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SILICON WEB PROCESS DEVELOPMENT

SECOND QUARTERLY REPORT

July 1, 1977 - September 30, 1977

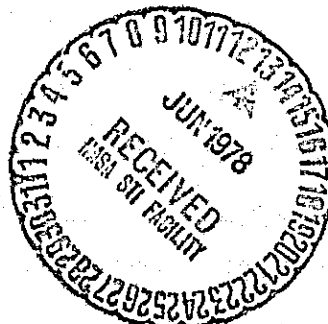
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## ABSTRACT

Thirty-five (35) furnace runs were carried out during this quarter, of which 25 produced a total of 120 web crystals. Lengths in excess of two meters and widths over 27 mm were achieved. A variety of lid and susceptor configurations have been used to modify the thermal geometry of the system in an effort to grow wider and longer web crystals of high quality.

The two main thermal models for the dendritic growth process have been completed and are being used to assist the design of the thermal geometry of the web growth apparatus. The first model, a finite element representation of the susceptor and crucible, has been refined to give greater precision and resolution in the critical central region of the melt. The second thermal model, which describes the dissipation of the latent heat to generate thickness-velocity data, has been completed. Both models have been validated by comparison of predicted results with experimental data; both are in excellent agreement with reality. The second model also gives temperature distributions in the growing web so that it can be applied to the evaluation of thermally generated stress in the crystal.

Width versus length data generated for dendritic web crystals indicate that the widening rates of the crystal are related to the lid design, however, the differences between most of the lid configurations are relatively small. More importantly, the data indicates that even in the current system which has only a 76 mm diameter crucible, ultimate widths of dendritic web crystals should be in the 30 to 40 mm range. Thickness measurements on the crystals being grown are in excellent agreement with the predictions of the thermal model, and modifications of the lid designs to increase the growth velocity are being investigated.

As longer and wider web is being grown, strain in some crystals has been noted. In these cases growth runs are intentionally terminated because of crystal warpage, rather than because of temperature fluctuations as in the past. Residual stress measurements based on crystal splitting are being made in some of the crystals being grown and these results will be correlated with predictions of the thermal models. The models will then be used to generate susceptor lid configurations producing smaller thermal stresses in the growing crystal.

In addition to the residual stress measurements, both x-ray topographic and etching examinations have been made on web crystals. To date, the results confirm earlier conclusions that most dislocations are generated in either the initial button or in the bounding dendrites. These studies are being continued to correlate crystal perfection with the growth conditions and with solar cell performance.

Dendritic web samples have been fabricated into solar cells using a standard cell configuration and a standard process for a  $N^+P-P^+$  configuration. The data indicates that web material can make very good solar cells with AM1 efficiencies greater than 14%. In a given fabrication run, cells made from a given crystal have almost identical characteristics. Further, analysis of the cell characteristics indicates that  $N^+P$  junction on web cells is of extremely high quality. Work is presently in progress to correlate the cell performance with the material quality. Studies are also underway to develop improved processing techniques for dendritic web material.

The detailed engineering design was completed for a new dendritic web growth facility of greater width capability than previous facilities. Fabrication of component parts and assembly have begun.

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## 1. INTRODUCTION

The overall intent of this program is to further develop the dendritic web crystal growth process to the extent that it supports the economic goals of the Large Area Silicon Sheet Task of the Low-Cost Silicon Solar Array Project.

The ability of this process to produce crystals for high efficiency solar cells, 14 percent AM-1 or higher, is well known and has been demonstrated in pilot production and in this program. The prior state of development of the process did not, however, have sufficient throughput to satisfy the cost goals of the LSSA Project.

Consequently, a key goal of this program is to increase the throughput of the process in terms of greater width (to 7.5 cm), greater speed (to 7.5 cm/min) and greater length (to >10 meters) within the web thickness range of 100 to 200  $\mu\text{m}$ . These goals are being sought via two growth facilities: an existing facility which is undergoing continued development and a new facility now in the construction and assembly phase.

The existing facility has produced crystals to 2.7 cm width and 3 meters length. Growth rates for useful material in the range of 100 to 200  $\mu\text{m}$  thickness have reached 2.5 cm/min although some experimental growth at rates as high as 10 cm/min have been achieved for very thin web. The goal of this phase of the program is to achieve a growth width equal to the 5 cm dimensional capacity of the facility and a growth rate of 5 cm/minute. Both facilities have provision for adding polycrystalline silicon feed material to the melt for achieving a quasi-continuous growth.

The new facility, when completed, will have capacity to meet the full throughput goals stated above. The growth run experiments with both facilities will be used to identify the necessary on-line process parameter measurements and control.



Computer thermal models are a critical factor in the successful development of the process. The models are verified and refined initially by temperature measurements of sensors located in the thermal system and subsequently by correlation with actual web growth results. As the program progresses, a large volume of data is being generated and related to growth conditions, crucible system geometry, crystal quality, etc.

During the process development period with both facilities the web crystals grown will be used for several purposes. The growth is routinely selected and evaluated in terms of its dimensional, crystalline, electronic, and solar cell properties. For solar cell evaluation a "standard" fabrication procedure suitable for web crystals is used. Crystals are also provided for another program goal which is developing improved solar cell fabrication techniques especially suited to web crystals. Finally, selected web crystals and solar cells are being sent to JPL.

Growth runs will also be performed to determine the interaction of controlled amounts of selected impurities with growth conditions and parameters. This evaluation will be performed in a third web growth facility which is also used for other web programs.

As the program progresses, an economic analysis will be developed and updated in response to continued process development.

## 2. TECHNICAL DISCUSSION

### Experimental Web Growth

The major objectives of the work during this reporting period have been (1) to improve the thermal geometry as required to increase web width, (2) to gather baseline thermal data both for system characterization and for input to the thermal modeling, (3) to verify experimentally the results of the thermal modeling, and (4) to grow web material for evaluation and solar cell processing.

During this reporting period, 35 furnace runs were made, of which 25 were productive web growth runs. A total of 120 identified web crystals were grown. Pertinent data for each is tabulated in Section 6.1. Continuous lengths of over two meters and widths over 27 mm were obtained.

The experimental procedures in the web growth runs have involved systematic variations in lid and susceptor configurations so as to alter heat losses and thus refine the thermal geometry of the melt in an effort to grow wider web crystals. In order to strengthen the data base, configurational features, e.g., slot geometry, are sometimes used which are not necessarily expected to be productive from a web throughput point of view, but provide valuable information as part of a systematic series of changes. We feel that this approach provides an extended data base which will be very beneficial in the long run. In addition, this approach permits us to test and verify the results of the thermal modeling. Thus, we have established a consistency between experiment and modeling results which give confidence in the usefulness of the modeling for guidance in future design changes.

As longer and wider web crystals have been grown, we have observed in some cases crystal deformation due to thermally induced strain. This has resulted in prematurely terminating the crystal

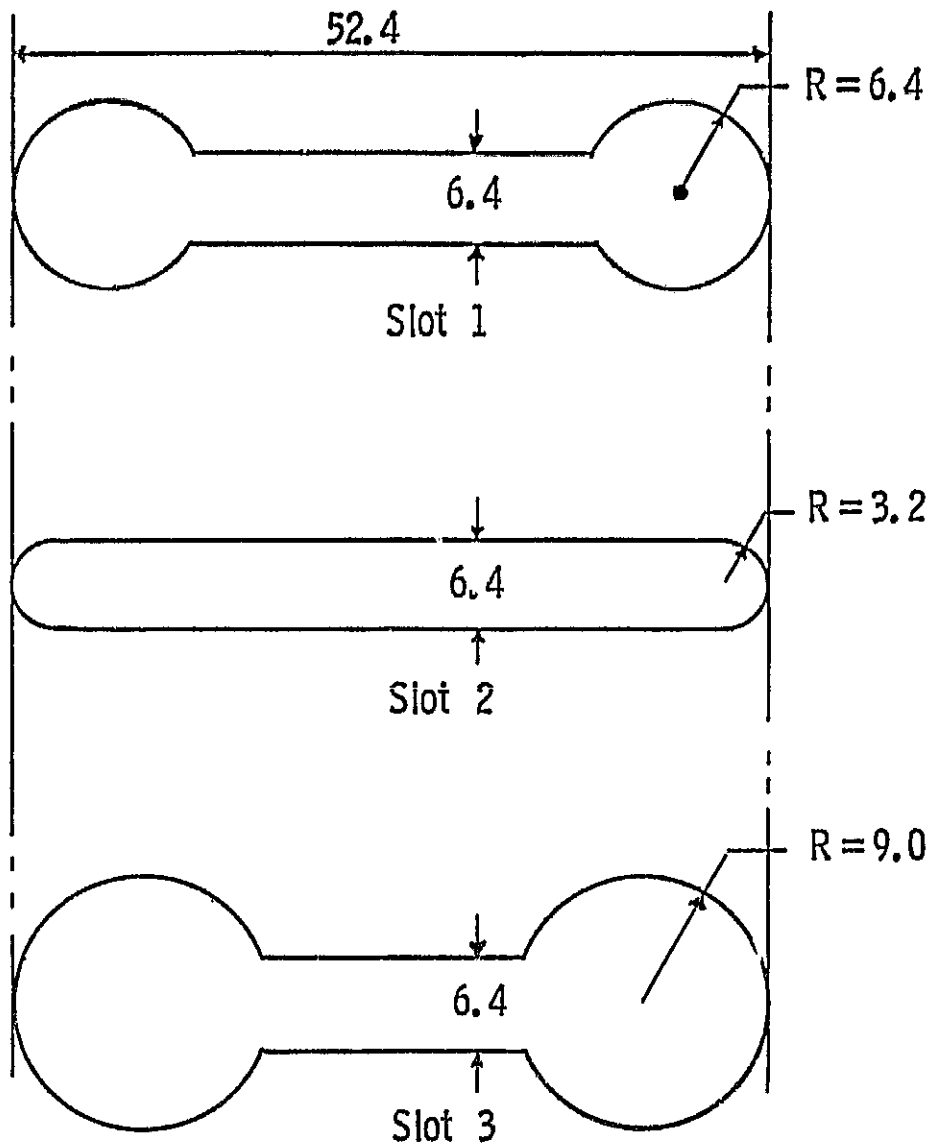
growth while the web was still widening. Thus the full width capabilities of our experimental configurations have not yet been realized. This factor introduces an extra thermal requirement in the design of experimental configurations in addition to maximizing web width. The origin of the thermally induced strain and strategies for minimizing its harmful effects are discussed in more detail later in this report.

Crucibles fabricated by Amersil Corp. have been obtained and used during this period. These have substantially improved run-to-run reproducibility by minimizing the variations in fit between crucible and susceptor which had plagued us previously.

#### Thermal Modeling Related to Dendritic Web Growth

In the present development program two separate thermal models are being developed as design tools to facilitate the development of appropriate crucible and susceptor configurations. The first model, which calculates the three dimensional temperature distribution in the susceptor and melt, has as its goal the development of a temperature distribution conducive to the growth of wide dendritic web. The second model, which analyzes the dissipation of the latent heat of fusion both to the web itself and to the supercooled melt, has as its main goal the development of a slot geometry conducive to increased growth velocity. This model also provides the basic temperature data necessary for an analysis of any thermally induced stress in the growing ribbon.

During this quarter, the first model was completed and temperature distributions were calculated for a series of lid slot geometries, some of which are shown in Fig. 1. These initial results showed considerable scatter in the temperature plot, a "grain" which was attributed to the rather coarse net of connections used to model the radiation transfer from the melt surface. The melt surface was modeled as a rather large number of elements, and several elements were grouped to a single radiation link. Initially, it was thought that the "grain"



Dimensions in mm

Fig. 1 - Lid slot geometries

in the output could be tolerated and reasonable results obtained by averaging the points. In one instance, however, the calculations showed an unmistakable temperature minimum in the temperature profile when there was no physical reason for such a minimum to occur. Since a modest amount of precision if not accuracy was desired, especially near the center of the melt, the model was refined by making radiation links to every surface node. These three links represented the radiation transfer to the slot, to the lid, and to the wall of the susceptor above the melt. When this modified version of the model was run, the scatter in the temperature profiles was essentially eliminated and the unexpected minimum was not observed. Two typical melt surface temperature profiles are shown in Fig. 2. One of the profiles is for the lid geometry with slot 1, and the other profile is for slot 5, a modification of slot 2 where the total length has been increased to 70 mm. Also shown in Fig. 2 is the temperature profile along a radius perpendicular to the slot. This profile is essentially the same for both slots. It can be seen that the temperature profile parallel to the slot is essentially flat for 1 to 1.5 cm either side of center, which is consistent with the observation that the web continues to widen even at 27 mm total width.

It should be noted that the temperatures plotted in Fig. 2 are "adjusted temperatures;" the computed temperatures have been adjusted to give 1685°K at the center of the slot. Although measured temperatures in the susceptor wall have been used as the boundary conditions for the model there is some uncertainty in the actual thermocouple calibrations, etc. and the actual calculated temperatures differ by about 6° from the measured temperatures in a system. From a thermal model standpoint, this differential is not significant, and considering the uncertainties in the thermal constants of the materials, especially the heat transfer from the molybdenum susceptor to the silicon melt, this agreement seems excellent.

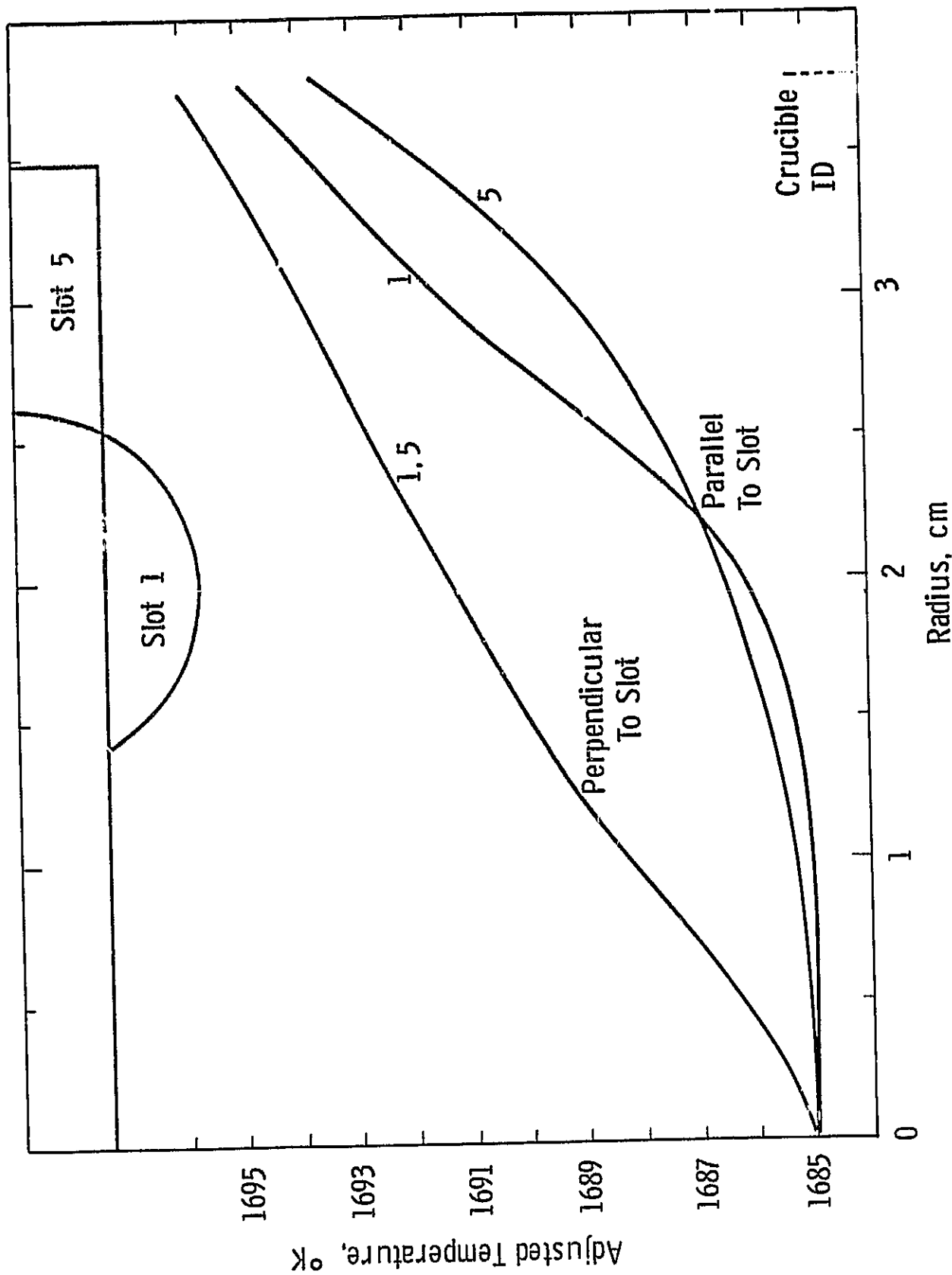


Fig. 2 - Calculated temperatures on melt surface

These results seem to validate the thermal model and it can now be used as a design tool for further development of susceptor and lid configurations. Two extensions of the model are presently under development. The first is a circular crucible and susceptor similar to the present design but with a 106 mm diameter crucible instead of the present 79 mm crucible; the susceptor dimensions are unchanged (see Drawings 1689B31, items 1 and 2, and Drawing 8520D49). In addition, an elongated crucible and susceptor are being modeled (Drawings 8520D52 and 1691B62).

The second thermal model describes the modes of dissipation of the latent heat of freezing in order to develop thermal designs for faster growth. As with any ribbon growth technique, part of the latent heat is dissipated through the growing ribbon itself. In addition, since dendritic web grows from a supercooled melt, some of the latent heat is dissipated to the liquid silicon. Both heat loss modes have been modeled, and a thickness-velocity curve has been generated for a lid configuration which has actually been used to grow web. A comparison of the experimentally observed thickness-velocity data with the predictions of the model is shown in Fig. 3. It can be seen that the agreement between theory and experiment is excellent, which gives a high degree of confidence both for the overall model and for the individual components of the model.

The particular lid design for the case shown in Fig. 3 was the starting geometry in a series of experiments on the effect of beveling the edges of the slot. The lid was relatively thick (8 mm) and had no bevel on the slot. As can be seen, this low heat loss condition gave relatively slow growth, e.g., a 150  $\mu\text{m}$  web would grow at only 1.3 cm/min. A 3 mm x 3 mm bevel on the slot increased this velocity to about 2 cm/min, and a 6 mm x 6 mm bevel increased the velocity to about 3.5 cm/min. In addition to such parameters as the effective lid thickness (slot bevel), the thermal model also indicates that other parameters such as lid temperature, top shield temperature, slot width, melt level below lid, etc. can be used to tailor the temperature profile in the growing web.

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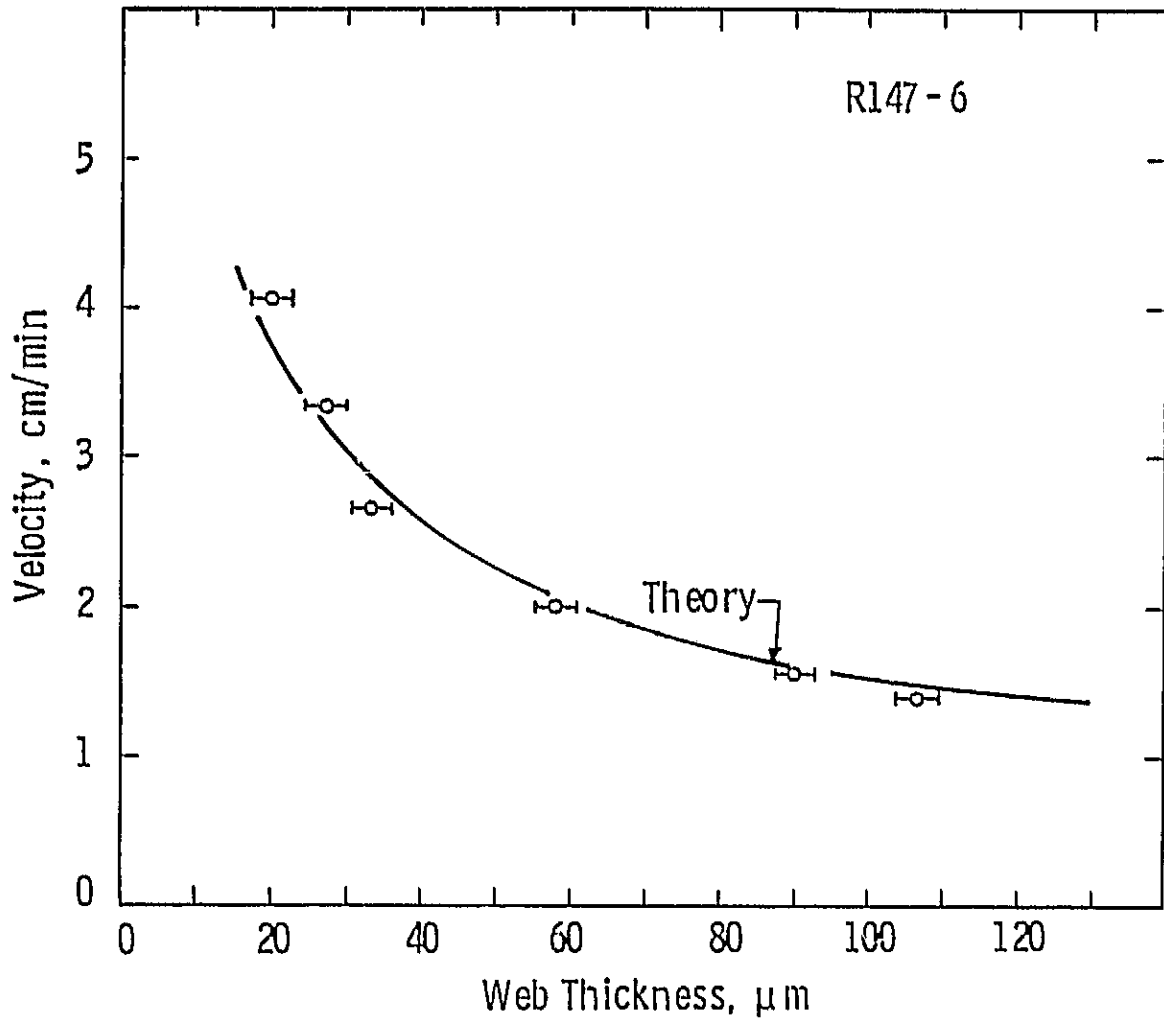


Fig. 3 — Thickness - velocity behavior



Since these factors all produce a multitude of other interactions in the growth behavior, continued study and development is necessary to arrive at a configuration which could be considered optimum.

#### Mechanical and Dimensional Characterization

In keeping with the program emphasis on the growth of wide dendritic web, much of the material characterization has been dimensional. The widening rate of the crystals is of particular interest, as well as the steady state width for a given system configuration. The widening rate data for the crystals grown during the quarter is shown in Table 1, both in terms of  $dW/dL$  and  $dW/dt$ . There is a moderate amount of scatter in the data, but some trends can be discerned. First, the first crystals pulled during a run tend to have the fastest widening rates. This apparently has to do with the level of the melt below the crucible lid which in turn affects the heat loss from the meniscus. Second, crystals pulled from melts having beveled slots in the lid widen faster than crystals pulled through unbeveled slots. This apparently is the result of modification of the heat loss from the meniscus at the edges of the dendritic web. The variations in slot geometry should have little effect on the temperature distribution near the center of the melt as a whole, but could have a somewhat greater effect on the heat loss from the meniscus regions. A variety of slot designs are being considered for other reasons and the effect on the widening rate will be studied.

Perhaps more important than the widening rate itself, is the tendency for the crystals to reach a steady state width. In most instances, the dendritic webs are continuing to widen when growth is purposely terminated. Although in some instances a tendency for steady state width is seen, most widening behavior is exemplified by the width-length curve shown in Fig. 4 for crystals R172-4 and R172-6. This result is consistent with the calculated melt temperature profile for slot 5 shown in Fig. 2. Even with a 76 mm diameter crucible, the

Table 1  
Dendritic Web Widening Rates

Crystal Number	Widening Rate $10^3 \times \frac{dW}{dL}$	Thickness $\mu\text{m}$	Widening Rate $10^3 \times \frac{dW}{dt}$ cm/min	Remarks
140-1	7.25	210	16.0	
140-6	6.45	152	13.4	
141-1	7.35	315	15.3	
141-2	6.68	215	13.9	
141-4	7.40	203	15.4	
147-3	7.05	127	11.7	7.9 mm thick lid with 6.4 x 57.2 mm straight slot; no bevel in slot.
147-4	6.15	130	9.5	"
147-5	5.50	116	8.36	"
149-1	6.65	127	12.9	12.7 mm dia. holes added to above slot.
149-4	5.70	125	9.5	"
150-6	7.67	121	16.1	"
151-5	8.95	124	16.1	"
151-7	9.10	114	16.4	"
151-9	7.90	124	13.1	"
152-1	9.20	193	17.7	Lid as above with 3 x 3 mm beveled slot.
152-2	8.35	175	16.1	"
153-1	8.25	188	16.0	"
153-3	8.16	132	15.8	"

Table 1 (cont.)  
Dendritic Web Widening Rates

Crystal Number	Widening Rate $10^3 \times \frac{dW}{dL}$	Thickness $\mu\text{m}$	Widening Rate $10^3 \times \frac{dW}{dt}$ cm/min	Remarks
154-1	8.14	150	15.0	
154-2	7.92	150	14.3	
154-3	6.14	155	11.9	
154-6	5.76	165	9.6	
156-1	6.90	160	13.4	Dogbone slotted lid; 6.3 mm wide terminated by 12.7 mm dia. holes on 44.5 mm centers; 3 x 3 mm bevel. (oxide problems)
156-2	4.80	168	9.3	
156-3	5.54	150	10.5	
157-1	7.78	165	15.1	"
157-3	7.78	140	15.1	
157-4	4.80	122	8.7	
160-1	8.65	210	18.0	"
160-2	8.67	165	16.8	
160-3	7.80	170	14.0	
163-1	8.30	146	15.6	Straight slot, 6.4 mm wide by 66.6 mm long. No level.
163-2	7.00	120	12.6	
165-1	7.80	145	15.1	
165-2	6.40	162	11.5	"

Table 1 (cont.)  
Dendritic Web Widening Rates

Crystal Number	Widening Rate $10^3 \times \frac{dW}{dL}$	Thickness $\mu\text{m}$	Widening Rate $10^3 \times \frac{dW}{dt}$ cm/min	Remarks
170-1	7.76	173	15.1	Straight slot, 6.4 mm wide by 66.6 long. No bevel.
170-2	6.67	130	12.9	
170-3	7.30	128	13.1	
171-2	6.10	148	11.8	Slot as above, but beveled at ends.
171-3	6.10	150	11.8	
172-4	7.00	160	14.0	Straight slot, 7.4 mm wide by 66.6 mm long, beveled at slot ends only.
172-6	8.10	150	14.6	
173-2	7.70	165	15.0	
173-4	7.10	113	15.6	"
173-5	7.06	113	13.5	

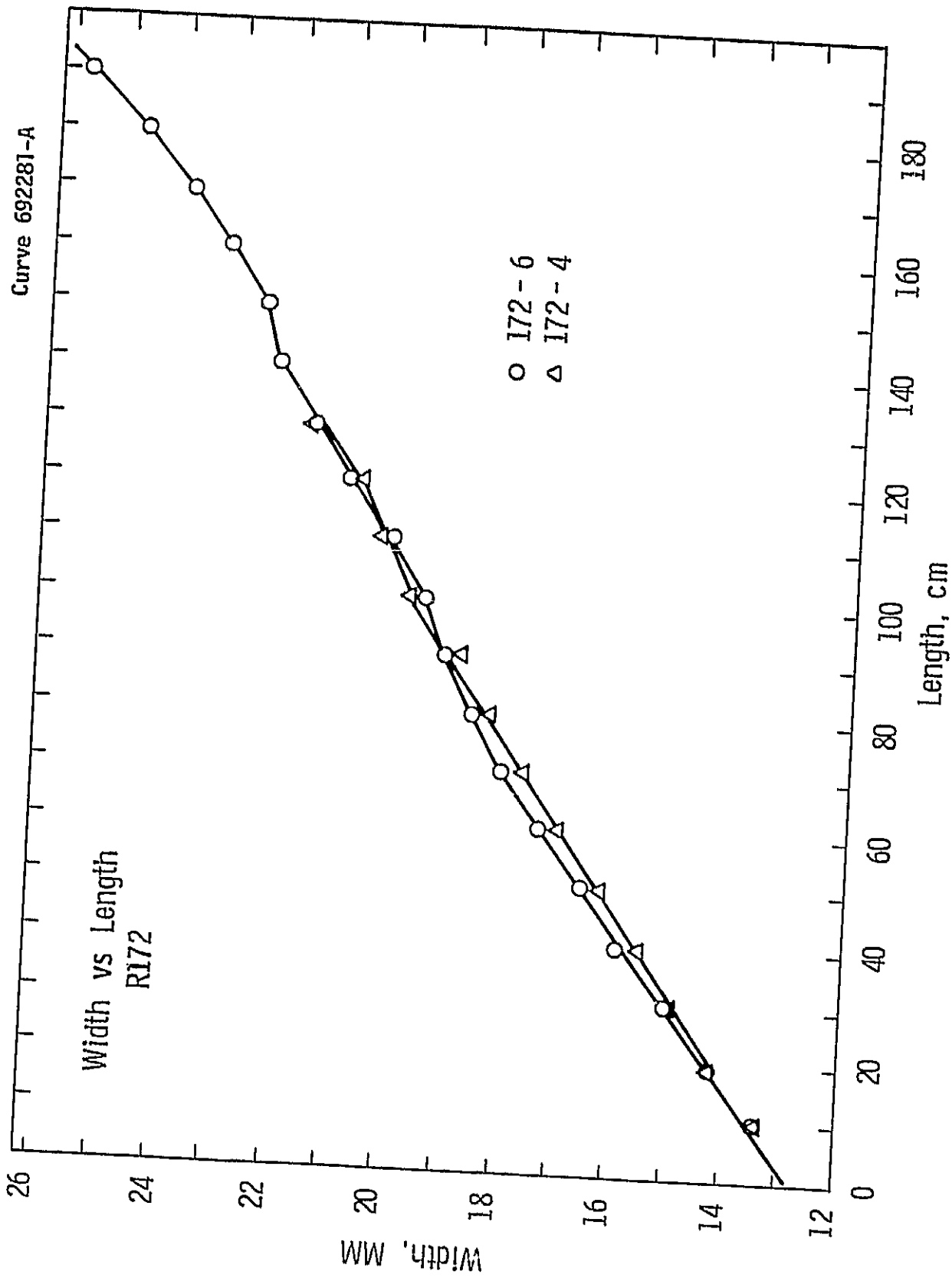


Fig. 4 - Typical dendritic web widening

ultimate steady state width for dendritic web has not yet been reached. Data from runs where some curvature is seen in the W-L curve leads to an estimate of 30 to 40 mm as the steady state width for the present system. This would be consistent with the calculated thermal profiles.

### Web Thickness

The thickness of a web crystal growing at a given velocity depends on the supercooling of the melt and on the ability of the web itself to radiate heat. Both of these factors were included in the thermal modeling for the velocity-thickness calculations, and it was found that such factors as the lid thickness and bevel on the slot should have a strong effect. Web thickness measurements have, therefore, been directed toward validating the thermal model; specific data is given in Table 1 with the widening rate data and in the run summary, Appendix 6.1. For practical reasons, the growth velocity for most runs is adjusted to give crystal thicknesses between 100 and 200  $\mu\text{m}$ .

### Residual Stress

Strain in dendritic web crystals is becoming an increasingly important consideration as longer and wider crystals are being grown. Early in the program, the growth of many crystals terminated spontaneously because of what we believe to be convectively generated temperature fluctuations in the melt. With improvement in thermal conditions, this phenomenon has become rare and instead some crystals develop a warp and twist after several meters of growth and the pull must be terminated in order to remove the crystal through the withdrawal duct. This behavior is suggestive of the thermally generated stress found by people working with other ribbon growth techniques in that the problem is accentuated in wider crystals. An excellent general discussion of the phenomenon is given in the Mobil-Tyco Annual Progress Report of September, 1976. (1)

Briefly, a non-linear temperature profile along the length of the growing ribbon can cause stresses which in turn can produce both plastic and elastic deformations in the ribbon. These stresses are functions of both the ribbon width and the higher derivatives of the temperature profile. For example, a major component of the axial stress is given by

$$\sigma_{zz} = \frac{\alpha Y W^2}{6} \left( 1 - 3 \frac{y^2}{W^2} \right) \frac{d^2 T}{dz^2}$$

where  $\alpha$  is the thermal expansivity,  $Y$  is Young's modulus,  $W$  is the half width of the ribbon, the  $z$  coordinate is along the length of the ribbon and the  $y$  coordinate is in the plane of the ribbon perpendicular to  $z$ . Other stress components depend on higher derivatives and also have a higher power in the width dependence. Thus as wider ribbons are grown, thermal stresses should become of increasing importance. In order to reduce the stress in the growing crystal, the curvature of the temperature profile must be reduced. Other ribbon growth techniques accomplish this flattening of the temperature gradient by the use of after heaters; in the dendritic web technique, the thermal analysis developed for increasing the velocity also shows that a great deal of control over the temperature profile is possible by careful design of the susceptor cover. In fact, in some instances, the second derivative,  $d^2 T/dz^2$  is actually negative over a portion of the crystal near the melt; the hot slotted lid actually is heating the web.

The experimental study of the residual stress in dendritic web crystals has only recently been started. The technique which has been used to characterize any residual stress in the dendritic web is the well known method of measuring the curvature of a ribbon which has been split down the center. The relevant equation is

$$\sigma = \frac{Y W}{4} b_2$$

where  $\sigma$  is the stress (before splitting, the ribbon has a tension  $\sigma$  at the edges, and a compression  $-\sigma$  at the center),  $Y$  is Young's modulus,  $W$  is the total width of the ribbon and  $b_2$  is the coefficient in quadratic expression for the width of the split as a function of length

$$y = b_0 + b_1x + b_2x^2$$

Here  $y$  is the separation between the two halves of the crystal and  $x$  is a coordinate along the length of the crystal. Fitting the experimental data to this quadratic form removes a variety of experimental uncertainties such as the origin of the crack, and any possible tilt in the  $x$  axis or constant separation of the two pieces of the crystal. In practice, the actual data shows a coefficient of determination of 0.998 or better, indicating an excellent agreement of the experiment to the assumed model. Data for some of the web samples is shown in Table 2. The stress values seem to be generally smaller than reported for other ribbon growth techniques. Although it may be a fortuitous result, the crystal with the lowest residual stress was grown with a lid which should have had a smaller  $d^2T/dz^2$  than the other lids. Further design studies and experiments along this direction are being undertaken.

Table 2

<u>Crystal No.</u>	<u>Width</u> cm	<u>Thickness</u> $\mu\text{m}$	<u>Growth Speed</u> cm/min	<u>Residual Stress</u> $\text{dynes/cm}^2$	<u>Residual Stress</u> psi
R136-9	1.60	188	1.94	$2.4 \times 10^8$	3480
R153-1	1.65	170	1.94	$2.0 \times 10^8$	2915
R160-2	2.28	165	1.94	$2.1 \times 10^8$	3090
R165-4	1.52	84	1.94	$1.9 \times 10^8$	2712
R172-5	1.46	173	1.80	$1.0 \times 10^8$	1522



### Crystal Perfection Studies

To date, only a limited amount of study has been given to the crystalline perfection of the dendritic web crystals. A limited number of x-ray topographs and etching studies have been done, however, and so far the results are in agreement with the observations of earlier investigators.<sup>(2-6)</sup> Dislocations apparently arise primarily from two sources: the button portion of the crystal, and as bursts in the bounding dendrites. Various possible techniques will be investigated for reducing these imperfections in the crystal. Although the thermal stress may be a significant factor in the degeneration of the web crystals, other mechanisms involving dislocations cannot be ruled out, and these studies will be continued at an accelerated pace.

### Solar Cell Studies

Since solar cells are the anticipated end product of a dendritic web crystal growth process, solar cell studies are being conducted as part of the overall growth program. Two general tasks are being undertaken in the solar cell area: 1) the use of a standard cell design and fabrication process to provide an evaluation of the material on a semi-routine basis and 2) an investigation of techniques for improving the efficiency of solar cells made on dendritic web.

The solar cell design chosen as a standard for material evaluation is one that has been in use for some while in other studies.<sup>(7)</sup> The general design of the test device is shown in Fig. 5. This design was originally intended for making standard test cells on Czochralski material, and contains a number of test devices in addition to the 1 cm square cell in the center of the pattern. When this mask is used for fabricating devices on dendritic web material, only the central portion of the patterns is used. A typical dendritic web cell and a "baseline" cell on a Czochralski wafer are shown in Fig. 6.



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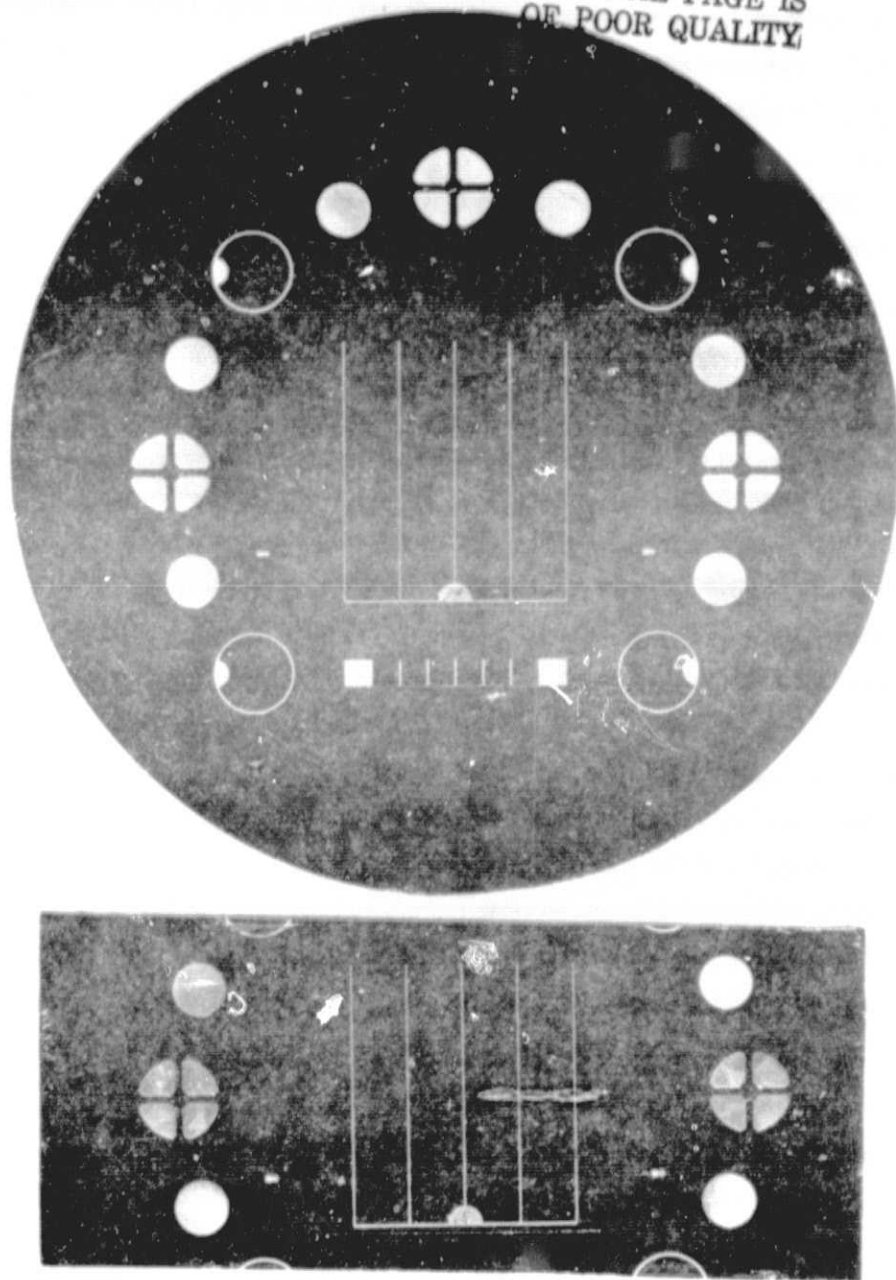


Fig. 6 Dendritic Web and Baseline Czoehralski Cells

The device processing technique being used for cell fabrication is also very similar to that being used for other studies, with several small changes appropriate to the web material being processed. First, the web surface is in a highly perfect condition as grown, so no other surface preparation other than an oxide removing rinse is done. More importantly, since the material being grown on this program is of the order of 150  $\mu\text{m}$  thick (6 mils), the cell structure includes a  $\text{P}^+$  layer on the back surface to provide a minority carrier reflecting back surface field (BSF). The entire process is summarized in the sample run sheet shown as Fig. 7. In a given fabrication run, the individual cell blanks are identified so that material from several crystals can be run and separately identified. Also included in every run are five Czochralski wafers run as baseline material to give a check on the processing reproducibility.

Once the cells are fabricated, they are measured under simulated AM1 illumination and the data fed to a computerized data bank for reduction and printout of the device characteristics. A typical printout is shown in Fig. 8. The Baseline cells are identified by a "B" in their ID, and dendritic web cells by an "R" (except for 1R\* which is a standard cell for calibrating the light source). An asterisk by the ID means that sample was not used in calculating the group averages. ISC is the short circuit current; VOC the open circuit voltage; IP the peak power; FF the fill factor, EFF is the efficiency and OCD is a lifetime measured from the diode decay of the device. The other data, LOG(IO), N, and R are parameters used in fitting the data to a standard model. The computer program computes the parameter averages and standard deviations for the baseline cells and the experiment cells and also gives percent of baseline for the experiment cell averages.

Generally, the solar cells fabricated on this program are measured without an anti-reflectance (AR) coating; if an AR coating is used, it is noted on the data printout. Several sets of cells have

Web grown silicon N+/P/P+ Solar Cells (Back Side, P+ identified by number)

Start Date:		PROCESSING LOG	Run or Sample RIBON	
Material:			9C40 RIBON 77	
Quantity:	Engr. P. Blais			
Date Tech.	Process	Special Instructions, Measurements, etc.	Disp. C E	
	Identification	Scribe serial numbers on either side of web near one end to identify P+ side of structure		
	CLEAN (1)	HF:H <sub>2</sub> O (1 to 10 ratio) dip 15 sec. H <sub>2</sub> O <sub>2</sub> - NH <sub>4</sub> , H <sub>2</sub> O <sub>2</sub> - HCl		
	BORON DIFF. (2)	Boron Deposition, BBr <sub>3</sub> @ 960°C 2-20-2 min. Numbered side up. Very slow pull (5 min/2 inches)		
	REMOVE (3) OXIDE	3:1 (H <sub>2</sub> O:HF) until all oxide is removed R <sub>s</sub> = _____ Ω/□ (Target value = 60 Ω/□)		
	CVD (4) SiO <sub>2</sub>	Deposit 5000 Å CVD oxide @ 850°C on back (numbered) side. Slow cool by reducing power very slowly (10 min.)		
	ETCH (5) SILICON	Mask CVD SiO <sub>2</sub> with apeizon wax etch silicon on bare side, strip wax, H <sub>2</sub> SO <sub>4</sub> @ 90°C for 5 min. 44 cc HF + 26 cc HNO <sub>3</sub> + 29 cc Acetic 5°C, Etch time = 5-10 sec Etch silicon between 5 to 8 μm deep Check Conductivity Type		
	CLEAN (6)	HF:H <sub>2</sub> O (1 to 10 Ratio) dip 5 sec. H <sub>2</sub> O <sub>2</sub> - NH <sub>4</sub> , H <sub>2</sub> O <sub>2</sub> - HCl		
	POC <sub>2</sub> (7) DIFFUSION	Diffusion Temp. 825°C Time 50 min. Source Temp. = 0°C Flow Rates 200 cc/min - N <sub>2</sub> /Source; 1560 cc/min - N <sub>2</sub> Carrier 62.5 cc/min O <sub>2</sub> Slow cool by pulling 3 inches/5 min.		
	REMOVE (8) OXIDE	Strip deposition oxide 3:1 (H <sub>2</sub> O:HF) Measure, R <sub>s</sub> = _____ Ω/□ (Target value = 60 Ω/□)		
	CLEAN (9)	H <sub>2</sub> SO <sub>4</sub> : H <sub>2</sub> O <sub>2</sub> 87°C, 5 min. Strip all oxides in darkness with buffered HF. 10/1 H <sub>2</sub> O/HF Dip 10 sec		
	METAL (10)	Top Side (side not numbered) only Ti 1500 Å 20 Å/sec Pd 500 Å 10 Å/sec Ag 20000 Å 40 Å/sec		
	PHOTO (11) RESIST	Mask #1 (contact grid) Waycoat IC, 4000 rpm, h = 1.7 μm Exposure time = 3 sec (I <sub>d</sub> = 0.2 μa)		
	ETCH (12) METAL	Ag-20-60 H <sub>2</sub> O <sub>2</sub> & Ammonium Hydrox. -10-15 sec. Pd + 30 cc HCl + 10 cc HNO <sub>3</sub> -5 sec Ti-150 cc H <sub>2</sub> O + 60cc HCl + 30cc Ammonium Fl. 5 sec		
	CLEAN (13)	H <sub>2</sub> SO <sub>4</sub> at 75°C - 3 min Rinse in D.I. H <sub>2</sub> O		
	METAL (14) BACK	Ti 1500 Å - Pd 500 Å Back side is numbered Ag 20 KA		
	SINTFR (15)	Temperature 550 °C Time 15 Min. Atmosphere = H <sub>2</sub> , 500cc/min.		
	PHOTO- (16) RESIST	Mask #2 (Mesa) Waycoat SC, 7000 rpm, h - 4.0 μm Exposure time = 15 ser (I <sub>2</sub> = 0.6 μa), Apiezon wax back side		
	ETCH (17) SILICON	44 cc HF + 26 cc HNO <sub>3</sub> + 29 cc Acetic 5°C, Etch time = 5-10 sec Etch silicon between 5 to 8 μm deep, Talystep _____ μm.		
	TEST (18)			

original 6/3/77

Fig. 7. Solar Cell Run Sheet

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70621R RIBON 1003 RETEST W071 00 000  
RIBON 10/20/77 AM1: PO=91.60MW/CM<sup>2</sup> AR COATING

ID	ISC	VOC	IP	LOG(10)	N	k	FF	EFF	ODD
1R*	22.50	.549	20.11	-6.162	2.03	-.34	.712	9.30	.00
1B	31.00	.579	28.77	-8.419	1.40	.21	.765	14.51	15.60
2B	32.50	.583	30.19	-8.527	1.38	.28	.764	15.31	19.50
3B	31.00	.569	28.72	-8.216	1.42	.14	.763	14.24	12.35
4B*	23.90	.524	14.99	-4.686	2.86	10.86	.345	4.56	.00
5B.*	31.40	.547	28.90	-6.697	1.76	-1.67	.807	14.65	13.00
1k	30.40	.561	28.32	-8.950	1.26	.49	.762	13.75	9.10
5k	29.30	.542	26.72	-6.945	1.67	-.27	.746	12.53	4.94
6k	29.80	.539	26.94	-6.498	1.81	-.29	.732	12.44	1.82
8k	29.60	.538	24.92	-4.011	3.62	-2.73	.677	11.40	3.38

AVERAGES: 70621R BASELINE W071 00 000

	31.50	.577	29.23	-8.387	1.40	.21	.764	14.69	15.82
STD	.71	.006	.68	.129	.01	.06	.001	.45	2.92

70621R RIBON 1003 RETEST

	29.78	.545	26.72	-6.601	2.09	-.70	.729	12.53	4.81
STD	.40	.009	1.21	1.758	.90	1.22	.032	.83	2.71

PERCENT OF BASFLINE

	94.5	94.5	91.4	121.3	149	*****	95.5	85.3	30.4
STDZ	3.4	2.6	6.4	22.5	67	814.2	4.3	8.5	25.9

Fig. 8 Sample Data Print-Out

been measured before and after a standard AR coating of  $850 \overset{\circ}{\text{Å}}$  of SiO and the results indicate that the efficiency of the cell is increased by  $41.2 \pm 2\%$ . A cell with an AM1 efficiency of 10.2% uncoated, will thus yield a 14.4% cell when coated. Therefore, in order to facilitate comparison of our data with cell data from other sources, we will report cell efficiencies converted to AR coated values unless otherwise noted.

Several general conclusions can be stated from the data generated so far. First, within a cell fabrication run, data from a given dendritic web crystal clusters very tightly. This would indicate that solar cell parameters are a valid means for characterizing the web material. Cell data from a given crystal processed in different runs is somewhat more scattered, but still is representative of the crystal. Second, dendritic web can be processed into extremely good solar cells; some crystals yield devices with greater than 14% AM1 efficiency. Conversely, web samples chosen from crystals with obvious defects such as lineage or mosaic structure yield cells with only about 10.3% efficiency. Moderate quality material yields cells in the 12 to 13 percent range. Studies are now in progress to correlate solar cell performance with the structural perfection of the starting material.

The second aspect of the solar cell program is to develop processing techniques for dendritic web which will yield solar cells with higher efficiency. The current approach to this task is to consider that the processing of dendritic web is the same as for Czochralski material if due account is taken of the generally smaller thickness of the web. Studies so far indicate that the actual junction on the web is of extremely high quality. Attention is, therefore, being given to the matter of the back surface P<sup>+</sup> layer. Presently this is being fabricated by a boron diffusion process, which has an industry reputation for some variability. A process based on an aluminum doped back surface is under investigation. This process has the promise of greater reproducibility as well as possibly providing optical as well as electrical reflection

at the cell back surface. Since solar cells with greater than 14% efficiency have already been processed with the boron technique, enhanced optical reflectivity could bring this figure above 15%. Currently, equipment and materials are being set up to implement this process.

#### Facility Design and Construction

Design has been completed for a new web growth facility which will have dimensional capacity for web widths to four inches. Mechanical and electrical design of the system closely follows the concept of the most recent existing facility and is scaled up where needed to satisfy the greater dimensional requirements. The thermal design of the system is based upon thermal models and recent experience. Fabrication of components and assembly are in progress.

A conceptual design has been developed to permit, at some possible future time, conversion of the new facility from low frequency induction heating to more conventional and lower cost resistance heating.

The existing web growth facility is in the process of being modified to permit web growth of width up to three inches.



### 3. PLANS FOR THE NEXT PERIOD

Systematic changes in susceptor and lid configuration aimed at maximizing web width and minimizing thermally induced strain will be continued, utilizing guidance from the thermal modeling results.

The experimental effort to date has utilized 75 mm diameter crucibles. Crucibles of 100 mm diameter have been ordered and will be tested in the near future.

Thermal models of two new crucible/susceptor configurations will be completed and applied to the design of appropriate hardware. The first new design will be a circular crucible/susceptor with a 100 mm ID crucible. The second will be an elongated susceptor for use in the new web growth facility. The second thermal model (model of latent heat dissipation) will be applied to the problem of reducing curvature in the temperature profile in the web. The object will be to reduce possible thermal stress in the growing crystal.

Much of the characterization of the dendritic web will still be of a dimensional character. In addition, measurement of residual stress in appropriate sample will be continued to evaluate the effect of lid design. Similarly measurement of crystalline perfection will be continued and expanded. Solar cell fabrication to characterize the dendritic web material will be continued.

The new web growth facility will be completed and placed in operation. The existing facility will be modified to provide greater capacity.

4. NEW TECHNOLOGY

No new technology occurred during this reporting period.

## 5. REFERENCES

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6. APPENDIX

6.1 Growth Run Detail Summary for This Reporting Period

6.2 Complete Set of Design Drawings for Silicon Web Growth Facility

GROWTH RUN DETAIL SUMMARY

Run No.	Web No.	$\Delta T$ °C	Pull Rate cm/min	Length cm	Width mm	Thickness µm	Comments
R-139		Dry run to test temperature stability and response time.					
R-140	1	4.4	2.2	75	12.5/16.7	203	Same configuration as R-138 116.3 gm Si 2 x 1017 DOPSIL pellet
	2	4.8	2.2	18	14.2	190	
	3	4.7	2.2	16	12.5/14	168	
	4	5.4	2.2	32	13.5/15.1	147	
	5	-	2.2	13	14.2/15.2	145	
	6	5.9	2.1	81	13/17.4	152	
	7	4.5	2.0	134	11.7/13	145	
R-141	1	4.8	2.1	59	12.6/16.6	250	Same configuration as R-138 110.3 gm Si 2 x 1017 DOPSIL pellet
	2	4.7	2.0	75	12.7/16.4	212	
	3	5.0	2.0	39	15/15.8	160	
	4	3.9	2.0	84	14.7/20.2	212	
R-142	1	5.2	2.0	28	12/14.2	183	0.95 cm high x 2.70 cm long after shields added along slot 114.9 gm Si 2 x 1017 DOPSIL pellet Plagued by oxide deposition
	2	4.7	1.8	32	15/16.8	208	
R-143		Abort, inadequate power coil returned					
R-144		Power Failure					
R-145		Lid dvg. 2612C82-07 119.3 gm Si 2 x 1017 DOPSIL pellet					
R-146		Same configuration as R-143 119.6 gm Si 2 x 1017 DOPSIL pellet					
R-147		Dry Run, Check controls					
R-148		Dry Run, Frequency meter check of coil frequency					

GROWTH RUN DETAIL SUMMARY

Run No.	Web No.	$\Delta T$ °C	Pull Rate cm/min	Length cm	Width mm	Thickness mm	Comments
R-147	1	4.7	1.7	42	8.3/9.8	108	Same configuration as R-143 118.2 gm Si 2 x 1017 DOPSIL Pellet
	2	4.8	1.7	41	8/9.2	115	
	3	*	1.7	77	9.2/13.7	133	
	4	*	1.5	101	8.9/14.3	145	
	5	*	1.5	136	8.6/15.7	150	
	6	*	1.5-4.0	102	-	10.7-20	
R-148	1	3.9	1.7	8	9.5	170	Same configuration as R-143 119.2 gm Si 2 x 1017 DOPSIL Pellet
	2	2.8	1.7	36	9.6/11.2	168	
	3	3.7	1.7	7	7.8	145	
	4	3.7	1.7	29	9/10.2	163	
	5	3.3	1.7	17	9.4/10.2	165	
	6	-	2.1	12	9.4	93	
	7	4.3	1.7	12	13.2/13.5	163	
	8	3.7	1.8	31	9.8/10.4	125	
	9	3.8	1.8	15	9.6/9.9	113	
	10	-	1.7	56	8.6/10.8	118	
R-149	1	*	1.9	220	10.7/21.1	113	Lid dwg. 2612C82-08 119.4 gm Si 2 x 1017 DOPSIL pellet
	2	*	1.8	201	10.8/18.5	135	
	3	3.6	1.8	11	-	100	
	4	-	1.7	117	8/14.3	125	
R-150	1	3.6	1.8	18	8.8/9.8	150	Same configuration as R-149 119.2 gm Si 2 x 1017 DOPSIL Pellet
	2	-	1.8	6	11.7	155	
	3	3.4	1.8	12	8.9/9.6	138	
	4	3.6	1.8	22	6/7	110	
	5	-	1.7	24	9.3/10.2	138	
	6	3.0	1.7	71	8.2/13.6	121	
	7	3.6	1.5-3.3	92	7/10.6	114-30	

\* Strong drift of "hold" during growth.

GROWTH RUN DETAIL SUMMARY

Run No.	Web No.	$\Delta T$ °C	Pull Rate cm/min	Length cm	Width mm	Thickness µm	Comments
R-151	1	3.8	1.9	20	10.3/10.8	138	Six vent slots added to bottom of lid No.-08  119.8 gm Si 2 x 1017 DOPSIL Pellet
	2	3.9	1.8	7	9.8	163	
	3	4.1	1.8	9	10.6/11.0	145	
	4	2.9	1.8	40	9/11.2	150	
	5	2.9	1.8	127	8/18.6	124	
	6	2.4	1.8	41	11.6/14.6	138	
	7	2.5	1.8	89	11.4/18.0	111	
	8	2.5	1.7	6	8.9/9.3	109	
	9	2.5	1.7	132	10.5/20.3	123	
R-152	1	3.0	1.9	101	8.5/16.7	175	Slot beveled, .125 x .125 in. To lid No. -08. 119.9 gm Si 2 x 1017 DOPSIL pellet
	2	3.4	1.9	126	10.5/18.4	150	
	3	4.8	1.9	13	13.4/14	150	
	4	6.0	1.9	145	8.8/11.8	118	
R-153	1	4.0	1.9	195	8.8/23.2	170	Same configuration as R-152 120-1 gm Si 2 x 1017 DOPSIL Pellet Thickness vs velocity run
	2	-	1.9	20	8.8/9.3	108	
	3	3.3	1.8	143	10/19.3	163	
	4	4.2	1.8-2.9	118	8.7/15.1	109-51	

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GROWTH RUN DETAIL SUMMARY

<u>Run No.</u>	<u>Web No.</u>	<u>ΔT</u> <u>°C</u>	<u>Pull Rate</u> <u>cm/min</u>	<u>Length</u> <u>cm</u>	<u>Width</u> <u>mm</u>	<u>Thickness</u> <u>μm</u>	<u>Comments</u>
R-154	1	3.9	1.9	111	8.8/16.5	150	Accumulate more growth experience on repeat of same configuration as R-152 $1/17$ 119.9 gm Si 2 x 10 <sup>17</sup> DOP SIL pellet
	2	3.9	1.8	109	10.9/17.0	150	
	3	3.4	1.9/2.6	95	7.8/12.8	155/60	
	4	3.5	1.8	86	9.9/13.2	115	
	5	1.8	77	9.6/13.1	113		
	6	3.2	1.7/2.1	198	8.0/11.7	165/110	
R-155	1	5.5	2.0	41			Provide independent experience to 2nd furnace operator. Same configuration as R-152
	2	5.2	2.0	95	8.7/13.5	200	
	3		2.0				
	4		2.0				
	5		2.0	20	9.9/11.1	150	
	6		2.0	101	9.4/17.0	113	
R-156	1	3.4	1.9	65	8.4/11.4	160	Test new lot of crucibles in known configuration, same as R-152 119.5 gm Si 2 x 10 <sup>17</sup> DOP SIL pellet Oxide in slot
	2	3.7	1.9	67	9.7/13.0	162	
	3	2.7	1.9	57	10.4/13.3	146	
R-157	1	3.2	1.9	217	9.7/26.2	165	Gather more growth data Measure melt surface temperatures Same configuration as R-152 120.6 gm Si 2 x 10 <sup>17</sup> DOP SIL Pellet
	2	3.0	1.9	30	10/11.5	119	
	3	2.8	1.8	221	8.6/20.2	140	
	4	2.8	1.8/2.6	120	10.8/12.8	122/58	

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GROWTH RUN DETAIL SUMMARY

Run No.	Web No.	$\Delta T$ °C	Pull Rate cm/min	Length cm	Width mm	Thickness µm	Comments
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R-158 No web growth - Dry run to measure susceptor temperatures for modeling input.

R-159 This run dedicated to measuring melt surface and melt bottom temperatures.  
The introduction of oxide during these manipulations negated subsequent efforts to grow useful web.

P-160	1	4.7	2.1	88	11.8/18.4	210	Test growth with higher melt level
	2	4.6	1.9	182	11.5/25.2	165	Same configuration as R-152
	3	2.7	1.8/1.5	167	9.4/18.5	170/220	134.7 gm Si
	4	3.1			Thickness vs. velocity run		2 x 10 <sup>17</sup> DOPSIL Pellet

R-161	1	3.1	1.9	102	11.5/17.2	220	Repeat run with high melt level
	2	3.4	1.9	74	10.7/14.5	183	Same configuration as R-152
	3	3.8	1.9	45	10.2/12.9	163	134.4 gm Si
	4	3.9	1.9	22	13.1/14.2	145	2 x 10 <sup>17</sup> DOPSIL Pellet.
	5	3.8	1.9	101	7.7/13.3	138	

R-162 Run aborted due to power failure after melting.

Test new lid configuration.  
Straight slot 6.67 cm long x 0.64 cm wide  
Lid no. -10.

R-163	1	2.6	1.9	154	11.6/22.6	146	Repeat of R-162
	2	2.3	1.8	119	11.1/17.6	120	133.2 gm. Si

Run aborted due to loss of power.  
2 x 10<sup>17</sup> DOPSIL Pellet

GROWTH RUN DETAIL SUMMARY

Run No.	Web No.	$\Delta T$ °C	Pull Rate cm/min	Length cm	Width mm	Thickness mm	Comments
R-164	Abort; Si touched lid during melt down						Repeat R-162 lid configuration
R-165	1	3.7	1.9	160	11.1/22.1	145	Repeat R-162 lid configuration
	2			128	10.5/15.3		135.2 gms Si
	3	3.4		82	11.3/14.4		2 x 10 <sup>17</sup> DOPSIL pellet
	a	-	1.4	-	-	165	
	b	-	1.9	-	-	86	
	c	-	2.6	-	-	48	
	4			112	12.2/14.6		
	5			32			
R-166	Abort; Si touched lid during melt down						
R-167	1		2.4	29	11.7	388	Test effect of 6.4 x 6.4 mm bevel (45°)
	2		2.6	24	10.2/10.8	263	on long straight slot of above lid
	3		2.4	11	9.9/10.4	300	121.6 gms Si
	4		2.6	27	10.6/11.1	-	2 x 10 <sup>17</sup> DOPSIL pellet
	5		2.4/3.4	72	-	283/125	
	6		2.4	24	12.9/13.7	238	
R-168	Abort; Si touched lid during melt down						
R-169	1		2.4	22	10.5/11.7	338	Repeat of R-167 configuration
	2		2.4	43	10.2/12.4	285	118.6 gms Si
	3		-	37	12.6/13.2		2 x 10 <sup>17</sup> DOPSIL pellet
	a		2.1			365	
	b		2.6			208	
	c		3.4			110	
	4		2.4	12	12.2/12/6	173	
	5		-	12	11.5	-	
	a		2.4	-	-	210	
	b		2.9	-	-	118	

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GROWTH RUN DETAIL SUMMARY

Run No.	Web No.	$\Delta T$ °C	Pull. Rate cm/min	Length cm	Width mm	Thickness $\mu m$	Comments
R-170	1	2.7	1.9	83	11.2/17.1	173	Test new lid configuration: 6.4 x 66.7 mm straight slot, beveled on ends only, beginning 9.5 mm from ends 118.9 gm Si 2 x 10 <sup>17</sup> DOPSIL pellet
	2	3.5	1.9	169	8.6/19.3	130	
	3	4.0	1.8	140	10.0/19.9	128	
	4	3.3	-	144	8.8/16.3	-	
	a	-	1.8	-	-	100	
	b	-	1.7	-	-	113	
	c	-	1.9	-	-	90	
	d	-	2.2	-	-	70	
R-171	1	3.2	1.9	107	10.3/13.3	163	Bevel on above lid (R-170) slot extended additional 6.4 mm towards center 113.6 gm Si, 2 x 10 <sup>17</sup> DOPSIL pellet
	2	4.8	1.9	99	13.3/16.6	148	
	3	4.1	1.9	122	13.5/20.5	150	
R-172	1	3.5	2.2	58	11.1/14.7	200	Test effect of wider slot. Slot of above lid (R-171) widened to 7.4 mm  124.0 gm Si 2 x 10 <sup>17</sup> DOPSIL pellet
	2	6.0	2.2	53	14.5/16.8	155	
	3	4.5	2.2	89	13.1/17.6	140	
	4	4.9	2.0	132	13.5/21.6	160	
	5	5.3	1.8	Terminated		-	
	6	5.0	1.8	194	13.3/26.4	150	
R-173	1	4.4	2.0	39	11.5/14.3	273	Repeat of R-172  123.1 gm Si 2 x 10 <sup>17</sup> DOPSIL pellet
	2	3.4	2.0	212	11.5/27.2	165	
	3	4.8	2.2	18	13.3/14.3	130	
	4	4.3	2.2	174	12.7/23.4	113	
	5	3.9	1.9	181	9.4/22.0	113	

SILICON WEB PROCESS DEVELOPMENT

Research Memo 77-9C4-RIBON-M 4

DESIGN DRAWINGS FOR SILICON WEB GROWTH FACILITY  
Date of Issue 22, September, 1977

C. S. Duncan

Contract No. 954654

This work was performed for the Jet Propulsion Laboratory, California Institute of Technology, under NASA Contract NAS7-100 for the U. S. Energy Research and Development Administration, Division of Solar Energy.

The JPL Low-Cost Silicon Solar Array Project is funded by ERDA and forms part of the ERDA Photovoltaic Conversion Program to initiate a major effort toward the development of low-cost solar arrays.



Westinghouse R&D Center  
1310 Beulah Road  
Pittsburgh, Pennsylvania 15235

ROUTING	FIREPROOF VAULT				
					ORIGINAL PAGE IS OF POOR QUALITY

**DRAWING LIST**

INDEX	LINE	TITLE OF DRAWING	DRAWING NO.	PAGE			
	1	CHAMBER & FRAME ASS'Y	1289J18	1			
	2	GENERAL ASS'Y	1289J19	2			
	3						
	4	CHAMBER BOX WELDM'T	639F477	3			
	5	FRAME DET	639F478	4			
	6						
	7	WORK COIL VERT ADJ DET'S	8504D76	5			
	8	WORK COIL HORIZ ADJ DET'S	8504D77	6			
	9	DETAILS	8506D61	7			
	10	RIBON GUIDE ROLL MECH	8507D32	8			
	11	COVER DETAILS	8508D18	9			
	12	BOX DETAILS	8519D87	10			
	13	COIL LIFT DET'S	8519D93	11			
	14	COIL LIFT DET'S	8519D94	12			
	15	COIL LIFT DET'S	8520D06	13			
	16	BOT. PL COIL LIFT SUB-ASS'Y	8520D12	14			
	17	DETAILS	8520D13	15			
	18	TAPE REEL DET'S	8520D14	16			
	19	TAPE REEL DET'S	8520D15	17			
	20	WEB WITHDRAWAL DUCT	8520D16	18			
	21	MID PL COIL LIFT SUB-ASS'Y	8520D17	19			
	22	SUB-ASS'Y	8520D18	20			
	23	DETAILS	8520D19	21			
	24	DETAILS	8520D31	22			
	25	RIBBON GUIDE DET'S	8520D34	23			
	26	DETAILS	8520D39	24			
	27	COIL DETAILS	8520D40	25			
	28	TOP PL COIL LIFT SUB-ASS'Y	8520D42	26			
	29	ROUND SUSCETOR DET	8520D49	27			

STOCK ORDER (1ST S.O. ON WHICH INF. HAS BEEN SENT TO SHOP) IDENTIFYING DATA: IN SPECIFYING THIS D NO. ON A STOCK ORDER THE ENGINEER MUST GIVE: -

NAME OF APPARATUS **SILICON WEB FURNACE MOD-2**

**ENG'R S. DUNCAN**

CHECKED BY AND DATE <b>W. SUMP MAN</b> 9-22-77					
DESIGN SPEC <b>D 903066</b>	SUB. LETTER <b>A</b>	SUB. LETTER	SUB. LETTER	SUB. LETTER	SUB. LETTER
WESTINGHOUSE FORM 6541 J	PAGE <b>1</b> OF <b>3</b>	SUB. LETTER	SUB. LETTER	SUB. LETTER	SUB. LETTER

ROUTING	FIREPROOF VAULT					

**DRAWING LIST**

INDEX	LINE	TITLE OF DRAWING	DRAWING NO.	PAGE		
	1	TOP COVER PL DET	8520D50	28		
	2	OVAL SUSCEPTOR DET	8520D51	29		
	3	TOP ROLLER SYS DET	8520D52	30		
	4	DETAILS	8520D61	31		
	5	WEB GUIDE DET'S	8520D69	32		
	6	DETAILS	8520D78	33		
	7					
	8					
	9					
	10	KNOB DETAILS	257C034	34		
	11	ROD HOUSING SUB ASSY	257C074	35		
	12	BACK COVER WELDM'T	257C251	36		
	13	ROUGHING PUMP ASSY	257C261	37		
	14	BR'G SUPPORT FRAME	2613C30	38		
	15	STORAGE REEL WELDM'T	2613C34	39		
	16	STORAGE REEL DET	2613C35	40		
	17	STORAGE REEL DET	2613C36	41		
	18	VACUUM ELBOW WELDM'T	2613C43	42		
	19	ROUND WORK COIL DET	2613C50	43		
	20	TAP REEL BRACKETS	2613C61	44		
	21	OVAL WORK COIL DET	2613C64	45		
	22	SUPPORT PL DET	2613C70	46		
	23	ROUND SHIELD DET	2613C71	47		
	24	OVAL SHIELD DET	2613C82	48		
	25	OVAL SUPPORT PL DET	2613C83	49		
	26	ROUND WORK COIL ASSY	2613C98	50		
	27	WEB GUIDE SUB-ASSY	2614C09	51		
	28	ROUND TOP SHIELD DET	2614C18	52		
	29	ROUND SUSCEPTOR COVER	2614C19	53		

STOCK ORDER (LIST S.O. IN WHICH INFO. HAS BEEN SENT TO SHOP) IDENTIFYING DATA. IN SPECIFYING THIS D NO. ON A STOCK ORDER THE ENGINEER MUST GIVE: -

NAME OF APPARATUS: **SILICON WEB FURNACE MOD-2**

**ENG'R S. DUNCAN**

CHECKED BY AND DATE <b>W. SUMPMAN</b> 9-22-77					
DESIGN SPEC. <b>D 903066</b>	SUB. LETTER <b>A</b>	SUB. LETTER	SUB. LETTER	SUB. LETTER	SUB. LETTER
WESTINGHOUSE FORM 6541 J	PAGE <b>2</b> OF <b>3</b>	SUB. LETTER	SUB. LETTER	SUB. LETTER	SUB. LETTER

ROUTING	FIREPROOF VAULT					

**DRAWING LIST**

INDEX	LINE	TITLE OF DRAWING	DRAWING NO.	PAGE		
	1	PUSH ROD ASSY	2614C20	54		
	2	OVAL WORK COIL ASSY	2614C23	55		
	3					
	4	ROUND CRUCIBLE DET	1689B31	56		
	5	BLANK COVER PL'S	1690B07	57		
	6	SENSOR HOLDER ASSY	1691B12	58		
	7	OVAL CRUCIBLE DET	1691B62	59		
	8					
	9	WORK COIL STANDOFF	6414A97	60		
	10	ADJ. SCR SUB-ASSY	6416A16	61		
	11	DUCT GUIDE ASSY	6417A44	62		
	12	ROUND CRUCIBLE	6417A57	63		
	13	OVAL TOP SHIELD	8521D13	64		
	14	OVAL SUSCEPTOR COVER DET.	8521D14	65		
	15	SILICON WEB FURNACE CONCEPTUAL DESIGN FOR		66		
	16	CONVERSION TO RESISTANCE HEATING				
	17					
	18					
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	21					
	22					
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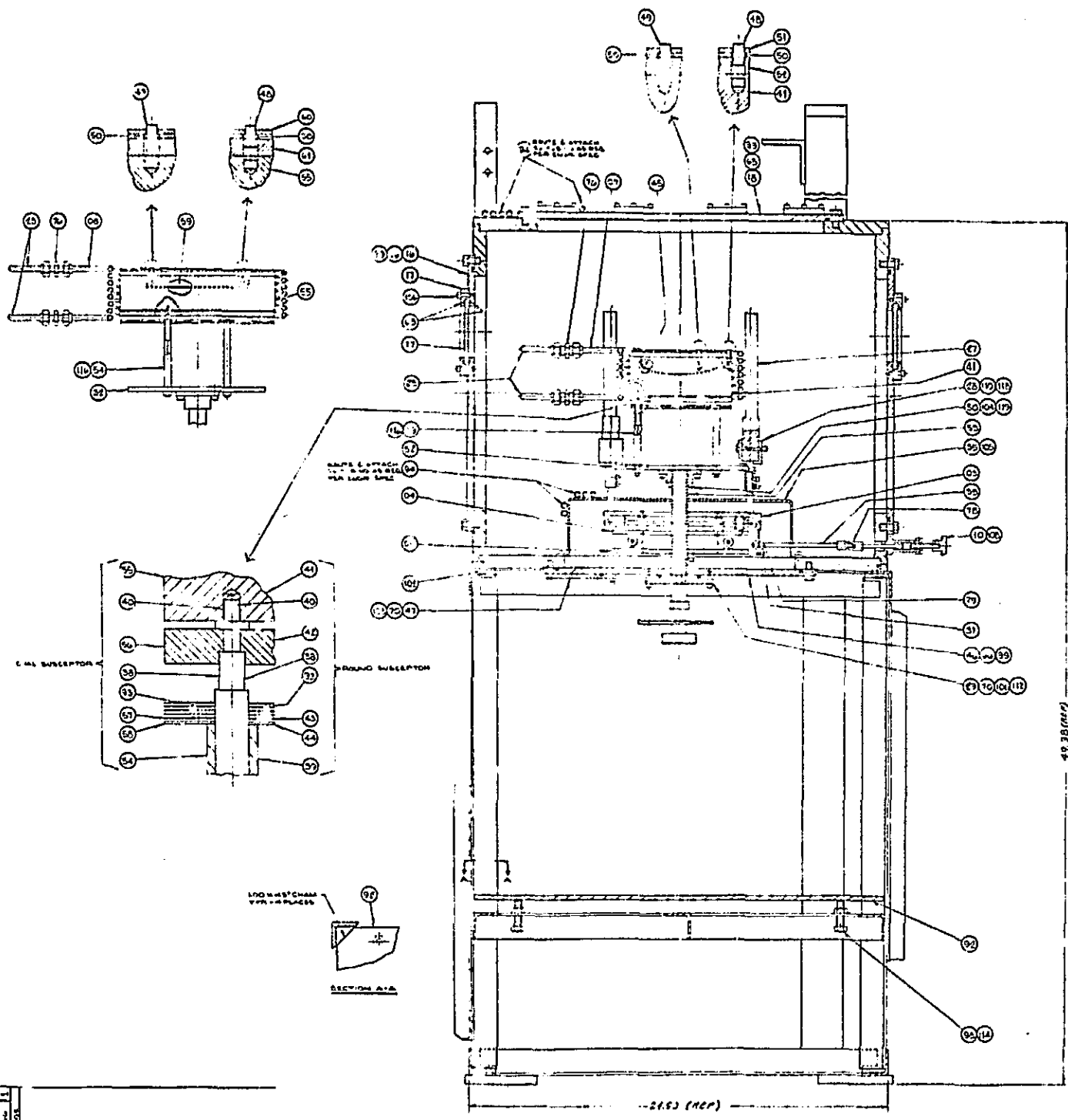
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NAME OF APPARATUS **SILICON WEB FURNACE MOD-2**

**ENGR S. DUNCAN**

CHECKED BY AND DATE <b>W. SUMPMAN</b> <b>9-22-77</b>					
DESIGN SPEC. <b>D 903066</b>	SUB. LETTER <b>A</b>	SUB. LETTER	SUB. LETTER	SUB. LETTER	SUB. LETTER
WESTINGHOUSE FORM 6541 J	PAGE <b>3 OF 3</b>	SUB. LETTER	SUB. LETTER	SUB. LETTER	SUB. LETTER

**FOLDOUT FRAME** /

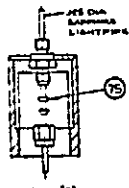
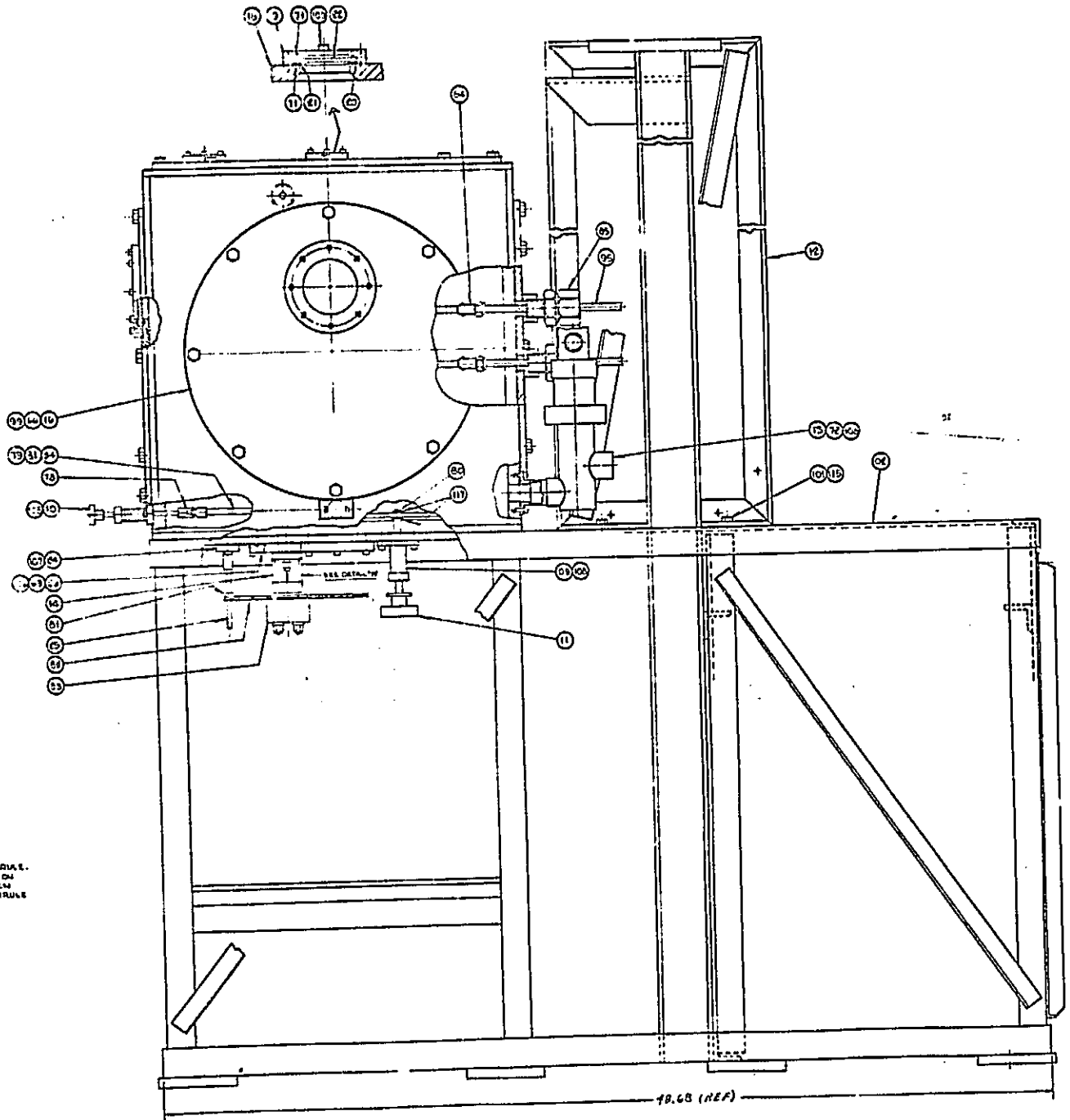


ORIGINAL PAGE IS  
OF POOR QUALITY

1289J18



FOLDOUT FRAME 2



NOTE:  
 REMOVE FRONT FERRULE.  
 PLACE DIMS, FITS ON  
 LIGHTPIPE AND THEN  
 REVERSE BACK FERRULE  
 AS SHOWN.  
 REPLACE WHT

1289J18



FOLDOUT FRAME

✓

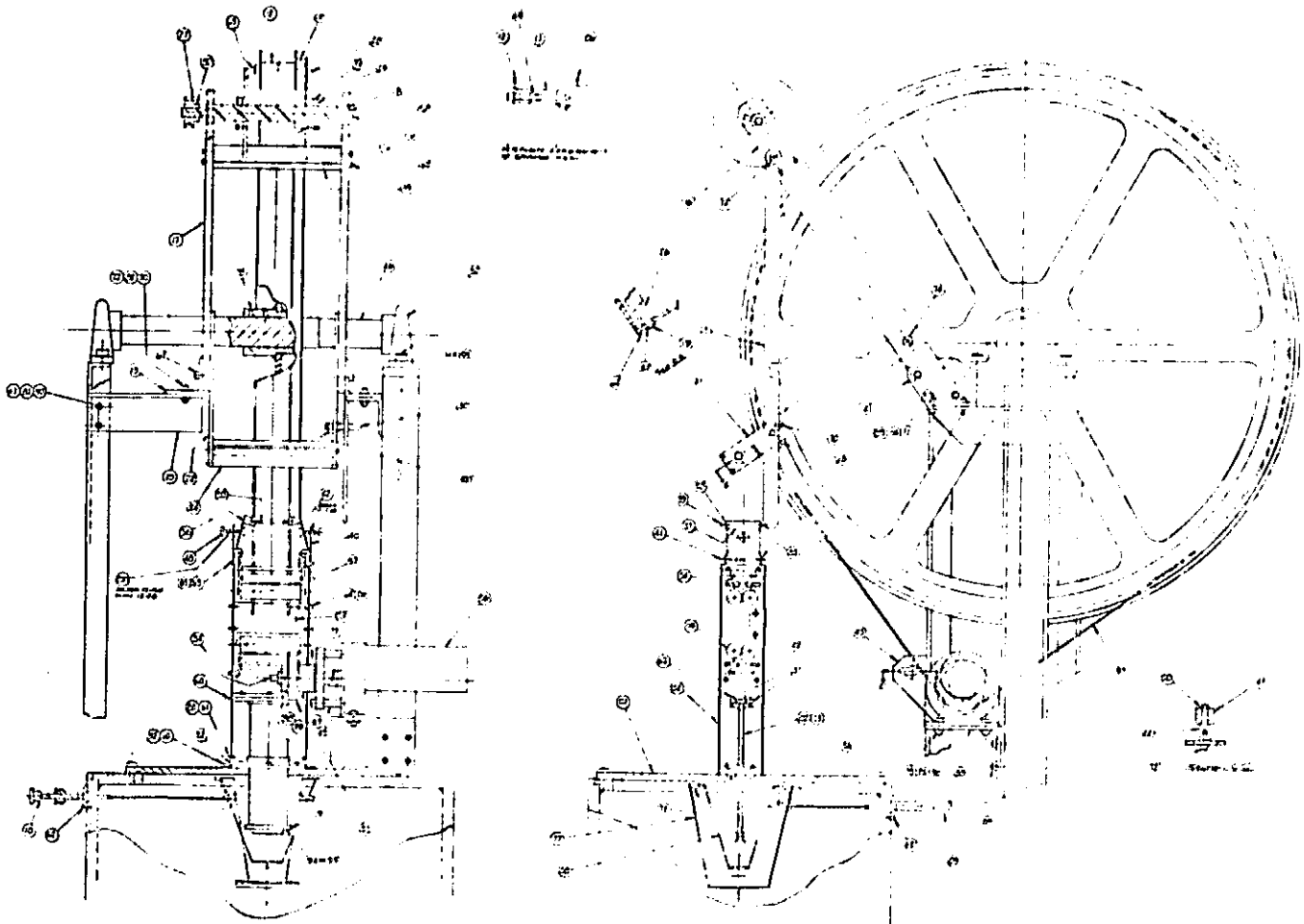
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EN ASSY DWG 1289J19

1289J18

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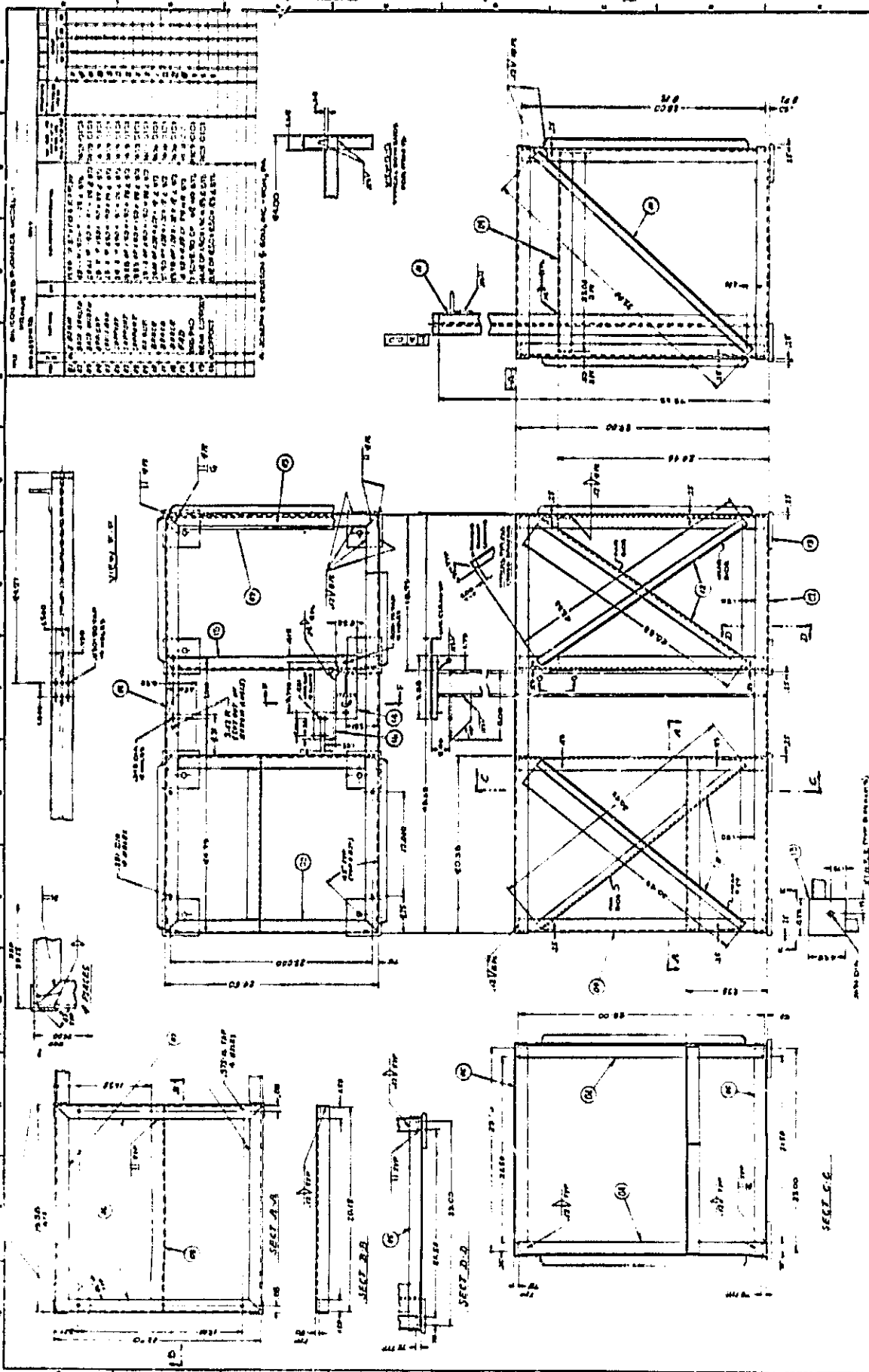
FOLDOUT FRAMES



ORIGINAL PAGE IS  
OF POOR QUALITY







SECTION SHEET

NO.	DESCRIPTION	QTY.	UNIT	REMARKS
1	CONCRETE	100	CU YD	
2	STEEL	50	TON	
3	BRICK	200	1000	
4	CEMENT	100	TON	
5	SAND	200	CU YD	
6	GRAVEL	100	CU YD	
7	WOOD	50	CU YD	
8	GLASS	100	SQ FT	
9	PAINT	100	GA	
10	ROOFING	100	SQ FT	
11	MECHANICAL	100	HR	
12	ELECTRICAL	100	HR	
13	PLUMBING	100	HR	
14	LANDSCAPE	100	HR	
15	INTERIOR	100	HR	
16	EXTERIOR	100	HR	
17	FINISH	100	HR	
18	INSULATION	100	HR	
19	MECHANICAL	100	HR	
20	ELECTRICAL	100	HR	
21	PLUMBING	100	HR	
22	LANDSCAPE	100	HR	
23	INTERIOR	100	HR	
24	EXTERIOR	100	HR	
25	FINISH	100	HR	
26	INSULATION	100	HR	
27	MECHANICAL	100	HR	
28	ELECTRICAL	100	HR	
29	PLUMBING	100	HR	
30	LANDSCAPE	100	HR	
31	INTERIOR	100	HR	
32	EXTERIOR	100	HR	
33	FINISH	100	HR	
34	INSULATION	100	HR	
35	MECHANICAL	100	HR	
36	ELECTRICAL	100	HR	
37	PLUMBING	100	HR	
38	LANDSCAPE	100	HR	
39	INTERIOR	100	HR	
40	EXTERIOR	100	HR	
41	FINISH	100	HR	
42	INSULATION	100	HR	
43	MECHANICAL	100	HR	
44	ELECTRICAL	100	HR	
45	PLUMBING	100	HR	
46	LANDSCAPE	100	HR	
47	INTERIOR	100	HR	
48	EXTERIOR	100	HR	
49	FINISH	100	HR	
50	INSULATION	100	HR	

SECTION SHEET

NO. 1

DATE

SCALE

PROJECT

ARCHITECT

ENGINEER

CONTRACTOR

OWNER

LOCATION

DESCRIPTION

REVISIONS

NO.

DATE

DESCRIPTION

BY

CHECKED

APPROVED

DATE

SCALE

PROJECT

ARCHITECT

ENGINEER

CONTRACTOR

OWNER

LOCATION

DESCRIPTION

REVISIONS

NO.

DATE

DESCRIPTION

BY

CHECKED

APPROVED

DATE

THIS DRAWING IS THE PROPERTY OF WESTINGHOUSE ELECTRIC CORPORATION  
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REV	DATE	DESCRIPTION	BY	CHKD
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216	9-15-72	...	...	...
217	10-15-72	...	...	...
218	11-15-72	...	...	...
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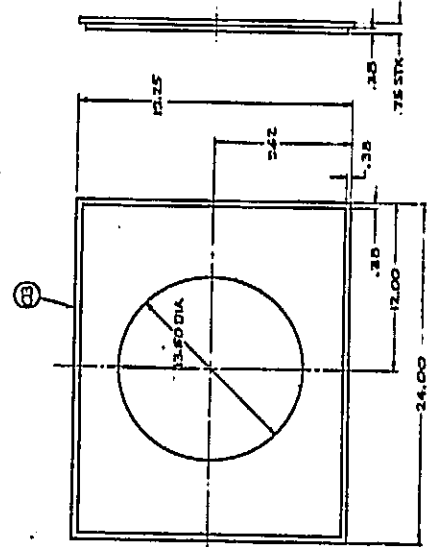
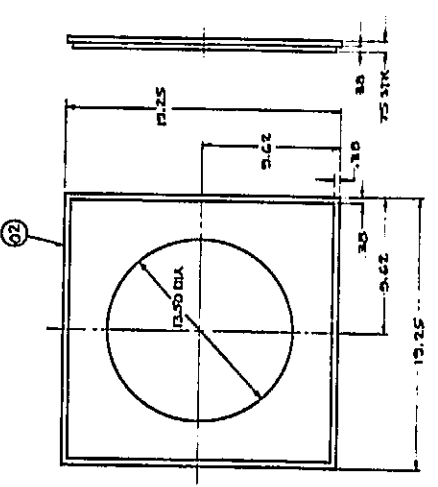
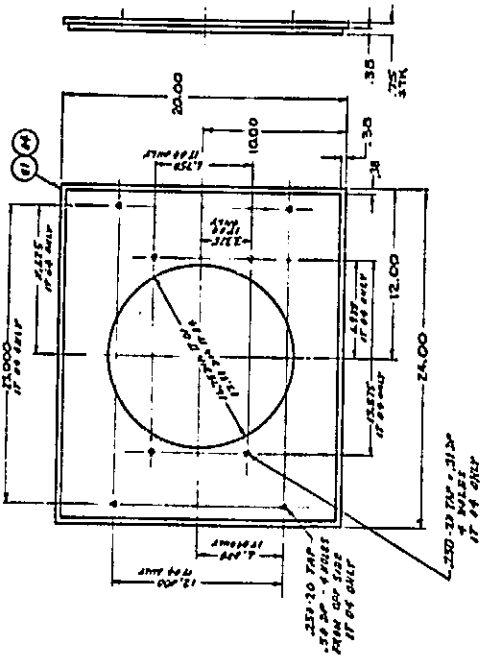






VM SILICON WEB FURNACE MODEL 2  
BOX DETAILS NO-1

REV	DATE	DESCRIPTION	BY	CHK	APP'D
01		TOP PL.			
02		CHD PL.			
03		FRONT BLANK			
04		BOT PL.			



Westinghouse Electric Corporation  
VM SILICON WEB FURNACE MODEL 2  
BOX DETAILS  
REV. 1  
8519D87

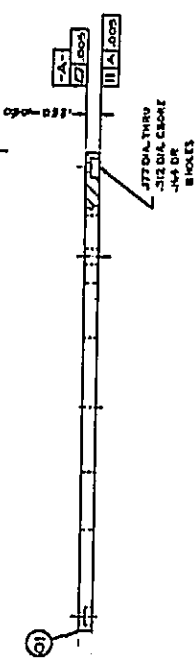
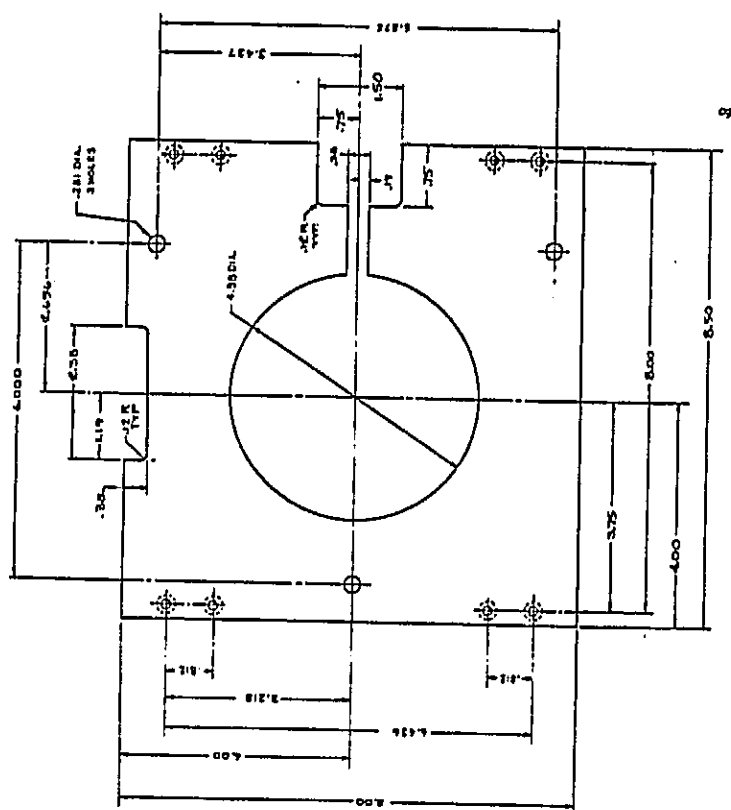
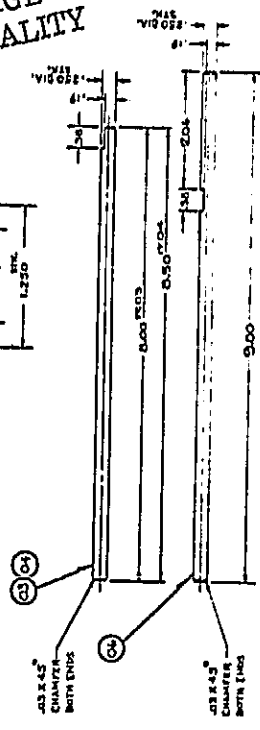
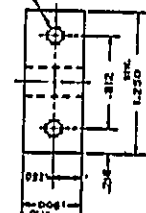
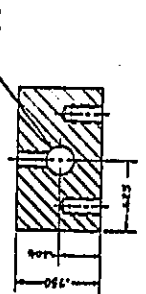
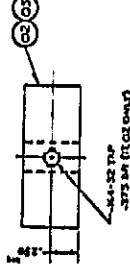
REV	DATE	DESCRIPTION	BY	CHK	APP'D
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REV	DATE	DESCRIPTION	BY	CHK	APP'D
01					

THE SILECON WEB PURCHASE MODEL-2  
 CHIL LIFT DET'S. NO. 225

ITEM NO.	DESCRIPTION	QTY	UNIT	PRICE	TOTAL
01	BASE PLATE	1	PCB	1.00	1.00
02	ROD SUPPORT	2	PCB	0.50	1.00
03	ROD	2	PCB	0.25	0.50
04	ROD	2	PCB	0.25	0.50
05	ROD SUPPORT	2	PCB	0.50	1.00
06	ROD	2	PCB	0.25	0.50
07	ROD	2	PCB	0.25	0.50
08	ROD SUPPORT	2	PCB	0.50	1.00
09	ROD	2	PCB	0.25	0.50
10	ROD	2	PCB	0.25	0.50
11	ROD SUPPORT	2	PCB	0.50	1.00
12	ROD	2	PCB	0.25	0.50
13	ROD	2	PCB	0.25	0.50
14	ROD SUPPORT	2	PCB	0.50	1.00
15	ROD	2	PCB	0.25	0.50
16	ROD	2	PCB	0.25	0.50
17	ROD SUPPORT	2	PCB	0.50	1.00
18	ROD	2	PCB	0.25	0.50
19	ROD	2	PCB	0.25	0.50
20	ROD SUPPORT	2	PCB	0.50	1.00
21	ROD	2	PCB	0.25	0.50
22	ROD	2	PCB	0.25	0.50
23	ROD SUPPORT	2	PCB	0.50	1.00
24	ROD	2	PCB	0.25	0.50
25	ROD	2	PCB	0.25	0.50
26	ROD SUPPORT	2	PCB	0.50	1.00
27	ROD	2	PCB	0.25	0.50
28	ROD	2	PCB	0.25	0.50
29	ROD SUPPORT	2	PCB	0.50	1.00
30	ROD	2	PCB	0.25	0.50
31	ROD	2	PCB	0.25	0.50
32	ROD SUPPORT	2	PCB	0.50	1.00
33	ROD	2	PCB	0.25	0.50
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35	ROD SUPPORT	2	PCB	0.50	1.00
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42	ROD	2	PCB	0.25	0.50
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44	ROD SUPPORT	2	PCB	0.50	1.00
45	ROD	2	PCB	0.25	0.50
46	ROD	2	PCB	0.25	0.50
47	ROD SUPPORT	2	PCB	0.50	1.00
48	ROD	2	PCB	0.25	0.50
49	ROD	2	PCB	0.25	0.50
50	ROD SUPPORT	2	PCB	0.50	1.00

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Westinghouse Electric Corporation  
 THE SILECON WEB PURCHASE MODEL-2  
 CHIL LIFT DET'S. NO. 225  
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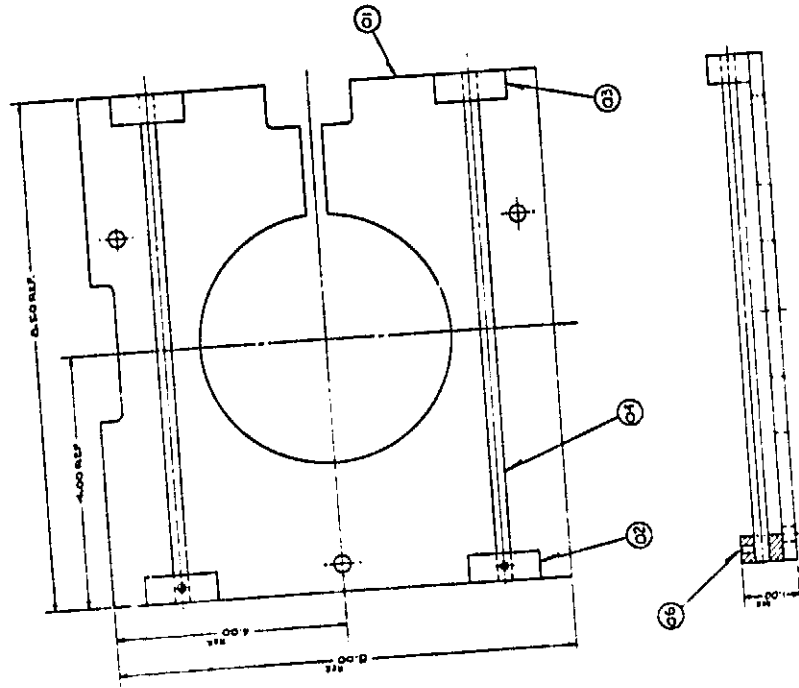
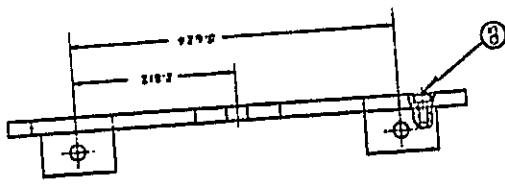






WHEATON MED. PURCHASE MODEL "2"  
 SCH. PL. COIL LIFT 3-8 ASST  
 FIG. 1

Part No.	Part Name	Material	Quantity	Notes
011	SYSTEM BOLT	304	1	
012	WAS SUPPORT	304	1	
013	WAS SUPPORT	304	1	
014	WAS SUPPORT	304	1	
015	WAS SUPPORT	304	1	
016	WAS SUPPORT	304	1	
017	WAS SUPPORT	304	1	
018	WAS SUPPORT	304	1	
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035	WAS SUPPORT	304	1	
036	WAS SUPPORT	304	1	
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038	WAS SUPPORT	304	1	
039	WAS SUPPORT	304	1	
040	WAS SUPPORT	304	1	
041	WAS SUPPORT	304	1	
042	WAS SUPPORT	304	1	
043	WAS SUPPORT	304	1	
044	WAS SUPPORT	304	1	
045	WAS SUPPORT	304	1	
046	WAS SUPPORT	304	1	
047	WAS SUPPORT	304	1	
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080	WAS SUPPORT	304	1	
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082	WAS SUPPORT	304	1	
083	WAS SUPPORT	304	1	
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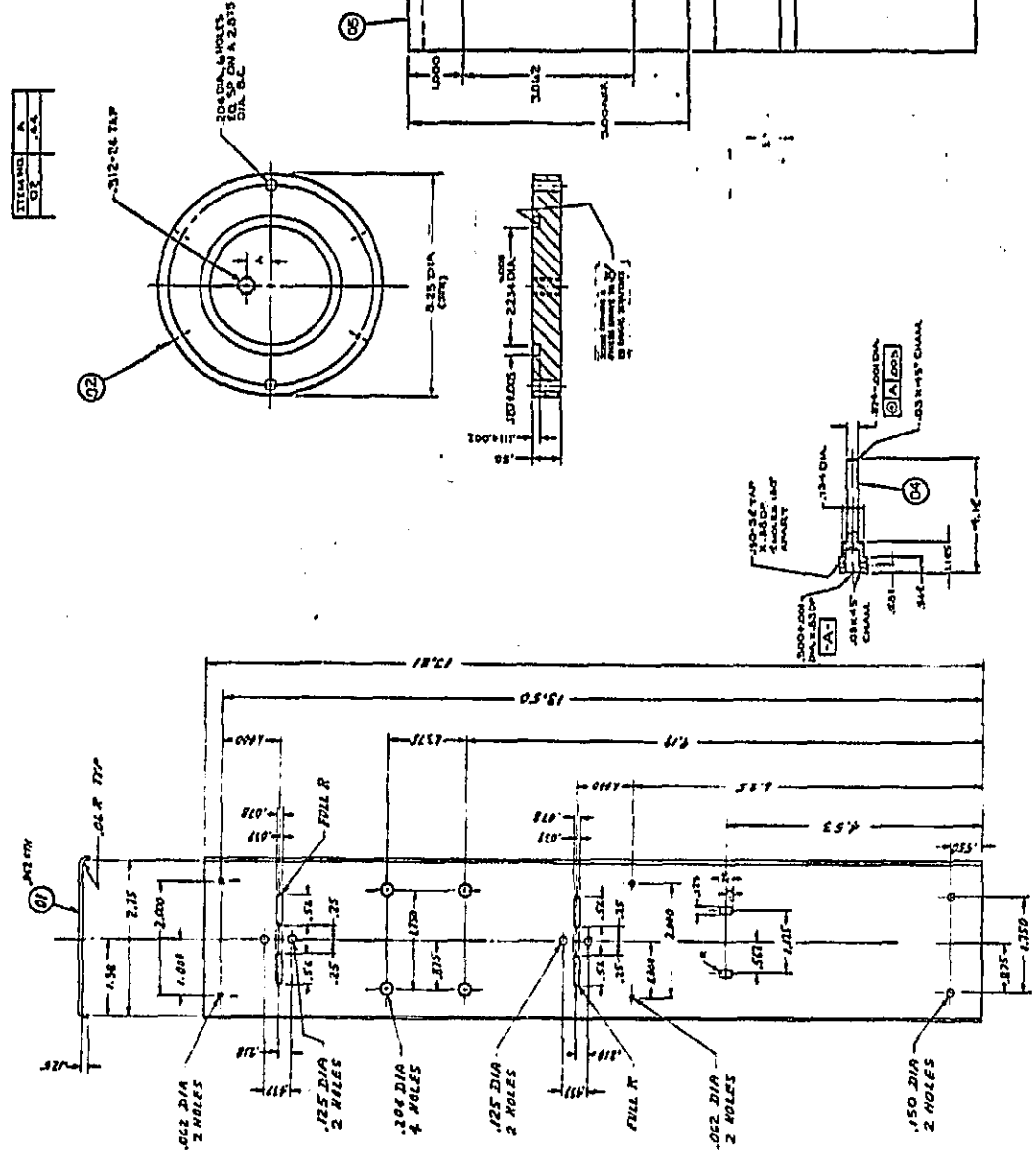


WESTINGHOUSE ELECTRIC CORPORATION  
 THE WESTINGHOUSE WORKS  
 PITTSBURGH, PA.  
 8920 D 17

REV	DESCRIPTION	DATE	BY	CHK
01	COVER PL.	11-07-53	J.P.	J.P.
02	COVER PL.	11-07-53	J.P.	J.P.
03	COVER PL.	11-07-53	J.P.	J.P.
04	COVER PL.	11-07-53	J.P.	J.P.
05	COVER PL.	11-07-53	J.P.	J.P.

A. JOSEPH T. REYNOLDS & SON, INC. - PHIL., PA.

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REV	DESCRIPTION	DATE	BY	CHK
01	COVER PL.	11-07-53	J.P.	J.P.
02	COVER PL.	11-07-53	J.P.	J.P.
03	COVER PL.	11-07-53	J.P.	J.P.
04	COVER PL.	11-07-53	J.P.	J.P.
05	COVER PL.	11-07-53	J.P.	J.P.

Westinghouse Electric Corporation  
 THE WESTINGHOUSE ELECTRIC CORPORATION  
 PITTSBURGH, PA.  
 DRAWING NO. 100000000  
 SHEET NO. 1 OF 1  
 DATE 11-07-53  
 BY J.P.  
 CHK J.P.

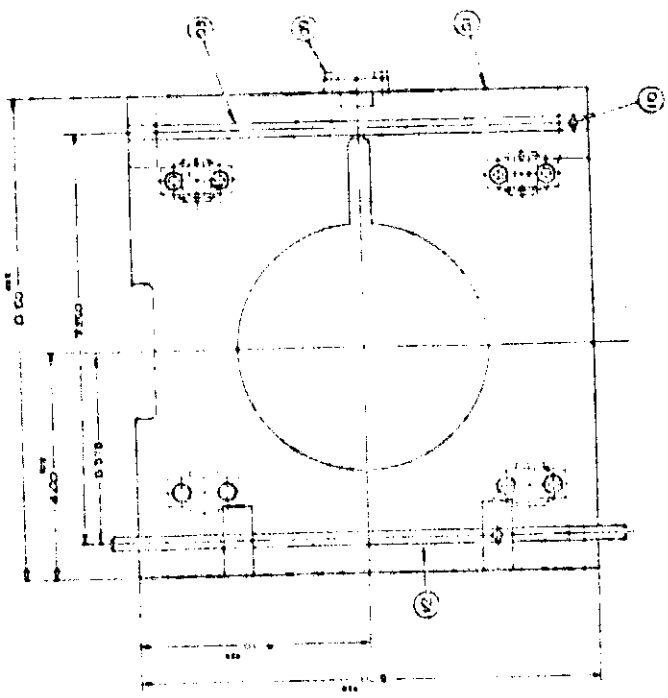
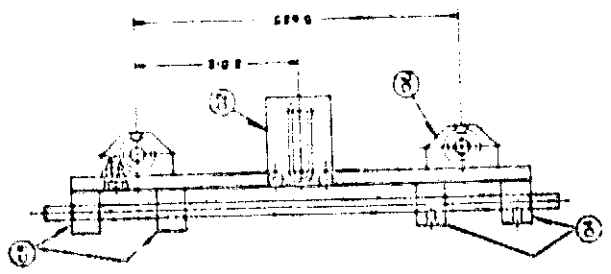






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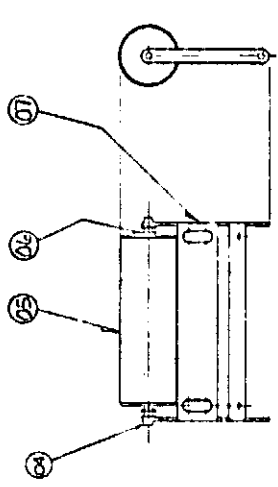
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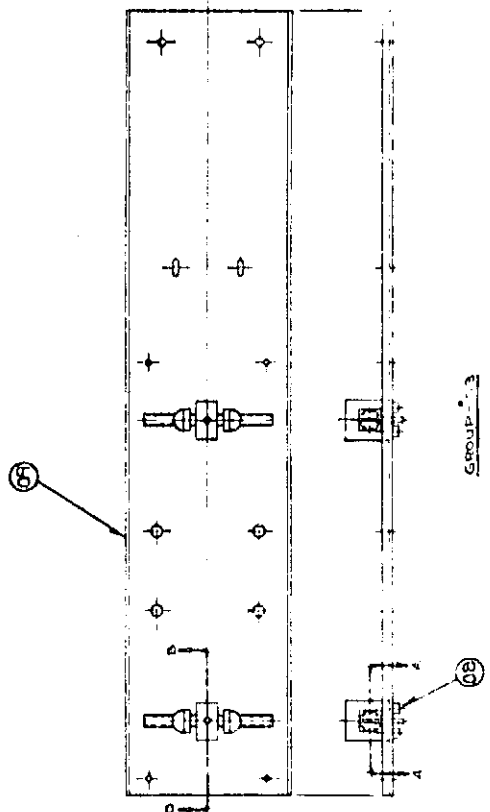
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THE MILKON WELD EQUIPMENT CO. I		SUD - A3575		REV. 12 5	
DESIGN		MATERIALS		FINISHES	
NO.	DESCRIPTION	QTY.	UNIT	QTY.	UNIT
01	WELD HEAD	1	PC		
02	WELD HEAD	1	PC		
03	WELD HEAD	1	PC		
04	WELD HEAD	1	PC		
05	WELD HEAD	1	PC		
06	WELD HEAD	1	PC		
07	WELD HEAD	1	PC		
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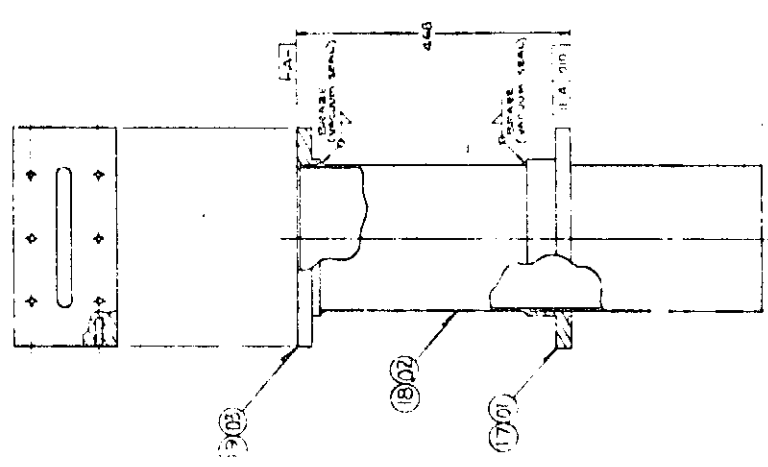
A. WALTERS ROBINSON, INC., LONG ISLAND, N.Y.



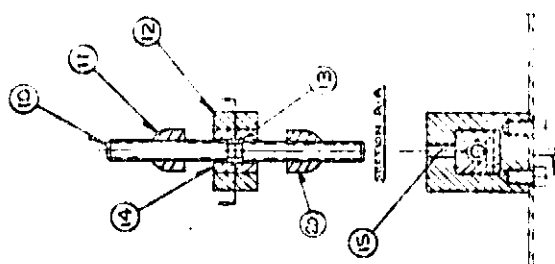
GROUP 02



GROUP 03



GROUP 04



GROUP 05

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3	DESIGN	3	CHECK	3	DATE
4	DESIGN	4	CHECK	4	DATE
5	DESIGN	5	CHECK	5	DATE
6	DESIGN	6	CHECK	6	DATE
7	DESIGN	7	CHECK	7	DATE
8	DESIGN	8	CHECK	8	DATE
9	DESIGN	9	CHECK	9	DATE
10	DESIGN	10	CHECK	10	DATE
11	DESIGN	11	CHECK	11	DATE
12	DESIGN	12	CHECK	12	DATE
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30	DESIGN	30	CHECK	30	DATE
31	DESIGN	31	CHECK	31	DATE
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38	DESIGN	38	CHECK	38	DATE
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41	DESIGN	41	CHECK	41	DATE
42	DESIGN	42	CHECK	42	DATE
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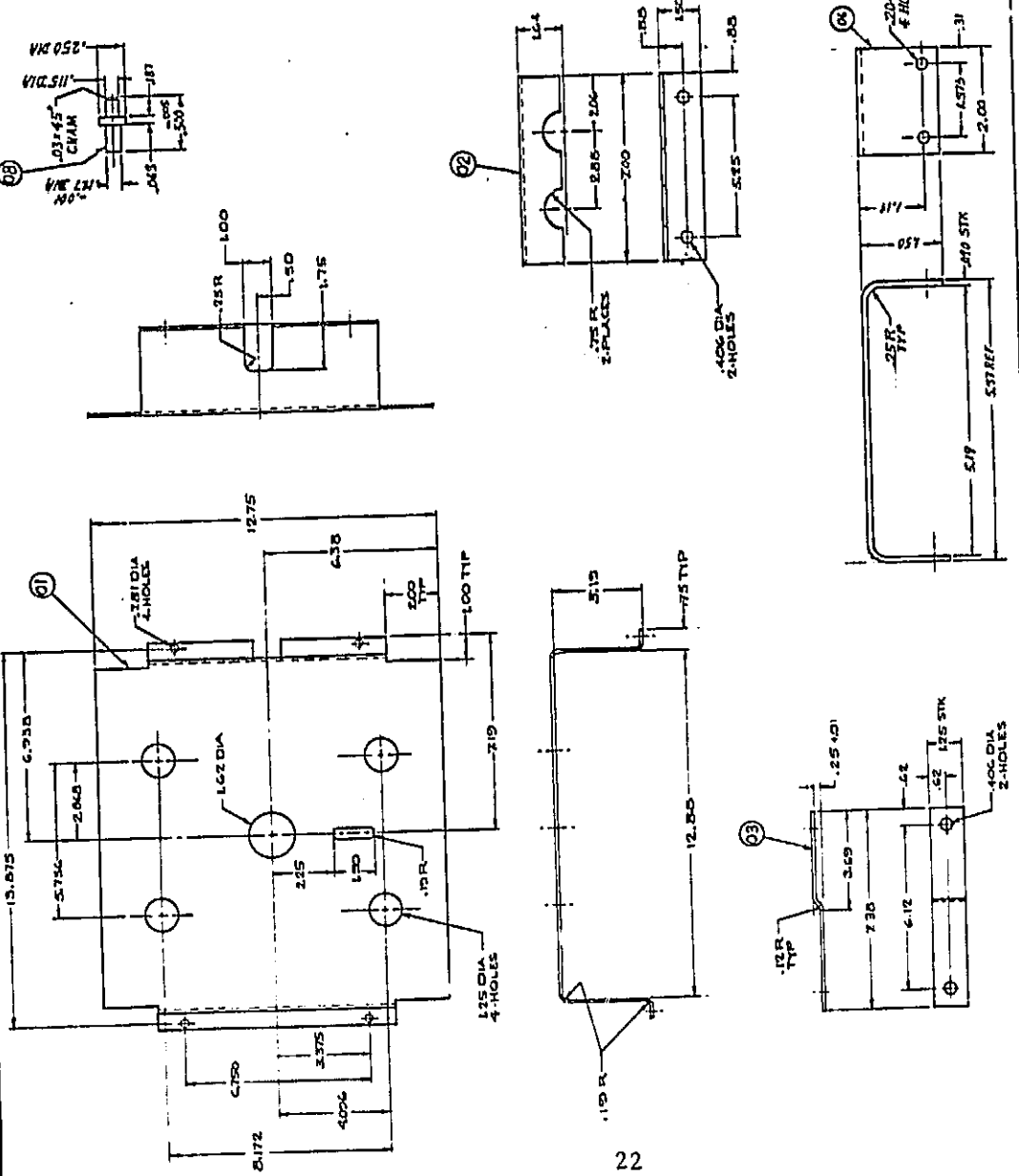




THE SILICON NER BURNANCE MOD. 2  
 DETAIL  
 810001

ITEM	QTY	DESCRIPTION	UNIT	REMARKS
01	1	SHIELD	PC	7.00 X 8.88 OF .125 THK CU
02	1	PUMP SUPPORT	PC	7.00 X 8.88 X .50 X .50 X .2
03	1	BRG CASE	PC	7.18 X 8.18 X .115 CD STL
04	1	CLAMP	PC	1.62 OF .31 DIA CERAMIC
05	1	WIND OFF	PC	2.91 OF .315 DIA MOLY
06	1	WIND ON	PC	2.91 OF .315 DIA MOLY
07	1	STAND OFF	PC	4.50 OF .315 DIA MOLY
08	1	WIND	PC	6.30 OF .315 DIA MOLY

A - FURNISHED BY ENGR



ITEM	QTY	DESCRIPTION
05	3.137	
07	3.227	

Westinghouse Electric C  
 THE WESTINGHOUSE ELECTRIC CORPORATION  
 PITTSBURGH, PA. 15205  
 MADE IN U.S.A.  
 WESTINGHOUSE  
 SEE MOD 2  
 1350031

NO	REV	DATE	BY	CHKD
01	ADD	8-11-77		
02	ADD			
03	ADD			
04	ADD			
05	ADD			



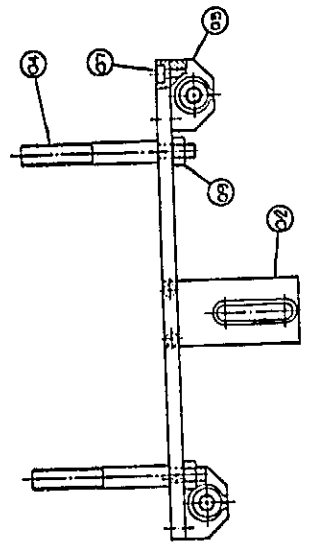
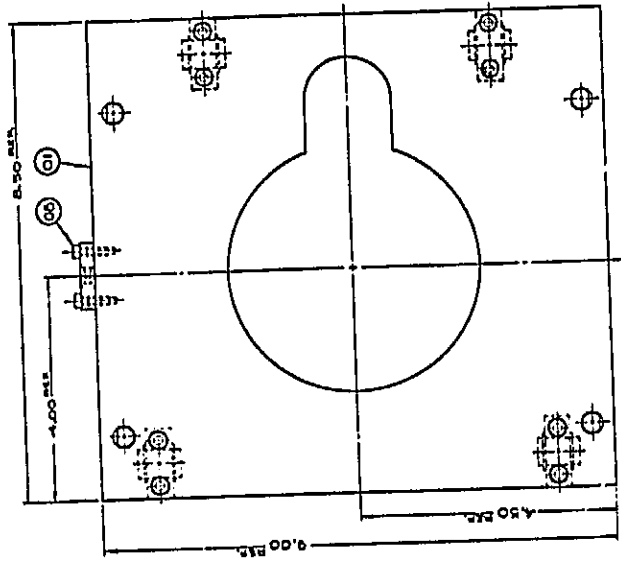
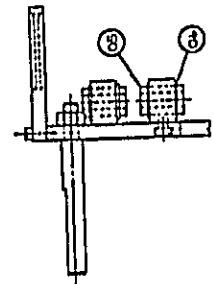




THIS DRAWING AND PURCHASE ORDER ARE TO BE USED FOR THE TOP PLATE ONLY. SUB. 4357. 10/12

QTY	ITEM NO.	DESCRIPTION	UNIT PRICE	TOTAL PRICE
1	101	TOP PLATE		
1	102	SLIDE		
1	103	ROCK		
1	104	ROCK		
1	105	ROCK		
1	106	ROCK		
1	107	ROCK		
1	108	ROCK		
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1	148	ROCK		
1	149	ROCK		
1	150	ROCK		

ATTORNEY INDUSTRIES, INC., MANHASSET, N.Y.



Waltham Electric Corporation  
 THIS DRAWING AND PURCHASE ORDER ARE TO BE USED FOR THE TOP PLATE ONLY. SUB. 4357. 10/12  
 8520D42

QTY	ITEM NO.	DESCRIPTION	UNIT PRICE	TOTAL PRICE
1	101	TOP PLATE		
1	102	SLIDE		
1	103	ROCK		
1	104	ROCK		
1	105	ROCK		
1	106	ROCK		
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1	149	ROCK		
1	150	ROCK		

9176021 10/12

1 ABOVE  
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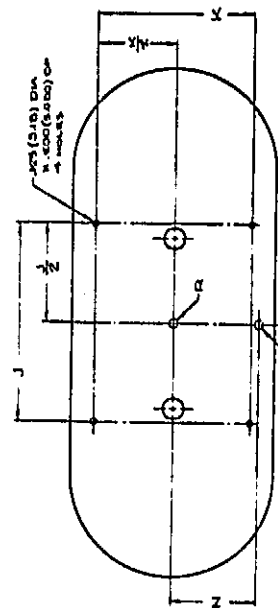
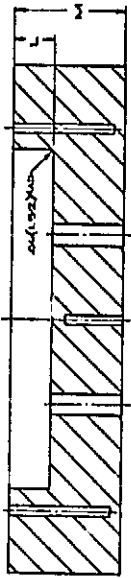
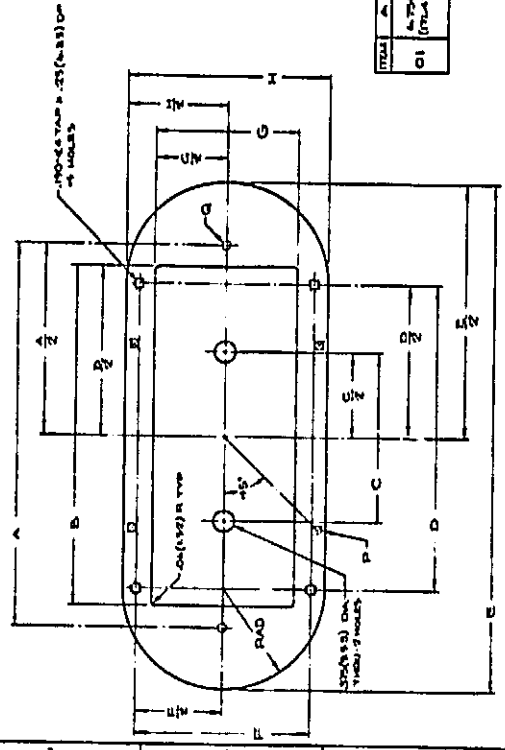




SILICON WEB SURFACE MOD. 1  
RECEPTOR DETAIL

REV	DATE	DESCRIPTION	BY	CHKD
01		RECEPTOR DETAIL		

REV	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q	R	S	
01	4.750 (121.43)	4.000 (101.60)	3.000 (76.20)	5.375 (136.95)	8.875 (225.38)	3.062 (77.71)	4.500 (114.30)	2.562 (65.08)	3.316 (84.14)	4.750 (120.65)	7.625 (194.17)	1.500 (38.10)	1.914 (48.66)	1.500 (38.10)	7.625 (194.17)	1.500 (38.10)	1.500 (38.10)	1.500 (38.10)



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OF POOR QUALITY

NOTE: DIMENSIONS ENCLOSED BY ( ) ARE IN MILLIMETERS

WESTGHOUSE ELECTRIC CORPORATION  
THIS DRAWING IS THE PROPERTY OF WESTGHOUSE ELECTRIC CORPORATION  
IT IS TO BE KEPT IN CONFIDENCE AND NOT TO BE REPRODUCED OR COPIED IN ANY MANNER WITHOUT THE WRITTEN PERMISSION OF WESTGHOUSE ELECTRIC CORPORATION

DATE: 1952  
DRAWN BY: [Signature]  
CHECKED BY: [Signature]

1



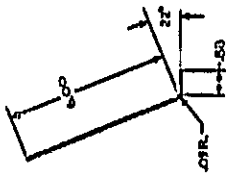
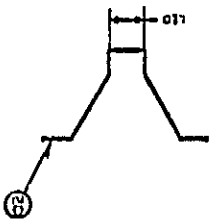
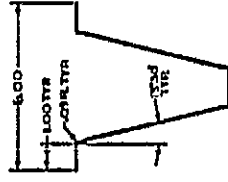
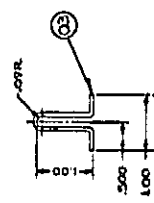
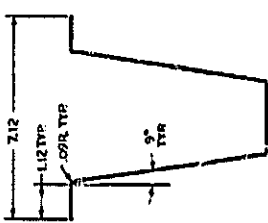
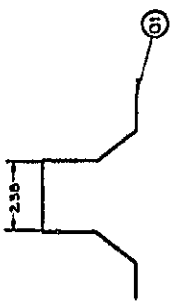
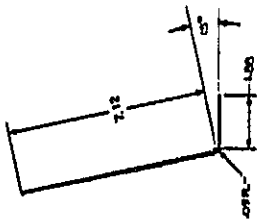
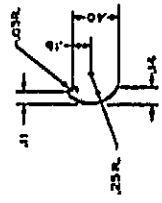
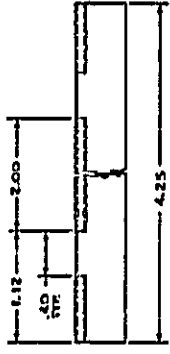
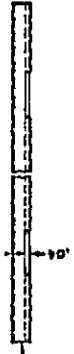




WPA DIVISION WEB FURNACE M20-2  
WEB GUIDE LENS

Part No.	Part Name	Material	Quantity	Notes
01	FACE GUIDE SOP	31000 CF. ONE DIA. SUT		
02	EDGE GUIDE SIB	17,500 CF. ONE DIA. SUT		
03	LOOP	8,500 CF. ONE DIA. SUT		
04	WALE GUIDE	4,384.75 CF. ONE DIA. SUT		

WILLIAMS CO., INC. - P.O. BOX 14



Engineering Drawing Convention  
 WPA DIVISION WEB FURNACE M20-2  
 WEB GUIDE LENS  
 8520 D 69

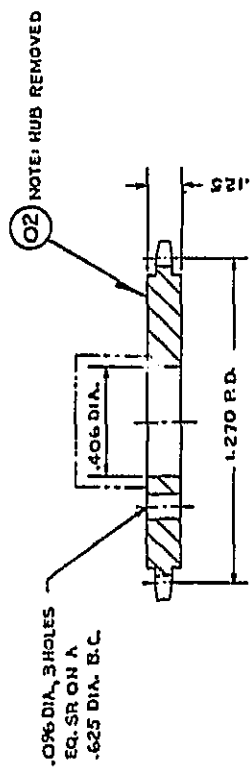
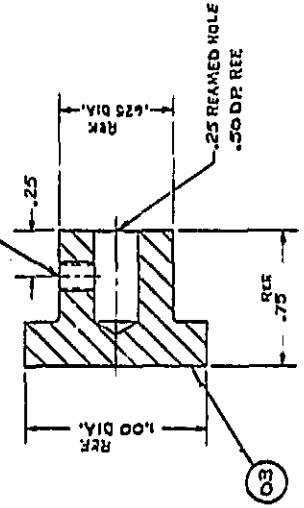
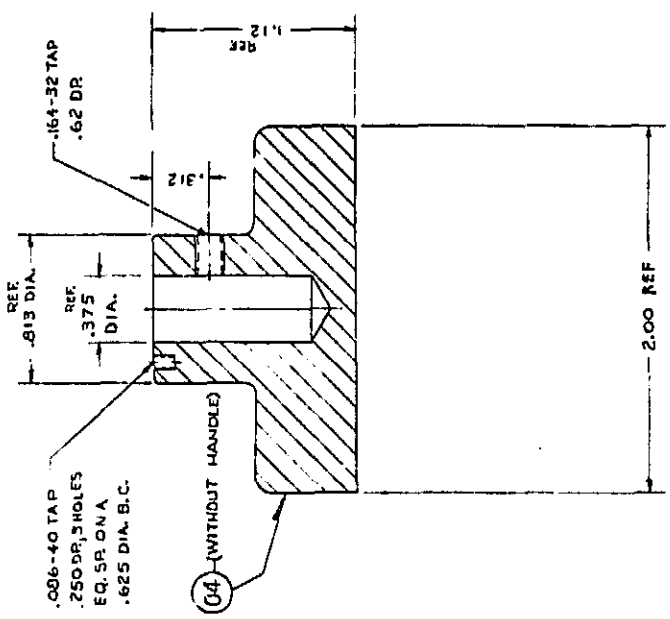
17 CHANGES  
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TITLE SILICON WEB FURNACE MODEL-1 & MODEL-2  
 KNOB DETAILS  
 DWG 257C034 REV. 23

ITEM	NOTE	PART NAME	REF	CRZD REFERENCE INFORMATION	MAT. SPEC CODE PART NAME OR REF DWG	GROUP NOTE PROCESS OR MATERIAL	GROUP
01	A	KNOB		REID #GH-IN NATURAL ANODIZED FIN			
02	B	CHAIN SPROCKET		PIC #EM 5-27 303 SST 10 TEETH 27			
03	A	KNOB		REID #KKR 2A BLACK PENTRATE FIN			
04	A	KNOB		REID #G-3N NATURAL ANODIZED FIN			

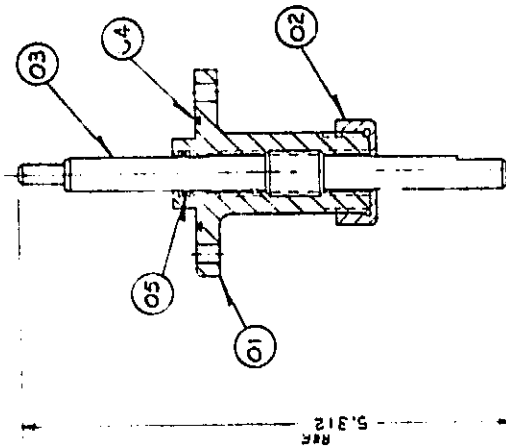
-A- REID TOOL SUPPLY CO., MUSKOGEE, MICH.  
 -B- PIC, PITTSBURGH, PA.



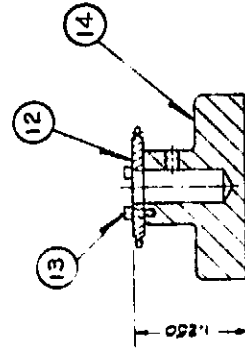
903066 MOD-2	DESIGN SPEC	NO 903066	MOD-2 ADDED	REMOVED	ITEM 01	FC B-25-77
1	CHANGE	2	3	3		
TOLERANCES UNLESS OTHERWISE SPECIFIED						
FINISH TO BE UNLESS OTHERWISE SPECIFIED						
DIMS 257C034 WESTINGHOUSE ELECTRIC CORPORATION PITTSBURGH, PA. 15223						
TITLE SILICON WEB FURNACE MODEL-1 & MODEL-2 KNOB DETAILS REV. 23 257 C 034						

TITLE SILICON WEB PURNACE MODEL-1 & MODEL-2  
 ROD HOUSING SUB ASSY  
 DWG 257C074 REV 23

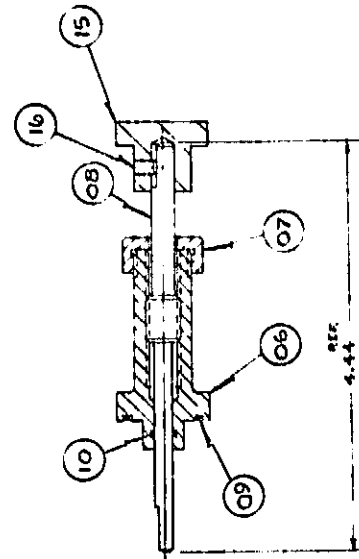
ITEM	PART NAME	QTY	REF	GROUP NOTE	GROUP
01	ROD HOUSING	DWG		8504D76H01	
02	HOUSING CAP	DWG		8504D76H02	
03	ROD	DWG		8504D76H03	
04	O-RING	305	CAT. NO. 2-024		
05	O-RING	305	CAT. NO. 2-110		
06	ROD HOUSING	DWG		8504D77H01	
07	HOUSING CAP	DWG		8504D77H02	
08	ROD	DWG		8504D77H03	
09	A O-RING	305	CAT. NO. 2-018		
10	A O-RING	305	CAT. NO. 2-025		
11	KNOB	DWG		257C034H01	
12	CHAIN SPROCKET	DWG		257C034H02	
13	SCR		.086 - 40 X .25 506 HD CAP SCR		
14	KNOB	DWG		257C034H04	
15	KNOB	DWG		257C034H03	
16	SCR		.138 - 32 X .25 LG. STL.		



GR.01



GR.04



GR.02

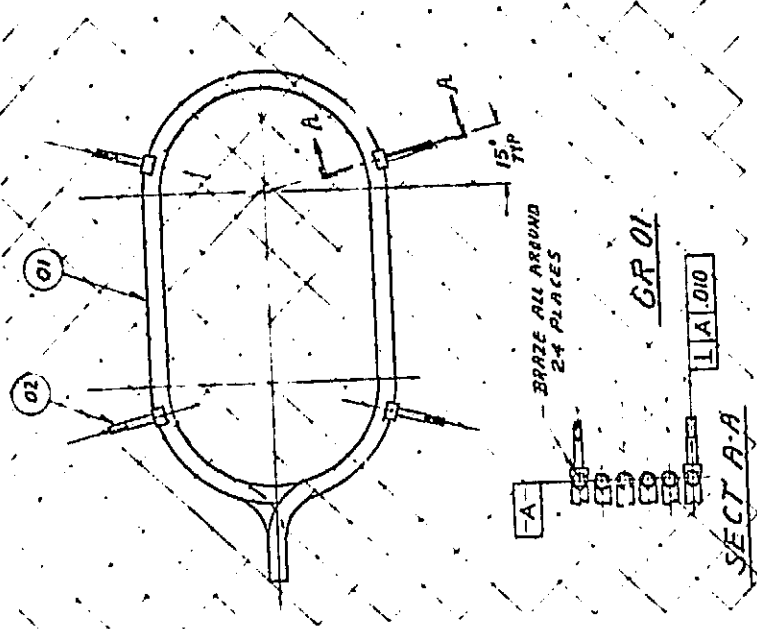
WESTINGHOUSE ELECTRIC CORPORATION RESEARCH LABORATORIES - PITTSBURGH, PENNSYLVANIA	TITLE SILICON WEB PURNACE MODEL-1 & MODEL-2 ROD HOUSING SUB ASSY REV 23	DWG NO 257C074
DESIGN SPEC NO 905066 MOD 2 ADDD MK 6-16-77 REMOVED GROUP 03 FC 8-25-77	CHANGE 1 902993 MOD-1	TOLERANCES UNLESS OTHERWISE SPECIFIED .0015 .001 .002 .005 .010 .015 .030 .050 .100 .150 .300 .500 1.000 1.500 2.000 3.000 4.000 5.000 6.000 8.000 10.000 15.000 20.000 30.000 40.000 50.000 60.000 80.000 100.000 150.000 200.000 300.000 400.000 500.000 600.000 800.000 1000.000 1500.000 2000.000 3000.000 4000.000 5000.000 6000.000 8000.000 10000.000



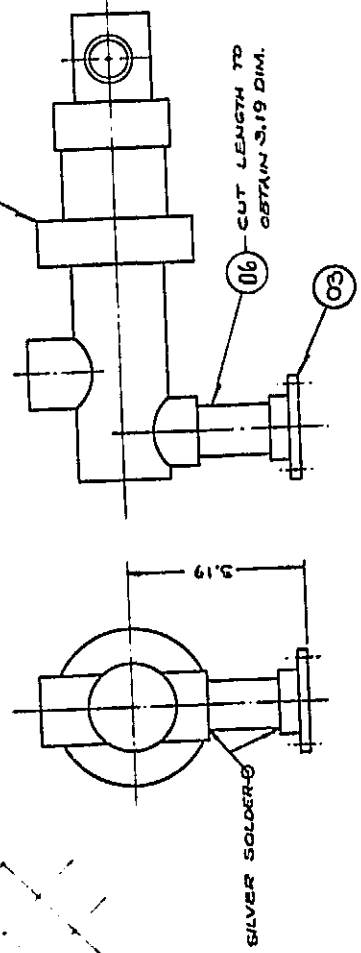
TITLE SILICON WEB FURNACE MODEL-1 & MODEL-2  
COIL & ROUGHING PUMP SUB-ASSY.  
REV. #2  
2570261

ITEM	QTY	PART NAME	DEF	DESIGN REFERENCE INFORMATION	MATERIAL CODE PART NUMBER OR REF DIM	GROUP NOTE	PROJ NO OR LWB NO	GROUP
01		COIL	DWG		350135011			
02		STAND-OFF	DWG		9586758112			
03		FLANGE	DWG		9501611103			24
04		90° FITTING ELB	B35	1/8" 1018 STYLE #1E-503 PART #230 (FITTING TO SOLDER)				
05		SILICIA WAVE B35	B35	1/8" PART # 1254 - B5176-31B				
06		TUBING		3.10 OF 1.125 OD - LAMPID CU - 1014-0112				

WESTINGHOUSE ELECTRIC CORP., PHILA., PA. (SALES OFFICE)  
3 - VARIAN IND EQ GR., EUCLID, OHIO



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GR-02

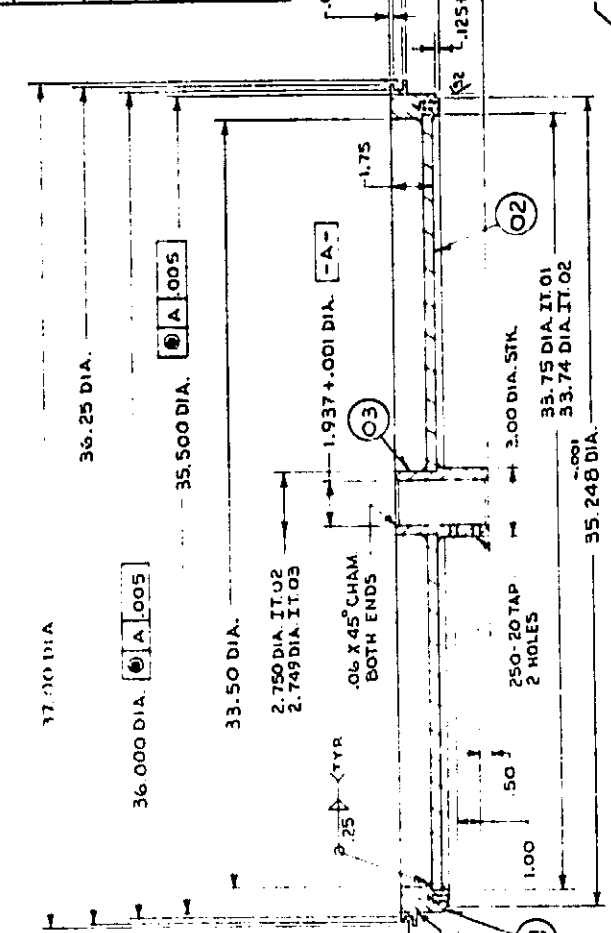
WESTINGHOUSE ELECTRIC CORPORATION TITLE: SILICON WEB FURNACE MODEL-1 & MODEL-2 COIL & ROUGHING PUMP SUB ASSY REV #2 DRAWN BY: C. ROHRMAN CHECKED BY: W. C. S. DATE: 12-25-52 SCALE: 1:1 REVISIONS: 1:1 2570261		DWD 120918 MOD 2 247573 MOD 1 1010914-1 (DRAFT) 1010914-1 (DRAFT) 1010914-1 (DRAFT) 1010914-1 (DRAFT)
SCHEMATIC COLLECTIVE SYMBOLS FINISH TO BE UNLESS OTHERWISE SPECIFIED 10.02 10.04 10.08 10.12 10.16 10.20 10.24 10.28 10.32 10.36 10.40 10.44 10.48 10.52 10.56 10.60 10.64 10.68 10.72 10.76 10.80 10.84 10.88 10.92 10.96 11.00 11.04 11.08 11.12 11.16 11.20 11.24 11.28 11.32 11.36 11.40 11.44 11.48 11.52 11.56 11.60 11.64 11.68 11.72 11.76 11.80 11.84 11.88 11.92 11.96 12.00 12.04 12.08 12.12 12.16 12.20 12.24 12.28 12.32 12.36 12.40 12.44 12.48 12.52 12.56 12.60 12.64 12.68 12.72 12.76 12.80 12.84 12.88 12.92 12.96 13.00 13.04 13.08 13.12 13.16 13.20 13.24 13.28 13.32 13.36 13.40 13.44 13.48 13.52 13.56 13.60 13.64 13.68 13.72 13.76 13.80 13.84 13.88 13.92 13.96 14.00 14.04 14.08 14.12 14.16 14.20 14.24 14.28 14.32 14.36 14.40 14.44 14.48 14.52 14.56 14.60 14.64 14.68 14.72 14.76 14.80 14.84 14.88 14.92 14.96 15.00 15.04 15.08 15.12 15.16 15.20 15.24 15.28 15.32 15.36 15.40 15.44 15.48 15.52 15.56 15.60 15.64 15.68 15.72 15.76 15.80 15.84 15.88 15.92 15.96 16.00 16.04 16.08 16.12 16.16 16.20 16.24 16.28 16.32 16.36 16.40 16.44 16.48 16.52 16.56 16.60 16.64 16.68 16.72 16.76 16.80 16.84 16.88 16.92 16.96 17.00 17.04 17.08 17.12 17.16 17.20 17.24 17.28 17.32 17.36 17.40 17.44 17.48 17.52 17.56 17.60 17.64 17.68 17.72 17.76 17.80 17.84 17.88 17.92 17.96 18.00 18.04 18.08 18.12 18.16 18.20 18.24 18.28 18.32 18.36 18.40 18.44 18.48 18.52 18.56 18.60 18.64 18.68 18.72 18.76 18.80 18.84 18.88 18.92 18.96 19.00 19.04 19.08 19.12 19.16 19.20 19.24 19.28 19.32 19.36 19.40 19.44 19.48 19.52 19.56 19.60 19.64 19.68 19.72 19.76 19.80 19.84 19.88 19.92 19.96 20.00 20.04 20.08 20.12 20.16 20.20 20.24 20.28 20.32 20.36 20.40 20.44 20.48 20.52 20.56 20.60 20.64 20.68 20.72 20.76 20.80 20.84 20.88 20.92 20.96 21.00 21.04 21.08 21.12 21.16 21.20 21.24 21.28 21.32 21.36 21.40 21.44 21.48 21.52 21.56 21.60 21.64 21.68 21.72 21.76 21.80 21.84 21.88 21.92 21.96 22.00 22.04 22.08 22.12 22.16 22.20 22.24 22.28 22.32 22.36 22.40 22.44 22.48 22.52 22.56 22.60 22.64 22.68 22.72 22.76 22.80 22.84 22.88 22.92 22.96 23.00 23.04 23.08 23.12 23.16 23.20 23.24 23.28 23.32 23.36 23.40 23.44 23.48 23.52 23.56 23.60 23.64 23.68 23.72 23.76 23.80 23.84 23.88 23.92 23.96 24.00 24.04 24.08 24.12 24.16 24.20 24.24 24.28 24.32 24.36 24.40 24.44 24.48 24.52 24.56 24.60 24.64 24.68 24.72 24.76 24.80 24.84 24.88 24.92 24.96 25.00 25.04 25.08 25.12 25.16 25.20 25.24 25.28 25.32 25.36 25.40 25.44 25.48 25.52 25.56 25.60 25.64 25.68 25.72 25.76 25.80 25.84 25.88 25.92 25.96 26.00 26.04 26.08 26.12 26.16 26.20 26.24 26.28 26.32 26.36 26.40 26.44 26.48 26.52 26.56 26.60 26.64 26.68 26.72 26.76 26.80 26.84 26.88 26.92 26.96 27.00 27.04 27.08 27.12 27.16 27.20 27.24 27.28 27.32 27.36 27.40 27.44 27.48 27.52 27.56 27.60 27.64 27.68 27.72 27.76 27.80 27.84 27.88 27.92 27.96 28.00 28.04 28.08 28.12 28.16 28.20 28.24 28.28 28.32 28.36 28.40 28.44 28.48 28.52 28.56 28.60 28.64 28.68 28.72 28.76 28.80 28.84 28.88 28.92 28.96 29.00 29.04 29.08 29.12 29.16 29.20 29.24 29.28 29.32 29.36 29.40 29.44 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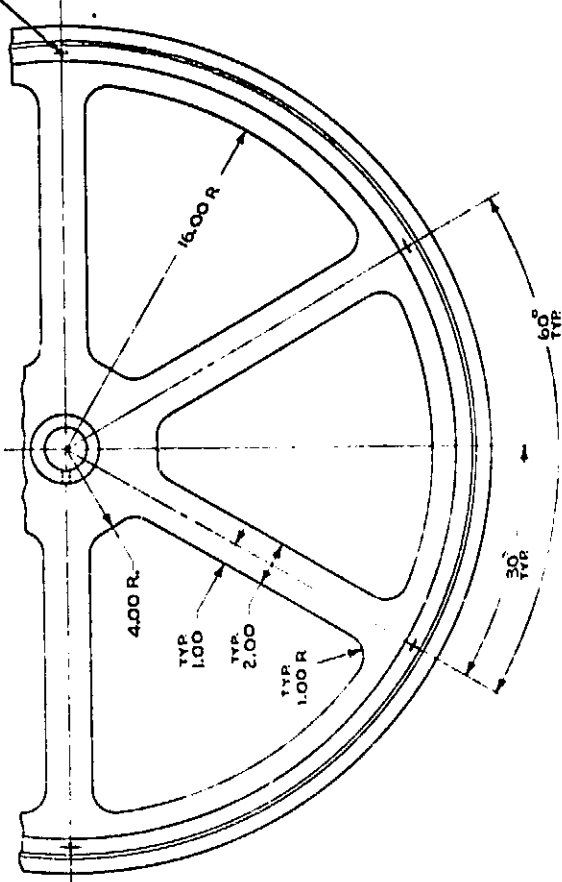


SILICON WEB FURNACE - MODEL - 2  
 STORAGE REEL DETAIL WELDMENT

ITEM	QTY	PART NAME	REF	ISSUE REFERENCE INFORMATION	MATL SUT. OR PART NUMBER FOR ORDER	RAD. STK. NO.	GROUP NOTE	PROCESSOR TIME NO.	GROUP
01		RIM		MAKE FROM AL.				6061-T651	
02		RIB		34.00 X .38 THK AL.	7904-0101			6061-T651	
03		HUB		4.25 OF 3.00 DIA. AL.	6102-0101			6061 T651	



375-18 TAP X .75 DR & HOLES EQ. SP. ON A 34.500 B.C.



REV 1

DWG 2. 30

WESTINGHOUSE ELECTRIC CORPORATION

TITLE SILICON WEB FURNACE - MODEL - 2  
 STORAGE REEL DETAIL WELDMENT

REVISIONS

NO.	DATE	DESCRIPTION
1		

DESIGNED BY: F. ARDELLO  
 DRAWN BY: C. S. [unclear]  
 CHECKED BY: [unclear]  
 APPROVED BY: [unclear]

2613 C 34

RESEARCH LABORATORIES, PITTSBURGH, PENNSYLVANIA, U.S.A.









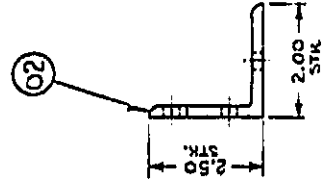
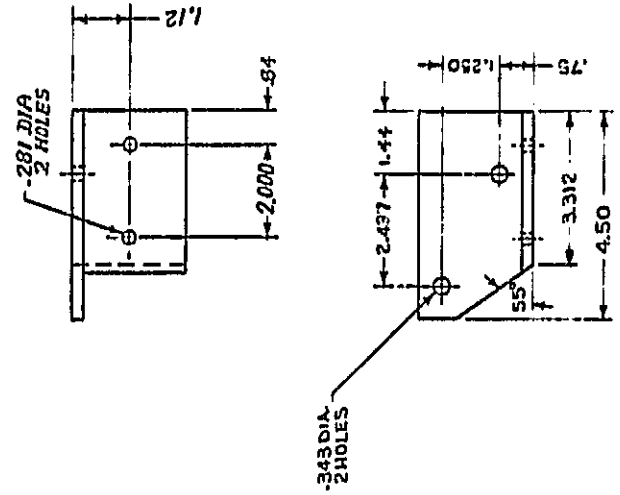
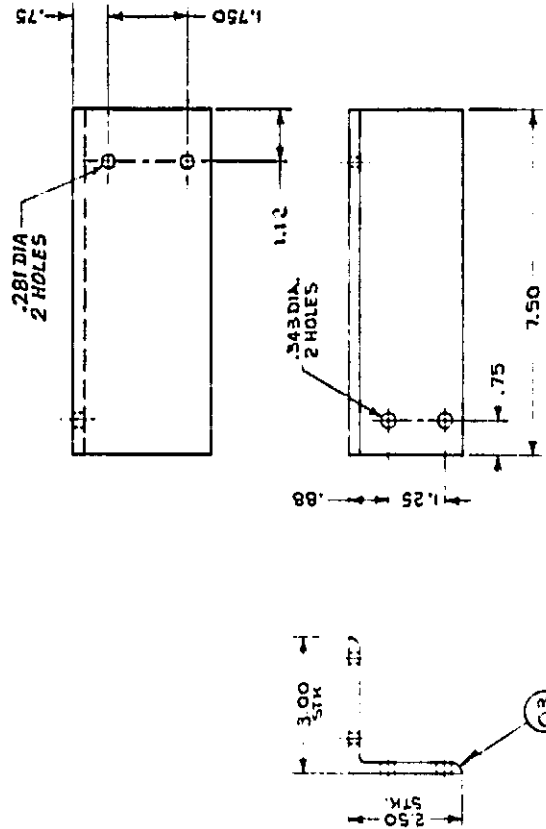
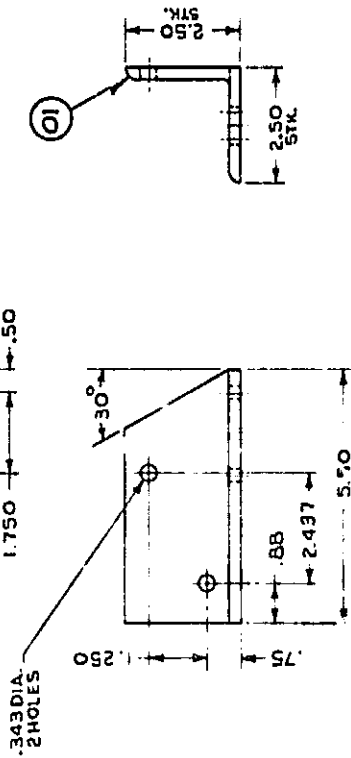
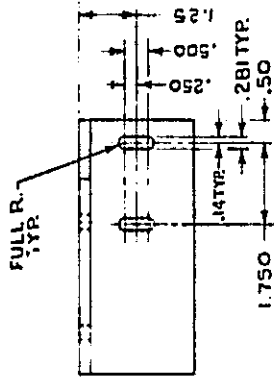
TITLE SILICON WEB FURNACE MOD. 2  
TAPE REEL BRACKETS

DWG 2613C61

REV 1

ITEM	QTY	PART NAME	DEF	REQD NOTATION & DIMENSION	MATERIAL SPECIFICATION	GROUP NOTE		PROCESSOR		GROUP
						PROCESSOR LINE NO	LINE NO	Q1	Q2	
01	A	BRACKET			5.62 OF 2.50X2.50X.257 STL					
02	A	BRACKET			4.62 OF 2.50X2.00X.257 STL					
03	A	BRACKET			7.62 OF 3.00X2.50X.257 STL					

A- JOSEPH T. RYERSON & SON, INC., PCH, PA.



WESTINGHOUSE CORPORATION

TITLE SILICON WEB FURNACE MOD 2  
TAPE REEL BRACKETS

REV. 1

2613 C 61

RESEARCH LABORATORIES - PITTSBURGH, PENNSYLVANIA

DATE: 11/17/50

BY: W. C. S.

CHKD: W. C. S.

APP: W. C. S.

DESIGNED BY: W. C. S.

DRAWN BY: W. C. S.

10 4903066

CHANGE









**SILICON WEB FURNACE - MOD. 2**

**SHIELD DET**

**2613C82**

**REV 1**

**TITLE**

**DWG**

**ITEM**

**NO.**

**GROUP**

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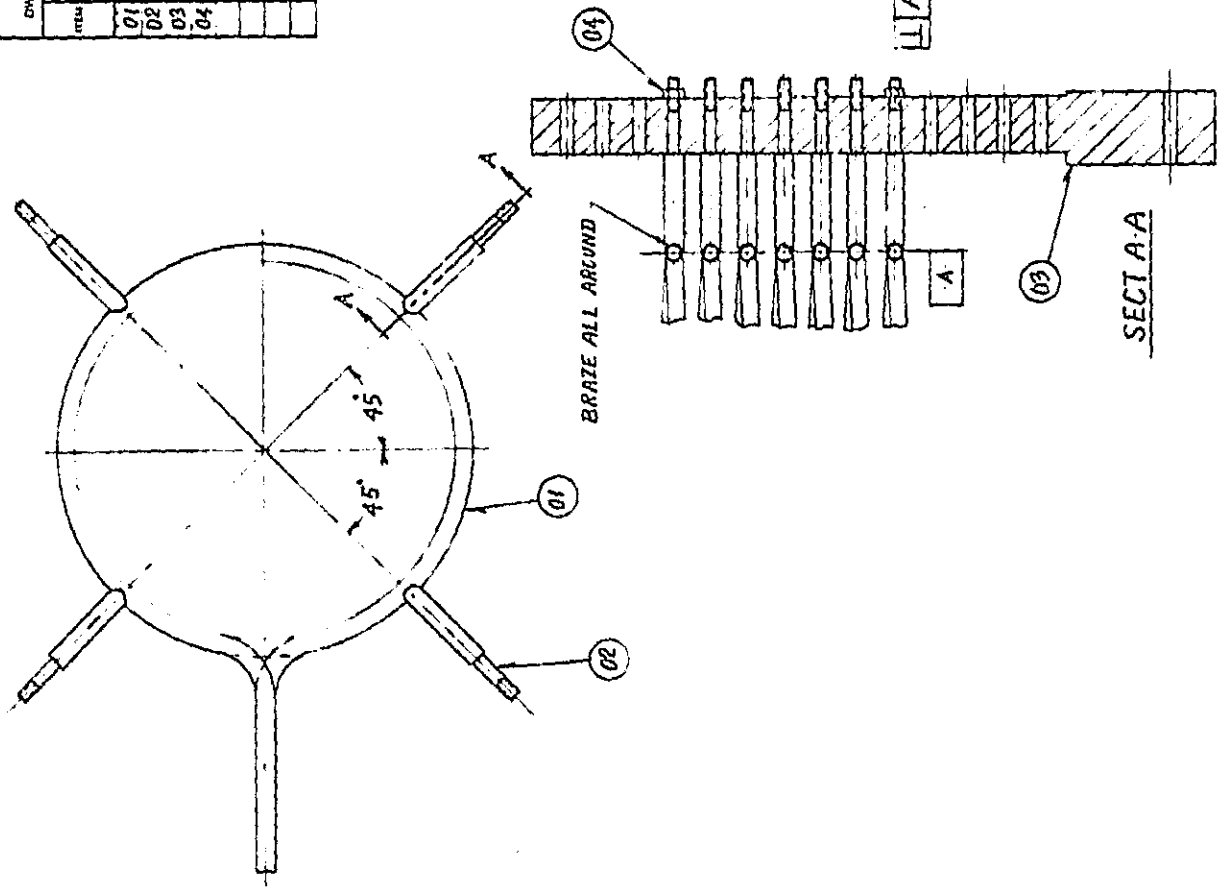
**277**



TITLE SILICON WEB TURNING 2613C98  
ROUND WORK COIL ASSY REV 1

ITEM	EQUIV	PART NAME	QTY	UNIT	MATERIAL REFERENCE INFORMATION	MATERIAL CODE PART NUMBER OR EQV DWG	GROUP	PROJECT OR LINE NO			
								D	B	C	W
01		WORK COIL		DWG		2613C98D01		1			
02		STAND OFF		DWG		4414A97H01		40			
03		A FAL POST		DWG		8520B4CH02		4			
04		KEY NUT						40			

A - USED FOR FIXTURING ONLY



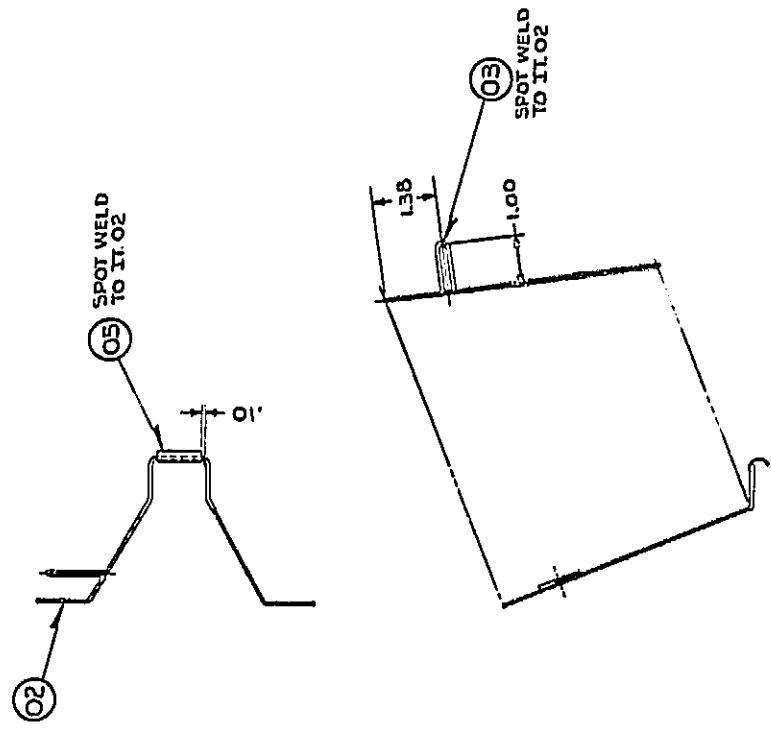
WESTINGHOUSE ELECTRIC CORPORATION TITLE <u>SILICON WEB FURNACE MODEL 2</u> <u>ROUND WORK COIL ASSY</u> REV 1		2613C98
DRAWING NO. <u>2613C98</u> REV. <u>1</u>		DATE <u>12-29-58</u>
DESIGNED BY <u>C. HOHMAN</u> CHECKED BY <u>S. P. S.</u> APPROVED BY <u>P. A. S.</u>		RESEARCH LABORATORIES DIVISION, WESTINGHOUSE ELECTRIC CORPORATION, PITTSBURGH, PA.
QUANTITIES TO BE MANUFACTURED: 1000 FINISH TO BE UNLESS OTHERWISE SPECIFIED UNLESS OTHERWISE SPECIFIED TOLERANCES: .005, .010, .015, .020, .030, .040, .050, .060, .070, .080, .090, .100, .125, .150, .175, .200, .250, .300, .375, .450, .500, .625, .750, .875, 1.000, 1.250, 1.500, 1.750, 2.000, 2.500, 3.000, 3.750, 4.500, 5.000, 6.000, 7.500, 9.000, 10.000, 12.500, 15.000, 18.000, 20.000, 25.000, 30.000, 37.500, 45.000, 50.000, 60.000, 75.000, 90.000, 100.000, 125.000, 150.000, 175.000, 200.000, 250.000, 300.000, 375.000, 450.000, 500.000, 600.000, 750.000, 900.000, 1000.000		

TITLE SILICON WEB FURNACE MOD-2  
WEB GUIDE SUB ASSY

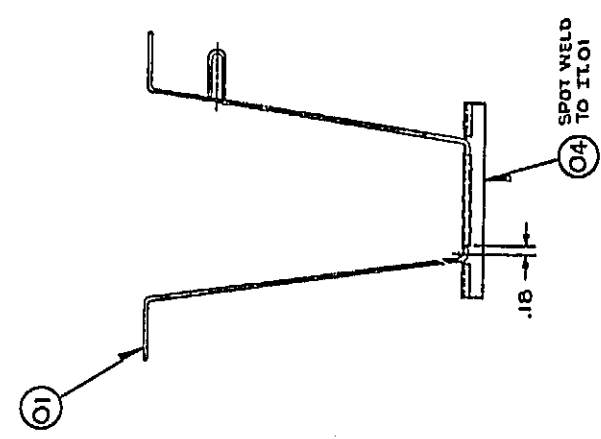
DWG 2614C09

REV 1

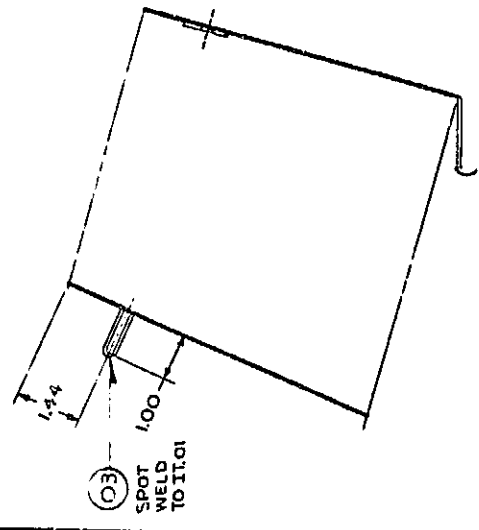
ITEM	QTY	PART NAME	DEF	SIZE REFERENCE INFORMATION	MATL SIZE CODE PART NUMBER OR REF DWG	GROUP NOTE PROCESS OR LINE NO	CHK'D	DATE
01		FACE GUIDE SUP	DWG		8520D69H01			
02		EDGE GUIDE SUP	DWG		8520D69H02			
03		LOOP	DWG		8520D69H03			
04		FACE GUIDE	DWG		8520D69H04			
05		EDGE GUIDE	DWG		8520D34H04			



GR.02



GR.01



ORIGINAL PAGE IS OF POOR QUALITY

1		CHANGE		p 903066	
WESTINGHOUSE ELECTRIC CORPORATION		RESEARCH LABORATORIES - PITTSBURGH, PENNSYLVANIA		2614 C09	
TITLE SILICON WEB FURNACE MOD-2		WEB GUIDE SUB ASSY		REV. 1	
DESIGNED BY SCARDELLO		CHECKED BY C. S.		DATE 8-27-57	
DRAWN BY		APP'D		DATE	
SCALE 1:2		REV. 1		DATE	
Dwg No. 2614C09		Part No. 8520D69H01		Rev. 1	
MATERIAL SPECIFICATIONS		FINISH TO BE UNLESS OTHERWISE SPECIFIED		TOLERANCES	
ALUMINUM		AS SPECIFIED		UNLESS OTHERWISE SPECIFIED	
STEEL		AS SPECIFIED		UNLESS OTHERWISE SPECIFIED	
BRASS		AS SPECIFIED		UNLESS OTHERWISE SPECIFIED	
COPPER		AS SPECIFIED		UNLESS OTHERWISE SPECIFIED	
SILICON		AS SPECIFIED		UNLESS OTHERWISE SPECIFIED	
GLASS		AS SPECIFIED		UNLESS OTHERWISE SPECIFIED	
OTHER		AS SPECIFIED		UNLESS OTHERWISE SPECIFIED	





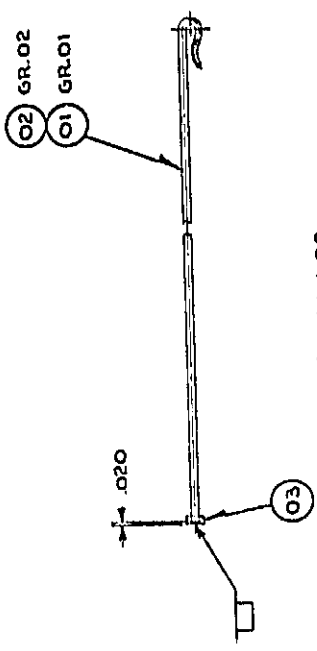


TITLE SILICON WEB FURNACE MOD-2  
PUSH ROD SUB ASSY'S

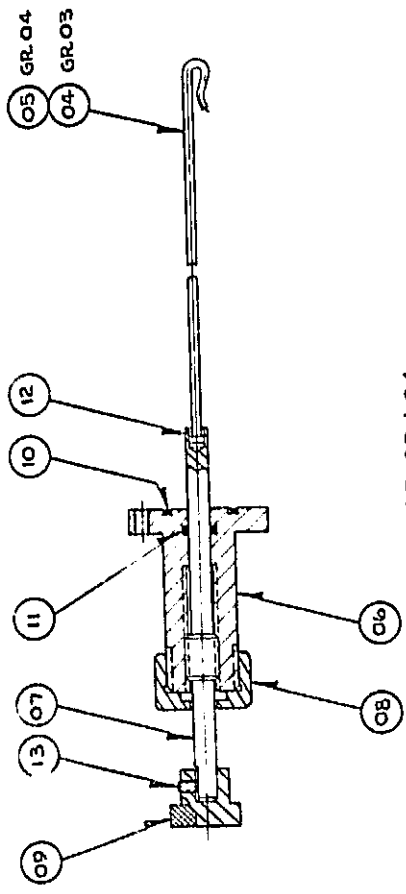
DWG 2614C20 REV1

ITEM	PART NAME	QTY	MATERIAL	DIMENSIONS	GROUP	PROCESSOR	GROUP NOTE	GROUP						
								1	2	3	4			
01	PUSH ROD	1	DWG											
02	PUSH ROD	1	DWG											
03	ROD CAP	1	DWG											
04	PUSH ROD ASSY	1	DWG											
05	PUSH ROD ASSY	1	DWG											
06	ADJ. SCR. H.S.G.	1	DWG											
07	ADJ. SCR.	1	DWG											
08	ADJ. SCR. H.S.G. CAP	1	DWG											
09	KNOB	1	DWG											
10	A. O-RING	1	BOS	.62 I.D. X .75 O.D. X .06 W. #2-106-V747-75										
11	A. O-RING	1	BOS	.25 I.D. X .38 O.D. X .05 W. #2-106-V747-75										
12	B. SPIROL PIN	1	BOS	.032 DIA. X .25 LG. PIC # C5-9										
13	SET SCR.	1		.138-32 X .25 LG. STL										

-A-PARKER SEAL CO., LEXINGTON, KY.  
 -B-PIC DESIGN CORP., RIDGEFIELD, CT.



GR.01 & 02



GR.03 & 04

Westinghouse Electric Corporation

TITLE SILICON V URNACE MOD-2  
PUSH ROD SUB ASSY'S

DESIGNED BY F. CARDELLI  
 CHECKED BY J. C. S

DATE 11-22-57

REVISIONS

REV. 1	2614 C 20
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RESEARCH LABORATORIES DIVISION, WESTINGHOUSE ELECTRIC CORP., PITTSBURGH, PA.

61 P 6821

NO.	DESCRIPTION	DATE
1	DESIGNED BY F. CARDELLI	11-22-57
2	CHECKED BY J. C. S	11-22-57
3	APPROVED BY [Signature]	11-22-57
4	APPROVED BY [Signature]	11-22-57
5	APPROVED BY [Signature]	11-22-57
6	APPROVED BY [Signature]	11-22-57
7	APPROVED BY [Signature]	11-22-57
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10	APPROVED BY [Signature]	11-22-57
11	APPROVED BY [Signature]	11-22-57
12	APPROVED BY [Signature]	11-22-57
13	APPROVED BY [Signature]	11-22-57

UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES AND DECIMALS THEREOF.

FINISH TO BE SPECIFIED

OTHERWISE LISTED

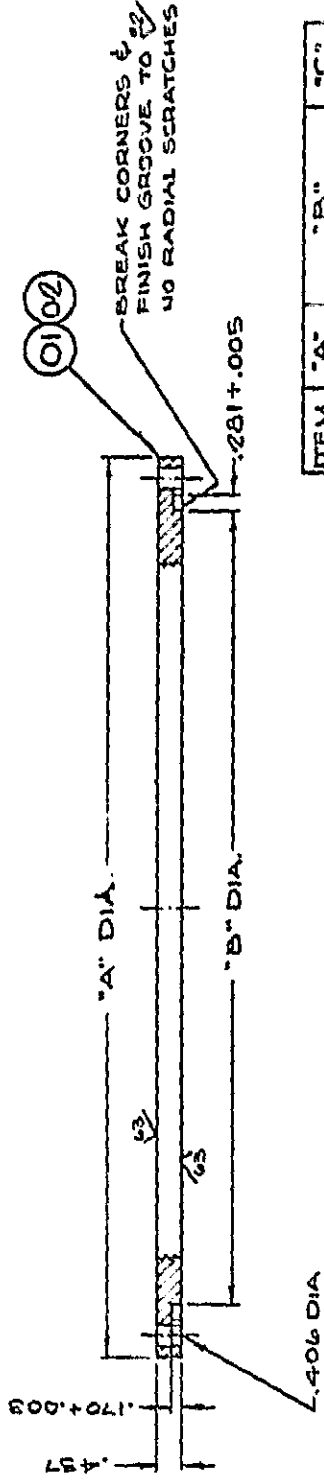
1 2 3 4 5 6 7 8 9 10 11 12 13





TITLE **SILICON WEB FURNACE MODEL-1E2**  
**BLANK COVER PLATES**  
 DWG 1690B07 REV 1

ITEM NO	PART NAME	QTY	QTY REFERENCE INFORMATION	MAT. SIZE CODE PART NUMBER (OR REP. CHG)	GROUP NOTE PROCESS OR LISE NO	GROUP
01	BLK COVER PL		16.00 DIA OF .50 THK SST TYPE 304/309 - 0101	RED STK NO		
02	BLK COVER PL		19 1/2 DIA OF .50 THK SST TYPE 304/309 - 0101			



ITEM	"A"	"B"	"C"
01	15.88	14.000 ± .030	15.125
02	19.00	16.955 ± .045	15.125

Westinghouse Electric Corporation  
 TITLE **SILICON WEB FURNACE MODEL-1E2**  
 DESIGNER D. ROCHER-SCALE  
 DATE 10/14/54  
 CDS W. C. S.  
 REV. 1  
**1690B07**  
 RESEARCH LABORATORY 25 GARDNER BORO PITTSBURGH PA. 15138 U.S.A.

REF 157-251  
 DWD 8520018  
 8520018

**GENETIC CHARACTERISTICS SYMBOLS**  
 PLANT: 100  
 PROCESS: 100  
 MATERIAL: 100  
 FINISH: 100  
 TOLERANCE: 100  
 SURFACE: 100  
 DIMENSIONS: 100  
 WEIGHT: 100  
 QUANTITY: 100  
 INSPECTION: 100  
 ACCEPTANCE: 100  
 REJECTION: 100  
 REWORK: 100  
 REPAIR: 100  
 DISCARD: 100  
 REUSE: 100  
 RECYCLE: 100  
 REWORK: 100  
 REPAIR: 100  
 DISCARD: 100  
 REUSE: 100  
 RECYCLE: 100

FINISH TO BE UNLESS OTHERWISE SPECIFIED  
 UNLESS OTHERWISE SPECIFIED  
 TOLERANCES  
 F. P. DEC. ± P. P. DEC. UNLESS OTHERWISE SPECIFIED  
 ± .005 ± .005 ± .005  
 OTHERWISE SPECIFIED

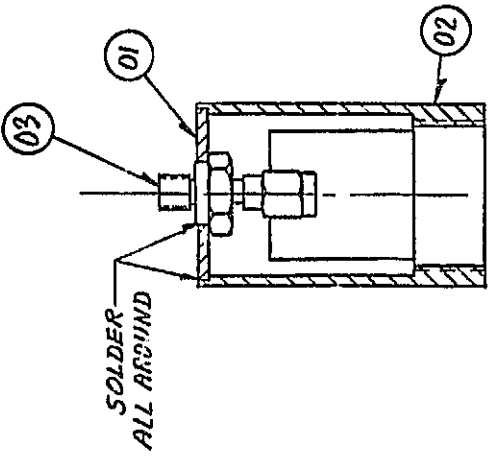
CHANGE  
 17  
 D 9029R2 M/P1  
 9030C M/P2

TITLE SILICON WEB FURNACE MOD-2  
SENSOR HOLDER  
1691B12

REV 1

ITEM NO.	PART NAME	DEF	(SIZE) REFERENCE INFORMATION	MATERIAL CODE PART NUMBER OR REF DWG	GROUP NOTE				
					PROCESS OR LINE NO.	GROUP			
01	CAP	DWG		8520D78H04					
02	SENSOR HLDR	DWG		8520D78H05					
03	A CONN.	BDS	SWAGelok O-SEAL STRIP	B-200-1-OR					

A- PGR VALVE & FITTING CO., PUGH, PA.



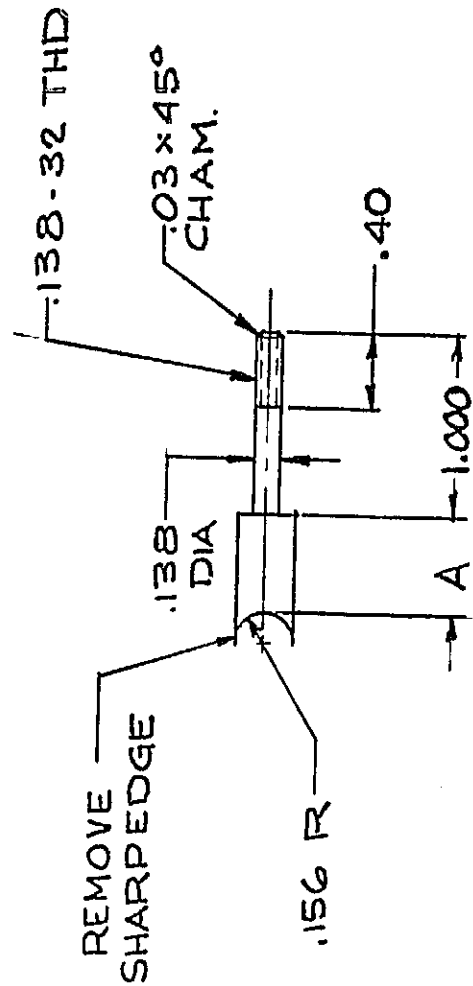
WESTINGHOUSE ELECTRIC CORPORATION SILICON WEB FURNACE MOD-2 SENSOR HOLDER ASSY DIMENSIONS IN INCHES—SCALE 1:1 C. HOHMAN W.C.S. SUPP		REV 1 1691B12		RESEARCH LABORATORIES CHURCHILL ROAD PITTSBURGH PA 15136 USA	
GEOMETRIC CHARACTERISTIC SYMBOLS FINISH TO BE UNLESS OTHERWISE SPECIFIED ±.008 ±.008 UNLESS OTHERWISE SPECIFIED TOLERANCES		1289UB DWG		1 2 3 4 5	
PRACTICES DIMENSIONS UNLESS OTHERWISE SPECIFIED CYLINDRICITY PROFILE OF ANY LINE PROFILE OF ANY SURFACE PARALLELISM PERPENDICULARITY (TO SURFACES) PERPENDICULARITY (TO AXES) SQUARENESS TAPER CHAMFER SURFACE FINISH MATERIALS BALL BEARING MATERIALS PRESSURES OF FIT AND SIZE		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		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	
CHANGE 903066		IT.		1 2 3 4 5	



Westinghouse Electric Corporation RESEARCH LABORATORIES CHURCHILL BORO. PITTSBURGH, PA. 15233, U.S.A.  
 TITLE SILICON WEB FURNACE MOD-2  
 WORK COIL STAND-OFF DET

903066

REF DWG 2613095	TOLERANCES		FINISH TO BE <input checked="" type="checkbox"/> UNLESS OTHERWISE SPECIFIED	DIMENSIONS IN INCHES—SCALE	SUB. DATA SHEETS	AMND	GROUP
	UNLESS OTHERWISE SPECIFIED	3 PL. DEC					
	± .02	± .005	± 0.5°				
ITEM	PART NAME	DEF	(SIZE) REFERENCE INFORMATION	MATL SIZE CODE PART NUMBER OR REF DWG	GROUP NOTE	PROCESS OR LINE NO.	GROUP
01	STANDOFF		2.75 OF .312 DIA BR	R&D STK NO 6105-0501	ASTM B-16		01 02 03 04 05



IT. NO.	A
01	1.40

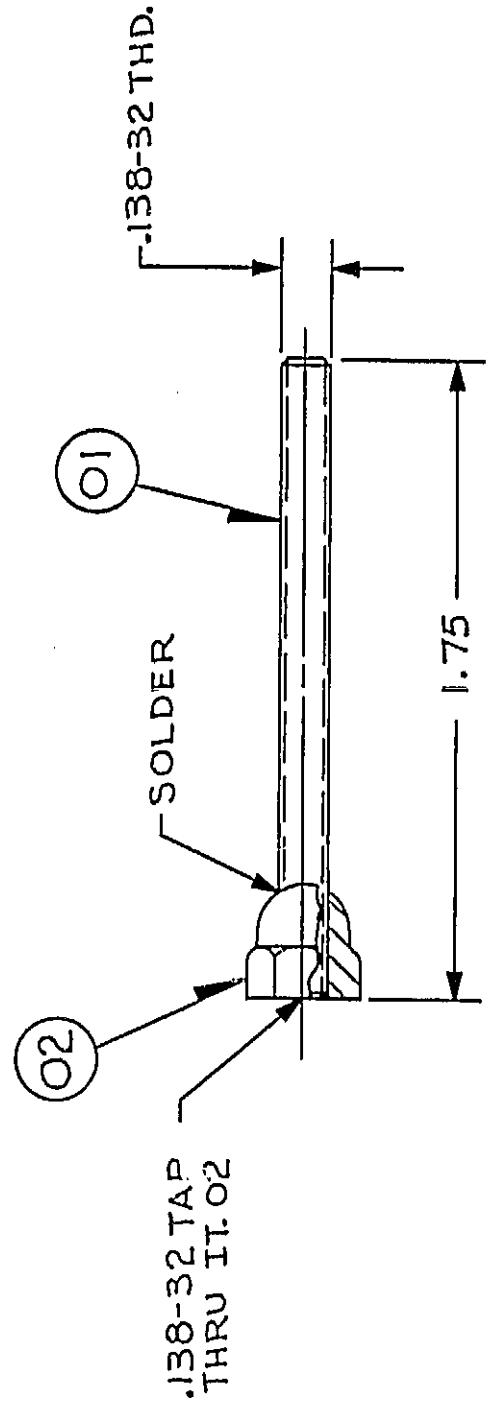
6414 A97

**Westinghouse Electric Corporation** RESEARCH LABORATORIES CHURCHILL BORO. PITTSBURGH, PA. 15233, U.S.A.  
**TITLE SILICON WEB FURNACE MOD-1&2**  
 ADJ. SCR. SUB ASSY.

REF DWG \_\_\_\_\_  
 DIMENSIONS IN INCHES—SCALE  
 2=1

ITEM	PART NAME	DEF	(SIZE) REFERENCE INFORMATION	MATERIAL SIZE CODE PART NUMBER OR REF DWG R&D STK. NO.	GROUP NOTE	GROUP				
						PROCESS OR LINE NO.	01	02	03	04
01	ALL THD.		1.88 OF .138-32 STL.	6506-0901		1				
02	ACORN NUT		.138-32 STL.			1				

NUM. DTM. FCARDELLO  
 1  
 APPD. M.C.S. 27  
 D-903066



6416 A 16

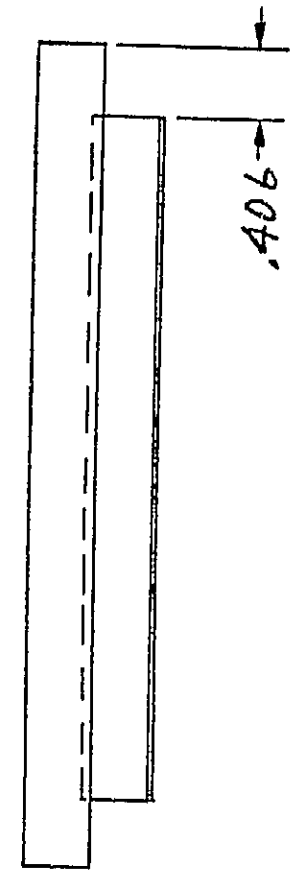
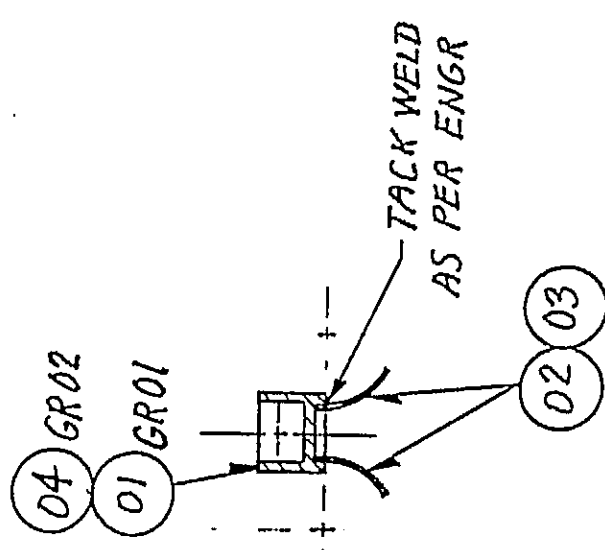


Westinghouse Electric Corporation RESEARCH LABORATORIES CHURCHILL BORO, PITTSBURGH, PA. 15233, U.S.A.

TITLE SILICON WEB FURNACE MOD-2

DUCT GUIDE

REF DWG	1289J19	TOLERANCES			FINISH TO BE UNLESS OTHERWISE SPECIFIED	DIMENSIONS IN INCHES—SCALE	SUB. DTM. C. HOHMAN	APPRO. W. C. S. 8-29	D 903066
		UNLESS OTHERWISE SPECIFIED	2 PL. DEC.	3 PL. DEC.					
		± .02	± .005	± 0.5°		1:1			
ITEM	NOTE	PART NAME	DEF	(SIZE) REFERENCE INFORMATION	MATL SIZE CODE PART NUMBER OR REF DWG	GROUP NOTE	PROCESS OR LINE NO.	GROUP	
01		GUIDE HSG	DWG		8520D78H01		1	01 02 03 04 05	
02		GUIDE	DWG		8520D78H02		2		
03		GUIDE	DWG		8520D78H03		2		
04		GUIDE HSG	DWG		8520D78H06		1		



GR 01 & 02

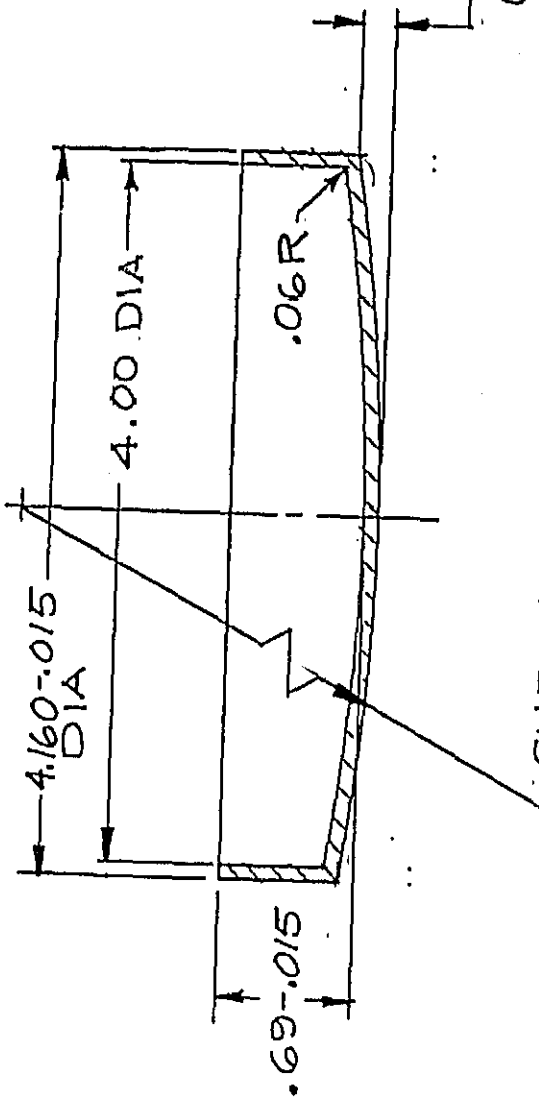
6417A 44

Westinghouse Electric Corporation  
 TITLE SILICON WEB FURNACE  
 CRUCIBLE

RESEARCH LABORATORIES CHURCHILL BORO, PITTSBURGH, PA. 15233, U.S.A.

REF DWG	TOLERANCES			FINISH TO BE ✓ UNLESS OTHERWISE SPECIFIED	DIMENSIONS IN INCHES—SCALE	GROUP NOTE	PROCESS OR LINE NO.	GROUP
	UNLESS OTHERWISE SPECIFIED	2 PL. DEC	3 PL. DEC.					
ITEM	PART NAME	DEF	(SIZE) REFERENCE INFORMATION	MATL SIZE CODE PART NUMBER OR REF DWG				
01	CRUCIBLE	MKF	AMERSIL CFQ TOB				01 02 03 04 05	

RTM(C.S. 72) SUB. 1 APTD.



.12 OR .25  
 (.12 PREFERRED)

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6417 A57





