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DEVELOPMENT OF ADVANCED METHODS FOR CONTINUOUS
CZOCHELSKI GROWTH

Silicon Sheet Growth Development for the Large Area Silicon Sheet
Task of the Low Cost Silicon Solar Array Project

Third Quarterly Progress Report, March 18—July 14, 1978

By
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C. B. Sibley
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July 14, 1978

Work Performed Under Contract No. NAS-7-100-954884

Varian Associates
Lexington Vacuum Division
Lexington, Massachusetts

U.S. Department of Energy

MASTER

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DEVELOPMENT OF ADVANCED METHODS
FOR CONTINUOUS CZOCHRALSKI GROWTH

Silicon Sheet Growth Development for the
Large Area Silicon Sheet Task of the Low
Cost Silicon Solar Array Project

THIRD QUARTERLY PROGRESS REPORT

by

R. G. WOLFSON
C. B. SIBLEY
C. P. CHARTIER

July 14, 1978

Reporting Period March 18, 1978 to July 14, 1978

JPL Contract No. 954884

Varian Associates
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1.0 SUMMARY

Six batch melt-replenishment runs were performed. In the most recent, five crystals were grown with a total throughput of 48 kg. In addition to its stated purpose of developing the growth and recharge process for continuous silicon production, this experimentation has served to prove completely both the concept of charging with granular (viz., "niblet") feed and the design of the pellet-feeder/isolation-lock assembly.

The design of the prototype Czochralski puller was begun on schedule. Layouts of all major components have been prepared, and detailing is currently in progress; bills of material for long-delivery items were released to Manufacturing in June. Two critical components have already undergone advance trials: the recharging mechanism, which has been in use for four months, and the crystal lift mechanism, which has been bench-tested and is to be mounted on the laboratory Varian 2850 puller. Further, the fabrication of the transducer/control assembly -- the automation system -- has been accelerated in order to permit testing and preliminary process development on the 2850 furnace prior to the completion of the prototype puller.

The SAMICS analysis of ingot growth and wafering has been completely revised and has been extended to 1986.

2.0 INTRODUCTION

The overall purpose of this program is the demonstration of continuous Czochralski growth, defined as a throughput of silicon that produces 100 kg of single-crystal material, 10 cm or greater in diameter, from one common container. The program is in two coordinated stages, each of which yields a functioning Czochralski puller. Under Stage 1, the feasibility of 100 kg growth cycles has been demonstrated by simulation, an existing Varian 2850 Czochralski furnace has been modified for recharging, and batch melt replenishment has been accomplished using granular silicon. In addition, continuous recharging with granular silicon is to be attempted, and recharging with molten silicon is to be considered. Under State 2, a new, prototype Czochralski puller is currently being designed for the production of 100 kg of crystal from the same crucible with an after-grind yield of 70% or greater.

3.0 RESULTS

3.1 Batch Recharging with Solid

The modification of the Varian 2850 Czochralski furnace for continuous growth was completed at the start of the reporting period, and batch melt-replenishment experimentation was begun. The first such recharge run (Reference No. 179) did not result in satisfactory crystal growth, but it did demonstrate the basic reliability of the recharging system; further, it pointed up the need for the following improvements, which were subsequently effected:

- The retractable extension at the end of the lower feed tube was provided with coarser gears and an inboard bearing, for smoother high-temperature operation.

- A bridge-breaker rod with a flexible tip was added to permit clearing of the lower feed tube; this is occasionally needed when using very coarse polycrystalline feed (≈ 2 cm).
- The seed shaft was replaced with a newly designed water-cooled model which permits the immediate withdrawal of the as-grown crystal into the removal chamber without overheating the shaft seals.
- A manual-assist crystal removal mechanism was added to facilitate the handling of hot, massive ingots; it comprises a simple tong arrangement which pivots in from the furnace post to clamp onto and support the crystal during removal.

The second and third melt-replenishment runs (Reference No. 180 and 181, respectively) each comprised three crystal growths. Neither produced acceptable results in that dislocation-free growth could not be maintained after the first recharge. The problem was excessive silicon monoxide deposition, the occurrence of which was traced to changes in the argon flow pattern induced by the furnace modification; specifically, the interposition of the vacuum valve between the growth chamber and the crystal-removal chamber. Preliminary experimentation indicated that the effective sweeping action of the argon could be restored by straightforward modification of the flow path. This was done, several one-crystal growths were then performed in order to re-establish the baseline, and, finally, the melt-replenishment experimentation was resumed.

Three more recharge runs were made, with the following results:

- Recharge Run No. 4 (Reference No. 185)
21 kg throughput, 4 crystals, 46h:25min duration

- Recharge Run No. 5 (Reference No. 188)
28 kg throughput, 3 crystals, 33h:10min. duration
- Recharge Run No. 6 (Reference No. 190)
48 kg throughput, 5 crystals, 45h:57min. duration

The growth records of these three runs are summarized in Appendix III, and the recharge process itself is discussed in Section 4.1.

3.2 Prototype Puller

The design of the prototype Czochralski puller was begun on schedule, with the following specifications established:

- Crucible Size (OD), Maximum 16 inch (41 cm)
- Crucible Capacity, Maximum 60 kg
- Crystal Length, Maximum 72 inch (1.8 m)
- Crystal Diameter, Maximum 6¼ inch (16.0 cm)
- Seed Lift, Slow Range 0.1-24 inch/h (0.04-10 mm/min)
- Seed Lift, Fast Range 24 inch/min (60 cm/min)
- Seed Rotation 0 - 35 rpm
- Crucible Travel 14 inch (36 cm)
- Crucible Lift, Slow Range 0.1-2 inch/h (0.04-0.8 mm/min)
- Crucible Lift, Fast Range 4 inch/h (1.7 mm/min)
- Crucible Rotation 0 - 30 rpm
- Furnace Height, Overall 16 ft (4.9 m)
- Preferred Recharge Feed Granular
- Alternate Recharge Feed One-piece rod

Layouts of the major subassemblies have been prepared, and detailing of the several components is currently in progress; viz.,

- Lower assembly, comprising the furnace tank and crucible shaft, the crucible lift and rotation mechanisms, and the main vacuum system.

- Hot zone and power supply.
- Crystal lift mechanism.
- Upper assembly, comprising the transition section, the crystal-removal chamber with its vacuum isolation valve, and the recharging mechanism with its isolation locks and vacuum valving.
- Transducers and controls, including the automation system.

Bills of material for long-delivery items were released in June, and manufacturing schedules are being generated.

Of these components, three are deemed critical in the sense of being innovations: the recharging mechanism, the crystal lift and rotation mechanism, and the automation system. The recharging mechanism has been in place on the modified Varian 2850 Czochralski furnace for four months, with 220 hours of service and a total throughput of 138 kg in batch melt-replenishment experimentation. Its design will be modified only slightly for the prototype puller; specifically, the lower feeder tube will be redirected to impart a more nearly vertical trajectory to the feed particles, and its inner diameter will be increased slightly. The crystal lift and rotation mechanism has been built and completely bench-tested; it is capable of handling a 40 kg ingot, and it constitutes a self-contained system which is vacuum-tight to 10^{-9} cm³ per sec. It is to be mounted on the Varian 2850 furnace for preliminary testing as soon as the schedule of recharge runs permits. The fabrication of the automation system has been accelerated in order to permit advance trial and process development on the 2850 furnace prior to the completion of the prototype puller. Since it is compatible with the transducer arrays and process controls of both, it can be transferred directly from the one to the other.

The structural design of the prototype puller is shown in the outline drawings of Fig. 1 and 2. The two features of particular importance are the elevator-type lower assembly, which retracts for access, and the rigid platform system, which provides safe support during operation and servicing. The lowest level (level A) is used to reach the furnace tank-hot zone assembly; the pumping system and power transformer are also located here. The first platform (level B) is the main station for the operator during crystal growth, with both viewports and process controls. The second platform (level C) is for crystal removal and for operating the recharging mechanism. The highest and smallest platform (level D) permits safe access to the seed lift and rotation mechanism.

3.3 Economic Analysis

In compliance with the request of JPL, we have extended our SAMICS analysis of ingot growth and wafering to 1984 and 1986. In addition, the previously reported calculations for 1978-1982[†] have been completely revised in order to bring them into conformity with the most recent version of the price estimation guidelines;^{††} as suggested by JPL, both the cost of the polysilicon and its overhead were omitted.

[†] S.C. Holden and J.R. Fleming, "Slicing of Silicon into Sheet Material", JPL Contract No. 954374, Eighth Quarterly Report (April 3, 1978), Appendix I. R.G. Wolfson, C.B. Sibley, and C.P. Chartier, "Development of Advanced Methods for Continuous Czochralski Growth", JPL Contract No. 954884, Second Quarterly Report (March 17, 1978), Appendix III.

^{††} "SAMICS Usage Update Number 1" (1 February 1978).

2860 CRYSTAL GROWING FURNACE
PRELIMINARY OUTLINE - FRONT ELEVATION

FIGURE 1

2860 CRYSTAL GROWING FURNACE
PRELIMINARY OUTLINE - SIDE ELEVATION
FIGURE 2

There has been sufficient variance in the interpretation of the price estimation guidelines and their application to sheet technology to warrant emphasizing the following features of our economic analysis:

- The number of person-years required is 4.7 times the number of people required per shift; it is not 4.0 times that latter number.
- The overhead multiplier C_2 for floor space, which is the cost per year per ft^2 , is inflated at an annual rate $R = 0.06$; it is not kept constant at its 1975 value of \$97.
- All yields are predicated on the basis of no material recovery and no product rework; if either recovery or rework is projected, it is explicitly defined and cost-loaded according to the established guidelines.

The results of the analysis are summarized in Tables I through XI of Appendix III; their discussion will be deferred to an interim report to be issued shortly.

4.0 DISCUSSION

4.1 Recharge Process

The batch melt-replenishment experimentation, although not yet brought to completion, has served to prove completely both the concept of charging with granular feed and the design of the pellet-feeder/isolation-lock assembly. The recharge process developed thus far is described below.

The temperature of the residual melt is lowered until its surface begins to freeze. (We use a setting that stabilizes a disk of solid ~9 inch in diameter within our 12 inch crucible.)

Approximately 3 kg of granular poly, preferably "niblet" form, is then charged on top of the floating disk, which cushions the impact and prevents splashing. The temperature is raised, and, when ~90% of the solid has been melted, 3 kg more is added. This incremental mode of recharging is continued until the desired mass is attained. Adding too much poly in one increment results in the freezing of feed granules to the crucible wall. The recharging rate itself, ~20 kg per h, is determined by the rate of melting, which is fixed in turn by the power input. This is deliberately limited in order to minimize the devitrification of the quartz crucible.

4.2 Conclusions and Recommendations

The following conclusions have been drawn on the basis of the recharge runs performed thus far:

- Batch melt replenishment with granular feed is a feasible technique for continuous Czochralski growth.
- The design of the recharging mechanism, as embodied in the currently used pellet-feeder/isolation-lock assembly, is entirely satisfactory.

It is recommended that the melt-replenishment experimentation be interrupted at the end of August for the installation of the crystal lift and rotation mechanism on the Varian 2850 Czochralski furnace. This further modification of the laboratory puller will both permit advance trials of the subassembly and also facilitate work in progress by providing a greater pull length.

5.0 PLANS

Plans for the immediate future are as follows:

- Completion of batch melt-replenishment experimentation.
- Start of continuous melt-replenishment experimentation.

Plans for the next quarter conform to the Program Plan.

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APPENDIX I

New Technology

Engineering Drawings and Sketches

NEW TECHNOLOGY

The crystal lift and rotation mechanism includes a sufficiently innovative design feature to warrant patent protection.

ENGINEERING DRAWINGS AND SKETCHES

The detail and assembly drawings of the several components of the recharging system are presented.

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DIMENSIONS ARE IN INCHES

DESCRIPTION OF CHANGE	NOTICE		DRAWN LATINO		DATE 12-6-77		APPROVED		DATE		CODE	
	THIS DRAWING IS NOT COMPLETE AND HAS NOT BEEN OFFICIALLY RELEASED PRINTS MADE TO THIS DRAWING ARE FOR PRELIMINARY INFORMATION ONLY		CHECKED		DATE		APPROVED		DATE		CLASS	
			BOTTOM FLANGE									
			NOT OTHERWISE SPEC. FRAC = ANG = SCALE = 1/2" = 1"									
			FIN. V DEC. X = XX = .020 XXX = .005									
NUM			VAC/LEX		B K 6998		DIVISION		SIZE		DRAWING NO.	
ED			VAC/LEX		B K 6998		DIVISION		SIZE		DRAWING NO.	
DIT			VAC/LEX		B K 6998		DIVISION		SIZE		DRAWING NO.	
CHK			VAC/LEX		B K 6998		DIVISION		SIZE		DRAWING NO.	
DATE			VAC/LEX		B K 6998		DIVISION		SIZE		DRAWING NO.	
REV			VAC/LEX		B K 6998		DIVISION		SIZE		DRAWING NO.	

DASH NO	TYPE OR MODEL	NEXT ASSEMBLY
	E-K7018	

113	REV. HISTORY	REVISIONS BY DATE
-----	--------------	-------------------

MAT'L. ALUM. 6061-T651

DO NOT SCALE THIS PRINT
UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
DIMENSIONS ARE IN INCHES

DESCRIPTION OF CHANGE	NOTICE					DRAWN LATINO	DATE 12-6-77	APPROVED	DATE	CODE
	THIS DRAWING IS NOT COMPLETE AND HAS NOT BEEN OFFICIALLY RELEASED PRINTS MADE TO THIS DRAWING ARE FOR PRELIMINARY INFORMATION ONLY					CHECKED	DATE	APPROVED	DATE	CLASS
						NUT (2 5/8 SIGHT PORT)				
	NOT OTHERWISE SPEC: FRAC = ANG = 10 SCALE 125 FIN. V DEC. X = XX = .020XXX = 1:1									
INUM ED DIT ENG DATE REV						VAC/LEX B K6999 DIVISION SIZE DRAWING NO. REV				

DASH NO	TYPE OR MODEL	NEXT ASSEMBLY	B K7000	REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM
	E-K7018						

5.00
3.38
7.5
1.00

$.06 \times 45^\circ$ TYP

MED KNURL

UNDERCUT TO ROOT DIA
OF THR'D $\frac{1}{16}$ WIDE

$4 \frac{3}{4}$ - 12 THR'D

MAT'L. ALUM 6061-T651

DO NOT SCALE THIS PRINT
UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
DIMENSIONS ARE IN INCHES

DESCRIPTION OF CHANGE	NOTICE	THIS DRAWING IS NOT COMPLETE AND HAS NOT BEEN OFFICIALLY RELEASED PRINTS MADE TO THIS DRAWING ARE FOR PRELIMINARY INFORMATION ONLY		DRAWN LATINO	DATE 12-6-77	APPROVED	DATE	CODE
				CHECKED	DATE	APPROVED	DATE	CLASS
				NUT (4" SIGHTPORT)				
				<div style="display: flex; align-items: center;"> <div style="text-align: center; margin-right: 5px;"> VAC/LEX </div> <div style="text-align: center; margin-right: 5px;"> <div style="border: 1px solid black; padding: 2px;">B</div> <div style="border: 1px solid black; padding: 2px;">K7000</div> </div> </div>				
NUM				<div style="display: flex; justify-content: space-between; font-size: x-small;"> <div>NOT OTHERWISE SPEC: FRAC ±</div> <div>ANG ± 10°</div> <div>SCALE</div> </div> <div style="display: flex; justify-content: space-between; font-size: x-small;"> <div>125 FIN. V DEC. X ±</div> <div>XX ± .020 XXX ±</div> <div>1:1</div> </div>				
EO				<div style="display: flex; justify-content: space-between; font-size: x-small;"> <div>VAC/LEX</div> <div>B K7000</div> <div></div> </div>				
DIT				<div style="display: flex; justify-content: space-between; font-size: x-small;"> <div>DIVISION</div> <div>SIZE</div> <div>DRAWING NO.</div> </div>				
CHK				<div style="display: flex; justify-content: space-between; font-size: x-small;"> <div></div> <div></div> <div>REV</div> </div>				
DATE								
REV								

B K7001

DASH NO	TYPE OR MODEL	NEXT ASSEMBLY

REG	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM

MAT'L. ALUM 6061-T651

DO NOT SCALE THIS PRINT
UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
DIMENSIONS ARE IN INCHES

NOTICE

THIS DRAWING IS NOT COMPLETE AND
HAS NOT BEEN OFFICIALLY RELEASED
REVISIONS MADE TO THIS DRAWING ARE
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DESCRIPTION OF CHANGE	DATE	BY

DRAWN	DATE	APPROVED	DATE	CODE
LATINO	12-14-77			
CHECKED	DATE	APPROVED	DATE	CLASS

CLAMP (6" SIGHT GLASS)

NOT OTHERWISE SPEC: FRAC =	ANG = 1°	SCALE
12.5 FIN. ✓ DEC. X ±	XX ± 0.020 XXX ± 0.005	1/2" = 1"
VAC/LEX	B K7001	
DIVISION	SIZE	DRAWING NO.
		REV

DASH NO.	TYPE OR MODEL	NEXT ASSEMBLY	REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM

A K7002

DO NOT SCALE DRAWING

MAT L. DRILL ROD

DO NOT SCALE THIS PRINT
UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
DIMENSIONS ARE IN INCHES

NOTICE

THIS DRAWING IS NOT COMPLETE AND
HAS NOT BEEN OFFICIALLY RELEASED
PRINTS MADE TO THIS DRAWING ARE
FOR PRELIMINARY INFORMATION ONLY

DESCRIPTION OF CHANGE		DRAWN		DATE		APPROVED		DATE		CODE	
LATINO		12-15-77									
CHECKED		DATE		APPROVED		DATE		CLASS			
<p>ROD - BRIDGE BREAKER</p> <p>NOT OTHERWISE SPEC: FRAC ± ANG ± 1° SCALE 1:1</p> <p>FIN. V DEC X ± 069X ± 020XXX ±</p> <p>VAC/LEX A K7002</p>											
NUMBER		DIVISION		SIZE		DRAWING NO.		REV			
DFT		CHK		DATE		REV					

DASH NO.	TYPE OR MODEL	NEXT ASSEMBLY	REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM

A K7003

DO NOT SCALE DRAWING

3/4" PIPE NIPPLE BRASS

DO NOT SCALE THIS PRINT
UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
DIMENSIONS ARE IN INCHES

NOTICE

THIS DRAWING IS NOT COMPLETE AND
HAS NOT BEEN OFFICIALLY RELEASED
PRINTS MADE TO THIS DRAWING ARE
FOR PRELIMINARY INFORMATION ONLY

PIPE NIPPLE, ALTER. BRIDGE BRKR

DESCRIPTION OF CHANGE		DRAWN		DATE		APPROVED		DATE		CODE	
		LATINO		12-15-77							
		CHECKED		DATE		APPROVED		DATE		CLASS	
NUM FOR PRELIMINARY INFORMATION ONLY											
EO											
DFT											
CHK											
DATE											
REV

NOT OTHERWISE SPEC: FRAC ± ANG ± 1° SCALE
FIN V DEC .X ± .XX ± 0.20 .XXX ±
VAC/LEX A K7003
1:1

varian DIVISION SIZE DRAWING NO. REV

DASH NO.	TYPE OR MODEL	NEXT ASSEMBLY	REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM

MAT'L. BRASS

A K7004

DO NOT SCALE THIS DRAWING

DO NOT SCALE THIS PRINT
UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
DIMENSIONS ARE IN INCHES

NOTICE

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HAS NOT BEEN OFFICIALLY RELEASED
PRINTS MADE TO THIS DRAWING ARE
FOR PRELIMINARY INFORMATION ONLY

DESCRIPTION		DRAWN		DATE		APPROVED		DATE		CODE	
OF CHANGE		LATINO		12-15-77							
		CHECKED		DATE		APPROVED		DATE		CLASS	

BUSHING

BRIDGE BRKR

NOT OTHERWISE SPEC: FRAC ± ANG ±
125/ DEC. X ± XX ±.020XXX ±
SCALE 1:1

NUM	ED	DFT	CHK	DATE	REV

VAR	DIVISION	SIZE	DRAWING NO.	REV
144	VAC/LEX	A	K7004	

DASH NO.	TYPE OR MODEL	NEXT ASSEMBLY	REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM

A K7005

DO NOT SCALE DRAWING

MAT'L. DRILL ROD

-001
-002

A B
3.56 - 3.81
4.56 4.81

DO NOT SCALE THIS PRINT
UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
DIMENSIONS ARE IN INCHES

NOTICE

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HAS NOT BEEN OFFICIALLY RELEASED

PRINTS MADE TO THIS DRAWING ARE
FOR PRELIMINARY INFORMATION ONLY

REV	DATE	CHK	DFT	ED	NUM

NOT OTHERWISE SPEC: FRAC ±	ANG ± 1°	SCALE
FIN. V DEC. X ±	XX ± 0.20 XXX ±	1:1
VAC/LEX	A	K7005
DIVISION	SIZE	DRAWING NO.
		REV

HINGE PIN

DRAWN	DATE	APPROVED	DATE	CODE
LATINO	12-12-77			
CHECKED	DATE	APPROVED	DATE	CLASS

3			4			B K7006			2			1		
DASH NO	TYPE OR MODEL	NEXT ASSEMBLY	REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM								
			1		SAE 1020 HRS	1								
			2		SAE 1020 HRS	2								
			2		SAE 1020 HRS	3								

4.50
3.562
.50
.19
.50
.28
.25
.75
.38 TYP
.375 / .380 (2 SLOTS IN LINE)

.38
1.0
2.38
1.00
.50
.56
1.06

DO NOT SCALE THIS PRINT
UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
DIMENSIONS ARE IN INCHES

DESCRIPTION OF CHANGE	NOTICE		DRAWN LATINO		DATE 12-12-77		APPROVED		DATE		CODE	
	THIS DRAWING IS NOT COMPLETE AND HAS NOT BEEN OFFICIALLY RELEASED PRINTS MADE TO THIS DRAWING ARE FOR PRELIMINARY INFORMATION ONLY		CHECKED		DATE		APPROVED		DATE		CLASS	
			HINGE, LOWER									
			NOT OTHERWISE SPEC: FRAC ± ANG ± SCALE 1:1									
			FIN. ✓ DEC. X ± XX ± 020XXX ±									
NUM			VAC/LEX		B K7006							
ED			DIVISION		SIZE		DRAWING NO.		REV			
DIT												
CHK												
DATE												
REV												

B K7007

DASH NO	TYPE OF MODEL	TEST ASSEMBLY

REV	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM

MAT'L. SAE 1020 CRS

add C'Base for $\frac{1}{4}$ " screw

R

DO NOT SCALE THIS PRINT
UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
DIMENSIONS ARE IN INCHES

REVISION NO. 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100	NOTICE THIS DRAWING IS NOT COMPLETE AND HAS NOT BEEN OFFICIALLY RELEASED PRINTS MADE TO THIS DRAWING ARE FOR PRELIMINARY INFORMATION ONLY		DRAWN LATINO DATE 12-12-77 APPROVED DATE CODE
	CHECKED DATE APPROVED DATE CLASS		HINGE, TOP
	NOT OTHERWISE SPEC: FRAC $\pm$ ANG $\pm$ 0 SCALE 1:1		FIN. $\checkmark$ DEC. X $\pm$.XX = 020.XXX $\pm$
	VAC/LEX DIVISION SIZE DRAWING NO.		B K7007 REV

5		4		B K7008		2		1	
DASH NO	TYPE OR MODEL	NEXT ASSEMBLY		REQ	PART NUMBER	DESCRIPTION OR MATERIAL		ITEM	

MAT'L. BRASS

DO NOT SCALE THIS PRINT
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BREAK ALL SHARP EDGES
DIMENSIONS ARE IN INCHES

DESCRIPTION OF CHANGE	NOTICE				DRAWN	DATE	APPROVED	DATE	CODE
	THIS DRAWING IS NOT COMPLETE AND HAS NOT BEEN OFFICIALLY RELEASED PRINTS MADE TO THIS DRAWING ARE FOR PRELIMINARY INFORMATION ONLY				LATINO	12-15-77			
					CHECKED	DATE	APPROVED	DATE	CLASS
					JACK SCREW				
NUM					NOT OTHERWISE SPEC: FRAC = ANG ± °		SCALE		
EO					125/ FIN. V DEC. X = .050 X X = .020 XXX ±		1:1		
DIT							VAC/LEX B K7008		
CHE									
DATE					DIVISION		SIZE	DRAWING NO.	REV
REV									

B K7009

DASH NO	TYPE OR MODEL	NEXT ASSEMBLY

REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM
1		SAE 1020 HRS	1
1		SAE 1020 HRS	2

DO NOT SCALE THIS PRINT
UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
DIMENSIONS ARE IN INCHES

DESCRIPTION OF CHANGE	NOTICE				DRAWN LATINO		DATE 12-9-77	APPROVED	DATE	CODE
	THIS DRAWING IS NOT COMPLETE AND HAS NOT BEEN OFFICIALLY RELEASED				CHECKED		DATE	APPROVED	DATE	CLASS
	PRINTS MADE TO THIS DRAWING ARE FOR PRELIMINARY INFORMATION ONLY				ADJUSTABLE HINGE PIN, TOP					
					NOT OTHERWISE SPEC: FRAC = ANG = 1/2° SCALE FIN. ✓ DEC. X = .XX ± .020XXX ± 1:1					
					VAC/LEX B K7009 DIVISION SIZE DRAWING NO. REV					
NUM					varian					
TO										
DIT										
CHE										
DATE										
REV										

5 4 3 2 1
B K 7010

DASH NO	TYPE OR MODEL	NEXT ASSEMBLY

NO	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM

MAT'L. SAE 1020 CR5

DO NOT SCALE THIS PRINT
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BREAK ALL SHARP EDGES
DIMENSIONS ARE IN INCHES

DESCRIPTION OF CHANGE	NOTICE	
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NUM		
LO		
DFT		
CHK		
DATE		
REV		

DRAWN LATINO	DATE 12-15-77	APPROVED	DATE	CODE
CHECKED	DATE	APPROVED	DATE	CLASS
BLOCK, ADJ.				
NOT OTHERWISE SPEC: FRAC = ANG ± SCALE				
FIN. ✓ DEC. X ± .XX ± .020.XXX ± 1:1				
VAC/LEX		B	K 7010	
DIVISION		SIZE	DRAWING NO.	REV

R

DO NOT SCALE DRAWING		R	
1 2 3 4 5 6 7 8 9 10 11 12	1 2 3 4 5 6 7 8 9 10 11 12	DRAWN LAT/WD DATE 1-19-70 APPROVED CBS DATE 1-28-70 BY GOOD SCALE	
		FEEDER TRAY	
NOTICE THIS DRAWING IS NOT COMPLETE AND HAS NOT BEEN OFFICIALLY RELEASED UNLESS SO INDICATED FOR MILITARY INFORMATION ONLY		(VAC) VAC/LEX DATE 1-1-70 BY 1-1-70 BY	

DASH NO.	TYPE OR MODEL	NEXT ASSEMBLY	REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM

A K7019

DIM 'A'
-001 3.75
-002 3.50

MAT'L #304 S/S

DO NOT SCALE THIS PRINT
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DIMENSIONS ARE IN INCHES

NOTICE

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DRAWN		DATE		APPROVED		DATE		CODE	
LATINO		12-21-77							
CHECKED		DATE		APPROVED		DATE		CLASS	
Pivot Bracket									
NOT OTHERWISE SPEC: FRAC = ANG = SCALE									
FIN V DEC X ± .XX ± .020XXX ± .005 ± 1" = 1"									
VAC/LEX		A		K7019					
DIVISION		SIZE		DRAWING NO.		REV			

5			B K7020		2		1	
DASH NO	TYPE OR MODEL	NEXT ASSEMBLY	REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM		
		E-K7018	1		FLANGE B-K7175	1		
			1		COUPLING A-K7176	2		

SILVER BRAZE

2.50 REF

R/C REF

DO NOT SCALE THIS PRINT
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BREAK ALL SHARP EDGES
DIMENSIONS ARE IN INCHES

DESCRIPTION IN FINISH	NOTICE				FLANGE ASS'Y. (VAC PORT)				
	THIS DRAWING IS NOT COMPLETE AND HAS NOT BEEN OFFICIALLY RELEASED PRINTS MADE TO THIS DRAWING ARE FOR PRELIMINARY INFORMATION ONLY				DRAWN	DATE	APPROVED	DATE	CODE
NR					LATINO	12-21-77			
EX					CHECKED	DATE	APPROVED	DATE	CLASS
DP									
CR									
D-RE									
ST									

	NOT OTHERWISE SPEC: FRAC ± ANG ±		SCALE
	FIN. ✓ DEC X ± .060XX ± .020XX ±		1:1
VAC/LEX	B	K7020	
DIVISION	SIZE	DRAWING NO.	
		REV

449-9-2 REV 2 JAN 66

REV	DATE	CHANGE	FUNNEL - CHARGER CHUTE	ENGINEER CB S	DATE 12-20-77
				MATERIAL 304 5/8.062"	JOB ORDER 96-01000
			varian engineering sketch	SCALE 1:1	USE
					SKETCH NO. SK7022

USED ON E-K7018

REV	A	11-1684	6.25 WAS 5.62	RETRACT. CHUTE	ENGINEER		DATE
					CBS		12-20-77
					MATERIAL		JOB ORDER
					304 S/S		96-01000
					SCALE	USE	SKETCH NO.
				varian engineering sketch			5K7023

DASH NO	TYPE OR MODIF	NEXT ASSEMBLY	REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM
		D-K7164			*304 S/S	

1 A .002

NOTICE

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DIMENSIONS ARE IN INCHES

DESCRIPTION OR CHANGE	DRAWN	DATE	APPROVED	DATE	CODE
		LATINO	1-16-78	CBS	1-18-78
	CHECKED		APPROVED		CLASS
ADAPTER (TILT TRAY)					
	NOT OTHERWISE SPEC: FRAC = ANG ± 1°				SCALE
	FIN. √ DEC. X = .XX = 020XXX ± .005				1:1
	VAC/LEX		B	K7026	
	DIVISION		SIZE	DRAWING NO.	REV

5			4			2			1		
DASH NO	TYPE OR MODEL	NEXT ASSEMBLY	REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM					
		D-K7164			*304 S/S						

"O" RING GROOVE
PER B-F2146-001

TAP #10-32 THRU
(4 HOLES EQU. SP)

1.250

NOTICE

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DESCRIPTION OF CHANGE	NUM	TO	DIT	CHK	DATE	REV	DRAWN		DATE		APPROVED		DATE		CODE	
							LATINO	1-16-78	CRS	1-18-78						
							CHECKED									
FLANGE (TILT TRAY)																
							NOT OTHERWISE SPEC. FRAC ± ANG ± SCALE 125 FIN. √ DEC. X ± XX ± .020, XXX ± .005 1:1									
							<div style="display: flex; align-items: center;"> <div> <p>VAC/LEX</p> <p>DIVISION</p> </div> <div style="margin: 0 10px;"> <p>B</p> <p>SIZE</p> </div> <div> <p>K7027</p> <p>DRAWING NO.</p> </div> </div>									
							<div style="display: flex; justify-content: space-between;"> <div> <p>REV</p> </div> <div> <p>REV</p> </div> </div>									

B K7028

DASH NO	TYPE OR MODEL	NEXT ASSEMBLY
	E-K7018	
	D-K7164	

REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM
		*304 S/S

NOTICE
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HAS NOT BEEN OFFICIALLY RELEA
PRINTS MADE TO THIS DRAWING
FOR PRELIMINARY INFORMATION ONLY

DESCRIPTION OF CHANGE	DATE	BY	CHK	DATE	REV

DRAWN	DATE	APPROVED	DATE	CODE
LATINO	1-16-78	CBS	1-18-78	
CHECKED	DATE	APPROVED	DATE	CLASS
FLANGE, TUBE				
NOT OTHERWISE SPEC: FRAC ± ANG ±				SCALE
125 FIN. V DEC. X ± XX ± 020.XXX ± .005				1" = 1"
VAC/LEX		B K7028		
DIVISION		SIZE		REV

DASH NO.		TYPE OR MODEL		NEXT ASSEMBLY		REQ		PART NUMBER		DESCRIPTION OR MATERIAL		ITEM																															
				D-K7164						#304 S/S																																	
A K7029																																											
DO NOT SCALE THIS DRAWING																																											
<div style="border: 1px solid black; padding: 5px; transform: rotate(-10deg); display: inline-block;"> <p>NOTICE</p> <p>THIS DRAWING IS NOT COMPLETE AND HAS NOT BEEN OFFICIALLY RELEASED. PRINTS MADE TO THIS DRAWING ARE FOR PRELIMINARY INFORMATION ONLY.</p> </div>																																											
<table border="1"> <tr> <td colspan="2">DRAWN</td> <td colspan="2">DATE</td> <td colspan="2">APPROVED</td> <td colspan="2">DATE</td> <td colspan="2">CODE</td> </tr> <tr> <td colspan="2">LATINO</td> <td colspan="2">1-16-78</td> <td colspan="2">CBS</td> <td colspan="2">1-18-78</td> <td colspan="2"></td> </tr> <tr> <td>CHECKED</td> <td>DATE</td> <td>APPROVED</td> <td>DATE</td> <td>CLASS</td> <td colspan="5"></td> </tr> </table>														DRAWN		DATE		APPROVED		DATE		CODE		LATINO		1-16-78		CBS		1-18-78				CHECKED	DATE	APPROVED	DATE	CLASS					
DRAWN		DATE		APPROVED		DATE		CODE																																			
LATINO		1-16-78		CBS		1-18-78																																					
CHECKED	DATE	APPROVED	DATE	CLASS																																							
<table border="1"> <tr> <td colspan="4">PIVOT ROD (TILT TRAY)</td> </tr> <tr> <td colspan="4">NOT OTHERWISE SPEC: FRAC ± ANG ± SCALE</td> </tr> <tr> <td colspan="2">FIN. V DEC. X ±</td> <td colspan="2">XX ± 20XXX ±</td> </tr> <tr> <td colspan="2">1:1</td> <td colspan="2"></td> </tr> </table>														PIVOT ROD (TILT TRAY)				NOT OTHERWISE SPEC: FRAC ± ANG ± SCALE				FIN. V DEC. X ±		XX ± 20XXX ±		1:1																	
PIVOT ROD (TILT TRAY)																																											
NOT OTHERWISE SPEC: FRAC ± ANG ± SCALE																																											
FIN. V DEC. X ±		XX ± 20XXX ±																																									
1:1																																											
<table border="1"> <tr> <td>NUM</td> <td>DESCRIPTION OF CHANGE</td> <td>REV</td> </tr> <tr> <td>EO</td> <td></td> <td></td> </tr> <tr> <td>DFT</td> <td></td> <td></td> </tr> <tr> <td>CHK</td> <td></td> <td></td> </tr> <tr> <td>DATE</td> <td></td> <td></td> </tr> <tr> <td>REV</td> <td></td> <td></td> </tr> </table>														NUM	DESCRIPTION OF CHANGE	REV	EO			DFT			CHK			DATE			REV														
NUM	DESCRIPTION OF CHANGE	REV																																									
EO																																											
DFT																																											
CHK																																											
DATE																																											
REV																																											

DASH NO.	TYPE OR MODEL	NEXT ASSEMBLY	REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM
		D-K7164			KNOB * GH2N (REID)	

A K7030

DO NOT SCALE DRAWING

DO NOT SCALE THIS PRINT
UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
DIMENSIONS ARE IN INCHES

DESCRPT ON
OF CHANGE

NOTICE

THIS DRAWING IS NOT COMPLETE AND
HAS NOT BEEN OFFICIALLY RELEASED

NUM PRINTS MADE TO THIS DRAWING ARE

OF FOR PRELIMINARY INFORMATION ONLY

DATE

REV

KNOB

(TILT TRAY)

NOT OTHERWISE SPEC: FRAC ± ANG ± SCALE

FIN V DEC X ± XX ± XXX ± 1:1

Division

VAC/LEX A K7030

DIVISION SIZE DRAWING NO.

REV

DASH NO.	TYPE OR MODEL	NEXT ASSEMBLY	REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM
		D-K7164			*304 S/S	

A K7124

DO NOT SCALE DRAWING

DO NOT SCALE THIS PRINT
UNLESS OTHERWISE SPECIFIED
TEXT OR DIMENSIONS ARE IN
INCHES

NOTICE

THIS DRAWING IS NOT
HAS NOT BEEN OFFICIALLY
PRINTS MADE TO THIS
FOR PRELIMINARY INFORMATION ONLY

SHAFT
(TILT TRAY)

DRAWN	DATE	APPROVED	DATE	CODE
LATINO	1-16-78	C135	1-18-78	
CHECKED	DATE	APPROVED	DATE	CLASS

DESCRIPTION OF CHANGE	NUM	EO	DT	CHK	DATE	REV

NOT OTHERWISE SPEC: FRAC ±	ANG ±	SCALE
FIN. V DEC. X ±	XX ± 020.000 ±	1:1

varian	VAC/LEX	A	K7124
DIVISION	SIZE	DRAWING NO.	REV

DASH NO.	TYPE OR MODEL	NEXT ASSEMBLY	REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM
		D-K7164	1		MITER GEAR *L96Y-12144 BGW	1
			1		*304 S/S	2

DETAIL ITEM 2.

DO NOT SCALE THIS PRINT
UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
DIMENSIONS ARE IN INCHES

NOTICE
THIS DRAWING IS NOT COMPLETE AND
HAS NOT BEEN OFFICIALLY RELEASED
PRINTS MADE TO THIS DRAWING ARE
FOR PRELIMINARY INFORMATION ONLY

DESCRIPTION OF CHANGE	NUM	DRAWN	DATE	APPROVED	DATE	CODE
	EO	LATINO	1-16-78	CBS	1-18-78	
	DFT	CHECKED	DATE	APPROVED	DATE	CLASS
	CHK	MITER GEAR				
	DATE	NOT OTHERWISE SPEC: FRAC ± ANG ± SCALE				
	REV	FIN. ✓ DEC .X ± .XX → 020.XXX ± 1:1				
		VAC/LEX		A	K7125	
		DIVISION		SIZE	DRAWING NO.	REV

DASH NO.	TYPE OR MODEL	NEXT ASSEMBLY	REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM
		D-K7164			MITER GEAR *L96Y-12144 BGW

DO NOT SCALE DRAWING

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DESCRIPTION OF CHANGE	DRAWN	DATE	APPROVED	DATE	CODE
	LATINO	1-16-78	CBS	1-18-78	
NUM	CHECKED	DATE	APPROVED	DATE	CLASS
MITER GEAR (TILT TRAY)					
EO	NOT OTHERWISE SPEC: FRAC ± ANG ±				SCALE 1:1
DFT	FIN. ✓ DEC X ± XX ± .020 XXX ±				
CHK	VAC/LEX		A K7126		
DATE	DIVISION		SIZE	DRAWING NO.	REV
REV

B/K7127

DASH NO	TYPE OR MODEL	NEXT ASSEMBLY
		D-K7164

QID	PART NUMBER	DESCRIPTION OF MATERIAL	ITEM
		TANTALUM .016 THICK

DO NOT SCALE THIS PRINT
UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
DIMENSIONS ARE IN INCHES

DESCRIPTION OF DRAWING	NOTICE		DR. W. N. LATINO		DATE 1-16-78	APPROVED	DATE	CODE
	THIS DRAWING IS NOT COMPLETE AND HAS NOT BEEN OFFICIALLY RELEASED		CHECKED		DATE	APPROVED	DATE	CLASS
	PRINTS MADE TO THIS DRAWING ARE FOR PRELIMINARY INFORMATION ONLY		HEAT SHIELD					
			NOT OTHERWISE SPEC: FRAC ± ANG ± SCALE 1:1					
NUM			FIN. V DEC. X ±		XX ± .030XXX ±			
EQ			VAC/LEX		B K7127			
OP			DIVISION		SIZE		DRAWING NO.	
CHK							REV	
DATE								
REV								

DASH NO		TYPE OR MODEL		NEXT ASSEMBLY		REQ		PART NUMBER		DESCRIPTION OR MATERIAL		ITEM	
				B-K7165						BRASS			

A		K7129		DO NOT SCALE DRAWING									
				<p>NOTICE</p> <p>THIS DRAWING IS NOT COMPLETE AND HAS NOT BEEN OFFICIALLY RELEASED PRINTS MADE TO THIS DRAWING ARE FOR PRELIMINARY INFORMATION ONLY</p>									

DESCRIPTION OF CHANGE		NUM		EO		DFT		CHK		DATE		REV	

DRAWN		DATE		APPROVED		DATE		CODE	
LATINO		1-17-78		CIBS		1-18-78			
CHECKED		DATE		APPROVED		DATE		CLASS	

BUSHING (RETRACTABLE TUBE)		NOT OTHERWISE SPEC: FRAC ±		ANG ±		SCALE	
		FIN. V DEC X ±		XX ±		XXX ± .005	

VAC/LEX		A		K7129		REV	

DASH NO.		TYPE OR MODEL		NEXT ASSEMBLY		REQ		PART NUMBER		DESCRIPTION OR MATERIAL		ITEM	
				B-K7130						BRASS			

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DESCRIPTION OF CHANGE			
NUM	EO	DFT	CHK
DATE			
REV			

PLATE (ADT CHUTE)			
DRAWN	DATE	APPROVED	DATE
LATINO	1-17-78	CBS	1-18-78
CHECKED	DATE	APPROVED	DATE
NOT OTHERWISE SPEC: FRAC ±		ANG ±	
FIN ✓ DEC X ±		XX ±.02DXXX ±.005	
VAC/LEX		A K7130	
DIVISION		SIZE	
DRAWING NO.		REV	

5		4		B K7131		1		1	
DASH NO	TYPE OR MODEL	NEXT ASSEMBLY				REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM
	B-K7165							BRASS	

1.50
1.250
.408
.404
.260
.378
.374
1.50

"O" RING GROOVE
PER B-F2146-OC1

15° TYP
1.000
.38
13/64 DIA
(3 HOLES)

NOTICE

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DESCRIPTION OF CHANGE	NUM					DRAWN	DATE	APPROVED	DATE	CODE
	LO					LATINO	1-17-78	CBS	1-18-78	
	DPI					CHECKED	DATE	APPROVED	DATE	CLASS
	CNC					SEAL BODY (ADJ CHUTE)				
DATE					<div style="display: flex; justify-content: space-between;"> NOT OTHERWISE SPEC: FRAC = ANG = SCALE </div> <div style="display: flex; justify-content: space-between;"> 125/ FIN. V DEC .X = XX = .020 XXX = .005 1:1 </div>					
REV					<div style="display: flex; justify-content: space-between;"> VAC/LEX B K7131 </div> <div style="display: flex; justify-content: space-between; font-size: small;"> DIVISION SIZE DRAWING NO. REV </div>					

QARD RWB 44006 (2)
 "O" RWB 42006 (1)
 "H" RWB 42006 (4)
 "A" RWB 42006 (1)

NOTICE

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DO NOT SCALE DRAWING

[illegible]

5			4		B/K7165		2		1																					
DASH NO	TYPE OR MODEL	NEXT ASSEMBLY	REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM																								
<div style="border: 1px solid black; padding: 5px; display: inline-block;"> NOTICE THIS DRAWING IS NOT COMPLETE AND HAS NOT BEEN APPROVED FOR RELEASE. DO NOT SCALE OR PRINT UNLESS OTHERWISE SPECIALLY RELEASED. BREAK ALTERNATE EDGES FOR DIMENSIONS ARE 10 INCHES FOR PRELIMINARY INFORMATION ONLY. </div>																														
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 10%;">DRAWN</th> <th style="width: 10%;">DATE</th> <th style="width: 10%;">APPROVED</th> <th style="width: 10%;">DATE</th> <th style="width: 10%;">CODE</th> </tr> </thead> <tbody> <tr> <td>ATINO</td> <td>1-25-78</td> <td></td> <td></td> <td></td> </tr> </tbody> </table>							DRAWN	DATE	APPROVED	DATE	CODE	ATINO	1-25-78																	
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RETRACTABLE TUBE																														
NOT OTHERWISE SPEC: FRAC ±		ANG ±																												
FIN. √ DEC. X ±		XX ±																												
VAC/LEX		B K7165																												
DIVISION		SIZE																												
DRAWING NO.		REV																												

DASH NO.	TYPE OR MODEL	NEXT ASSEMBLY	REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM
		D-K7164			#304 S/S	

A K7166

DO NOT SCALE DRAWING

REAM .250

DO NOT SCALE THIS PRINT
UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
DIMENSIONS ARE IN INCHES

DESCRIPTION OF CHANGE		DRAWN		DATE	APPROVED	DATE	CODE
		LATINO		1-25-78	CBS	1-25-78	
		CHECKED	DATE	APPROVED	DATE	CLASS	
		SPACER					
		NOT OTHERWISE SPEC: FRAC ±		ANG ±		SCALE	
		FIN. V DEC. X ±		XX ±.020XXX ±		1:1	
NUM							
EO							
DFT							
CHK							
DATE							
REV							

VFA		NOT OTHERWISE SPEC: FRAC ±		ANG ±		SCALE	
FIN. V DEC. X ±		XX ±.020XXX ±				1:1	
VAC/LEX		A		K7166			
DIVISION		SIZE		DRAWING NO.		REV	

5		4		B K7175		2		1	
DASH NO	TYPE OR MODEL	HEAT ASSEMBLY				RTO	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM
	B-K7020							BRASS	

2.50

1.250
1.248

.25

.50

1.00

1.283
1.279

.03x45°

13/64 DIA
(4 HOLES EQU SP)

2.000

"O" RING GROOVE
PER B-F2146-002

DO NOT SCALE THIS PRINT
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DESCRIPTION OF CHANGE	NOTICE			
	THIS DRAWING IS NOT COMPLETE AND HAS NOT BEEN OFFICIALLY RELEASED			
	PRINTS MADE TO THIS DRAWING ARE FOR PRELIMINARY INFORMATION ONLY			
	NUM			
	ED			
DPT				
CHK				
DATE				
REV				

DRAWN LATINO	DATE 1-31-78	APPROVED	DATE	CODE
CHECKED	DATE	APPROVED	DATE	CLASS
FLANGE				
<div style="display: flex; justify-content: space-between;"> <div> </div> <div> NOT OTHERWISE SPEC: FRAC = ANG = 1/2° SCALE 125 FIN. V DEC. X = .XX = .030XXX = .005 1/1 </div> </div>				
VAC/LEX		B K7175		
DIVISION		SIZE		REV

DK7183

QTY	PART NUMBER	DESCRIPTION OF MATERIAL	REV
1		FLANGE B-K 7020	1
1		90° FTG EL (1/2") W-2344	2
1		STYLE WC-503 MUELLER	
2		ADAPTER (1/2") W-1164	3
1		STYLE WC-401 MUELLER	
1		FILTER #1P635	4
		TEEL	
3	6246-31-012	VALVE #1521M4B HOKE	5
1		FEMALE ELBOW #270-P	6
		1/2" TUBE 1/2" PT IMPL	
4		FITTING ADPTR W-1526	7
		STYLE WC-405 MUELLER	
1	1251-B724-318	VAC VALVE #1251-1A	8
1		STD VAC GAUGE-REAR CTR	9
		MOUNT #KE-30HS-25MC LENZ	
1		REDUCER 1/2" BRASS	10
1	6271-34-218	1/2" X 3/4" NIPPLE BRASS	11
1		1" NOM X 5' LG CU TUBE	12
1		HANGER RING F&M	13
1	0031F0472-301	TC GAUGE B70472	14
2		ADAPTER 1/2" X 1/2" W-1216	15
1		STYLE WC-402 MUELLER	
1		1" NOM X 5' LG CU TUBE	16
1		O-RING #2-124	17

* NOT SHOWN

810-32 X 3/4" SACS (2)

DO NOT SCALE DRAWING

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DATE	APPROVED	DATE	CODE
12-2-78			
DATE	APPROVED	DATE	CLASS

VACUUM MANIFOLD
(CHARGER)

	NOT OTHER THAN SPEC. FROM VAC/LEX 1:1	1:1 1:1
--	---	------------

DK7183

DK7184

NO.	PART NUMBER	DESCRIPTION OR MATERIAL	QTY
1		FLANGE B-K7185	1
2		1 1/2" NOM X 5' LG CU TUBE	2
2	0531-F0472-301	TC GAUGE B-F0472	3
2		ADAPTER 1/2" X 1/2" W-1216	4
2		STYLE WC-402 MUELLER	4
1		NUT A-K1472	5
1	1061-17532-001	QUITE DISC 1/2" O.D. X 1/4" TH OPT. CL TYPE 101 G.E.	6
1	6608-50-170	GASKET STYLE 920 TYPE J 1/2" O.D. X 1 1/8" I.D. X 1/8" TH CU SOETEC	7
1		O-RING TYPE 3957-25	8
1		1/2" NIP X 2' LG BRASS	9
2		ADAPTER 1/2" X 1/2" W-1226	10
2		STYLE WC-402 MUELLER	10
1		STD VAC GAUGE REAR CTR MT RKE-3046-253RC LENS	11
1		FLUSH BUSH 1/2" X 1/4" W-1751	12
1		STYLE WC-106 MUELLER	12
1	1251-B5246-318	VAC VALVE #1251-15	13
1		VALVE #3252 M+B	14
1		SOFT SEAL 2" X 1/2" WALE HOKA	14
1		ELBOW #100-B 1/2" BRASS W-4	15
1		1" NOM X 3' LG CU TUBE	16
1		90° ELBOW 1" X 1" W-147	17
1		STYLE WE-500 MUELLER	17
1		1" NOM X 5' LG CU TUBE	18
1		1" NOM X 2 1/2' LG CU TUBE	19
1		FLANGE B-K7195	20

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DO NOT SCALE DRAWING

REVISIONS BY DATE	DESIGNED LATINO	DATE 2-15-78	APPROVED	DATE	CODE
	ENGINEER	DATE	INTEGRATED	DATE	CLARK
VACUUM MANIFOLD (6" VALVE)					
NOT OTHERWISE SPECIFIED		SCALE 1:1		DRAWN BY D K 7184	
MATERIAL VAC/LEX		PROCESS B-171		DRAWING NO. B-171	

5		4		3		2		1	
DASH NO		TYPE OR MODEL		PART NUMBER		DESCRIPTION OR MATERIAL		ITEM	
		D-K7184				BRASS			

Side View Dimensions:

- Total Height: 3.00
- Top Flange Height: 1.50
- Bottom Flange Height: 1.635
- Top Hole Diameter: .50
- Chamfer: .06 x 45°

Top View Dimensions:

- Angle: 45°
- Radius: 1.19
- Hole Diameter: 9/32 DIA THRU (4 HOLES EQU SP)
- Dimension: 2.562

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DIMENSIONS ARE IN INCHES

DRAWN		DATE		APPROVED		DATE		CODE	
LATINO		2-3-78							
CHECKED		DATE		APPROVED		DATE		CLASS	
FLANGE									
<div style="display: flex; justify-content: space-between;"> <div> <p>NOT OTHERWISE SPEC: FRAC ±</p> <p>125/1000 DEC. X ±</p> <p>VAC/LEX</p> </div> <div> <p>ANG ± 1°</p> <p>XX ± .020XXX ± .005</p> <p>B K7185</p> </div> <div> <p>SCALE</p> <p>1:1</p> </div> </div>									
DIVISION		SIZE		DRAWING NO.		REV			

DESCRIPTION OF CHANGE		NOTICE	
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NUM			
ED			
DIT			
CHK			
DATE			
REV			

3			4			5 BK7195			2			1		
DASH NO	TYPE OR MODEL	NEXT ASSEMBLY	REQ	PART NUMBER	DESCRIPTION OF MATERIAL	ITEM								
	D-K7184				BRASS									

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DESCRIPTION OF PART	NOTICE				DRAWN	DATE	APPROVED	DATE	CODE
	THIS DRAWING IS NOT COMPLETE AND HAS NOT BEEN OFFICIALLY RELEASED PRINTS MADE TO THIS DRAWING ARE FOR PRELIMINARY INFORMATION ONLY				LATINO	2-15-78			
					CHECKED	DATE	APPROVED	DATE	CLASS
					FLANGE				
				NOT OTHERWISE SPEC: FRAC ± ANG ± SCALE 125/ DEC. X ± XX ± .020XXX ± .005 1:1					
						VAC/LEX BK7195			
				DIVISION SIZE DRAWING NO. REV

[illegible]

1 REQ'D

			RING		ENGINEER CBS		DATE 10-11-77	
					MATERIAL 304 SS		JOB ORDER 96-01000	
					SCALE 1:1		SKETCH NO. 5K7417	
					USE 1			
REV	DATE	CHANGE						

448-9-2 REV 2 JAN 66

UPPER

8 REQ'D

488-0-2 REV 2 JAN 65

			SPECIAL NUT ADAPTER		ENGINEER C.B.S.		DATE 10-11-77	
			varian engineering sketch		MATERIAL 3/4 BRASS HEX		JOB ORDER 96-01000	
REV					DATE		CHANGE	
					USE		SKETCH NO. 5K74-18

lower

8 RECD

440-P-J REV 2 JAN 66

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449-D-2 REV 2 JAN 68

REV		DATE	CHANGE	HEAT SHIELD		ENGINEER CBS	DATE 10-27-77
						MATERIAL 304 Pol. SHT	JOB ORDER 96-01000
						SCALE	USE
						SKETCH NO. 5K7420	

varian
engineering sketch

BASE NO.	TYPE OR MODEL	WELD ASSEMBLY

NO.	PART NUMBER	DESCRIPTION

MAT'L: .125 DIA WELD ROD #308 S/S

DO NOT SCALE THIS PRINT
UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
DIMENSIONS ARE IN INCHES

DRAWN LATINO	DATE	APPROVED	DATE	CODE
CHECKED	DATE	APPROVED	DATE	CLASS
HEAT SHIELD (GATE VALVE)				
NOT OTHERWISE SPEC: FRAC ±		ANG ±		SCALE
FIN. V DEC. II ±		XX ±		XXX ±
VARIATION		C		
DIVISION		SIZE		DRAWING NO.
				REV

NUM	
EQ	
DFT	
CHK	
DATE	
REV	

6	5	3	2	1
MODEL		PART NUMBER		DESCRIPTION OF MATERIAL
BEST ASSUMED				*304 S/S

DO NOT SCALE THIS PRINT
UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
DIMENSIONS ARE IN INCHES

REVISIONS DATE BY REV	DRAWN LATINO		DATE 3-24-78	APPROVED	DATE	CODE
	CHECKED		DATE	APPROVED	DATE	CLASS
	RETAINER (SIGHT PORT & BRIDGE BRKR)					
	NOT OTHERWISE SPEC: FRAC ± AND ±					
FIN. ✓ DEC. X ±		XX ± .020		XXX ± .005		SCALE 1:1
VAC/LEX		C		DIVISION		SIZE
DRAWING NO.		REV				

APPENDIX II

Program Plans, Updated

-- Milestone Chart

DEVELOPMENT OF ADVANCED METHODS FOR CONTINUOUS CZOCHRALSKI GROWTH

Varian Associates/Lexington Vacuum Division
JPL Contract 954884

SC-2 Program Plan
Page 1 of 3 pages

Recharging

1. Furnace Modification
2. 100 kg Growth Cycle
3. Batch Recharging with Solid
4. Continuous Recharging with Solid
5. Continuous Recharging with Liquid

Prototype Fuller

6. Lower Assembly: Design
Manufacture
7. Hot Zone and Power Supply
8. Crystal Lift Mechanism: Design
Manufacture
9. Upper Assembly: Design
Manufacture
10. Transducers and Control
11. Process Demonstration

Design Analysis Cost Study

12. Economic Model

MILESTONE CHART

RGW 10/22/77
Updated 7/14/78

APPENDIX III

Summary of Data

Summary of Economic Analysis

SUMMARY OF DATA

Abbreviated Logs of Recharge Runs

No. 4, 5, and 6 (Reference No. 185, 188, and 190)

ABBREVIATED LOG OF RECHARGE RUN NO. 4 (REFERENCE NO. 185)

Charge Mass - 20 kg; Seed Orientation - 100; Crystal Diameter - 4 inch (nominal)

Elapsed
Time
(hr:min)

Crystal 1	- -	Crucible charged with 20 kg
	0:0	Power on at 65 kw
	0:20	Power increased to 80 kw
	1:28	Charge molten
	1:49	Seed dipped
		Growth of neck and crown
	3:22	Over shoulder; start of body growth
	3:43	DF mode of growth lost at 1-3/8 inch below crown; remelt
	4:44	Seed dipped
		Growth of neck and crown
	6:08	Over shoulder; start of body growth
		Growth of 13-3/4 inch length
	10:56	Growth terminated
		Cool, remove, and weigh Crystal 1
Crystal 2	12:58	Crucible recharged with 7.450 kg
	13:33	Charge molten
		Delay to permit minor modification of equipment
	17:13	Seed dipped
		Growth of neck and crown
	18:47	Over shoulder; start of body growth
		Growth of 13½ inch length
	23:05	Growth terminated
		Cool, remove and weigh Crystal 2

ABBREVIATED LOG OF RECHARGE RUN NO. 4 (REFERENCE NO. 185)

(continued)

	Elapsed Time (hr: min)	
Crystal 3	24:43	Crucible recharged with 6.755 kg
	26:53	Seed dipped
	27:46	DF mode of growth lost on crown; remelt
	28:30	Seed dipped
		Growth of neck and crown
	29:41	Over shoulder; start of body growth
		Growth of 13-3/4 inch length
	34:41	Growth terminated
		Cool, remove and weigh Crystal 3
Crystal 4	35:36	Crucible recharged with 7.210 kg
	36:33	Seed dipped
	36:41	DF mode of growth lost on crown; remelt
	37:46	Seed dipped
	38:43	DF mode of growth lost on crown; remelt
	40:	Seed dipped
	41:42	DF mode of growth lost at 1 inch below crown; remelt
	42:51	Seed dipped
	43:08	DF mode of growth lost on crown; remelt
	43:48	Seed dipped
	44:11	DF mode of growth lost on crown; remelt
	44:51	Seed dipped
	45:30	DF mode of growth lost on crown; remelt
	46:13	Seed dipped
	46:25	DF mode of growth lost on crown; terminate experiment
		Solidification of polycrystalline ingot to empty crucible

ABBREVIATED LOG OF RECHARGE RUN NO. 5 (Reference No. 188)

Charge Mass - 20 kg; Seed Orientation - 100; Crystal Diameter - 4 inch (nominal)

	Elapsed Time (hr:min)	
Crystal 1	- -	Crucible charged with 20 kg
	0:0	Power on at 68 kw
	0:20	Power increased to 79 kw
	1:40	Charge molten; power reduced to 55.6 kw
	2:17	Seed dipped
		Growth of neck and crown
	3:04	Over shoulder; start of body growth
		Growth of 14 inch length
	7:00	Growth terminated
		Cool, remove, and weigh Crystal 1
Crystal 2	8:05	Crucible recharged with 6.360 kg
	8:45	Charge molten
	9:10	Seed dipped
	9:45	DF mode of growth lost on crown, remelt
	10:57	Seed dipped
	11:31	DF mode of growth lost on crown; remelt
	11:50	Seed dipped
	12:30	DF mode of growth lost on crown; remelt
	13:10	Seed dipped
		Growth of neck and crown
	14:11	Over shoulder; start of body growth
		Growth of 13¼ inch length
	18:50	Growth terminated
		Cool, remove and weigh Crystal 2

ABBREVIATED LOG OF RECHARGE RUN NO. 5. (REFERENCE NO. 188)

(continued)

	Elapsed Time (hr:min)	
Crystal 3	19:58	Crucible recharged with 7.065 kg
	20:38	Charge molten
	21:27	Seed dipped
		Growth of neck and crown
	22:32	Over shoulder; start of body growth
		Growth of 33 inch length
	33:10	Growth terminated

ABBREVIATED LOG OF RECHARGE RUN NO. 6 (REFERENCE NO. 190)

Charge Mass - 20 kg; Seed Orientation - 100; Crystal Diameter - 5 inch (nominal)

	Elapsed Time (hr:min)	
Crystal 1	- -	Crucible charged with 20 kg
	0:0	Power on at 68 kw
	0:10	Power increased to 78 kw
	3:54	Seed dipped
		Growth of neck and crown
	4:28	Over shoulder; start of body growth
		Growth of 13½ inch length
	9:13	Growth terminated
		Cool, remove, and weigh Crystal 1
Crystal 2	11:01	Crucible recharged with 10.840 kg
	11:32	Charge molten
	12:10	Seed dipped
		Growth of neck and crown
	13:35	Over shoulder; start of body growth
		Growth of 13 inch length
	18:07	Growth terminated
		Cool, remove, and weigh Crystal 2
Crystal 3	19:13	Crucible recharged with 9.875 kg
		Delay to permit minor modification of equipment
	23:23	Seed dipped
		Growth of neck and crown
	24:41	Over shoulder; start of body growth
		Growth of 12-3/4 inch length
	29:18	Growth terminated
		Cool, remove, and weigh Crystal 3

ABBREVIATED LOG OF RECHARGE RUN NO. 6 (REFERENCE NO. 190)

(continued)

	Elapsed Time (hr:min)	
Crystal 4	29:58	Crucible recharged with 10.215 kg
	31:03	Charge molten
	31:32	Seed dipped
		Growth of neck and crown
	32:45	Over shoulder; start of body growth
		Growth of 13 inch length
	37:21	Growth terminated
		Cool, remove, and weigh Crystal 4
		Crucible recharged with 9.875 kg
Crystal 5	40:19	Seed dipped
		Growth of neck and crown
	42:29	Over shoulder; start of body growth
		Growth of 9-3/8 inch length
	45:57	Growth terminated
		Recharge run terminated

SUMMARY OF ECONOMIC ANALYSIS

Table I	Waferco: Basis for Economic Evaluation Showing the Introduction of Cost Reduction Features
Table II	Waferco: 1978 Facilities and Operation Summary
Table III	Waferco: 1980 Facilities and Operation Summary
Table IV	Waferco: 1982 Facilities and Operation Summary
Table V	Waferco: 1984 Facilities and Operation Summary
Table VI	Waferco: 1986 Facilities and Operation Summary
Table VII	Waferco: 1978 Cost Summary
Table VIII	Waferco: 1980 Cost Summary
Table IX	Waferco: 1982 Cost Summary
Table X	Waferco: 1984 Cost Summary
Table XI	Waferco: 1986 Cost Summary

TABLE I

WAFERCO: BASIS FOR ECONOMIC EVALUATION SHOWING THE
INTRODUCTION OF COST REDUCTION FEATURES

	<u>Czochralski Growth</u>	<u>Multiblade Slicing</u>
1978	Current Equipment - one crystal (18 kg) from 12 inch diameter crucible - 55 percent after-grind yield - 2 kg per h solidification rate	Current Equipment - 300 slices per cycle - purchased blade packages - 0.67 m ² per kg - 3.5 mm per h cutting rate
1980	Current Equipment Modified for Recharging FIVE CRYSTALS (100 KG) FROM ONE 12 INCH DIAMETER CRUCIBLE - 55 percent after-grind yield - 2 kg per h solidification rate	Current Equipment - 300 slices per cycle IN-PLANT BLADE PACKAGE FABRIC- ATION 0.80 M ² PER KG LOW-COST SLURRY VEHICLE - 3.5 mm per h cutting rate
1982	Extended-capability Equipment - five crystals (100 kg) from one 12 inch diameter crucible 70 PERCENT AFTER-GRIND YIELD - 2 kg per h solidification rate	Extended-capability Equipment 900 SLICES PER CYCLE - in-plant blade package fabric- ation 0.89 M ² PER KG PARTIAL SLURRY RECLAMATION - 3.5 mm per h cutting rate
1984	Extended-capability Equipment FIVE CRYSTALS (148.5 KG) FROM ONE 14 INCH DIAMETER CRUCIBLE 75 PERCENT AFTER-GRIND YIELD REWORK OF DISLOCATED CRYSTAL 3 KG PER H SOLIDIFICATION RATE	Extended-capability Equipment 1000 SLICES PER CYCLE LOW-COST BLADE STOCK 1.0 M ² PER KG WATER-BASED SLURRY; RECLAIMED ABRASIVE - 3.5 mm per h cutting rate
1986	Extended-capability Equipment FIVE CRYSTALS (269 KG) FROM ONE 16 INCH DIAMETER CRUCIBLE 80 PERCENT AFTER-GRIND YIELD - rework of dislocated crystal - 3 kg per h solidification rate	Extended-capability Equipment - 1000 slices per cycle - low-cost blade stock - 1.0 m ² per kg - water-based slurry; reclaimed abrasive 9.0 MM PER H CUTTING RATE

TABLE II

WAFERCO: 1978 FACILITIES AND OPERATION SUMMARY

Annual Poly Consumption: 14,406 kg; Annual Sheet Production: 5,300 m²

	<u>Czochralski Growth</u>	<u>Multiblade Slicing</u>
<u>Factory Specifications</u>	2 furnaces negligible misc. equipment 160 ft ² floor space 1/3 operator per shift	9 saws \$5,000 misc. equipment 550 ft ² floor space 1 operator per shift
<u>Process Specification</u>	10 cm diameter ingot 20 kg virgin poly per cycle 1 kg left in crucible 55% after-grind yield 15 hour growth cycle 65% furnace utilization 720 cycles per year	10 cm diameter ingot 300 slices per cycle 0.014 inch (0.36 mm) slice 0.010 inch (0.25 mm) kerf 95% slicing yield 30 hour slicing cycle 95% saw utilization 2,368 cycles per year
<u>Annual Materials Input</u>	720 crucibles (12 in.OD) 3.88x10 ⁵ ft ³ argon 49 single-crystal seeds \$10,800 misc. supplies	2,368 blade packs 4,736 gal. vehicle 14,208 lb. abrasive \$11,500 misc. supplies
<u>Annual Energy Input</u>	5.41x10 ⁵ kw-hr	7.5x10 ⁴ kw-hr

TABLE III

WAFERCO: 1980 FACILITIES AND OPERATION SUMMARY

Annual Poly Consumption: 43,884 kg; Annual Sheet Production: 20,000 m²

	<u>Czochralski Growth</u>	<u>Multiblade Slicing</u>
<u>Factory Specifications</u>	4 furnaces negligible misc. equip- ment 400 ft ² floor space 1 operator per shift 1/3 foreman per shift	34 saws \$63,000 misc. equipment 1760 ft ² floor space 2 operators per shift 1/2 assembler per shift
<u>Process Specifications</u>	10 cm diameter ingot 106 kg virgin poly per cycle 1 kg left in crucible 55% after-grind yield 68 hour growth cycle 85% furnace utilization 414 cycles per year	10 cm diameter ingot 300 slices per cycle 0.012 inch (0.30 mm) slice 0.008 inch (0.20 mm) kerf 95% slicing yield 30 hour slicing cycle 95% saw utilization 8,935 cycles per year
<u>Annual Materials Input</u>	414 crucibles (12 in.OD) 1.65x10 ⁶ ft ³ argon 138 single-crystal seeds \$36,000 misc. supplies	25,997 lb. steel 17,870 gal. vehicle 53,610 lb. abrasive \$18,700 misc. supplies
<u>Annual Energy Input</u>	1.68x10 ⁶ kw-hr	2.00x10 ⁵ kw-hr

TABLE IV

WAFERCO: 1982 FACILITIES AND OPERATION SUMMARY

Annual Poly Consumption: 109,710 kg; Annual Sheet Production: 67,000 m²

	<u>Czochralski Growth</u>	<u>Multiblade Slicing</u>
<u>Factory Specifications</u>	10 furnaces negligible misc. equip- ment 1,000 ft ² floor space 2-1/3 operator per shift 1/3 foreman per shift	38 saws \$105,000 misc. equipment 2,350 ft ² floor space 2 operators per shift 3/4 assembler per shift
<u>Process Specifications</u>	10 cm diameter ingot 106 kg virgin poly per cycle 1 kg left in crucible 70% after-grind yield 68 hour growth cycle 85% furnace utilization 1,035 cycles per year	10 cm diameter ingot 900 slices per cycle 0.012 inch (0.30 mm) slice 0.006 inch (0.15 mm) kerf 95% slicing yield 30 hour slicing cycle 95% saw utilization 9,989 cycles per year
<u>Annual Materials Input</u>	1,035 crucibles (12 in.OD) 4.13x10 ⁶ ft ³ argon 345 single-crystal seeds \$106,000 misc. supplies	82,820 lb. steel 59,868 gal vehicle 119,736 lb. abrasive \$54,400 misc. supplies
<u>Annual Energy Input</u>	4.19x10 ⁶ kw-hr	5.00x10 ⁵ kw-hr

TABLE V

WAFERCO: 1984 FACILITIES AND OPERATION SUMMARY

Annual Poly Consumption: 388,584 kg; Annual Sheet Production: 353,000 m²

	<u>Czochralski Growth</u>	<u>Multiblade Slicing</u>
<u>Factory Specifications</u>	28 furnaces negligible misc. equip- ment 5,600 ft ² floor space 6 operators per shift 1 foreman per shift	180 saws \$255,000 misc. equipment 10,000 ft ² floor space 10 operators per shift 1 assembler per shift
<u>Process Specifications</u>	10 cm diameter ingot 128.5 kg virgin poly per cycle 26.5 kg rework poly per cycle 1.5 kg left in crucible 75% after-grind yield 69.1 hour growth cycle 90% furnace utilization 3,024 cycles per year	10 cm diameter ingot 1,000 slices per cycle 0.012 inch (0.30 mm) slice 0.004 inch (0.10 mm) kerf 95% slicing yield 30 hour slicing cycle 95% saw utilization 47,314 cycles per year
<u>Annual Materials Input</u>	3,024 crucibles (14 in.OD) 12.3x10 ⁶ ft ³ argon 1,008 single-crystal seeds \$360,000 misc. supplies	413,806 lb. steel 283,866 gal. vehicle 283,866 lg. abrasive \$302,000 misc. supplies
<u>Annual Energy Input</u>	14.6x10 ⁶ kw-hr	2.50x10 ⁶ kw-hr

TABLE VI

WAFERCO: 1986 FACILITIES AND OPERATION SUMMARY

Annual Poly Consumption: 1,430,176 kg; Annual Sheet Production: 1,330,000 m²

	<u>Czochralski Growth</u>	<u>Multiblade Slicing</u>
<u>Factory Specifications</u>	88 furnaces negligible misc. equipment 17,600 ft ² floor space 13 operators per shift	201 saws \$326,000 misc. equipment 11,000 ft ² floor space 11 operators per shift 2 assemblers per shift
<u>Process Specifications</u>	13 cm diameter ingot 239 kg virgin poly per cycle 37 kg rework poly per cycle 2 kg left in crucible 80% after-grind yield 109.3 hour growth cycle 90% furnace utilization 5,984 cycles per year	13 cm diameter ingot 1,000 slices per cycle 0.012 inch (0.30 mm) slice 0.004 inch (0.10 mm) kerf 95% slicing yield 15.8 hour slicing cycle 95% saw utilization 100,202 cycles per year
<u>Annual Materials Input</u>	5,984 crucibles(16 in.OD) 38.7x10 ⁶ ft ³ argon 1,995 single-crystal seeds \$825,000 misc. supplies	462,083 lb. steel 317,000 gal. vehicle 317,000 lb. abrasive \$393,000 misc. supplies
<u>Annual Energy Input</u>	52.1x10 ⁶ kw-hr	2.80x10 ⁶ kw-hr

TABLE VII

WAFERCO: 1978 COST SUMMARY (in inflated dollars)

CZOCHELSKI GROWTH

<u>Description</u>		<u>Amount</u>	<u>Unit Cost</u>	<u>Extended Cost</u>
<u>EQPT</u>	furnace	2	\$115,000	\$230,000
<u>SQFT</u>	floor space	160 ft ²	\$ 116	\$ 18,560
<u>DLAB</u>	operator	1 prsn-yr	\$ 12,247	\$ 19,595
<u>MATS</u>	crucible	720	\$ 210	\$151,200
	argon	3.88 x 10 ⁵ ft ³	\$ 0.0494	\$ 19,167
	seed	49	\$ 150	\$ 7,350
	misc.	- -	- -	\$ 10,784
<u>UTIL</u>	electricity	5.41 x 10 ⁵ kw-hr	\$ 0.03187	\$ 17,242

C ₁ x EQPT	\$ 112,700	<u>QUAN</u>	5.3 x 10 ³ m ²
C ₂ x SQFT	\$ 18,560		
C ₃ x DLAB	\$ 41,150	<u>PRICE(1978\$)</u>	\$83.0 per m ²
C ₄ x MATS	\$ 245,051		
C ₅ x UTIL	\$ 22,415	<u>PRICE(1975\$)</u>	\$69.0 per m ²
	\$ 439,876		

MULTIBLADE SLICING

<u>EQPT</u>	saw	9	\$ 20,000	\$180,000
	misc.	- -	- -	\$ 5,000
<u>SQFT</u>	floor space	550 ft ²	\$ 116	\$ 63,800
<u>DLAB</u>	operator	4.7 prsn-yr	\$ 10,694	\$ 50,262
<u>MATS</u>	blade pack	2,368	\$ 63.80	\$151,078
	vehicle	4,736 gal.	\$ 2.50	\$ 11,840
	abrasive	14,208 lb.	\$ 1.70	\$ 24,154
	misc.	- -	- -	\$ 11,472
<u>UTIL</u>	electricity	7.5 x 10 ⁴ kw-hr	\$ 0.03187	\$ 2,390

C ₁ x EQPT	\$ 90,650	<u>QUAN</u>	5.3 x 10 ³ m ²
C ₂ x SQFT	\$ 63,800		
C ₃ x DLAB	\$105,550	<u>PRICE(1978\$)</u>	\$98.3 per m ²
C ₄ x MATS	\$258,107		
C ₅ x UTIL	\$ 3,107	<u>PRICE(1975\$)</u>	\$81.8 per m ²
	\$521,214		

<u>PPOLY</u>	7,923 kg	\$ 54.50	\$431,804
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C₄ x PPOLY \$561,345

TOTALS

ADD-ON PRICE (1978 \$)	\$181 per m ²	TOTAL PRICE (1978 \$)	\$287 per m ²
ADD-ON PRICE (1975 \$)	\$151 per m ²	TOTAL PRICE (1975 \$)	\$239 per m ²

TABLE VIII

WAFERCO: 1980 COST SUMMARY (in inflated dollars)

CZOCHELSKI GROWTH

	Description	Amount	Unit Cost	Extended Cost
EQPT	furnace	4	\$147,600	\$590,400
SQFT	floor space	400 ft ²	\$ 130	\$ 52,000
DLAB	operator	4.7 prsn-yr	\$ 14,285	\$ 67,140
	foreman	1.5 prsn-yr	\$ 19,047	\$ 28,571
MATS	crucible	414	\$ 245	\$101,430
	argon	1.65 x 10 ⁶ ft ³	\$ 0.0576	\$ 95,040
	seed	138	\$ 175	\$ 24,150
	misc.	- -	- -	\$ 36,022
UTIL	electricity	1.68 x 10 ⁶ kw-hr	\$ 0.0400	\$ 67,200

C ₁ x EQPT	\$ 289,296	QUAN	20 x 10 ³ m ²
C ₂ x SQFT	\$ 52,000		
C ₃ x DLAB	\$ 200,993	PRICE(1980\$)	\$48.2 per m ²
C ₄ x MATS	\$ 333,635		
C ₅ x UTIL	\$ 87,360	PRICE(1975\$)	\$35.6 per m ²
	\$ 963,284		

MULTIBLADE SLICING

EQUPT	saw	34	\$ 22,898	\$778,532
	misc.	- -	- -	\$ 62,970
SQFT	floor space	1760 ft ²	\$ 130	\$228,800
DLAB	operator	9.4 prsn-yr	\$ 12,789	\$120,217
	assembler	2.4 prsn-yr	\$ 11,020	\$ 26,448
MATS	steel	25,997 lb.	\$ 5.83	\$151,563
	vehicle	17,870 gal.	\$ 1.17	\$ 20,908
	abrasive	53,610 lb.	\$ 1.98	\$106,148
	misc.	- -	- -	\$ 18,662
UTIL	electricity	2.00 x 10 ⁵ kw-hr	\$ 0.0400	\$ 8,000

C ₁ x EQPT	\$ 412,336	QUAN	20 x 10 ³ per m ²
C ₂ x SQFT	\$ 228,800		
C ₃ x DLAB	\$ 307,997	PRICE(1980\$)	\$67.3 per m ²
C ₄ x MATS	\$ 386,465		
C ₅ x UTIL	\$ 10,400	PRICE(1975\$)	\$49.8 per m ²
	\$1,345,998		

PPOLY	43,884 kg	\$ 61	\$2,676,924
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C₄ x PPOLY \$3,480,001

TOTALS

ADD-ON PRICE (1980 \$)	\$ 115 per m ²	TOTAL PRICE (1980 \$)	\$289 per m ²
ADD-ON PRICE (1975 \$)	\$ 85.4 per m ²	TOTAL PRICE (1975 \$)	\$214 per m ²

TABLE IX

WAFERCO: 1982 COST SUMMARY (in inflated dollars)

		Description	Amount	Unit Cost	Extended Cost
CZOCHELSKI GROWTH	EQPT	furnace	10	\$229,000	\$2,290,000
	SQFT	floor space	1,000 ft ²	\$ 146	\$ 146,000
	DLAB	operator	10.8 prsn-yr	\$ 16,662	\$ 180,719
		foreman	1.5 prsn-yr	\$ 22,217	\$ 33,326
	MATS	crucible	1,035	\$ 286	\$ 296,010
		argon	4.13 x 10 ⁶ ft ³	\$ 0.0672	\$ 277,536
		seed	345	\$ 204	\$ 70,380
		misc.	- -	- -	\$ 105,570
	UTIL	electricity	4.19 x 10 ⁶ kw-hr	\$ 0.0501	\$ 210,010
		C ₁ x EQPT	\$1,122,100	QUAN 67 x 10 ³ m ²	
		C ₂ x SQFT	\$ 146,000		
		C ₃ x DLAB	\$ 449,495	PRICE(1982\$) \$44.3 per m ²	
		C ₄ x MATS	\$ 974,345		
		C ₅ x UTIL	\$ 273,013	PRICE(1975\$) \$29.1 per m ²	
			\$2,964,953		
MULTIBLADE SLICING	EQUPT	saw	38	\$ 52,432	\$1,992,416
		misc.	- -	- -	\$ 104,864
	SQFT	floor space	2,350 ft ²	\$ 146	\$ 343,100
	DLAB	operator	9.4 prsn-yr	\$ 14,917	\$ 140,220
		assembler	3.5 prsn-yr	\$ 12,854	\$ 44,989
	MATS	steel	82,820 lb.	\$ 6.80	\$ 563,176
		vehicle	59,868 gal.	\$ 1.36	\$ 81,420
		abrasive	119,736 lb.	\$ 2.31	\$ 276,590
		misc.	- -	- -	\$ 54,420
	UTIL	electricity	5.00 x 10 ⁵ kw-hr	\$ 0.0501	\$ 25,050
		C ₁ x EQPT	\$1,027,667	QUAN 67 x 10 ³ m ²	
		C ₂ x SQFT	\$ 343,100		
		C ₃ x DLAB	\$ 388,939	PRICE(1982\$) \$45.7 per m ²	
		C ₄ x MATS	\$1,268,288		
		C ₅ x UTIL	\$ 32,565	PRICE(1975\$) \$30.1 per m ²	
			\$3,060,559		
		PPOLY	109,710 kg	\$ 38	\$4,168,980
		C ₄ x PPOLY	\$5,419,674		
TOTALS	ADD-ON PRICE (1982 \$)		\$ 90.0	TOTAL PRICE (1982 \$)	\$ 171 per m ²
	ADD-ON PRICE (1975 \$)		\$ 59.2	TOTAL PRICE (1975 \$)	\$ 113 per m ²

TABLE X

WAFERCO: 1984 COST SUMMARY (in inflated dollars)

		Description	Amount	Unit Cost	Extended Cost
CZOCHELSKI GROWTH	EQPT	furnace	28	\$222,700	\$6,235,000
	SQFT	floor space	5,600 ft ²	\$ 164	\$ 918,400
	DLAB	operator	28.2 prsn-yr	\$ 14,993	\$ 422,803
		foreman	4.7 prsn-yr	\$ 25,914	\$ 121,796
	MATS	crucible	3,024	\$ 226	\$ 683,424
		argon	12.3 x 10 ⁶ ft ³	\$ 0.0726	\$ 892,980
		seed	1,008	\$ 238	\$ 239,904
		misc.	- -	- -	\$ 359,856
	UTIL	electricity	14.6 x 10 ⁶ kw-hr	\$ 0.0628	\$ 916,880
MULTIBLADE SLICING	C ₁ x EQPT	\$3,055,444	QUAN	353 x 10 ³ m ²	
	C ₂ x SQFT	\$ 918,400	PRICE(1984\$)	\$ 25.9 per m ²	
	C ₃ x DLAB	\$1,143,658			
	C ₄ x MATS	\$2,829,013			
	C ₅ x UTIL	\$1,191,944	PRICE(1975\$)	\$ 15.2 per m ²	
		\$9,138,459			
	EQUPT	saw	180	\$ 51,025	\$9,184,500
		misc.	- -	- -	\$ 255,125
	SQFT	floor space	10,000 ft ²	\$ 164	\$1,640,000
TOTALS	DLAB	operator	47.0 prsn-yr	\$ 17,399	\$ 817,753
		assembler	4.7 prsn-yr	\$ 14,993	\$ 70,467
	MATS	steel	413,806 lb.	\$ 3.17	\$1,311,765
		vehicle	283,866 gal.	\$ 0.56	\$ 158,965
		abrasive	283,866 lb.	\$ 2.70	\$ 766,438
		misc.	- -	- -	\$ 301,506
	UTIL	electricity	2.50 x 10 ⁶ kw-hr	\$ 0.0628	\$ 157,000
	C ₁ x EQPT	\$ 4,625,416	QUAN	353 x 10 ³ m ²	
	C ₂ x SQFT	\$ 1,640,000	PRICE (1984\$)	\$ 33.0 per m ²	
	C ₃ x DLAB	\$ 1,865,262			
	C ₄ x MATS	\$ 3,300,276			
	C ₅ x UTIL	\$ 204,100	PRICE (1975\$)	\$ 19.3 per m ²	
		\$11,635,054			
	PPOLY	388,584 kg	\$ 29		\$11,268,936
	C ₄ x PPOLY	\$14,649,616			
	ADD-ON PRICE (1984 \$)	\$ 58.9 per m ²	TOTAL PRICE (1984 \$)	\$100 per m ²	
	ADD-ON PRICE (1975 \$)	\$ 34.5 per m ²	TOTAL PRICE (1975 \$)	\$ 58.8 per m ²	

TABLE XI

WAFERCO: 1986 COST SUMMARY (in inflated dollars)

CZOCHRALSKI GROWTH

Description		Amount	Unit Cost	Extended Cost
EQPT	furnace	88	\$240,000	\$21,120,000
SQFT	floor space	17,600 ft ²	\$ 184	\$ 3,238,400
DLAB	operator	61.1 prsn-yr	\$ 17,488	\$ 1,068,517
MATS	crucible	5,984	\$ 344	\$ 2,058,496
	argon	38.7 x 10 ⁶ ft ³	\$ 0.0847	\$ 3,278,272
	seed	1,995	\$ 278	\$ 554,610
	misc.	- -	- -	\$ 825,142
UTIL	electricity	52.1 x 10 ⁶ kw-hr	\$ 0.0788	\$ 4,104,277

C ₁ x EQPT	\$10,348,800	QUAN	1,330 x 10 ³ m ²	
C ₂ x SQFT	\$ 3,238,400			
C ₃ x DLAB	\$ 2,243,885	PRICE(1986\$)	\$22.5 per m ²	
C ₄ x MATS	\$ 8,731,476			
C ₅ x UTIL	\$ 5,335,560	PRICE(1975\$)	\$11.8 per m ²	
	\$29,898,121			

EQUPT	saw	201	\$ 54,982	\$11,051,382
	misc.	- -	- -	\$ 326,170
SQFT	floor space	11,000 ft ²	\$ 184	\$ 2,024,000
DLAB	operator	51.7 prsn-yr	\$ 20,294	\$ 1,049,200
	assembler	9.4 prsn-yr	\$ 17,488	\$ 164,387
MATS	steel	462,083 lb.	\$ 3.70	\$ 1,709,707
	vehicle	317,000 gal.	\$ 0.65	\$ 206,050
	abrasive	317,000 lb.	\$ 3.15	\$ 998,550
	misc.	- -	- -	\$ 392,706
UTIL	electricity	2.80 x 10 ⁶ kw-hr	\$ 0.0788	\$ 220,640

C ₁ x EQPT	\$ 5,575,000	QUAN	1,330 x 10 ³ m ²	
C ₂ x SQFT	\$ 2,024,000			
C ₃ x DLAB	\$ 2,548,533	PRICE (1986\$)	\$11.1 per m ²	
C ₄ x MATS	\$ 4,299,117			
C ₅ x UTIL	\$ 286,832	PRICE (1975\$)	\$5.78 per m ²	
	\$14,733,481			

PPOLY		1,430,176 kg	\$ 19.2	\$27,459,379

C ₄ x PPOLY	\$35,697.;92			

ADD-ON PRICE (1986 \$)	\$33.6 per m ²	TOTAL PRICE (1986 \$)	\$60.5 per m ²	
ADD-ON PRICE (1975 \$)	\$17.6 per m ²	TOTAL PRICE (1975 \$)	\$31.5 per m ²	

MULTIBLADE SLICING

TOTALS