006112 KW hr/ wafer x 200 wafers/min = .012224	.012224
	b. Conveyor chain drive @ 10 HP	7.457 KW hr/60 min = .124283	.124283
	c. Pumps & Centrifuges total 8 HP for pumps, 10 HP for centrifuges = 18 HP	13.423 KW hr/60 min = .223716	.223716
	d. Heating & Refrig. units in Freon tank	10 KW/60 min =	.016667
		Total Electricity	.37689 KW hr/min
	Alcohol		
	a. Wafer drag out	Drag out @ .83g/wafer (based on lab tests w/water & alcohol @ 3,141.17 g/gal) = 0002643 gal/wafer x 200 wafers/min	Gals/min .05286
	b. Filtration & Misc. Losses	Estimated @ 1 gal/hr	.016667
		Total Alcohol	.069526 Gal/Min

PART 5 (Continued) - TEXTURE ETCH

A-20 Catalog Number	A-21 Requirement Description	A-22 Amt. Req'd. per Batch	A-23 Units
F1080B	Water	Note: All water used is assumed to be tap water since a DI water recycle system is included as part of the texture etch installation	Cu Ft/min
	a. Drag out from NaOH tank	@ 1 cc/wafer (based on lab tests) = .00000215 Cu Ft/wafer x 200 wafers/min = .00043	.00043
	b. Drag out from acid	Same as (a)	.00043
	c. Drag out from DI water rinse	Same as (a)	.00043
	d. 10% of acid rinse tank sol'n neutralized & discarded @ 5 gal per minute flow	= .5 gal/min @ .1337 Cu Ft/gal = .1337/.5 = .06685	.06685
	e. Misc. losses to vapor, processing, etc.	@ 10 gal/hr = .16667 gal/min	.022284
		Total Water	.090454 Cu Ft/Min
	NaOH		Lb/Min
	a. Drag out loss	@ 2% by weight = .02 g/wafer x 200 = 4 g/min ÷ 454 g/lb = .0088105 lb/min	.0088105
	b. Losses to vapor & misc.	.05% by weight = .001 g/wafer x 200 wafers/min = .2 g/min ÷ 454 g/lb = .0004405 lb/min	.0004405
		Total	.00925 Lbs/Min

PART 5 (Continued) - TEXTURE ETCH

A-20 Catalog Number	A-21 Requirement Description	A-22 Amt. Req'd. per Batch	A-23 Units
	H_2SO_4		Lb/Min
	a. Drag out loss	@ 1% by weight = .019/ wafer x 200 wafer/min = 2 g/min ÷ 454 g/lb = .004405 lb/min	.004405
	b. Losses to 10% sol'n discard	@ 5 gal sol'n/min = .5 gal discard @ 10% strength = .05 gal acid/min (@ spec gravity of 1.86 = 15.504 lbs/gal) .05 x 15.504 = .7752 lbs/min	.7752
		Total	.779605 Lb/Min
	Freon		Gal/Min
	Misc. Losses	@ 1 gal/hr = .016667 gal/min	.016667

THE FORMAT A CHECKLIST (FOR PARTS 3, 4, AND 5)

The checklist that follows contains specific items that might appear as equipment cost factors (Part 3) or as direct requirements (Parts 4 and 5) in Format A. It is provided to assist the user in identifying appropriate items and catalogue numbers.

PART 3

_____ Each major equipment item.

_____ Hoods used for ventilation.

_____ Furnaces.

_____ Special material handling equipment (belts, cassette unloaders, etc.).

_____ Process control equipment (microprocessors, optical sensors, etc.).

_____ Workbenches.

_____ Special test or maintenance equipment.

_____ In-process storage devices (input hoppers or buffers, output trays or buffers).

PART 4

_____ Total direct floorspace per machine. Either:

	A2064D	(about 40 $(1977)/sq ft)
	A2080D	(about 120 $(1977)/sq ft)
and/or	A2096D	(about 19 $(1977)/sq ft).

_____ Storage space required per machine (A1336I).

_____ Direct operating labor per machine per shift, from:

B3016D	Chassis assembler
B3032D	Electronics assembler
B3064D	General assembler
B3080D	Module assembler
B3096D	Semiconductor assembler
B3752D	Production machine operator
B3104D	Welder
B3576D	Forklift truck operator
B3592D	Inventory clerk
B3608D	Material clerk (supplies clerk)
B3624D	Material handler
B3640D	Packager, hand
B3656D	Packager, machine
B3768D	Tester, electronic components

B3672D Chemical operator II
B3048D Encapsulator (electronics)
B3112D Wire worker (electronics sub-assembler)

Do not include foremen, supervisors or engineers.

_____ Maintenance labor per machine per shift. Either:

B3688D Electronics maintenance
B3736D Maintenance mechanic

_____ Inspection labor required per machine per shift.

B3720D Inspector/quality control
B3768D Tester, electronic components
B3272D Quality control engineer

PART 5

_____ Each direct material, including wastage, per minute of operation (please describe assumed wastage in the appendix to the Format A.).

_____ All supplies consumed (not recycled) per minute of operation.

_____ All electricity, including electricity used for:

Operating equipment
Hood ventilation
Material Transport

_____ Other utilities consumed per minute of operation, including:

C1048B Fuel oil (gallons)
C2096B Air conditioning (kWh)
(This should be proportional to the energy directly consumed at the work station)
C1032B Electricity (kWh)
C1144D Deionized water (ft^3)
C1064B Natural gas (ft^3)
C1128D Cooling water (ft^3)
C1016B Domestic water (ft^3)
C1080D Liquid nitrogen (ft^3)
C1096D Liquid oxygen (ft^3)
C2032D Compressed air (ft^3)

Do not include ventilation.

_____ Byproducts produced per minute of operation, including:

D1032D Poisonous acid (gallons)
D1048B Polluted water (gallons)
D1096B Solid waste (pounds)
or C2144B Solid waste (ft^3)

D1128D	Used solvent (gallons)
D1176D	Rejected cells (m^2)
D1064D	Rejected wafers (m^2)
D1016D	Fumes (ft^3)
DG1D	Used lubricant (gallons)
DG2D	Used abrasive slurry (gallons)
DG3D	Reusable polysilicon (kg)
D1208D	Rejected module (per module).

_____ The cost of spare parts (dollars worth).

SECTION III

COMPANY DESCRIPTION - FORMAT B

Company descriptions (Format B, page 3-3) are used in SAMICS to specify the technological structure of the modeled industry. The process sequence is described explicitly; the relationships among the companies in the industry are indicated by the purchased products.

When these formats are used with the SAMICS workbook, the industry structure is prespecified. The only information which needs to be added is the process sequence, which is specified by line B4, line B5, another line of type B4, another line of type B5, and so on.

B1. Company Referent. This is a unique and conveniently short identifier (no more than 9 characters with no embedded blanks) which will be used to refer to this company.

B2. Description (Optional). This provides an opportunity to describe the company without the 9 character limitation imposed on the company referent (line B1). This line may be left blank if line B1 is sufficiently descriptive.

PROCESS SEQUENCE

The technological structure of the company is defined by its process sequence. Each product, whether it is a product produced, an intermediate product, or a purchased product, is the output of some process. Each process produces only one output product, and usually only requires one input product. Format B is designed to accommodate this simple technological structure: product produced (by the company), the process that makes the product produced (by the company), the intermediate product that is required by the process and made by the next (chronologically earlier) process, that next process, and so on, until the required product is purchased from outside the company. The number of lines of types B4 and B5 available on Format B may be more or fewer than are needed; leave blanks or use additional sheets, as necessary.

The SAMICS methodology is not restricted to such a simple structure, however. The user will have to lay out a tree-like structure if any processes require two or more intermediate products.

B3. Product Produced. This is a reference to the product produced by the company. Only a reference - and not a full description - is required here, because products are defined on the Format A of the processes that make them.

B4. Process. This is a reference to the process that makes the product referred to in B3 above.

B5. Intermediate Product. The process referred to in line B4 will almost always be performed on another product. This required product is referenced here. (The process that makes it is referenced on the next line, and so on through the company's process sequence.) If more than one product is required by the process, some ingenuity is needed to display the relationship. If only commodities (that is, materials and supplies whose manufacture is not modeled) are required, then this line will be left blank.

PURCHASED PRODUCTS

B6. Purchased Product. The product required to begin company processing (the last listed in B5) is referenced on this line.

B7. Supplier. This company's purchased product, identified on line B6, may be manufactured by more than one company. The supplying companies are referenced on this line, along with the percentages of the total amount purchased that each supplies. Note: If the industry is described so as to be "vertically" but not "horizontally" complete, care must be taken in furnishing the percentages supplied to make sure the resulting production quantities of the next firm in sequence will be estimated correctly. If, on the other hand, a complete industry is defined, the percentages supplied should add to 100%.

SOLAR ARRAY MANUFACTURING INDUSTRY COSTING STANDARDS

FORMAT B

JET PROPULSION LABORATORY
California Institute of Technology
4800 Oak Grove Dr. / Pasadena, Calif. 91103

COMPANY DESCRIPTION

B1 Company Referent _____

B2 Description (Optional) _____

_____

B3 Product Produced _____

B4 Process _____

B5 Intermediate Product _____ Process _____

Intermediate Product _____ Process _____

Intermediate Product _____ Process _____

Intermediate Product _____ Process _____

Intermediate Product _____ Process _____

Intermediate Product _____ Process _____

Intermediate Product _____ Process _____

Intermediate Product _____ Process _____

Intermediate Product _____ Process _____

Intermediate Product _____ Process _____

Intermediate Product _____ Process _____

Intermediate Product _____ Process _____

B6 Purchased Product _____

B7 Supplier Company Reference _____ Percent Supplied _____

Supplier Company Reference _____ Percent Supplied _____

Prepared by _____ **Date** _____

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SECTION IV

INDUSTRY DESCRIPTION - FORMAT C

Industry descriptions (Format C, page 4-3) are used in SAMICS to specify the relationship between what the industry is really providing (the industry objective) and the hardware product that is manufactured. They also identify the company or companies that make that hardware product. The rest of the industry structure can then be determined by tracing through the suppliers listed on a Format B, then tracing the suppliers of those suppliers, and so on.

When these formats are used with the SAMICS workbook, the industry structure and size are prespecified. The only information which needs to be added is the hardware performance on line C7 and the product design description on line C8.

C1. Industry Referent. This is a unique and conveniently short identifier (no more than 9 characters with no embedded blanks) which will be used to refer to this industry description.

C2. Description (Optional). This provides an opportunity to describe the industry without the 9 character limitation imposed on the industry referent (line C1). This line may be left blank if line C1 is sufficiently descriptive.

INDUSTRY OBJECTIVE

The solar array manufacturing industry is engaged in providing new photovoltaic solar power production capability by manufacturing flat-plate silicon solar modules for installation in arrays.

C3. Industry Result. This is a description of what the industry is "really" providing - if that is a meaningful concept. If the distinction between "what the industry is really providing" and the industry's "final product" is not meaningful, this line can be simply a restatement of the name of the final product (which will be entered on line C5); then line C7 should be unity.

C4. Quantity Produced. This line has two parts. The first should give the annual quantity of the industry result (line C3) produced; the second should state the units in which that quantity is measured.

DESCRIPTION OF THE FINAL PRODUCT OF THE INDUSTRY

The industry's "result" has just been described. Now its "final product" and the relationship between the two are needed.

C5. Reference and Name. This is a restatement of the final product (from a Format B, line B3) and its descriptive name (from a Format A, line A4). It is referenced and named here for convenience in interpreting the rest of this section of data.

C6. Production is Measured in. ... This gives the type of units (e.g., "modules per year") in which production of the final industry product is expressed. These units must be consistent with the units given for this product on line A5 of the appropriate Format A(s).

C7. Hardware Performance. This gives the quantitative relationship between the "industry result" and the industry's "final product". The units of this ratio are those on line C4 divided by those on line C6.

C8. Product Design Description (Optional). This space enables clarification of differences between this industry description and others possibly being considered.

MAKERS OF THE FINAL PRODUCT OF THE INDUSTRY

The structure of the industry can be provided in one of two ways: as horizontally complete, or not. In a horizontally complete description, all of the suppliers of each product are listed on Format B; both market shares on Format C and suppliers' percentages on Format B will add to 100%. In a horizontally incomplete description, one or more representative suppliers of each product are described. In the latter case, care must be taken in defining market shares and percentages supplied to obtain companies of the correct capacity.

C9. Company References and Market Share. This gives a reference to a company defined on a Format B and the share of the industry's market for the final product which that company supplies. (The market share is expressed as a percentage.)

SOLAR ARRAY MANUFACTURING INDUSTRY COSTING STANDARDS

FORMAT C

JET PROPULSION LABORATORY
California Institute of Technology
4800 Oak Grove Dr. / Pasadena, Calif. 91103

INDUSTRY DESCRIPTION

C1 Industry Referent _____

C2 Description (Optional) _____

_____

INDUSTRY OBJECTIVE

C3 Industry Result _____

C4 Quantity Produced _____ _____

DESCRIPTION OF THE FINAL PRODUCT OF THE INDUSTRY

C5 Reference _____ Name _____

C6 Production is Measured in _____

C7 Hardware Performance _____ (C4 per C6)

C8 Product Design Description (Optional) _____

_____

_____

_____

MAKERS OF THE FINAL PRODUCT OF THE INDUSTRY

C9 Company Reference _____ Market Share _____

Company Reference _____ Market Share _____

Company Reference _____ Market Share _____

Prepared by _____ **Date** _____

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