FINAL REPORT

FOR

TASK NO. 3

APOLLO COMMUNICATIONS SYSTEM SUPPORT

IMPROVEMENTS IN CONTACT PRINTING AND METAL MASKING TECHNIQUES

1 August 1967 - 29 March 1968

Contract No. NAS 9-6636

Prepared by

WESTINGHOUSE ELECTRIC CORPORATION
DEFENSE AND SPACE CENTER
AEROSPACE DIVISION

General Order No. 51431CA

For

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GODDARD SPACE FLIGHT CENTER
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ABSTRACT AND SUMMARY

Methods of producing contact prints into an emulsion or chromium coated glass plate were investigated. Resolution of one to five micrometer lines were investigated. The three methods tested were:

1. The washout technique where chromium was evaporated over a resist pattern. The resist was dissolvedaway leaving a pattern of chromium on the glass substrate.
2. The formation of a resist pattern over chromium evaporated on a glass plate. The exposed chromium was etched leaving a pattern of chromium on the glass substrate.
3. The conventional contact printing of emulsion masks with consideration for very high resolution.

Positive and negative resists were examined for the chromium pattern formation. A method is given for improving resist adhesion to the glass substrate. A process for hardening the chromium is also given. Chromium evaporation techniques are described that limited pinholes to five per square inch.

A contact printer was designed, built and tested for high resolution printing. Light collimation and wavelength were examined for effect on the high resolution emulsion. The contact printer was designed to expose photo-engraving resists as well as silver halide emulsions.

Line widths and slots widths as small as 50×10^{-6} inches were produced on chromium as well as emulsion masks. There was no indication that this was a limiting size.

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1.0 Introduction

There are two methods in use today for the generation of photographic plates used in micro-electronics. The first system has to do with a final reduction of a step and repeat pattern onto a high resolution plate. Only one exposure is required to reproduce the stepped object so these reproductions may be made very rapidly. The image must necessarily cover an area sufficiently large to take in the entire stepped pattern therefore the lens must also be correspondingly large. These larger lenses have not yet been developed to the extent that they will produce with sufficient faithfulness the smaller lines, i.e. .0001", that are required to keep pace with the advancing art of micro-electronics.

The second system requires the stepping operation of generating multiple patterns to be performed as the object is reduced to its final size. It is necessary in this system to photograph each step independently before moving onto the next step location. It is apparent that one must make as many exposures as there are steps in the final pattern. It, therefore, requires a considerable amount of time to produce the final pattern.

Consideration must be given to the cost to produce this plate and to its useful life under normal operating conditions. It has been found that when an emulsion such as a Lippman emulsion is used in contact with a typical semi-conductor wafer that after one or two printings for the most exacting work, or perhaps as many as ten contacts for less critical work, that the mask has been damaged to the extent that its useful life has expired. Not only is

the cost of masks high, but the quality of contact printing onto the semiconductor wafer is degraded with each subsequent printing. The facility to produce the step and repeat plate is soon overloaded. It, therefore, cannot keep up with plate demands without the addition of more equipment. Since the machines capable of producing satisfactory step and repeat plates cost approximately $25,000, and more, it is practical to examine other methods of satisfactory reproduction of the master plate.

One such method is to contact print the master plate onto other high resolution plates generating submasters. These submasters can then be used to contact print working high resolution plates. The contact between high resolution plates is not so harsh as the contact between the high resolution plate and a semiconductor wafer. The decrease in severity in contact allows more contacts to be made before rejection occurs.

The use of chromium-on-glass submasters would further reduce the defects that occur in contact printing. The chromium master would be produced from the first contact from the master plate. Minimum defects would therefore be encountered. The chromium plate, being extremely hard compared to an emulsion mask, would not deteriorate with use. An infinite number of working plates can be made from such a chromium submaster.

An increase in the life of a working plate can be expected if chromium plates are used as working plates. Extended life of a chromium plate cannot be expected as with the sub-master plate because the semiconductor wafer can damage the mask. Epitaxial peaks on the wafer are capable of shattering the glass in small point locations which will cause the resist polymerization

to be incomplete at this point. The quality of the semiconductor wafer will therefore effect the economic justification for use of a chromium working plate.

2.0 Experimental Procedure and Discussion

2.1 Chromium Evaporation

The aim of this portion of the task was to achieve a technique for producing chromium deposits on 2 x 2 inch glass slides for use as metal masks. An evaluation of both chromium evaporation sources as well as suitable glass substrates was carried out. Glass cleaning and evaporation techniques were examined and a method for obtaining suitable chromium deposits will be discussed which results in masks having a low pinhole density.

2.1.1 Evaporation Sources

It is difficult to evaporate chromium by standard evaporation techniques since it sublimes rather than evaporating from the liquid phase. The usual techniques used are chromium pellets or chips in a refractory boat or conical basket. The chromium usually makes poor thermal contact with the evaporation source making reproducible evaporations difficult.

A recent development in chromium evaporation sources is the use of electroplated tungsten filaments. Sylvania Electric Products Division sells filaments (essentially line sources) with 20 to 30 mils of plated chromium in 2, 4, and 6 inch lengths. These filaments permit intimate contact between evaporant and refractory source and better reproducibility. A 1200Å thick deposit was possible for the 2 inch long source and a source to substrate distances of 8 inches if the chromium is evaporated to completion. The longer sources (i.e. 4" and 6") could be used to achieve thicker films or for greater thickness uniformity if a large number of substrates were being deposited onto simultaneously.

2.1.2 Glass Substrates

Several types of glass substrates were purchased for use in this application. In addition, several other glass suppliers were contacted and samples of other types of glass were obtained. Table I lists the types of glass used, the surface finish, and the supplier of the glass. Most of the substrates used were polished flat since these are readily available from most of the glass suppliers. The Corning 7059, a drawn sheet glass, is designated a substrate glass by the manufacturer. However, for the metal mask application the standard thicknesses (0.32" and .048") do not meet the required .060" thickness. In addition, although it is a drawn glass, it is not very flat, continuing many hills and valleys over the 2 x 2 inch area. The only drawn flat glass available for this work was the American St. Gobain "photo" glass,samples of which were supplied by the J. M. Freed Company.

Before discussing the cleaning technique it should be noted that all polished substrates contained minute surface imperfections that could not be removed using any of our standard cleaning procedures. These imperfections were visible before the evaporation. After the evaporation it was found that either no material covered the imperfections or if the film did, it was easily removed by scrubbing the glass substrate. These imperfections were of the order of about 0.1 mil and their density is quite high which means the polished glass is not useful as a substrate for metal masks. The imperfections are most probably introduced during the polishing operation. The imperfections were not picked up in a Talysurf IV measurement. Neither were any larger imperfections. The polished glass was very flat showing at most a .05 mil variation per half inch of length on the surface.

The "photo" glass after cleaning showed very little in the way of imperfections. Only a small number were noted which led to the relatively small pinhole density for this glass. The Talysurf IV measurement of the "photo" glass did not show any large imperfections on the surface. It did, however, indicate a definite bow or curvature (or camber) of the glass which can be attributed to the forming operation. From the Talysurf measurement the variation was about .15 mils over a half inch length of the surface. For metal masks this is a very small bow which probably would not be seen and which probably would be removed by the vacuum chucks used in photoengraving.

2.1.3 Glass Cleaning Procedures

A number of techniques for cleaning glass are available. However, care must be exercized in choosing a particular cleaning procedure. The usual technique used in our laboratory involves immersion into a hot (110°C) mixture of 100 gm sodium (or potassium) dichromate, 100cc water and 2.2 liter sulfuric acid for 30 seconds. This is followed by a rinse in de-ionized water and then suspension in isopropyl alcohol vapors. For most glasses this is a good technique. However, for the soda-lime type glass (of which the "photo" glass is an example) the dichromate-sulfuric mixture has a tendency to leach sodium out of the glass. The leaching adversely affects the adhesion of films on the glass when it is used as a substrate.

Since the compositions of some of the glasses are not known, it was felt that a glass cleaning procedure applicable to all type of glass would be desirable. The technique evolved was rather simple and straightforward and was applicable to all the glasses used on this task. The procedure is described as follows:

1. The glass was scrubbed well with cotton balls dipped in a concentrated Alconox and deionized water mixture.
2. The glass was then placed in a solution of Alconox and deionized water (in approximately the concentration specified by the manufacturer) in an ultrasonic cleaner for 30 minutes.
3. The glass was then placed in a beaker of deionized water in an ultrasonic cleaner for an additional 30 minutes.
4. The glass was then rinsed under running deionized water for at least 10 minutes.
5. The glass was not permitted to dry. It was rinsed thoroughly in isopropyl alcohol from a squirt bottle.
6. Drying was not permitted on any areas of the glass. The glass was immersed in hot isopropyl alcohol vapors for at least two minutes.
7. The glass was slowly withdrawn from the hot isopropyl vapors so that drying proceeded as the glass was withdrawn. Beads of alcohol would not form if the glass was clean.
8. The glass was then mounted on the substrate holder and immediately inserted into the vacuum station.

The above procedure was used to clean most of the glass substrates used in this effort. A variation of the above procedure was attempted which produced no noticeable difference in the pinhole density. The difference involved the use of cerium oxide instead of the Alconox in steps 1 and 2. A paste of cerium oxide and deionized water was used to scrub the glass and a dilute solution of cerium oxide and deionized water was used in the ultrasonic cleaner.

2.1.4 Deposition Procedure

The vacuum station in which the depositions were carried out was of the oil diffusion pump variety backed by a mechanical pump. A liquid nitrogen trap and water cooled baffle were located above the diffusion pump. An 18 inch diameter glass bell jar was used above the base plate so that visual observation of the deposition was possible.

All sources were mounted in the horizontal plane and the evaporations were carried out with the substrates located above the source. Only a few evaporations were carried out to the point where the chromium was completely removed from any one source. If the chromium was completely removed from the source, it was found that the last of the chromium evaporated in larger than atomic form and might contribute to pinholing in the substrate. Therefore, to overcome this problem two (or more) sources were used in parallel if enough chromium was not available from one source.

Immediately after cleaning the glass substrates, they were mounted in the vacuum chamber. Three types of mounting were used. If heating of the substrate was used with the idea of improving adhesion, then the substrates were mounted on a graphite block which was directly heated by passing a high current through it. The second type of mounting of the glass substrates was on a metal plate which was used for room temperature deposition. The graphite block could be used for room temperature depositions, but the advantage of the metal plate was that it could accommodate many more substrates than the block. The third type of substrate mounting was on a rotating holder. The belief was that the rotating substrate holder would

overcome pinholing in the films. No appreciable difference in the number of pinholes was noted. However, the substrate holder did aid in obtaining uniform thickness films if a large number of substrates were being deposited onto simultaneously. Instead of using the belljar for the rotating substrate the following arrangement was used. A 12 inch long Corning Pyrex cylinder 18 inches in diameter was mounted on the vacuum station baseplate. The cylinder was topped by an aluminum plate through the center of which passed an MRC rotary feedthrough. The substrate holder was mounted on the vacuum side. A (CRC) variable speed motor was mounted on the air side.

Heating of the substrate during the deposition did not improve adhesion as much as originally believed. The results could not be predicted since there was good adhesion on most substrates, but occasionally variable adhesion was obtained. Pinholing in the film was unaffected by heating. Post deposition heating of the substrates in air apparently gave the best results as far as adhesion was concerned.

When the pressure in the vacuum system was less than 5×10^{-6} torr, the evaporation source was preheated to permit outgassing. The chromium plated filaments were very gassy with the pressure rising appreciably. When the pressure again returned to less than 5×10^{-6} torr the temperature of the source was raised to the evaporation temperature, the shutter was moved out of the way and deposition begun. When the desired thickness was reached the deposition was halted. During the deposition the pressure decreased continuously reaching the high 10^{-7} torr range at the completion of the deposition. This pressure change can be explained by the fact that chromium

getters oxygen rather readily forming a number of different chromium oxides. The oxides can detrimentally affect the etch rate of the chromium as well as the color of the film. Therefore, the deposition should be carried out at a rather rapid rate. For depositions on the glass substrates for metal masks, the deposition rate was in the range of 300 to 600 angstroms per minute.

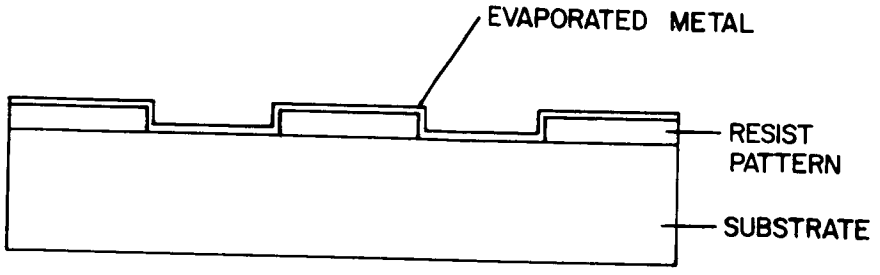
Table I

Type of Glass	Finish	Manufacturer (or Supplier)	Designation
Plate	Polished	O & S Research	
Crown	Polished	O & S Research	
Quartz	Polished	O & S Research	
Vycor	Polished	O & S Research	
Crown	Polished	Fish-Shurman	Water White
Flat (sheet)	Drawn	Corning	7059
Flat (sheet)	Drawn	American St. Gobain (Freed)	Photo

Glass for Substrates

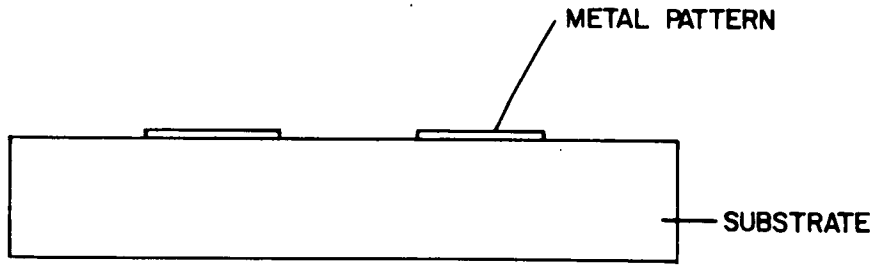
2.2 Resist Pattern Formation On Glass

Four resists were considered for use with the washout process. This process uses a resist image formed on a substrate. Metal was evaporated over the substrate and resist. The resist (and metal over the resist) was washed away with a solvent leaving the metal pattern on the substrate. Figure 1 shows the resist pattern with the evaporated metal. Figure 2 shows the substrate after the solvent has removed the resist and overlying metal.



Metal Evaporated Over Resist

Figure 1



Pattern By Washout Technique

Figure 2

Two of the resists selected for the washout technique were Shipley AZ111 and Shipley AZ1350. Two Kodak resists were also selected. They were Kodak Metal Etch Resist and Kodak Thin Film Resist.

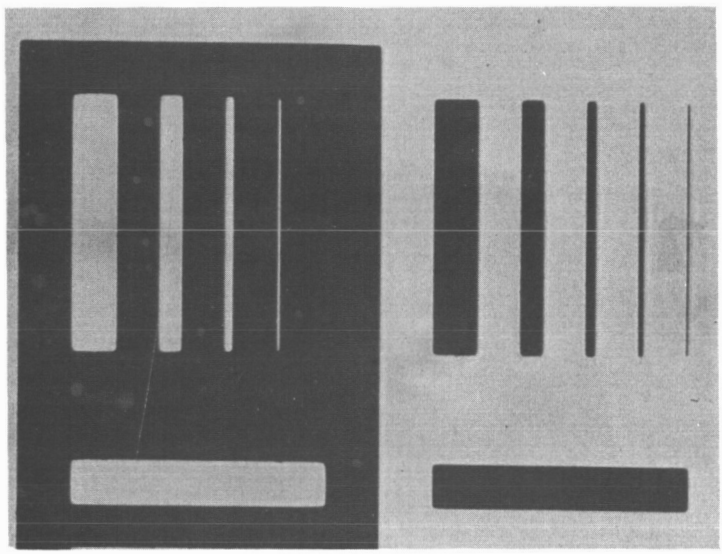
The basic consideration for a washout process differs from those requirements for processing integrated circuits. In the washout process resolution and cleanliness of the developed out areas are of primary importance. Permeability is not important as the evaporated metal will not penetrate the resist as does hydrofluoric acid used in etching oxides. This is the reason that thinner coatings of resist may be used to form the pattern.

The substrate used to hold the pattern was 2" x 2" x .060 glass plates. The glass was scrubbed using a cotton ball and Alconox in water. The substrate was ultrasonically cleaned in Alconox and water for one hour followed by one hour ultrasonic rinsing in .45 micrometer filtered water. The plate was placed in an oven at 180°C for thirty minutes to drive off all traces of moisture. The substrates were cooled before being coated with resist.

2.2.1 Shipley AZlll Resist

A 13mm sweeney containing a one micrometer Millipore filter (Type NR) and a glass prefilter was attached to a 10cc syringe filled with resist. The resist had a viscosity of 35cp. as measured by a National Instruments Company falling ball viscosimeter. The resist was dispensed onto a substrate that was positioned on a Headway Research spinner. The resist flooded the substrate. A spin speed of 3000 rpm for 20 seconds was used to give a thin, uniform coating onto the substrate. The substrate was placed on a 1/2 inch thick teflon boat and placed into an oven at 90°C for twenty minutes. The exposure of the resist was by use of a Sylvania sun gun held twelve inches from the substrate. Contact was maintained by vacuum. The intensity of the sun gun was adjusted by a Powerstat so that uniformity of exposure could be controlled. This intensity was arbitrarily measured using a light meter and a Corning filter #CS5-58 which peaks at 4000Å.

A test pattern, shown in Figure 3, was used to calibrate the exposure. The pattern consisted of line widths and slot widths of .0001, .0002, .0005, .0010 and .0020 inches. A series of exposures varying from 10 seconds to 30 seconds were made.



Resolution Test Pattern

(Transmitted Light)

Figure 3

The resist was developed in AZ303 developer mixed one part developer to four parts water. A glass petri dish was used as the developing tray. A slight agitation was given to the tray to aid developing. The image developed in thirty seconds and was rinsed under filtered running water. The ten second exposure did not completely depolymerize the resist as did the twenty and thirty second exposure. Difficulty was experienced in preventing the small lines of resist, (< .0005") from washing from the surface of the glass substrate.

The resist was stripped from the surface of the substrate by soaking it in acetone. The substrate was dried and placed in benzene sulfonic acid (BSA) at 65°C for five minutes. The acid was to provide a molecular bond

between the glass surface and the resist. Running water was used to rinse the BSA from the substrate. A drying cycle of 180°C for 30 minutes was used to remove any moisture.

The resist was again applied to the substrate and developed in the manner described above. Adhesion was improved so that all lines and spaces were properly resolved. (See Table II). Care was required to prevent the lines of resist under .0005 from washing off during developing.

2.2.2 Shipley AZ1350 Resist

The same procedure for coating, and exposing the substrate was used for AZ1350 resist as was employed for AZ111 resist. A slower spin speed of 1500rpm was found to be more desirable as the resolution improved. The adhesion of the resist to the glass was also better. An alternate substrate surface preparation was found in rinsing the substrate in the developer solution rather than the benzene sulfonic acid.

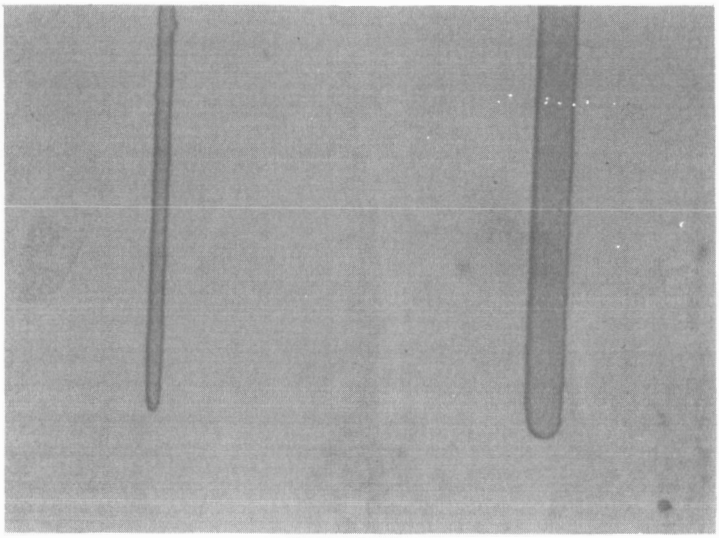
The exposed resist was developed in AZ1350 developer mixed 1 part developer to 1 part water for 30 seconds using a slight agitation of the bath. The wafer was rinsed under running filtered water and dried. The lines and slots of resist were measured and are recorded with the dimensions of the master plate in Table II. Figure 4 shows the smallest slot of the pattern at a magnification of 930X. The slot is clean and smooth.

Table II

		Line Width					Slot Width			Remarks
Master Plate (Emulsion Mask)		.00010	.00025	.00046	.00107	.00205	.00017	.00043	.00111	.00217	
Resist	Exposure (Seconds)	Positive Resists								
AZ111	10	Incomplete Exposure								
	20	.00008	.00021	.00044	.00106	.00207	*	.00039	.00106	.00212	* Slot Not Open
	30	.00007	.00021	.00045	.00105	.00205	.00013	.00038	.00108	.00216	
AZ1350	10	Incomplete Exposure								
	20	.00008	.00023	.00043	.00105	.00203	.00017	.00046	.00112	.00216	
	30	.00007	.00020	.00043	.00105	.00208	.00019	.00047	.00113	.00217	
		Slot Width					Line Width			
		Negative Resists								
KMER	10	.00011	.00025	.00045	.00110	.00205	.00017	.00041	.00112	.00215	
	20	.00010	.00025	.00047	.00107	.00204	.00018	.00043	.00109	.00217	
	30	.00010	.00024	.00045	.00107	.00204	.00019	.00043	.00111	.00217	
KTFR	10	.00012	.00026	.00046	.00107	.00205	.00016	.00042	.00111	.00215	
	20	.00009	.00025	.00044	.00107	.00205	.00018	.00044	.00114	.00214	
	30	.00010	.00025	.00043	.00106	.00205	.00018	.00045	.00113	.00218	

Exposure vs. Resist Resolution

Emulsion Mask



Slot In AZ1350 Resist

930X

Figure 4

2.2.3 Kodak Metal Etch Resist

Kodak Metal Etch Resist as received from the supplier is not a satisfactory resist for use in high resolution applications. Globular particles distributed throughout the resist prevent good resolution. Two processes have been used to remove these particles. The processes are electrophoresis* and centrifugation.[1] The resist for use in this test was mixed one part resist to one part thinner and placed into 50cc centrifuge tubes. An International Clinical Centrifuge spun at 3400 rpm for 16 hours was used to separate the resist from the globular particles. The viscosity of cleaned resist was 20 centipoise as measured by a National Instruments Company falling ball viscosimeter.

*Electrophoresis treatment of Kodak Metal Etch Resist is a proprietary process to Westinghouse Electric Corporation.

A 13mm sweeney containing a .8 micrometer Millipore filter (Type AA) and a glass prefilter was attached to a syringe filled with resist. The resist was dispensed onto a substrate that was positioned onto a Headway Research Spinner. The resist flooded the substrate. A spin speed of 5500 rpm for 20 seconds was used to give a thin, uniform coating onto the substrate. The substrate was laid onto a metal mesh rack in an oven at 110°C and baked for 10 minutes.

The exposure setup for the resist was the same as that used with the Shipley AZ1350 resist. Test exposures of 10, 20 and 30 seconds were made. The image was spray developed for thirty seconds with 60% KMER developer-40% dipropyl carbonate. A 15 second spray rinse of butyl acetate followed the developer. The wafer was blown dry. Measurements for each of the three exposures are shown in Table II.

2.2.4 Kodak Thin Film Resist

Kodak Thin Film Resist was diluted with Kodak Thin Film Thinner to a viscosity of 17cp. The same procedure for coating and exposing the substrate was used for KTFR as was used for KMER. Developing procedure was also the same except that KTFR developer and rinse was used on these substrates. Measurements for each of the three exposures are shown in Table II.

2.3 Pattern Washout and Chromium Hardening

Glass substrates containing a resist pattern were placed into an evaporator and coated with chromium. The substrates containing Shipley resist were placed in acetone which easily dissolved the resist. A light scrubbing with acetone and a cotton ball washed away the excess chromium and helped break

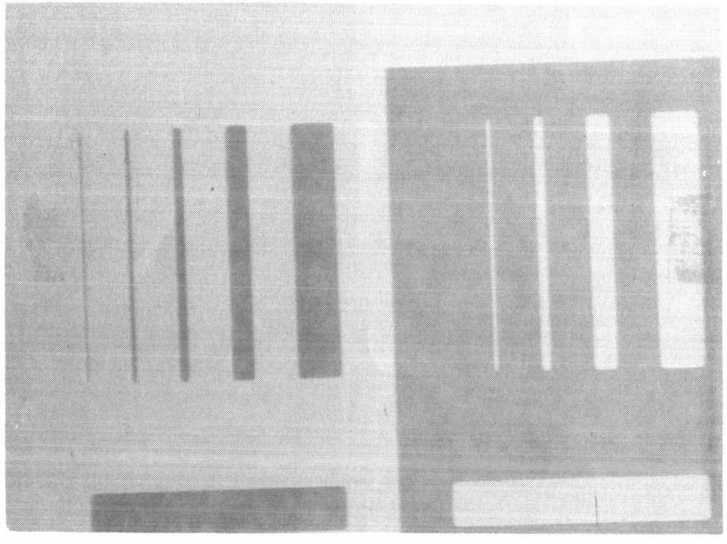
away the edges of the remaining chromium pattern. The resist that had been exposed the longest was easiest to washout. This was attributed to the sharper resist edge created by the longer exposure.

The substrates coated with the Kodak resists were placed in J-100 resist stripper heated to 65°C. The pattern was scrubbed with a cotton ball to aid in the removal of the resist and the chromium. The edge sharpness of the chromium pattern for the Kodak resists was not as good as for the Shipley resists. The deposited chromium was also much softer for the Kodak resist indicating that the chromium-glass interface was contaminated.

Tests were conducted to further harden the chromium on the plates processed with Shipley resists. Acceptable hardness was considered achieved when the chromium could not be scratched with a knife point. Heat treatment of the substrate up to a temperature of 450°C and for times varying up to 16 hours failed to completely harden the resist. Rather, a crumbling of the chromium occurred indicating an innerface that was not clean between the chromium and glass.

Substrates with a resist pattern developed on their surface were submerged in a 10% HF solution for one minute. The purpose was to slightly etch the glass assuring a clean surface. Undercutting occurred on the AZ1350 resist which caused the .0002" line of resist to be washed away. A solution of 1 pound ammonium fluoride to 1000cc water was then used as a rinse. This solution was followed by a 15 minute rinse in flowing filtered water. The substrates were dried in an oven at 110°C for 15 minutes.

Chromium was evaporated on the surface of the substrate. A washout in acetone with a light rubbing with a cotton swab produced a pattern with good resolution (Figure 5). The chromium was hard but did not pass the scratch test.

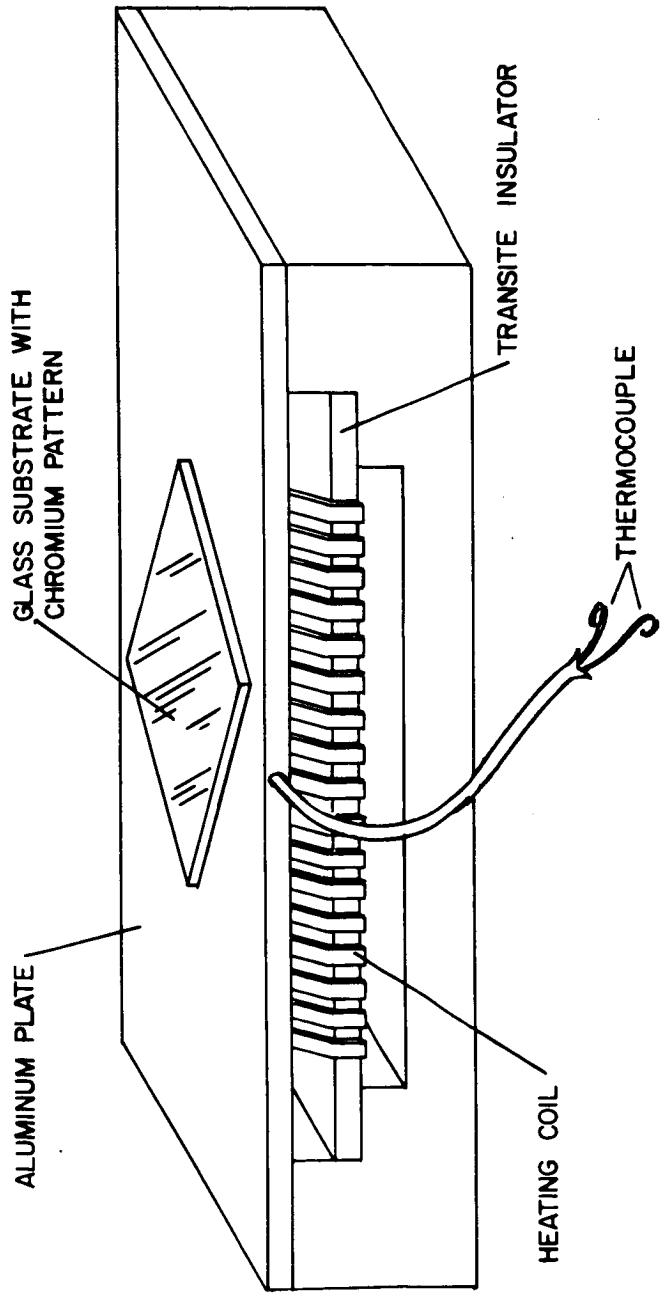


Chromium Mask By Washout (Reflected Light)

100X

Figure 5

A special heater was built (Figure 6) which would control the temperature of the substrate. A thermocouple was inserted in a hole in the aluminum heater plate and connected to a Wheelco temperature controller. The controller supplied current to a heating coil under the aluminum plate. A Variac was connected to the heating coil so that the rate of heating could be controlled by regulating the temperature of the heating coil.



Substrate Heater

Figure 6

The rate of heating was adjusted to the maximum that would not crack the glass substrate. The temperature was allowed to rise to the maximum that would not discolor the chromium by oxidation. It was found that if the substrate were heated from 250°C to 450°C in five minutes and immediately cooled that the chromium was hardened. The period of time required to heat the substrate did not allow for oxidation of the chromium layer. The chromium remained bright rather than turning a grayish color as is experienced with prolonged heating.

2.4 Pattern Formation in Resist Using High Acutance Masks

A chromium master made with AZ1350 resist was used to print a pattern onto a substrate for each of the four resists. It was found that line widths for each of the resists was substantially the same as the chromium pattern. The variations of up to 1/2 micrometer that occurred with the original emulsion mask (See Table II) were limited to a variation of 1/4 micrometer for the chromium mask. (See Table III) Although this particular emulsion mask had poor acutance, it will be seen later that a good emulsion mask can hold line widths as well as a chromium mask.

2.5 Formation and Etching of Chrome Patterns

An alternative to forming a washout pattern of chromium on glass is the formation of the pattern by etching. A glass substrate on which a deposit of chromium has been evaporated is coated with photoengraving resist. An image is printed and developed into the resist. The pattern is etched into the chromium and the resist is removed.

Table III

Resist Exposure (Seconds)		Slot Width					Line Width			
Master Plate (Chromium Mask)		.00007	.00020	.00043	.00105	.00208	.00019	.00047	.00113	.00217
		Slot Width		(Positive Resist)			Line Width			
AZ111	10	Incomplete Exposure								
	20									
	30									
AZ1350	10	Incomplete Exposure								
	20	.00007	.00019	.00041	.00104	.00205	.00018	.00045	.00111	.00217
	30	.00007	.00020	.00042	.00104	.00208	.00017	.00043	.00112	.00215
		Line Width		(Negative Resist)			Slot Width			
KMER	10	.00007	.00021	.00044	.00105	.00211	.00020	.00045	.00111	.00217
	20	.00008	.00020	.00042	.00105	.00208	.00019	.00047	.00111	.00217
	30	.00007	.00020	.00042	.00107	.00209	.00019	.00045	.00113	.00219
KTFR	10	.00008	.00021	.00043	.00105	.00210	.00020	.00046	.00111	.00218
	20	.00006	.00022	.00042	.00106	.00218	.00019	.00045	.00112	.00220
	30	.00006	.00022	.00043	.00105	.00218	.00021	.00045	.00110	.00219

Exposure vs. Resist Resolution

Chromium Mask

The principal problems to be investigated are the exacting reproduction of the image in the resist and etching of the exposed chromium. Consideration must be given to pattern reversal caused by the use of negative or positive resists. Since a negative resist protects the complementary area to the positive resist it is obvious that one of the resists will produce an undesirable mirror image. In the case of a substrate which is to be etched the negative resist produces the proper pattern (In the washout the positive resist gives the desired pattern). If it is desirable to use the complementary resist then the mirror image can be reversed by producing a second substrate pattern. The additional step, however, reproduces any defects produced in the first substrate as well as those produced in the additional step.

Eastman Kodak Company markets an evaporated chrome-on-glass substrate that is of superior quality. This substrate is furnished precoated with Kodak Thin Film Resist and a protective, water soluble coating. The chromium is virtually pinhole free. These substrates, substrates coated with Kodak Metal Etch resist and Shipley AZ1350 resist were examined for producing chromium masks.

Substrates with an evaporated chromium layer were coated with resist in the manner outlined in section 2.1. The resist was examined for defects in the coating. The negative resists, KTFR and KMER, were exposed without a mask. The substrates were placed in the bottom of a 2000cc beaker which was flooded with nitrogen gas. This was necessary to prevent the

sensitizer from combining with oxygen rather than converting the resist monomer into a polymer. Figure 7 shows this effect. It can be seen that with an absence of oxygen the conversion is still not complete. The positive resist was not exposed as it was already in the polymerized form. All substrates were developed and postbaked as in section 2.1.

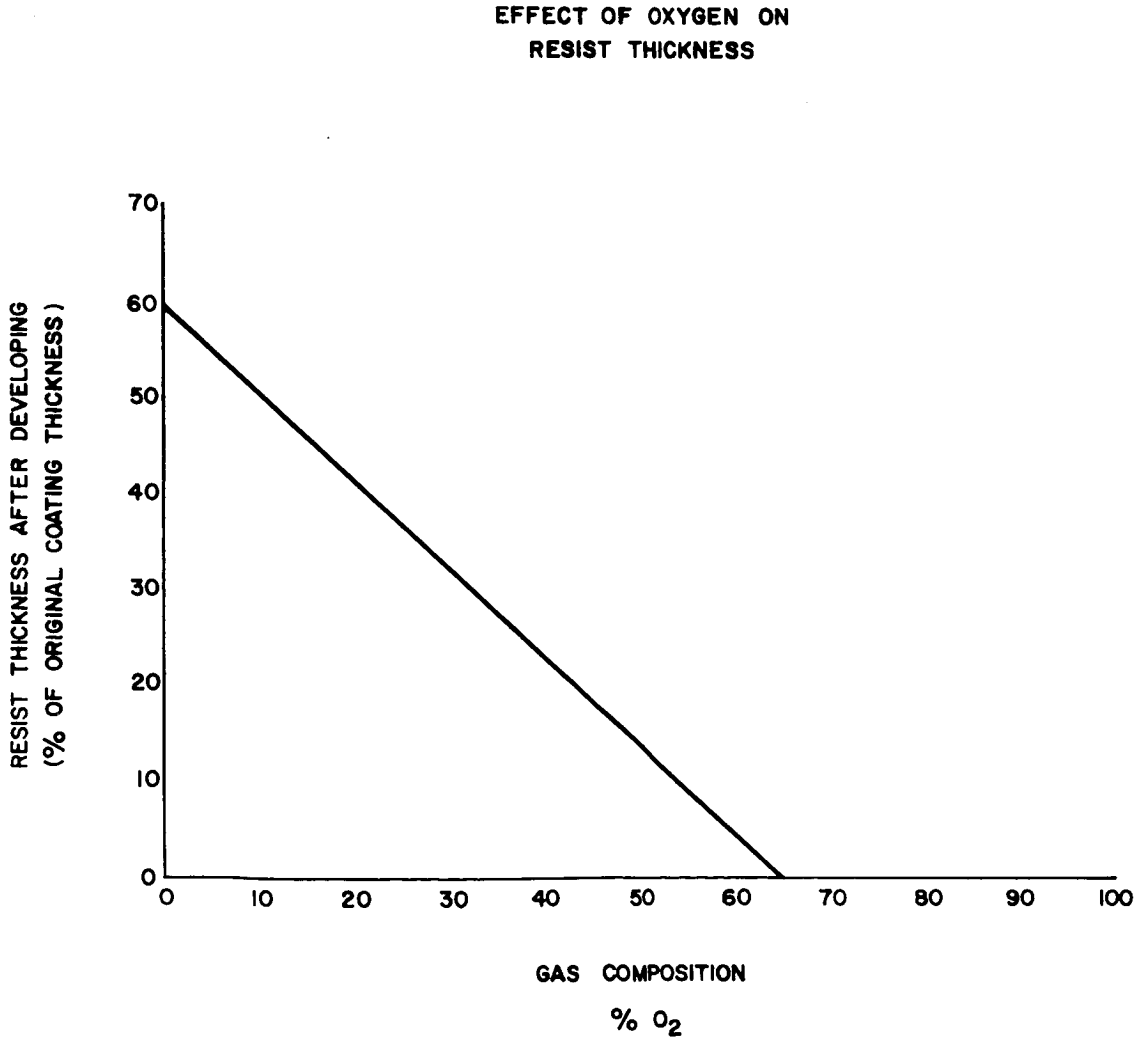


Figure 7

The substrates were submerged in the following solution at 40°C for forty seconds. This was sufficient time to allow any pinholes in the resist

100 Gm. Ceric Sulfate

150 ml. Nitric Acid

1000cc Water

to etch through the chromium layer and produce a pinhole. Figure 8 shows the number of pinholes that can be expected because of permeability of the thin resist coating. The density of pinholes for the negative resists was expected to be higher than the positive resist because of the loss in resist thickness during exposure and developing.

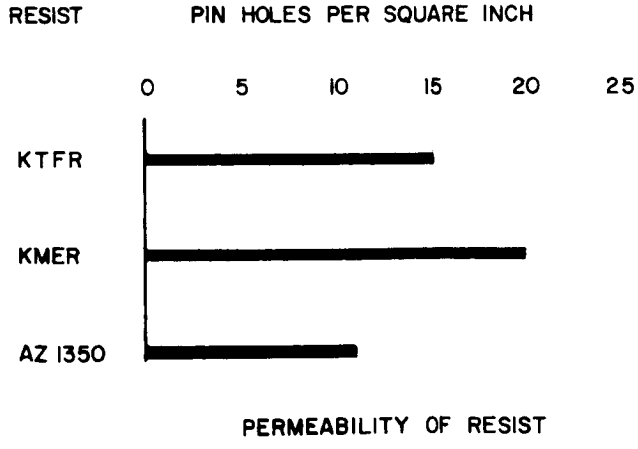


Figure 8

Two etches were examined for use as a chromium etchant. They were the ceric sulfate etch used above and the etchant recommended by Eastman Kodak. The Kodak etch was comprised of:

Stock Solution A

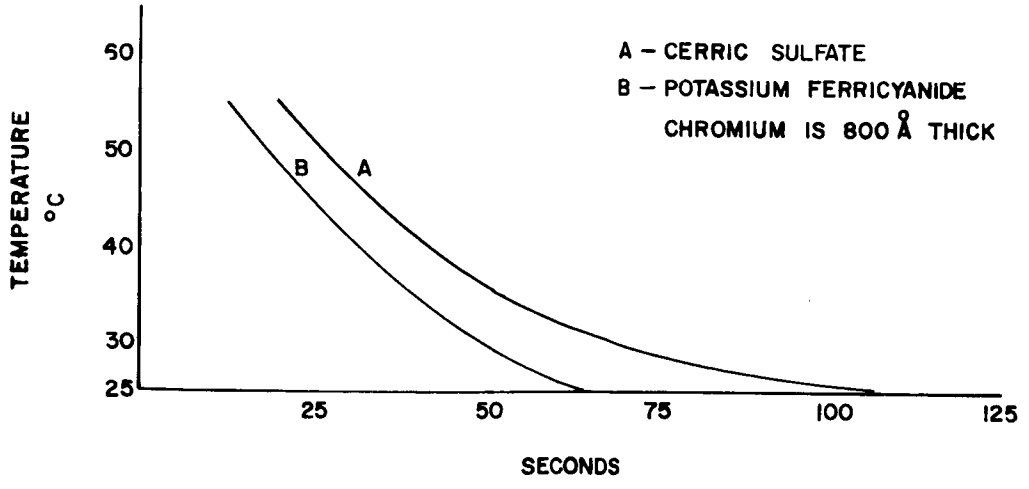
Water	1000cc
Sodium Hydroxide	500gm.

Stock Solution B

Water	3000cc
Potassium Ferricyanide	1000gr.

One part solution A and three parts of solution B compose the etching solution.

A substrate with 800Å chromium was sectioned and etched in the two baths at different temperatures. (Figure 9) Etch rates will vary depending on the percentage oxide in the evaporated chromium but relative etch times may be obtained from the curve.

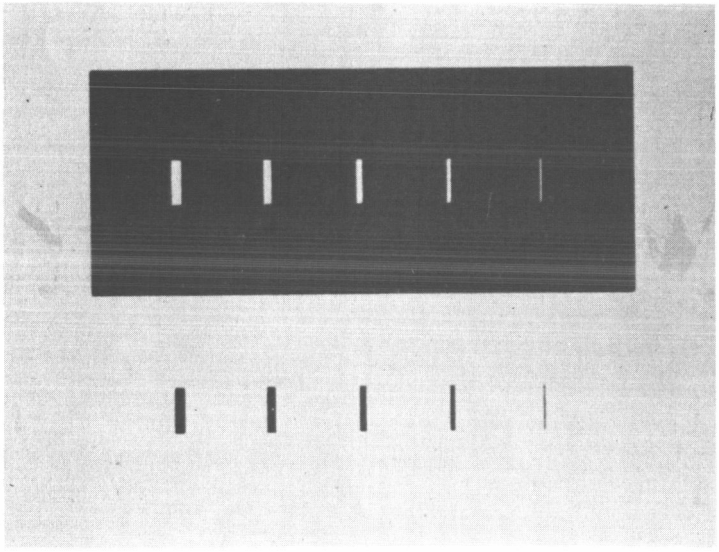


Etch Time vs. Temperature for Chromium

Figure 9

The ceric sulfate was selected for use over the potassium ferricyanide because it more easily removed the last traces of chromium from the surface of the substrate, especially chromium containing some chromium oxide.

The selected pattern used to examine the resist for resolution consisted of lines and slots varying from one to five micrometers. The pattern is shown in Figure 10. The one micrometer slot was partially fogged and the one micrometer line was grainy. The plate was otherwise of good quality.



Photographic Resolution Test Pattern (Transmitted Light)

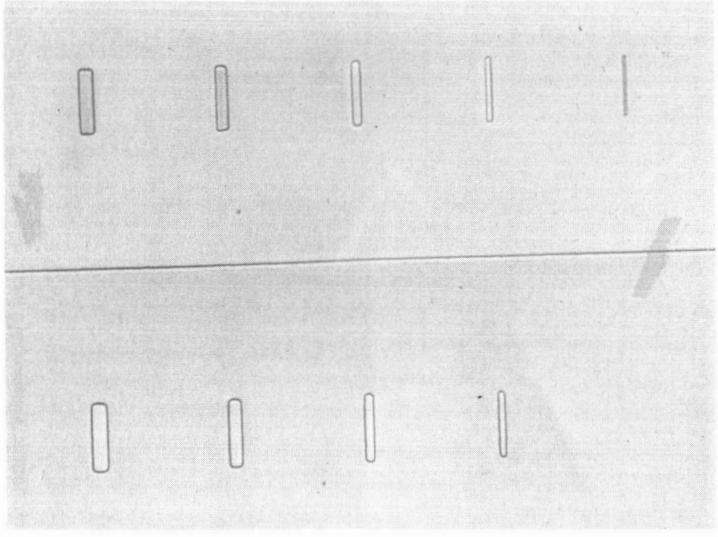
230X

Figure 10

2.5.1 Shipley AZ1350 Resist

The superior resolving power of this resist warranted an investigation into its use in etching a pattern into the chromium. Adhesion to the chromium was found to be excellent with the small lines of resist easy to develop. The process used in section 2.1.2 for developing the image was repeated here. A postbake operation of 110°C for fifteen minutes was found to be necessary to prevent the resist from lifting during the etching operation.

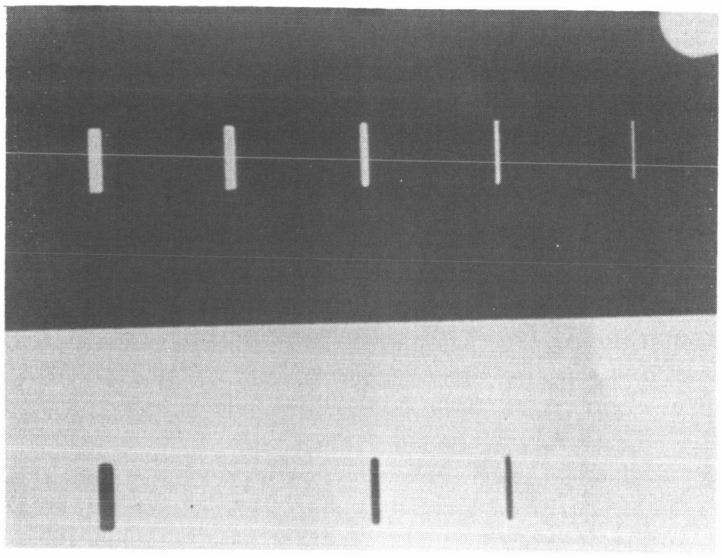
The developed out pattern, although appearing to be of excellent quality, would not consistently etch all of the small slots. Exposure was extended to thirty seconds. The developer was used at full strength extending the developing time to one minute. No improvement could be found in this condition as shown in Figure 11 and 12.



AZ1350 Resist Pattern Before Etching (Reflected Light)

350X

Figure 11



AZ1350 Chromium Pattern After Etching (Reflected Light)

350X

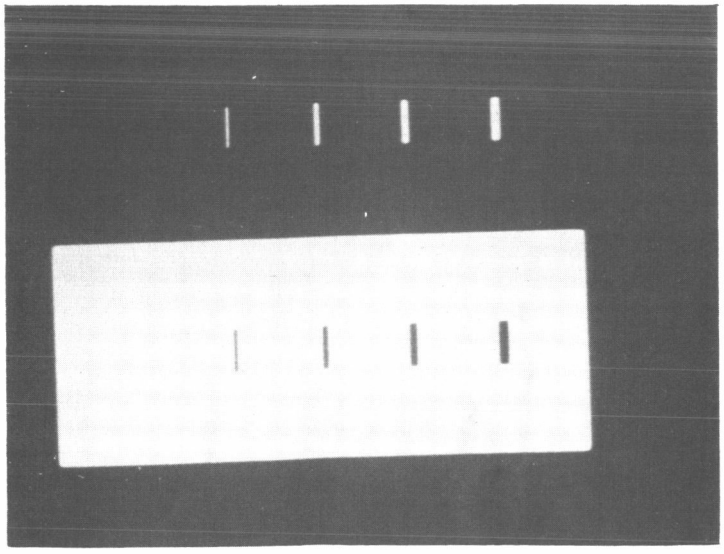
Figure 12

2.5.2 Kodak Thin Film Resist

Kodak Photosensitive Metal-Clad Plates were used for this test. The water soluble coating was removed under a stream of filtered water. The plates were blown dry. Exposure of 20 seconds was used. The pattern was spray developed using KTFR developer for 30 seconds followed by a 15 second spray of KTFR rinse. Lines of two micrometers and larger were easily developed. The one micrometer lines on the photographic plate were not sufficiently good to reproduce in the resist. Two micrometer lines and spaces, and larger, were well formed and of proper size.

It is sometimes desirable to recoat a substrate because of defects in the resist. The defective pattern can be stripped from the substrate by a soak in J-100 resist stripper at 80°C for five minutes. The substrate was sprayed with trichloroethene and blown dry. Recoating was as described in section 2.1.4. The resolution of this resist was equal to the coated substrates received from Eastman Kodak.

The substrates were placed on a 1/2" teflon boat and placed into a 180°C oven for 20 minutes. The substrates were cooled, then etched in ceric sulfate at 40°C for forty seconds. The resist was stripped in J-100. The lines and slots were of equal width indicating no undercut. Figure 13 shows the chromium mask produced by this process.



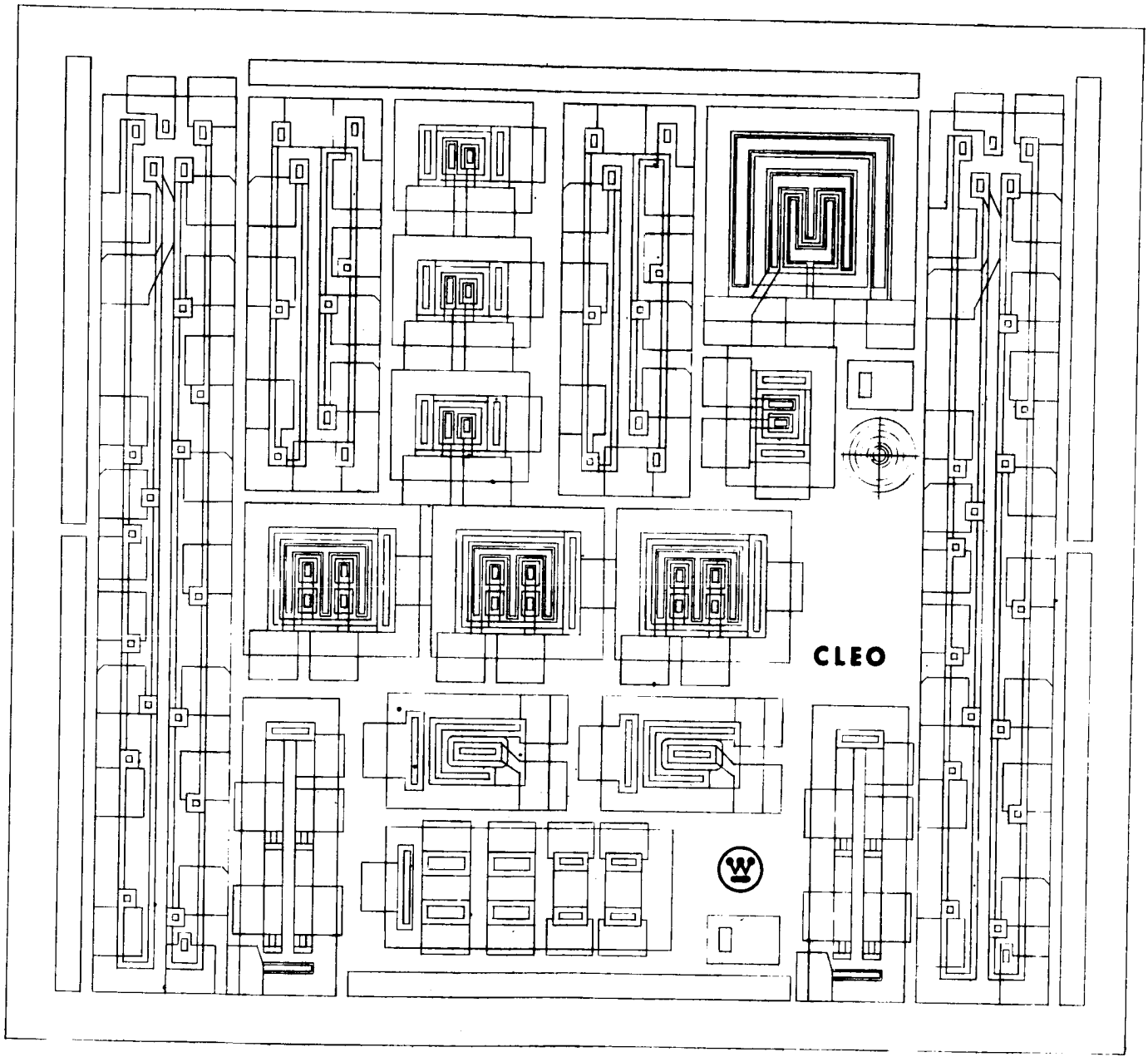
Chromium Mask Etched From KTFR Pattern (Reflected Light)
235X
Figure 13

The Kodak Photosensitive Metal-Clad plates were used to produce a set of working plates. The device was an integrated circuit shown in Figure 14. The chip size was .090" x .090". There were five working plates in the set. The resolution of the completed plates was of the quality expected from previous testing. The overall quality of these plates showed that the complete step and repeat pattern could be etched into chromium on glass with five defects per plate. These defects evidenced themselves as either pinholes or small spots of chromium that failed to etch.

2.5.3 Kodak Metal Etch Resist

The substrate was coated with KMER as described in section 2.1.3. Exposure was for 20 seconds. The resist was spray developed for 30 seconds in 60% KMER developer-40% dipropyl carbonate followed by a spray rinse for 15 seconds of butyl acetate. The substrate was blown dry. Resolution was equivalent to the KTFR resist with the two micrometer lines and slots well formed. The substrates were placed on a 1/2 inch teflon block and postbaked at 180°C for twenty minutes. The substrate was cooled, then etched in ceric sulfate at 40°C with no undercut.

The quality of the one micrometer line and slot on the resolution test pattern could cause the resist to be degraded. An examination of this condition was conducted by using the chromium test pattern produced using Shipley AZ1350 resist (Figure 12). The density of the one micrometer line was known to be sufficient to produce a good photoresist pattern. It was found that the one micrometer pattern would not reproduce even with this mask.



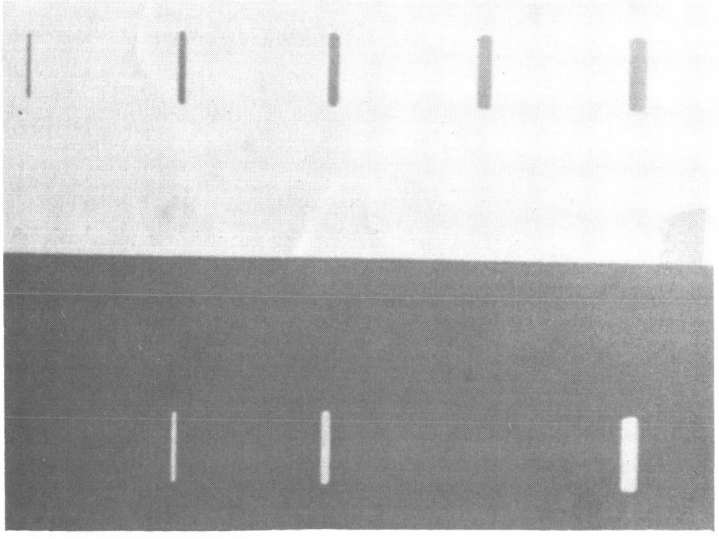
		ORIGINAL DATE OF DWG	9/28/66	Westinghouse Electric Corporation
		DFTM J.C. Francis	APPD	BALTIMORE DIVISIONS BALTIMORE MD., U.S.A.
		CHKD	APPD	TITLE BLACK & WHITE MASTER
		APPD	APPD	CLEO
NEXT ASSY	USED ON	DESIGN ACTIVITY APPROVAL		CODE IDENT NO. 97942 SIZE DWG NO. 219
APPLICATION		PROCURING ACTIVITY APPROVAL		SCALE 200:1 WEIGHT SHEET OF

Layout of an Integrated Circuit

Figure 14

Previous investigations performed under a Westinghouse Independent Research and Development program had shown that when KMER is exposed too rapidly polymerization at a line edge was not as uniform as when a slower exposure was used. An investigation of this phenomenon was conducted on the chromium substrate.

The intensity of the Sun Gun exposure lamp was reduced by 50% as measured through a Corning Glass Company CS5-58 filter. The exposure time was increased from 20 to 40 seconds. The coating, baking and developing operations were the same as previously outlined. An examination of the pattern after developing showed that the one micrometer slot had opened in the resist. The wafer was postbaked, then etched in ceric sulfate. Figure 15 shows the etched chromium pattern. Undercut had reduced the line widths by approximately .000015". The slots width were opened a corresponding amount.



KMER Chromium Pattern After Etching (Reflected Light

375X

Figure 15 2-30

2.6 Contact Printing Emulsion Masks

A contact printer was designed that would incorporate those features that were considered important to the efficient reproduction of a master image. The principal investigations were concerned with:

1. A light source that would provide a suitable intensity of light of proper frequency.
2. A method to condense the light so that collimation could be achieved if desired.
3. A means of obtaining intimate contact between the master image and the emulsion being exposed.

A six volt projection-type lamp was chosen for the light source. A Variac was supplied to regulate the light intensity. A filter holder was provided in front of the lamp to remove unwanted light frequencies from the actinic light. A timer, calibrated in seconds, was provided to control the length of exposure.

A pair of 6" diameter plano-convex condensing lenses were provided to allow for collimation of the light source. The position of this condensing system was made adjustable so that the light could be made to converge or diverge. The large diameter of the lenses was selected to eliminate much of the aberration found near the outer diameter of lenses.

Intimate contact between the master plate and contact plate is important or a faithful reproduction of the image will not occur.[2] Several methods may be used to obtain this contact.

1. Vacuum
2. Air Pressure
3. Mechanical Pressure

A vacuum was selected as the most suitable means to obtain intimate contact. Much higher pressures may be obtained by mechanical pressure or air pressure but separation of the master plate and contact plate can become a problem with either of these systems. The plates may become frozen together much the same as gage blocks and are difficult to separate.

The chromium plate shown in Figure 15 was used as the master contact plate. A chromium master was selected as the pattern because it would not degrade with use. The master plate was placed into vacuum contact with an unexposed high resolution plate and exposed.

The following process was used to chemically develop the latent image for all contact prints.

1. Soak plates in reagent alcohol for forty seconds. This will remove the antihalation backing.
2. Develop in Kodak H.R.P. developer for four minutes using nitrogen agitation. Hand rocking the developer requires a five minute developing cycle.
3. Soak in 4% acetic acid stop bath for twenty seconds.
4. Fix five minutes in Kodak rapid fixer. (The stop bath and fixer each contain 20% Kodak hardener. The hardener improves the life of a contact plate.)

5. Five minutes running water rinse.
6. Agitate in reagent alcohol fifteen seconds. The alcohol absorbs the water and accelerates the drying time.
7. Dry in an oven at 65°C for five minutes.

Each plate was measured and compared to the master contact plate. Measurements were made at 500X using a Leitz Panphot microscope and a Filar eyepiece. These measurements are shown in Table IV.

The first test was to compare different light frequencies. The light was filtered through Kodak Wratten Filters. Those filters tested were:

1. #58 Filter = 5200Å
2. #65A Filter = 5000Å
3. #36 Filter = 4100Å
4. #18A Filter = 3600Å

The lamp intensity was established to give a reasonable exposure time.

Preliminary testing indicated that uniform contact was not being obtained over the contact area. This condition was improved by placing a piece of 200 mesh stainless steel wire mesh between the rubber pressure pad (item 47 of contact printer) and the contact plate.

A range of exposures for each filter was made to determine which filter would give the best resolution. An examination of the resolution produced by each filter showed that the 58 filter was superior to the other filters. This filter was the only one that could reproduce the narrow slot without closing up at a density of 3. Although this slot did not close it was not as clear as would be required for good reproduction. The smallest line, 50×10^{-6}" wide was well formed at a density of 2.7.

The second test was conducted to determine if better contact could be obtained by allowing the master plate and the contact plate to remain under vacuum for a period of time before being exposed. Exposures were made after a period of vacuum contact of one minute, five minutes and ten minutes as well as an exposure that was made immediately after applying the vacuum contact. An additional exposure was made where xylene was placed at the interface of the master and contact plates. (See Table III plate # 16 through 20)

The three plates that were exposed after a vacuum had been applied for a time were found to be of equal quality. The small slot of each of these plates were clearer than that found on either the immediate exposure or the one having a xylene interface. The only advantage to the use of xylene was that a uniform density of the emulsion was obtained. The remaining plates contained a contour effect caused by Newton rings which could be observed under a bright xenon lamp. Three additional plates were printed with this test each having a xylene interface but a different exposure (plates 21, 22, 23). No improvement in line or slot quality was noted.

Test three was to determine if an emulsion mask could produce lines and slots of equal quality to the chromium master. It was also to examine the contact condition over a wider area than previously examined. The master pattern, shown in Figure 10, was positioned in the center of the plate (position A) and in each quadrant. The quadrant patterns were located 1/2 inch from the center.

The cleanliness of the lines and slots produced by the emulsion master were equal to that produced by the chromium master. Size control, or the variation in width of the lines and slots, were not as good on the emulsion mask. A comparison of line width change shows the average variation for the chromium master was about 10×10^{-6} inches (comparing chromium master to plate nos. 16, 17, 18, 19, 20). Average variation for the emulsion master was 20×10^{-6} inches (comparing emulsion master to plate no. 24 and 25).

The fourth test concerned the obtainable resolution without the use of a filter (plates 27, 28 and 29). Very poor resolution was obtained as the density approached 3. This indicated that a filter was required for good resolution.

The condensing lens system was tested to find what effect collimation had on the image resolution. The condensing lens was removed from the system. The light was allowed to pass from the filament through the filter to the master plate. The distance from the lamp filament to the master plate was ten inches. No improvement in the clearness of the narrow slot was found caused by the diverging light.

The condensing lens was replaced and positioned such that the light rays were made to converge at a point ten inches from the condensing system. This focal point was four inches above the contact plane. No improvement in the clearness or size of the narrow slot was found caused by the converging light (Plates 33-35A).

A final test was made to examine the reproducibility of the contact prints already made. Plate no. 20 was contact printed for test no. 6 of Table III. This test showed that the small line on plate 20 was reproducible giving a clean slot of 50×10^{-6} inches wide at a density of 2.7.

Table IV

Test	Plate No.	Time Sec.	Density (Approx.)	Width x 10^{-6} Inches 1	2	3	4		
Chromium Master Plate (Positive) Test #1				slot 50 line	slot 110 line	slot 240 line	line 70 slot	line 200 slot	
Collimated Light and #58 Filter	1	3	Under Exposed	45	90	210	75	230	
	2	5	2.7	47	105	225	65	210	
	3	8	3.0	55	105	225	60	200	
Collimated Light and #65A Filter	4	6	Under Exposed	40	85	210	75	225	
	5	10	2.7	50	95	210	60	220	
	6	16	3.0	65	120	240	closed	190	
Collimated Light and #36 Filter	7	12	Under Exposed						
	8	20	Under Exposed						
	9	32	Under Exposed						
	10	60	1.8	45	90	210	fogged	195	fogged
	11	120	2.7	60	105	270	closed		fogged
Collimated Light and #18A Filter	12	15	Under Exposed						
	13	30	Under Exposed						
	14	60	1.5	36	70	225	75	210	
	15	120	2.0	45	90	230	fogged	210	
Test #2 (Chromium Master Plate (Positive) Collimated Light and #58 Filter									
Immediate Exp.	16	5	3.0	50	90	225	65	220	
Xylene Interface	17	5	3.0	50	95	235	60	210	
5 min. vacuum	18	5	3.0	50	95	225	60	220	
10 min vacuum	19	5	3.0	55	100	230	60	210	
1 min vacuum	20	5	3.0	45	95	225	65	220	

	Plate No.	Time Sec.	Density (Approx.)	line	line	line	slot	slot
Test #2 (Con't.)	21	3	1.5	30	75	215	70	215
	22	4	2.5	40	90	225	65	215
	23	8	3.0	60	120	250	45	180
Test #3								
Emulsion Master (Positive)				slot	slot	slot	line	line
	A			60	100	225	90	225
	B			60	100	230	90	225
	C			60	105	230	100	210
	D			60	100	225	85	210
	E			60	105	230	85	210
Collimated Light				line	line	line	slot	slot
and #58 Filter	24A	5	2.7	45	75	210	90	230
	B			45	75	200	100	230
	C			Under Exposed	65	180	90	225
	D			"	65	210	100	225
	E			"	75	210	90	225
	25A	7	3.0	45	80	220	80	210
	B			45	75	225	75	225
	C			45	65	210	70	200
	D			40	75	210	75	210
	E			45	75	210	75	200
Test #4								
Chromium Master (Positive)								
Collimated Light	27	.5	Under Exposed					
and No Filter	28	1	2.0	40	65	220	65	225
	29	2	3.0	60	105	240	closed	foggy
Test #5								
Chromium Master (Positive)								
Diverging light	30	5	Under Exposure					
(no collimator)	31	10	Under Exposure					
58 Filter	32	20	1.5		60	180	90	240
	32A	40	2.7	60	110	235	60	195

	Plate No.	Time Sec.	Density (approx.)	line	line	line	slot	slot
Converging Light 58 Filter	33	1	under exposed					
	34	2	1.5	45	75		75	
	35	4	2.3	45	85	210	60	225
	35A	8	3.0	60	105	210	60	200
Test #6				slot	slot	slot	line	line
Contact Print of Plate 20	36	3	2.7	50	90	230	50	190
	37	5	3.0	30	75	195	60	220

Resolution of Contact Printed Emulsion Plates

3.0 Operating Instructions for the Contact Printer

The contact printer was designed and built for the contact printing of both emulsion masks and photoengraving resist-coated chromium plates. A low intensity lamp, light filter and collimator are provided for the contact printing of emulsion masks. These components pivot out of the way when it is desired to print into the photoengraving resist. A Sylvania sun gun has been provided as the exposure lamp for this operation.

The lamp, filter holder and collimator are adjustable along the axis of projection. The desired adjustment may be made by loosening the socket screws and manually adjusting the desired component. The position of the lamp along the projection axis is not important. The lamps should be so positioned, however, to place the filament plane perpendicular to the projection axis. The position of the filter holder should be close enough to the lamp so that the projected light completely covers the collimator. The plane of the filter holder should be perpendicular to the projection axis. The collimator assembly should have its optical axis parallel to the projection axis. These two axis should coincide.

3.1 Spare Parts for Contact Printer

The parts listed below may be expected to deteriorate and need replacing.

1. Micrscope Illuminator, General Electric 18A/T10/1P-6V.
2. Lamp (used in sun gun), General Electric #DWY 120 volt 650 watt.
3. Filter, 2" x 2", Wratten in "B" glass, Eastman Kodak Company.

4. Fuse, 20 amp, 3ag.

5. Indicator Lamp, #6073-634, 1/3 watt, 125v., Drake Company, 4626 N. Olcott, Chicago.

3.2 Emulsion Mask Contact Printing

a. Check the control switches for the following positions:

1. Master switch "off"

2. Vacuum switch "on"

3. Fan switch "off"

4. Vacuum pump "off"

5. Lamp switch "off"

6. Powerstat reading "90"

7. Time-O-Lite switch in "T" position

b. Turn on the master switch. The indicator light will glow red. Check 20 ampere fuze if indicator does not glow.

c. Turn lamp switch to low and Time-O-Lite switch to "F" position. Adjust light intensity to the desired level by adjusting the powerstat. The correct lamp brightness can be established by exposing a photographic plate for a light intensity level and time to give a plate density of approximately 3.

d. Turn the Time-O-Lite switch to the "T" position and set the timer for the desired exposure time.

e. Place a master plate against the three pins in the vacuum chamber. Place an unexposed plate into contact with the master plate. Close

the vacuum chamber and turn the vacuum pump on. The vacuum should show 24 inches minimum on the vacuum gage. (For extreme resolution a one minute vacuum pull down should be used before proceeding to f.)

f. Press the button on the Time-O-Lite to make the exposure. When the time indicator returns to the reset position turn the vacuum pump to the off position, open the vacuum chamber and remove the contact plate. Additional plates may be printed by repeating steps e and f.

3.3 Photoresist Contact Printing

a. Open the cabinet door and swing the filter unit out of the operating position. Close the cabinet door.

b. Check the control switches for the proper position as given in 3.2.a.

c. Turn on the master switch. The indicator light will glow red.

d. Turn the lamp switch to the high position and the Time-O-Lite switch to "F" position. Adjust the light intensity to the desired level by adjusting the powerstat.

e. Turn the Time-O-Lite switch to the "T" position and set the timer for the desired exposure. Turn the fan switch to the on position.

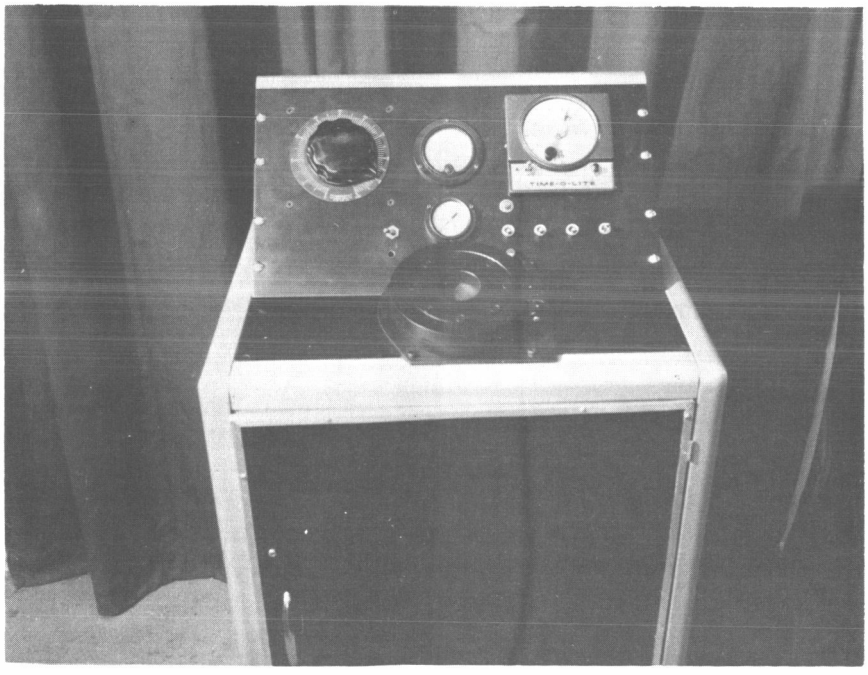
f. Place a master plate against the three pins in the vacuum chamber. Place an unexposed plate into contact with the master plate. Close the vacuum chamber and turn the vacuum pump on. The vacuum should show 24 inches minimum on the vacuum gage.

g. Press the button on the Time-O-Lite to make the exposure. When the time indicator returns to the reset position turn the vacuum pump to

the off position, open the vacuum chamber and remove the contact plate. Additional plates may be printed by repeating steps f and g.

h. On completion of the photoresist contact printing return to filter unit to its operating position. Return the lamp switch to off. Turn off main switch.

The contact printer is shown in Figure 16.



Contact Printer

Figure 16

4.0 Conclusion

It has beeen shown that line widths and slots widths of 50×10^{-6} inches can be produced equally well in an emulsion mask or a chromium mask by contact printing. There was no indication that this was a limiting dimension. Control of the line width proved to be difficult as variations of 20×10^{-6} inches were experienced. These variations could be attributed to several conditions. In the case of the chromium master poor contact caused by out-of-flat plates, improper exposure and the inability of accurate measurement were the principal causes of variation in the width of lines and slots. Variation in the emulsion master included the above three conditions as well as the consideration of line density and its related acutance. No conclusion could be drawn concerning possible lenticular effects caused by swelling of the emulsion in the opaque areas.[2] This effect would be closely related to the actuance and was certainly smaller than the line and slot variations experienced.

Improved contact was obtained by holding the contact plates under vacuum for one minute before exposing the plates. This time could undoubtedly have been reduced if a vacuum of 30 inches were used instead of the available vacuum (24 inches). It was also found that a more uniform density was obtained if xylene were placed between the contacting plates during exposure.

The evaporation of a defect free chromium layer proved to be difficult. Chromium layers were deposited that contained less than 5 pinholes per square inch. These pinholes were the result of dust particles in the air as the glass plates were being transferred to the vacuum chamber. Further

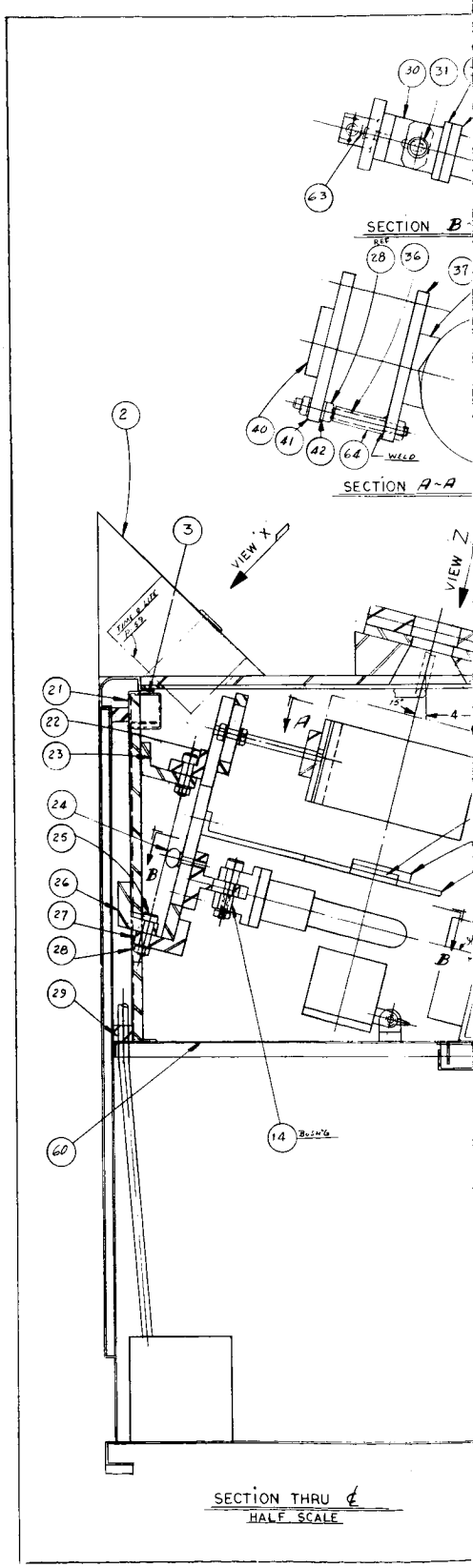
examination showed that after scrubbing the chromium coated glass plate pinholes of one micrometer diameter appeared in the chromium.

The vacuum deposited chromium layer was not hard as received from the evaporator. A hardening process that did not oxidize the chromium but rendered it scratch resistant was found. This process required the heating of the chromium coated glass plate to be heated from 250°C to 450°C in five minutes. An air atmosphere was used. The plate was immediately cooled.

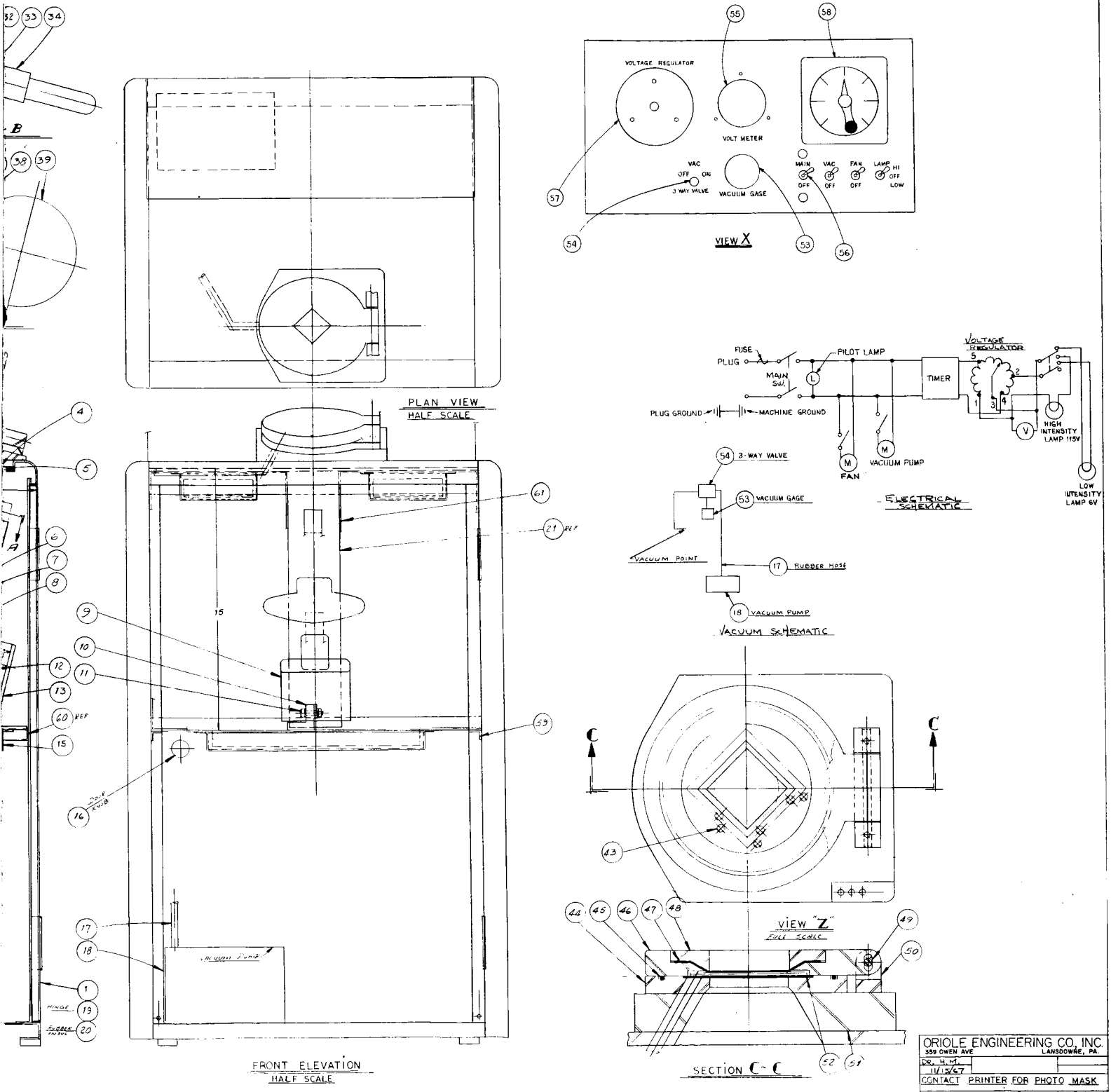
The availability of commercially produced chromium coated glass plates of superior quality at a reasonable cost caused the major effort for producing chromium master plates to be directed toward the etching technique. It was demonstrated, however, that chromium masks could be produced by the washout technique. Line widths and slot widths of 50×10^{-6} inches were produced in the chromium. A complete set of integrated circuit masks were produced to indicate the level of excellence that could be obtained in a chromium mask. The major problem encountered was found to be pinholes etched into the chromium. These holes were caused by the permeability of the very thin coating of photoresist. Defects in the etched chromium patterns numbered about five per plate.

5.0 Contact Printer Drawings

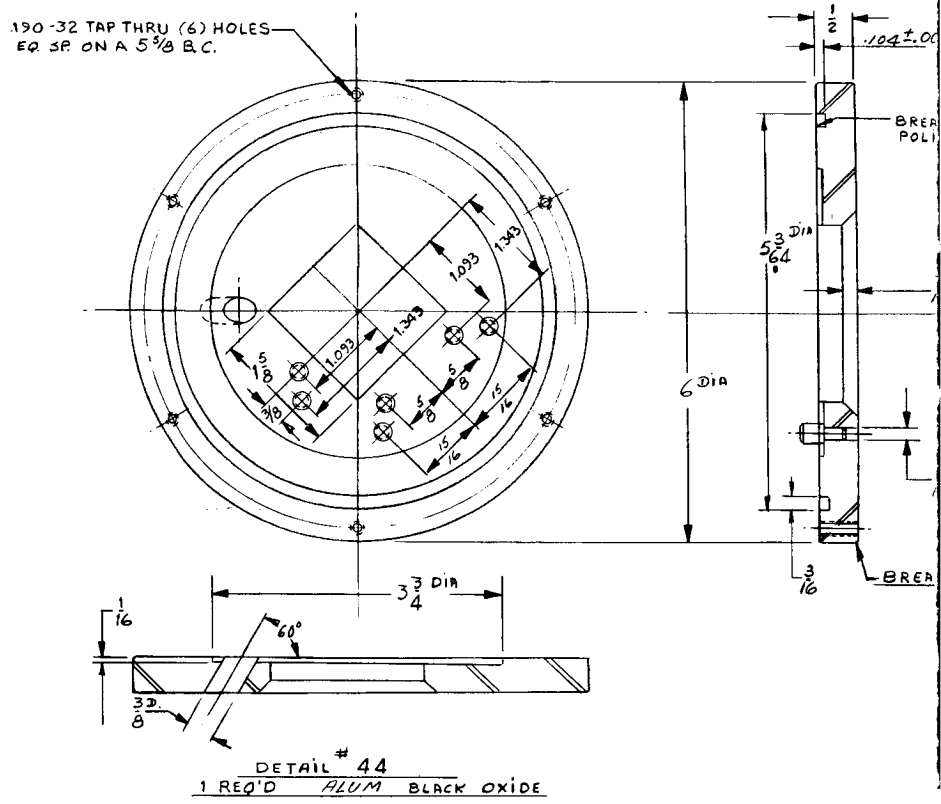
The following drawings are of the contact printer designed and built for this contract.



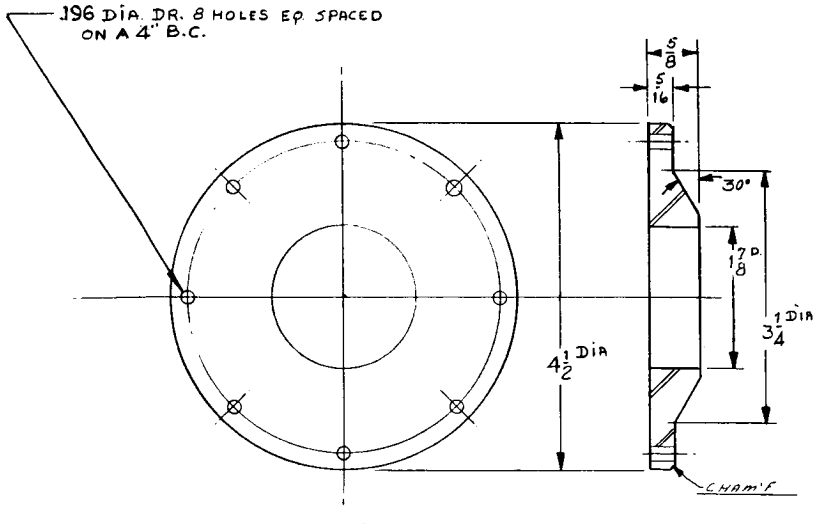
FOLDOUT FRAME 1



ORIOLE ENGINEERING CO, INC.
359 OWEN AVE LANSDOWNE, PA.
DR. H.M.
11/15/67
CONTACT PRINTER FOR PHOTO MASK
32001
SHEET 1 OF 6



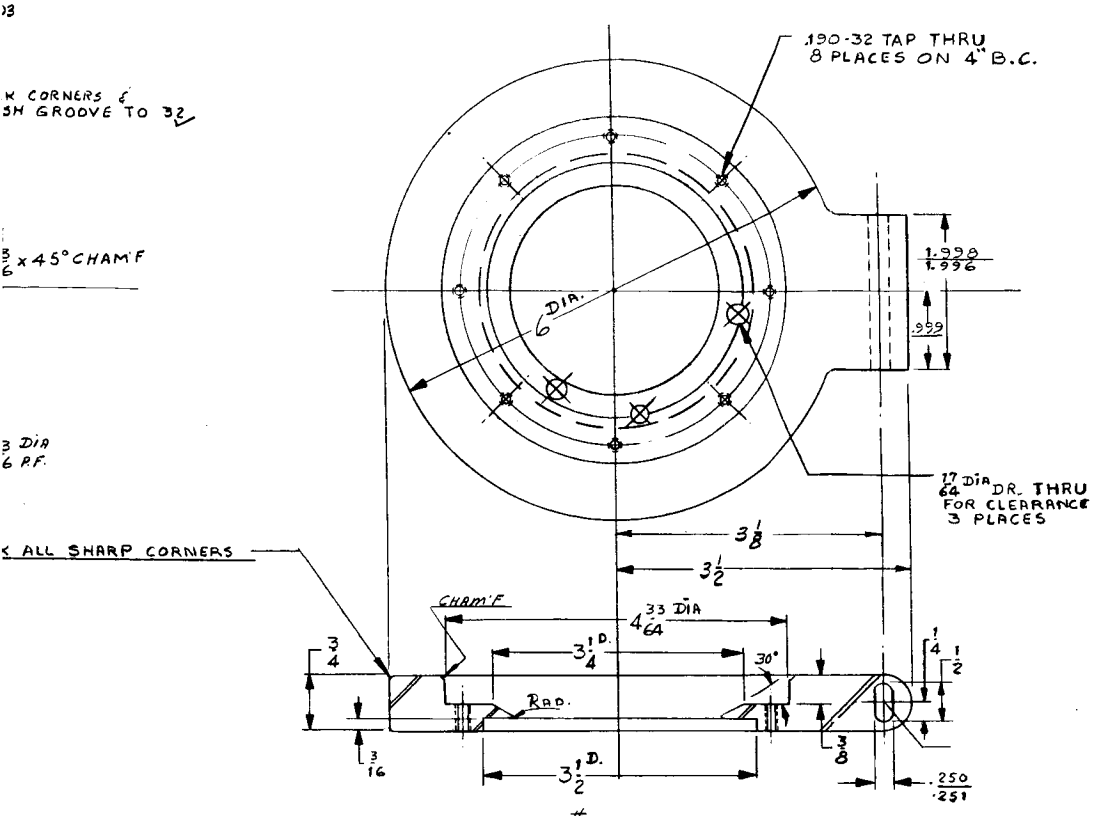
DETAIL # 44
1 REQ'D ALUM BLACK OXIDE



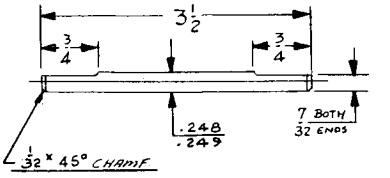
DETAIL # 48
1 REQ'D ALUM. BLACK ANODIZE

22 X 34 PRINTED ON NO. 194 SPEEDOLENE CAT. NO. 194 TBS

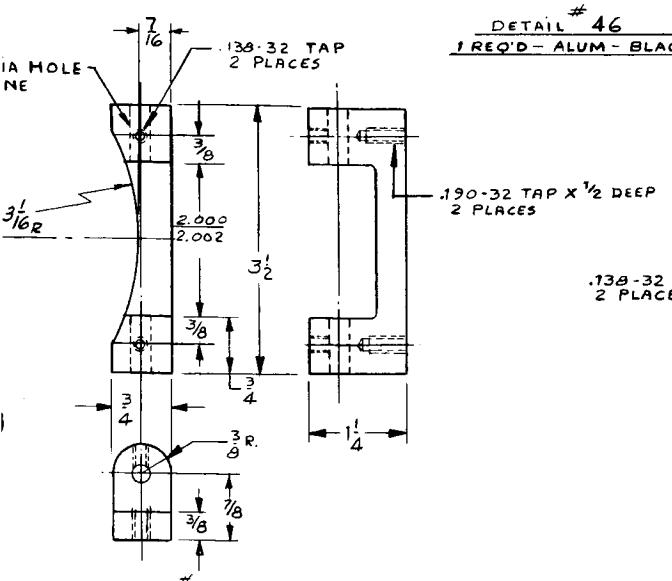
FOLDOUT FRAME 1



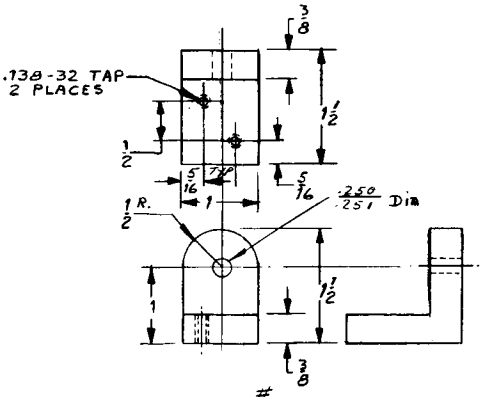
DETAIL # 46
1 REQ'D – ALUM – BLACK ANODIZE



DETAIL # 49
C.R.S 1 REQ'D



DETAIL # 50
1 REQ'D ALUM.



DETAIL # 10
1 REQ'D ALUM

ORIOLE ENGINEERING CO., INC.		
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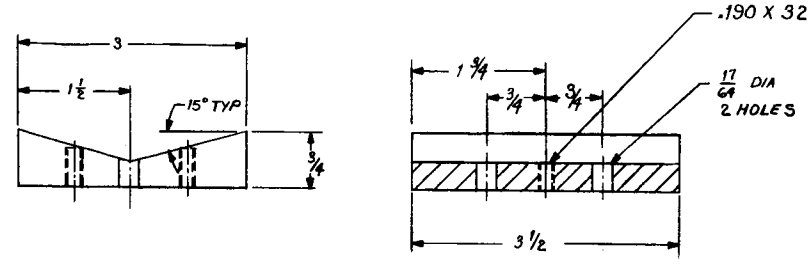
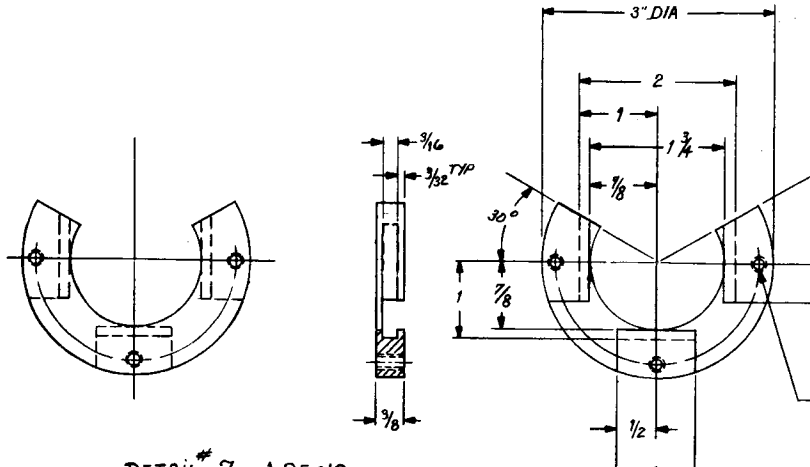
		DWG. NO. 32001

SHEET 2 OF 6

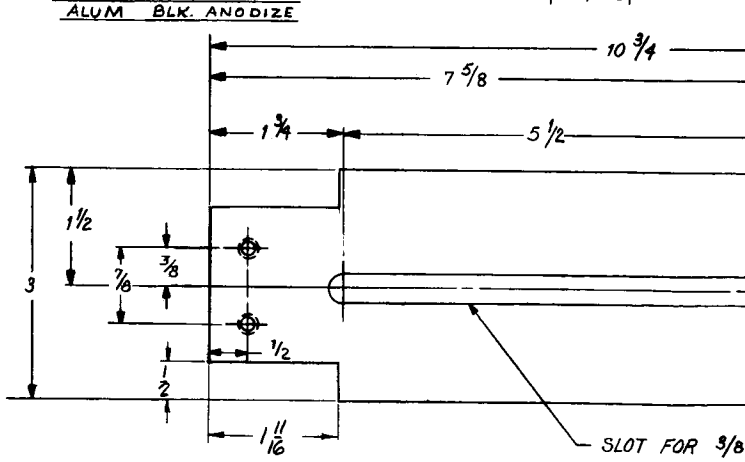
FOLDOUT FRAME 2



DETAIL # 38
1 REQ'D ALUM. BLK ANODIZE

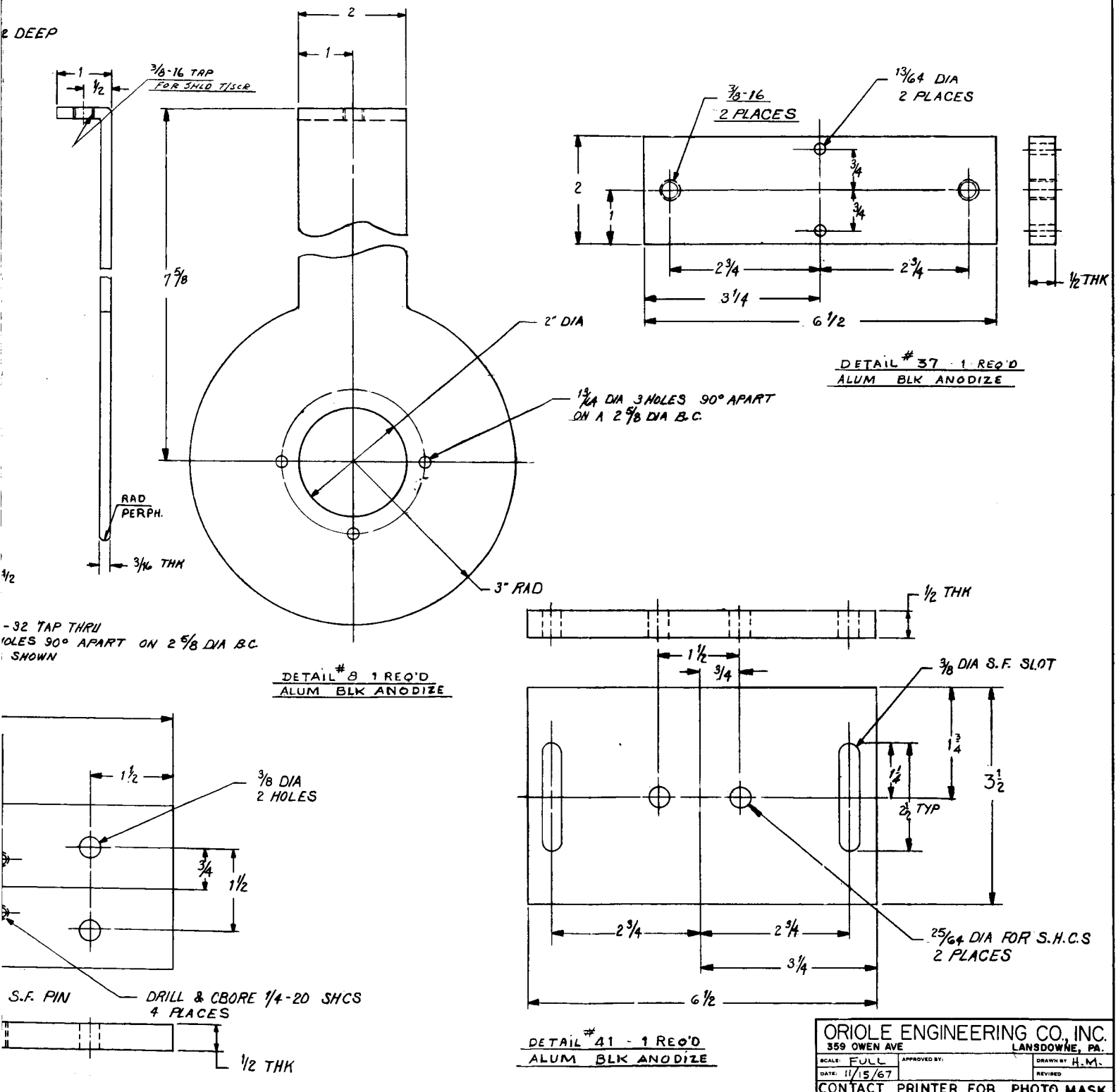


DETAIL # 7. 1 REQ'D
ALUM BLK. ANODIZE



DETAIL # 40 1 REQ'D
ALUM BLK ANODIZE

FOLDOUT FRAME 1



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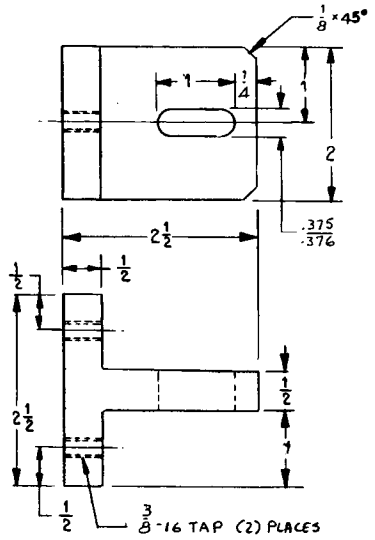
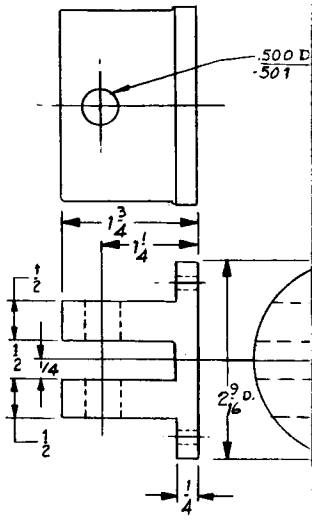
CONTACT PRINTER FOR PHOTO MASK	
	DWG. NO. 32001

SHEET 3 OF 6

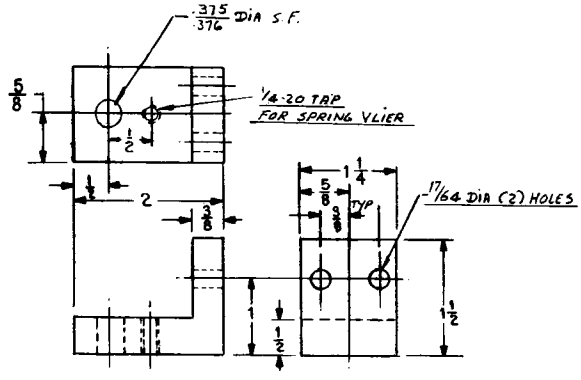
FOLDOUT FRAME 2



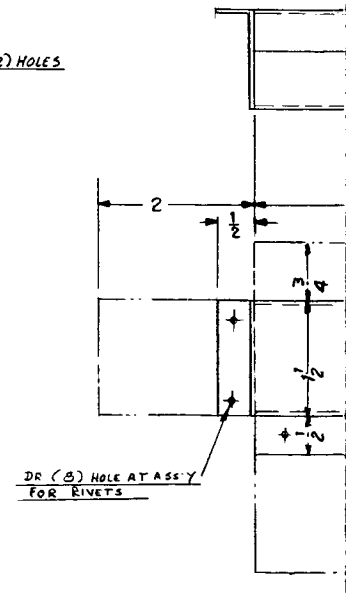
DETAIL # 30
1 REQ'D ALUM · BLACK ANODIZE



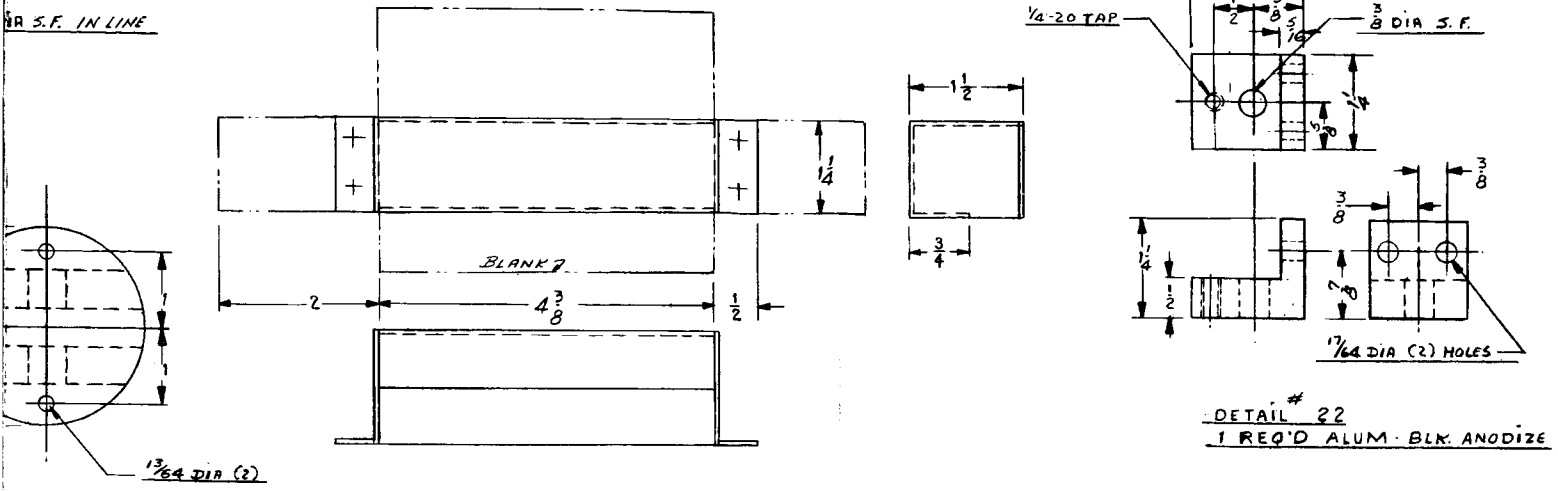
DETAIL #
1 REQ'D



DETAIL # 27
1 REQ'D ALUM BLK ANODIZE



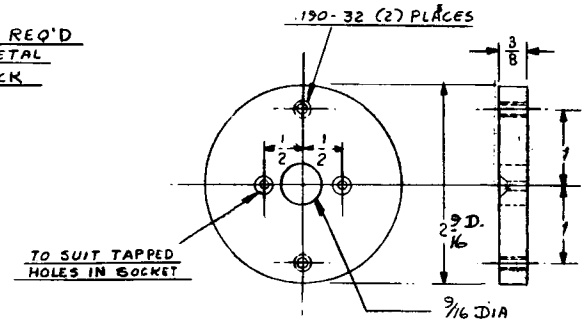
1/32



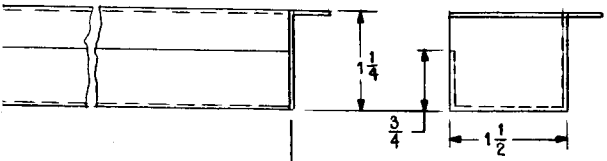
DETAIL # 3- 2 REQ'D
1/32 SHEET METAL
PAINT BLACK

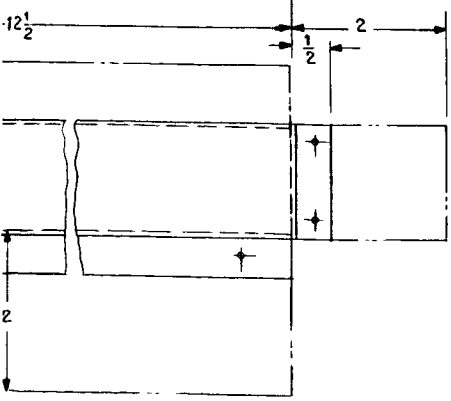
32
ALUM BLACK ANODIZE

DETAIL # 22
1 REQ'D ALUM. BLK. ANODIZE

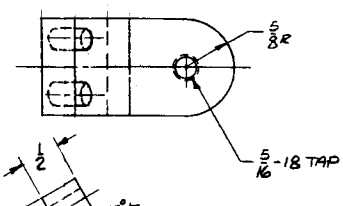


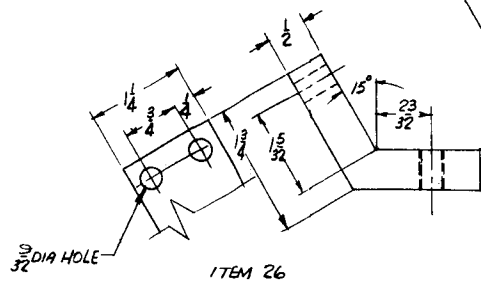
DETAIL # 33
1 REQ'D ALUM.



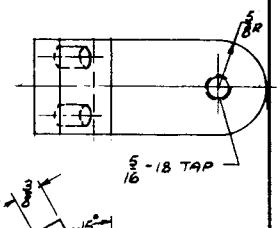


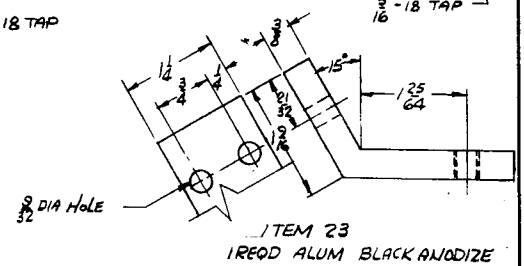
ETAIL # 15
SHEET METAL





ITEM 26
1 REQD ALUM BLK ANODIZE





ITEM 23
1 REQD ALUM BLACK ANODIZE

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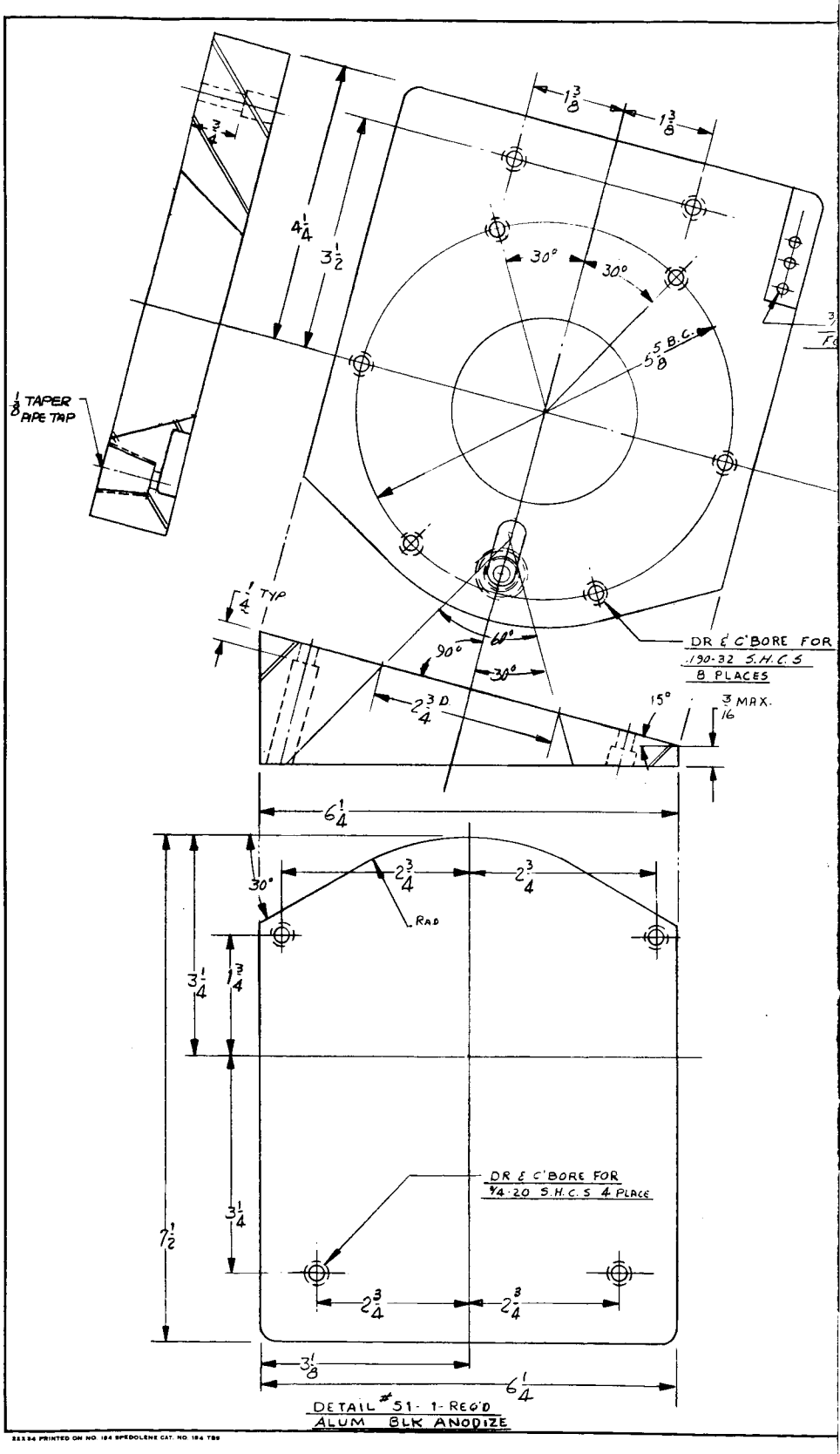
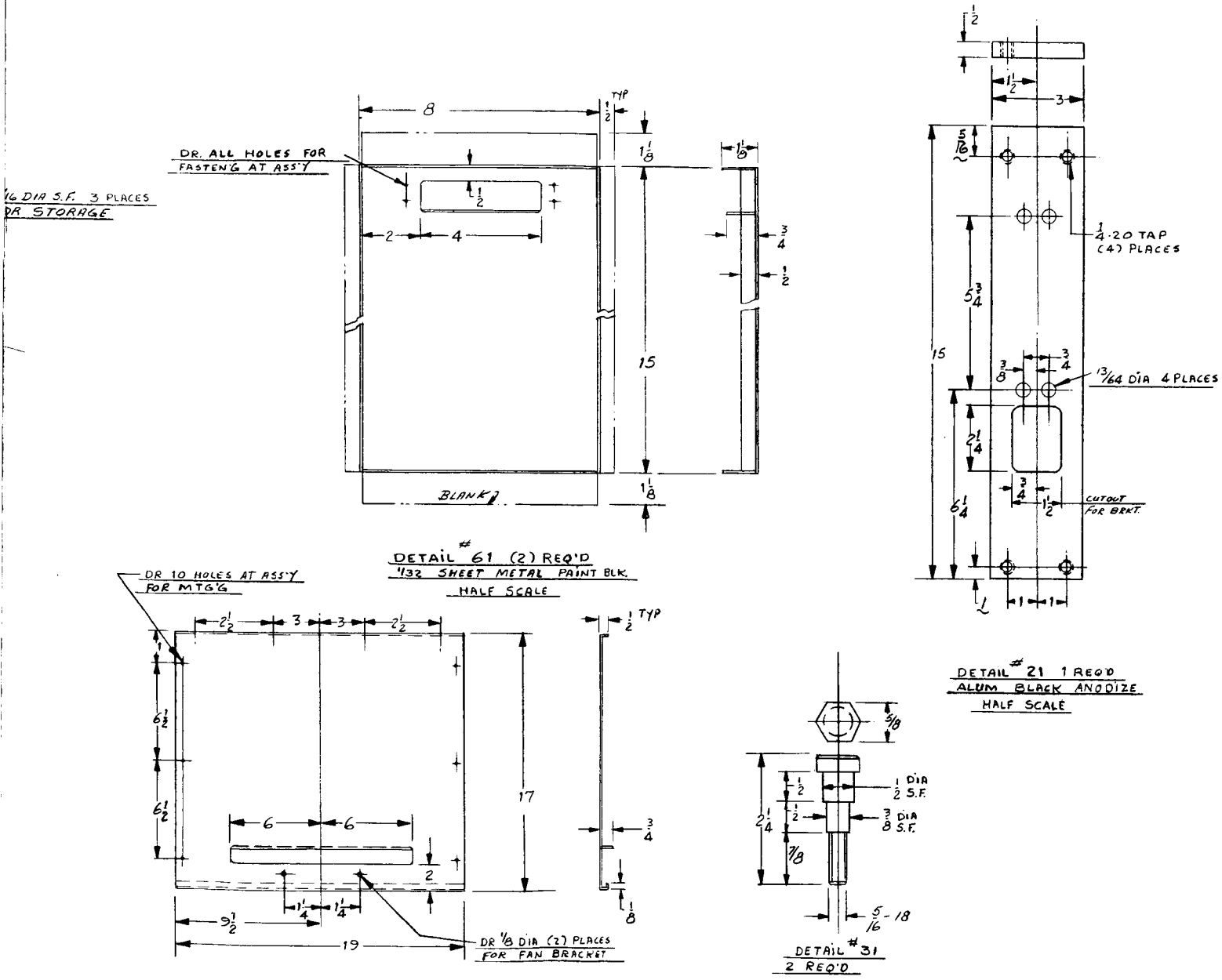
SHEET 4 of 6



DETAIL #51-1-REQ'D
ALUM BLK ANODIZE

FOLDOUT FRAME 1



ORIOLE ENGINEERING CO., INC.	
359 OWEN AVE — LANSDOWNE, PA.	
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DWG. NO. 32001	

SHEET 5 OF 6

FOLDOUT FRAME 2

BILL OF MATERIAL

	ITEM	QTY	SHT	MAT'L	SIZE	REM
*	1	1	1	ST'D	PREMIENE CABINET MODEL PoR-3118	P
*	2	1	1	ST'D	BUD: DUAL VIEW PNL MODEL PP S-1240	P
	3	2	1/4	SHEET METAL	1/32 x 3 1/2 x 8 1/2	BE
	4	1	1	ALUM	5/16 x 14 3/4 x 19	
	5	1	1	SHEET STL	1/8 x 1 x 68 (SPACER)	CU ZU KO WA
HOLD	6	1	1	STD	FILTER 2 x 2 (IN GLASS)	
	7	1	1	ALUM	3 DIA x 3/8 THK	
	8	1	1/3	ALUM	3/16 x 6 x 12	
	9	1	1	ST'D	SUN LAMP	P.
	10	1	1/2	ALUM	1 x 1 1/2 x 1 1/2	
	11	1	1	SHLD. SCR.	1/4 DIA x 1/2 LG	
*	12	1	1	EXHAUST FAN	4 1/2 x 4 1/2	P.
	13	1	1	ALUM	3/16 x 5 x 9 LG	BE
	14	1	1	BUSH'G	3/8 1.0 x 1/2 0.D x 1/2 LG	
	15	1	1/4	SHEET METAL	1/32 x 4 1/4 x 16 1/2	
	16	1	1	DOOR KNOB	TO SUIT	
	17	1	1	SOFT CU TUBE	3/8 O.D x 1/32 WALL x 4 FT	
	18	1	1	ST'D	VACUUM PUMP 3321-A 1/6 H.P. 1.3 CFM	3
	19	2	1	PIANO HINGE	3" LG	
	20	1	1	RUBBER INSUL.	50 FT ROLL	
	21	1	1/5	ALUM	1/2 x 3 x 15	
	22	1	1/4	ALUM	1 1/4 x 1 1/4 x 1 1/2	
	23	1	1	ALUM	1 x 1 1/4 x 3	
	24	3	1	THUMB SCR. SHLD	3/8-16 x 1 1/4	
	25	2	1	SHLD. SCR	3/8 DIA x 1 LG	
	26	1	1	ALUM	1 x 2 x 2	
	27	1	1/4	ALUM	1 1/4 x 1 1/2 x 2	
	28	12	1	JAM NUT	3/8-16	
	29	2	1	ALUM	5/8 x 7/8 x 19 1/16	
	30	1	1/4	ALUM	2 x 2 1/2 x 2 1/2	
	31	1	1/5	HEX STK	5/8 HEX x 2 1/4 LG	
	32	1	1/4	ALUM	2 5/8 DIA x 1 3/4	
	33	1	1/4	ALUM	2 5/8 DIA x 3/8 THK	
HOLD	34	1	1	STD	LOW INTENSITY LAMP	GE 18
	35				NOT USED	
	36	2	1	STUD	3/8-16 x 5 LG	
	37	1	1/3	ALUM	1/2 x 2 x 6 1/2	
	38	1	1/3	ALUM	3/4 x 3 x 3 1/2	
HOLD	39	2	1	ST'D	CONDENSER 6" DIA x 9" FL	#19 BUS
	40	1	1/3	ALUM	1/2 x 3 x 10 3/4	
	41	1	1/3	ALUM	1/2 x 3 1/2 x 6 1/2	
	42	4	1	WASHER	TO SUIT	
	43	4	1	DR. ROD	1/4 DIA x 5/8 LG	
	44	1	1/2	ALUM	6 DIA x 1/2 THK	
*	45	1	1	"O" RING	1/8 THK	12
	46	1	1/2	ALUM	3/4 x 6 x 7	
	47	1	1	NEOPRENE	4 1/2 DIA x 1/16 THK	
	48	1	1/2	ALUM	4 1/2 DIA x 5/8	
	49	1	1/2	C.R.S	1/4 DIA x 3 1/2 LG	
	50	1	1/2	ALUM	3/4 x 1 1/4 x 3 1/2	
					CONT OPP. COLUMN	

FOLDOUT FRAME 1

BILL OF MATERIAL

	ITEM	QTY	SHT	MAT'L	SIZE	REMARKS
	51	1	1/5	ALUM	1 3/4 x 6 1/4 x 7 1/2	
	52	1	1	NEOPRENE	3 3/4 DIA x 1/16 THK	
*	53	1	1	VACUUM GAGE	FISHER CAT # 11-279	2 1/2 DIA
	54	1	1	ST'D	REPUBLIC 3-WAY VALVE 310-3-1/8 D.	P.O.
*	55	1	1	VOLTMETER	SIMPSON 0 TO 100	
	56	5	1	ST'D	CANNERADIO NO. 143-2099 OR ESSEX STICKS STK 1630	TOGGLE SWITCH
*	57	1	1	ST'D	VARIABLE TRANSFORMER G.E. MODEL 9T92Y27	P.O.
*	58	1	1	ST'D	IND. TIME-O-LITE MODEL P-59	P.O.
	59	2	1	ALUM	3/32 x 1 x 17	
	60	1	1/5	SHEET METAL	1/16 x 18 1/2 x 19	BEND
	61	2	1/5	SHEET METAL	1/32 x 9 x 17 1/2	BEND
	62					
	63	2	1	SPRING CLIP	1/4-20 x 1/2 LG	
	64	2	1	ALUM TUBING	3/910 x 5/300 x 2 1/4 LG	

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SHEET 6 OF 6

FOLDOUT FRAME 2

6.0 List of Material Suppliers

1. Eastman Kodak Company, Rochester, New York

   Wratten filters, metal clad plates, high resolution plates, negative photoresists, miscellaneous supplies.

2. Oriole Engineering Company, 359 Owen Avenue, Lansdowne, Pennsylvania

   Contact printer construction.

3. Baltimore Instrument Company, 716 West Redwood Street, Baltimore, Maryland

   Olympus microscope.

4. Shipley Company, 2300 Washington Street, Newton, Massachusetts

   Positive photoresist, miscellaneous supplies.

5. National Semiconductor Company, 2950 San Ysidro Way, Santa Clara, California

   Resolution emulsion mask.

6. Sylvania Electric Products Inc., Portsmouth Avenue, Exeter, New Hampshire

   Evaporation filaments.

7. O. and S. Research Inc., 1912 Bannard Street, Riverton, New Jersey

   Glass substrates.

8. Fish-Schurman Corporation, 70 Portman Road, New Rochelle, New York

   Glass substrates.

9. Corning Glass Works, Corning, New York

   Glass substrates.

10. J. Melvin Freed Inc., Perkasie, Pennsylvania

    Glass substrates.

11. American Saint Gobain Corporation, Kingsport, Tennessee

    Glass substrates.

12. Materials Research Corporation, Orangeburg, New York

    Rotating feed-through.

13 Chemical Rubber Company, 18901 Cranwood Parkway, Cleveland, Ohio

    Variable speed motor.

7.0 References

1. Superior Photoengraving Processes for Semiconductor Devices, C. J. Taylor, NASA Contractor Report CR 597.

2. Stevens, G.W.W., "Microphotography, 183-184, 1957, Wiley and Company, New York, New York.