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**SELENIUM RECTIFIERS**  
**S.A.F., NÜRNBERG**  
**INSTITUT FÜR ANORGANISCHE UND**  
**PHYSIKALISCHE CHEMIE, DARMSTADT**

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**COMBINED INTELLIGENCE OBJECTIVES**  
**SUB-COMMITTEE**

REPORT ON  
SELENIUM RECTIFIERS  
S.A.F. NURNBERG  
AND  
INSTITUTE FOR ANORG. AND PHYS. CHEMIE  
DARMSTADT

Reported by

R. H. RANGER, Lt. Col. Sig. Corps

on behalf of the  
U.S. Technical Industrial Intelligence Committee

CIOS Target Nos. 1/289 & 9/323  
Radar  
Physical & Optical Instruments & Devices

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COMBINED INTELLIGENCE OBJECTIVES SUB-COMMITTEE  
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## TARGETS

S.A.F. Plants at Nürnberg and Weissenberg  
Prof. R. Brill, Inst. for Anorganische und  
Physikalische Chemie, Darmstadt.

## PHYSICAL CONDITION OF TARGET

The main SAF plant at Nürnberg had been repeatedly bombed and was perhaps 40% in condition. The branch at Weissenberg was undamaged.

Prof. Brill was seen at Heidelberg at his home; he stated that the Darmstadt Institute had been badly looted, but otherwise not particularly damaged.

## PERSONNEL

Those interviewed were

Herr Stegman, Manager SAF Nürnberg  
Dr. Lauckner, Laboratories Weissenberg  
Dr. Schweickert " "  
Dr. Jessberger " "  
Prof. Brill, Inst. for An. and Phys. Chemie, Darmstadt

## RESUME OF INTELLIGENCE GAINED BY INVESTIGATION

Selenium Rectifiers were such an important part of all electric equipment for the German war and civil economy, that great pressure was brought to bear to improve the quality and quantity of their manufacture.

It finally worked out that SAF at Weissenberg was the sole non-bombed source of these, and they were ordered to stop making exposure meters and concentrate entirely on the rectifiers.

The initial production difficulties of 1940 were pretty well ironed out by 1942.

Professor Brill was asked to investigate the theory of the cell with his X-Ray analysis facilities. This had not resulted in definite production assistance as yet.

## RECOMENDATIONS

It is believed that the basis for this manufacture has been pretty well explained by these people; but inasmuch as the Weissenberg plant is in perfect shape, it is suggested that pilot runs be initiated there, with the opportunity

for direct observation by concerned Allied manufacturing representatives.

#### MANUFACTURING SELENIUM RECTIFIERS, SAF

1. The business of making selenium rectifier discs up to three million a month continued right up to the end of the war at the Lorenz factories in Nürnberg and its branch at Weissenberg, fifty kilometers south.
2. The AEG, Telefunken and other rectifier concerns were practically bombed out of existence, and the S A F (Süd-deutsche Apparate Fabrik) was thrice bombed severely in Nürnberg, but the Weissenberg factory was undamaged.
3. The manufacture has been a troublesome one, ever since the invention of the device by Dr. Presser then of TKD in 1931.
4. Production has often had to be stopped in the various factories of the SAF (now a Lorenz concern) due to the tremendous rejections in the final inspections. This has happened in all countries.
5. Due to the extreme necessity of these discs in all sorts of equipments, the German command restricted the SAF to their manufacture exclusively. Previously the company had also made exposure meters, some telephone equipment and selenium photo cells for miscellaneous purposes.
6. Extensive research on the rectifier disc manufacture was conducted at the separate SAF laboratory in Weissenberg. Leaders in this were Drs. Lauckner, Schweickert and Jessberger.
7. The rectifier disc consists essentially of an iron base in the form of a telephone diaphragm in sizes from 18, can be as small as 4 mm, to 112 mm diameter. This base is sandblasted, then nickel plated. Then one side is painted with hot selenium; which then has to be heat treated to form the proper crystalline structure. Then the selenium is sprayed with a special metal alloy which is to form one electrode to the disc. The uncoated side of the disc is the other electrode.
8. The disc then undergoes an electro forming process which produces the uni-directional layer in the selenium coating immediately under the sprayed alloy.
9. It is the formation of this layer which has been uncertain.

10. Iodine in small proportion was added to the selenium, and this promoted the formation of the layer.

11. Originally this layer was obtained by adding Cerium Iodide to the selenium. Due to heat difficulties, this mixing of the iodide with the selenium had to be carried out in very small quantities.

12. In 1941, it was determined in the SAF laboratory that straight iodine could be used equally effectively. To this end, it is now possible to mix 1.5 kilograms of selenium in the appropriate sized retort of porcelain to a temperature of 450° C.

13. Previously a batch of 300 milligrams of Iodine has been mixed with 100 grams of selenium, and this is then added to the large batch of selenium.

14. Due to evaporation of the selenium, the net result is a mix in which the proportion of iodine to selenium is approximately 20 milligrams to 100 grams.

15. Considerable research on the function of the selenium with iodine mixture has been made not only at Weissenberg, but also by Dr. Rudolph Brill now at Maltkest, Heidelberg.

16. It seems that X-Ray investigations indicate that there is a correlation between the length of the selenium crystals and the rectifying properties, and the iodine limits the length of these crystals.

17. No particular function seems to have been exerted by the cerium in the former cerium iodide admixture, as the discs made without it now seem equally effective.

18. The alloy used as the top electrode consists of 26% Tin 53% Bismuth 21% Cadmium.

19. It has now been determined that the addition of a small amount of thalium has a very pronounced effect on the formation of the rectifying layer.

20. The inclusion in the alloy of thalium from .003 to .005% seems just right. Below, .003 it takes too long or may even be impossible to form the rectifying layer. If more than .005% is used, there is danger of overheating and ruining the crystalline structure of the selenium.

21. Investigations are continuing, and there seems to be promise in the introduction of manganese into the process.

22. One method consists in dipping the selenium coated disc before alloy spraying, into a 1:100 solution of  $KMnO_4$  in acetone.
23. Other possibilities are  $MnO_2$ ,  $K_2SeO_3$  and  $SeO_2$ .
24. Three methods of making the first coating of selenium on the disc are now in use.
25. The first is the original which consisted of painting the disc manually after the proper amount has been placed on the heated disc in the form of pellets.
26. This then required stacking the discs in jigs under considerable pressure with separators originally of mica and then aluminum. These stacks were then treated in ovens.
27. This time consuming process has now been eliminated by a hot press method.
28. The discs are first lightly coated with Bismuth vapor.
29. They are then placed on heated plates at  $110^\circ$  to put the discs dusted with the selenium powder sifted through a .3 mm mesh screen under a pressure 25 kgm for a 112 mm disc.
30. This pressure is applied for about thirty seconds and then the discs proceed into the tempering oven at  $218^\circ$  for about 30 minutes.
31. In order to promote the adhesion of the selenium dust to the discs, a very light painted coat of selenium may be applied by spatula to the discs.
32. After the tempering, the discs are held, coated side down, over the fumes of heated  $SeO_2$  for 3 to 5 seconds.
33. The spraying of the alloy to form the other electrode is then done at a pressure of approximately two atmospheres.
34. The alloy for spraying is maintained at a heat of  $240^\circ$ . The melting point is  $103^\circ$ .
35. It has now been possible to make all these operations automatic, in a continuous machine about thirty feet long.
36. A further method of coating the discs has been developed by AEG. This consists in vacuum evaporation of the selenium onto the discs.

37. It is stated that good results are obtained by this process, but no details as to efficiency and output are available, and the plant and personnel cannot be seen. But the sample discs available are excellent.

38. Automatic electroplating equipment has been developed at SAF Nürnberg for the nickelling of the sheet iron discs.

39. It is necessary to keep any traces of iron out of the selenium; this is accomplished by using porcelain receptacles instead of iron and general extreme caution.

40. 180 firms were customers for these discs or rectifiers.

41. Present production indicated 4% rejections for mechanical reasons, and 16% for non-formation of the good rectifier layer.

42. A patent agreement had recently been arranged between SAF and AEG by means of which SAF could use the AEG evaporation process.

43. Selenium was obtained from Sweden and was refined by Riedel de Haen/bei Hanover and also by Schuy in Nürnberg.

44. There is approximately 5% impurity in the original selenium.

45. The material is twice sublimated for purification.

46. Then a solution is made of two parts nitric acid to one part selenium and  $\text{SeO}_2$  results.

47. The  $\text{SeO}_2$  is allowed to crystallize out at  $400^\circ$ .

48. Two vessels are then arranged in series to pass  $\text{SO}_2$  through a water solution of the  $\text{SeO}_2$ . For this solution, 6 Kgm of  $\text{SeO}_2$  crystals are dissolved in 20 liters of distilled  $\text{H}_2\text{O}$ . The series arrangement gives the  $\text{SO}_2$  a double chance to work on the  $\text{SeO}_2$ .

49. Practically, it takes 145 Kgm of  $\text{SO}_2$  to work on 100 Kgm of  $\text{SeO}_2$ ; and the net deposit is about 73 Kgm of Se plus a little water.

50. After adding the Iodine as previously specified, the mix is cooled on marble slabs on which it is poured out.

51. The finished flakes are then ground in porcelain rotaries to pass through a .3 mm mesh seive; then ready for use.



## X-RAY ANALYSIS OF SELENIUM FOR RECTIFIERS.

1. Due to the irregularity in output of selenium rectifiers the Institute for "Anorganische und Physikalische Chemie" at Darmstadt was asked to make crystallographic study of the selenium surfaces used in these.
2. Professor R. Brill, Director, had Dr. Krebs undertake this analysis. Dr. Krebs cannot be located at present.
3. Prof. Brill stated at his home in Heidelberg, Moltkestr. 8, that definite conclusions had not been reached as yet, but that certain relations had been determined.
4. The selenium crystals appear to be built up with the hexagonal cross section in the plane of the metal being coated; and that they built up as long needles perpendicular to the metal.
5. The grid of the crystals is more uniform in the progressive build up, the higher the temperature during formation; up to the point where the crystals might melt.
6. The more uniform the crystal structure, the higher the resistance.
7. The larger the cross section of the crystals, the lower the resistance.
8. A small admixture of iodine, of the order of 1 part in a thousand, appears to increase the chances of irregularity in the grid build-up of the crystal, with the consequent lowering of the resistance.
9. Selenium has six outer electrons, whereas iodine has seven. It is assumed the long build-up of series of selenium molecules, will be completed more perfectly by an iodine molecule with its seven outer electrons.
10. It takes eight outer electrons to make a perfectly stable molecule, and so the selenium molecules build on each other with a common two electrons between each group of two molecules; until finally an iodine molecule comes along and ends the chain as there is only one electron then missing.
11. For the rectification property, Bismuth Selenide is built up at the first juncture on the plate with the bismuth coating put on the sand blasted iron disc. No such selenide is built at the other electrode which is the sprayed alloy coating on the top of the selenium.

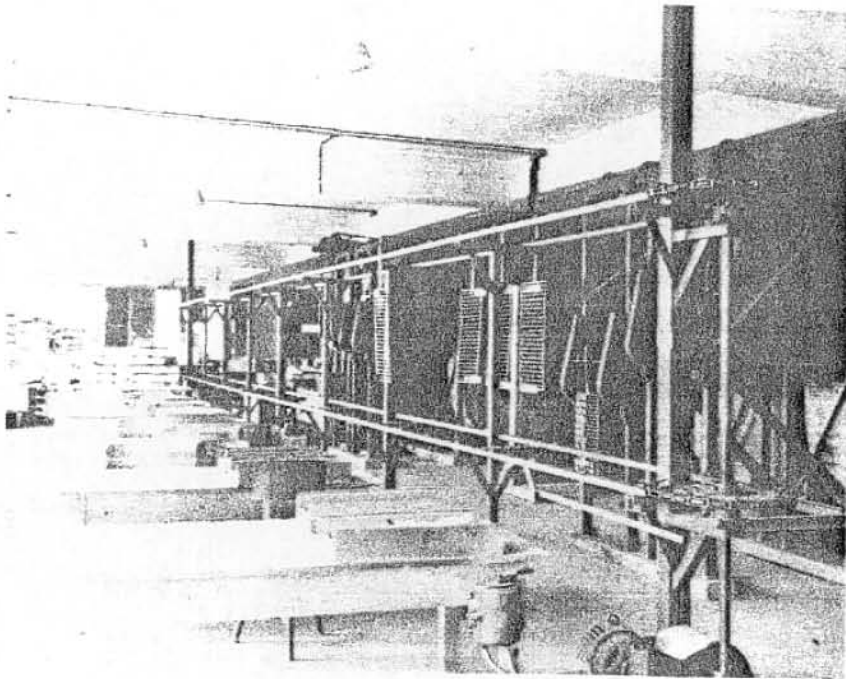
12. The AEG rectifiers which were made by high vacuum evaporation were more constantly of good quality, although the process itself is more involved.

13. Dr. Koch was responsible for the AEG development. He was last known to be around Lausitz/Schlesingen.

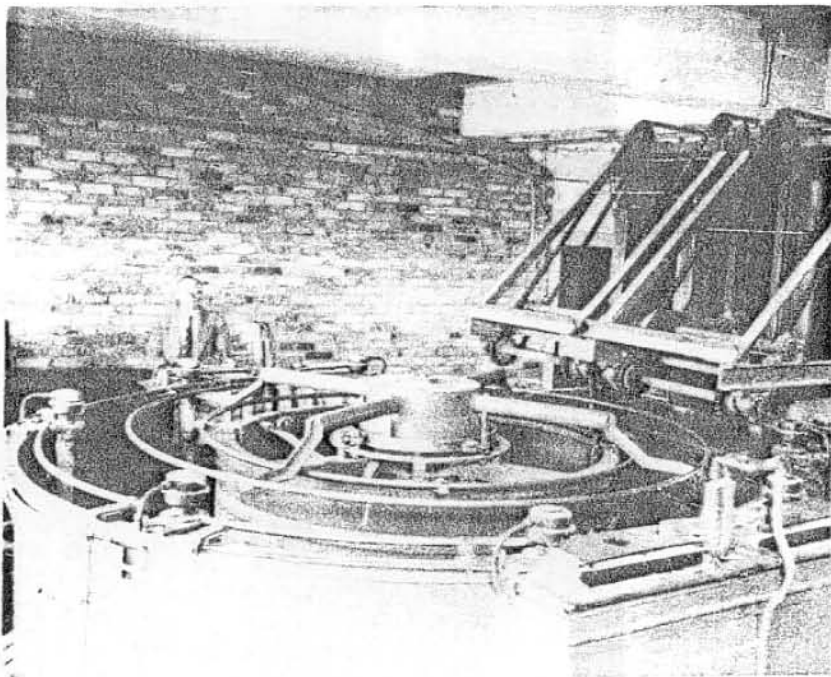
14. For the X-Ray analysis, a new type equipment has been developed which focuses the rays by means of a quartz concave mirror.

15. The specimen is rotated in the equipment at the same time that a shutter is moved around the recording film, which is formed as a half cylinder with the specimen at the center of the axis of the cylinder.

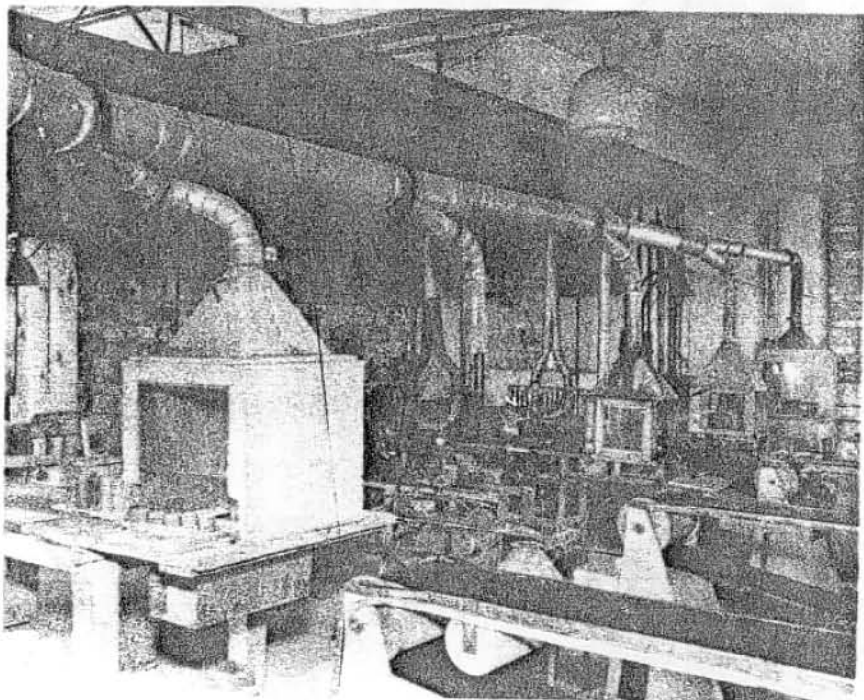
16. This constitutes a form of focal plane slit shutter; and greater effectiveness is obtained by means of which ample exposures are accomplished.



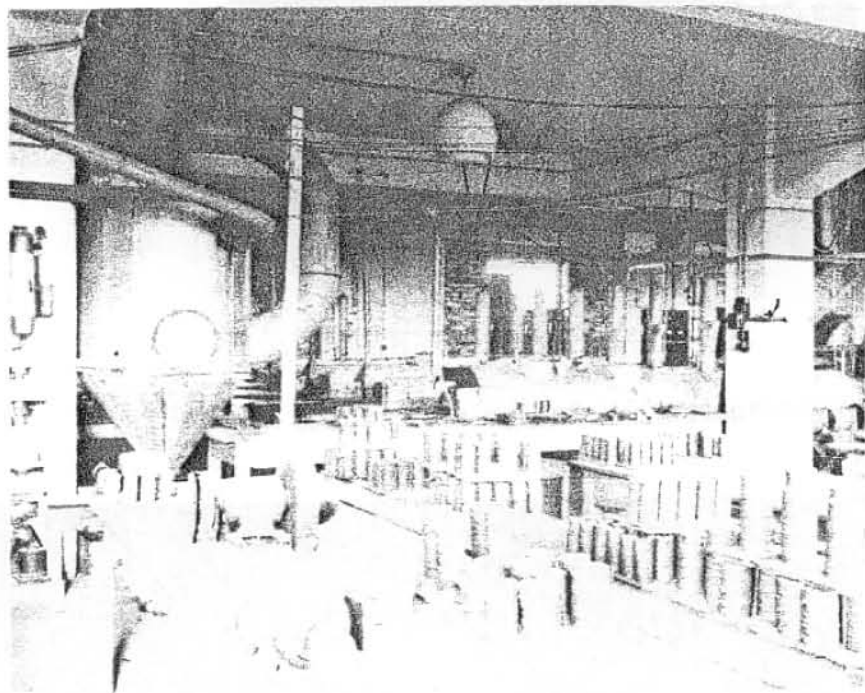
31 Disc Rack - Nuremberg



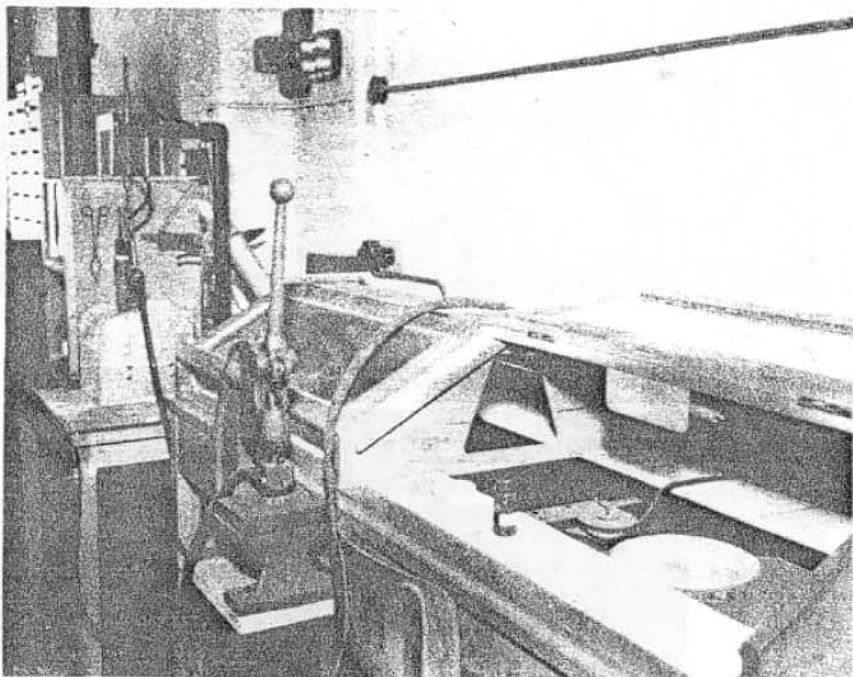
32 Large Nickeling Machine - Nuremberg



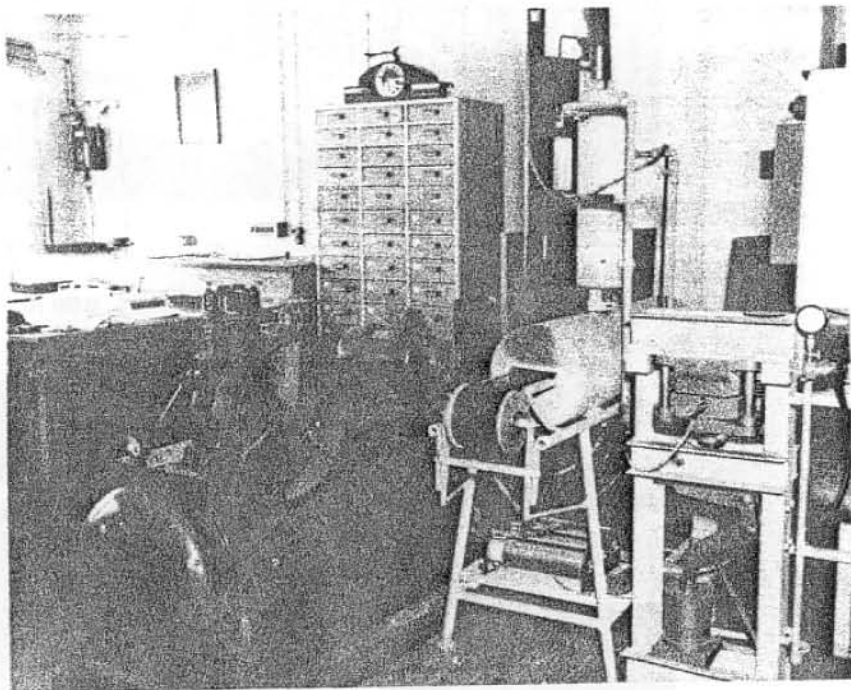
S3 Coating Hoods - Nuremberg



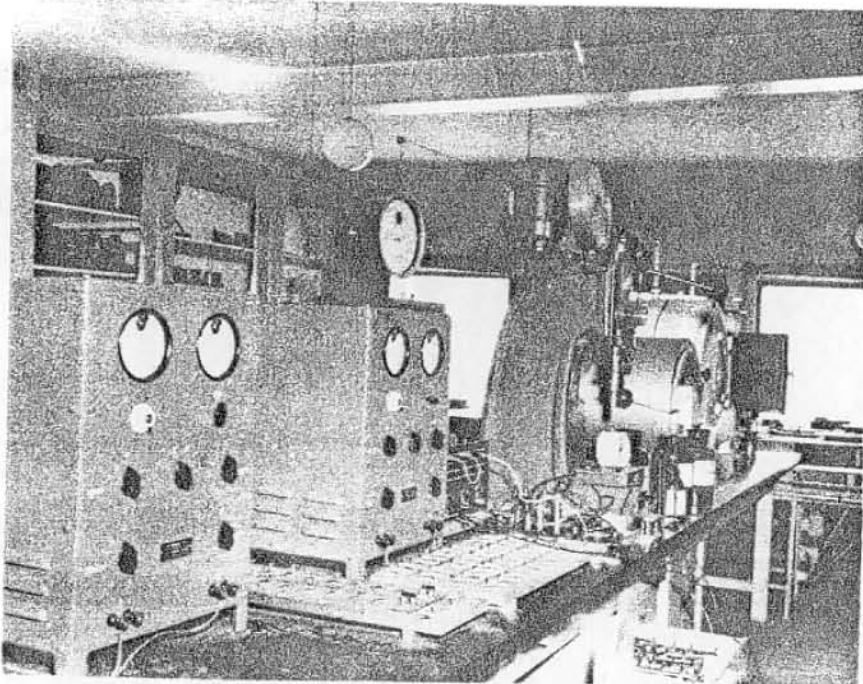
S4 General View of Disc treatment - Nuremberg



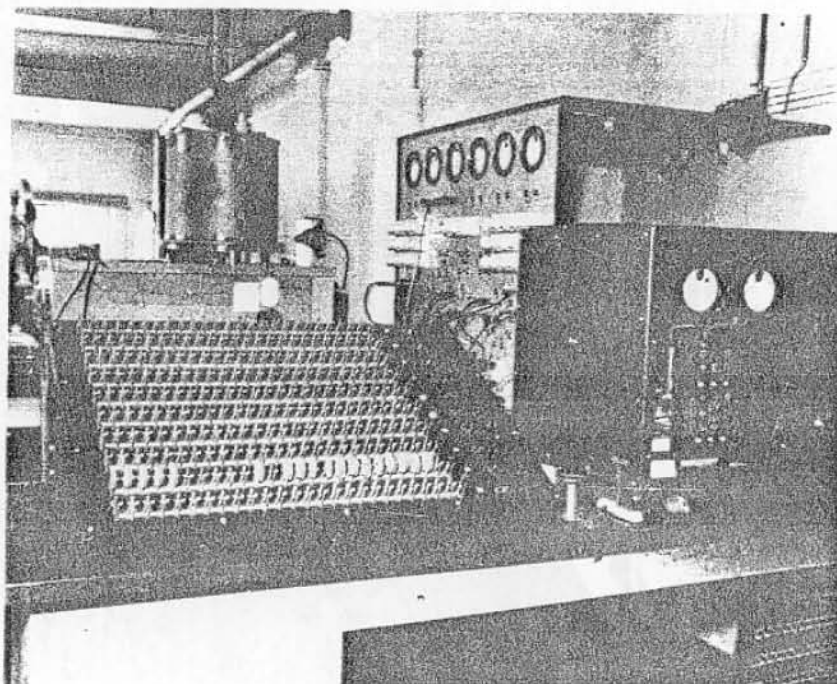
35 Coating hood - Weissenberg Laboratory



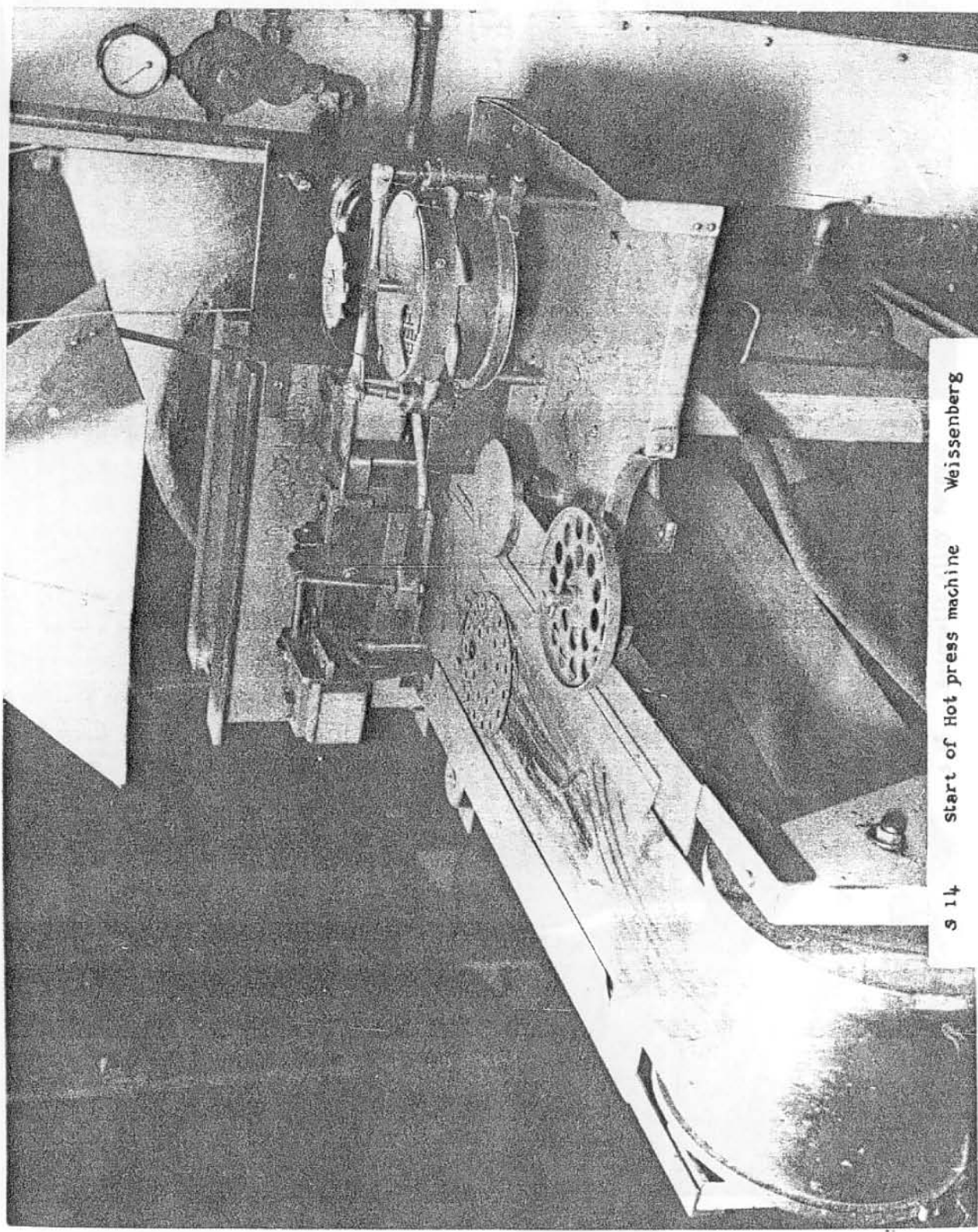
36 Hot press method - Weissenberg Laboratory



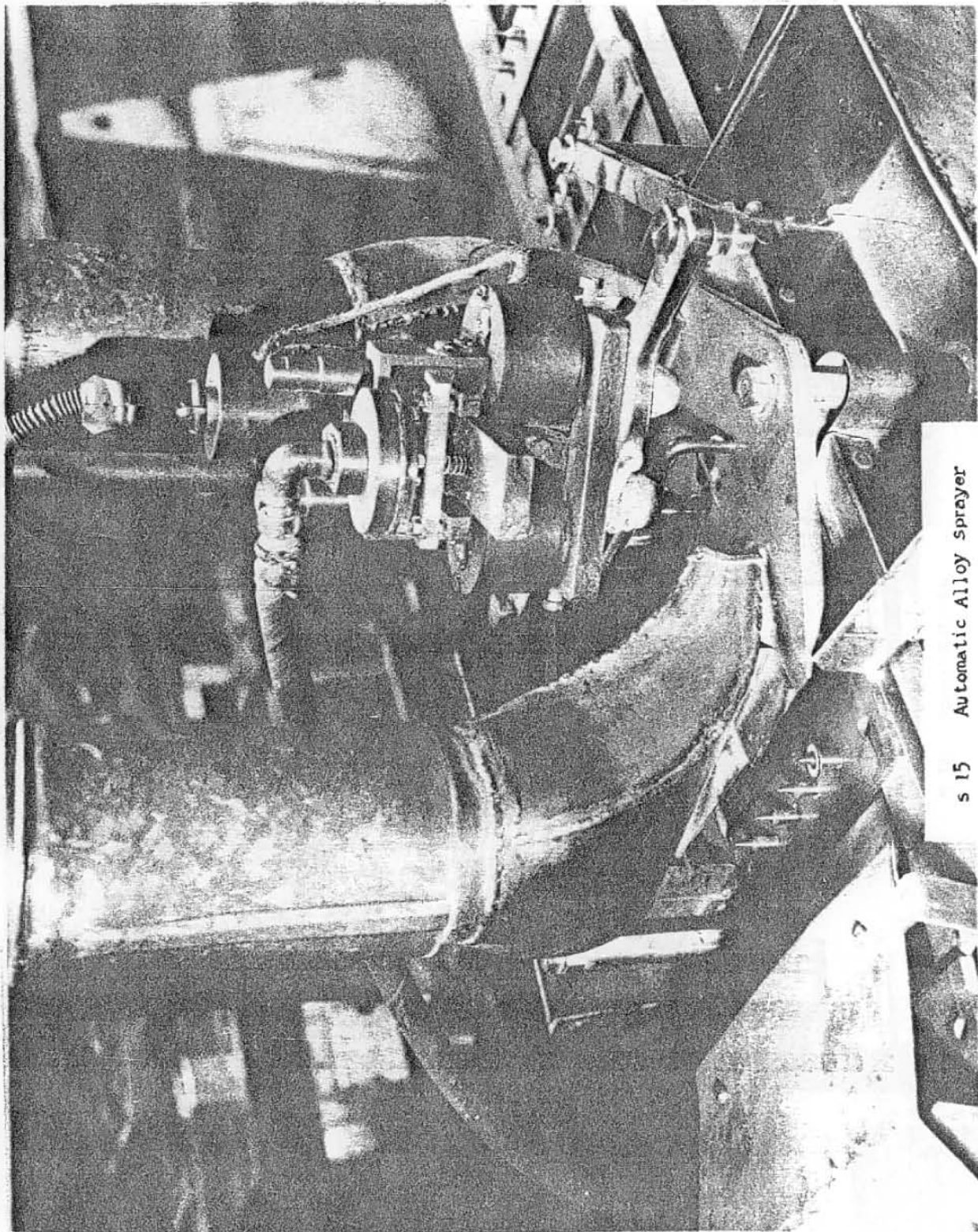
87 Test Ovens - Weissenberg Laboratory



88 Forming Bench - Weissenberg Laboratory

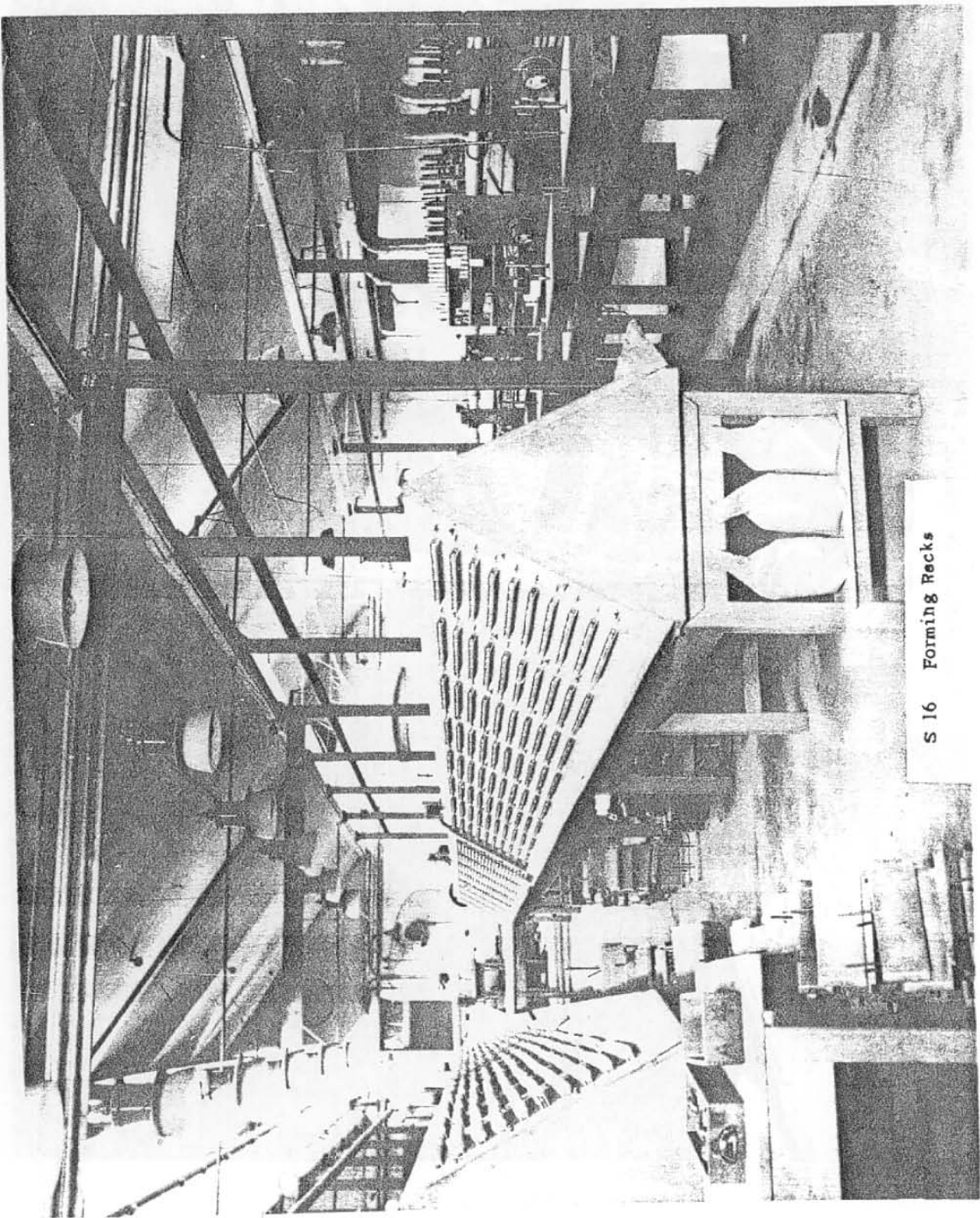


S 14 Start of Hot press machine Weissenberg

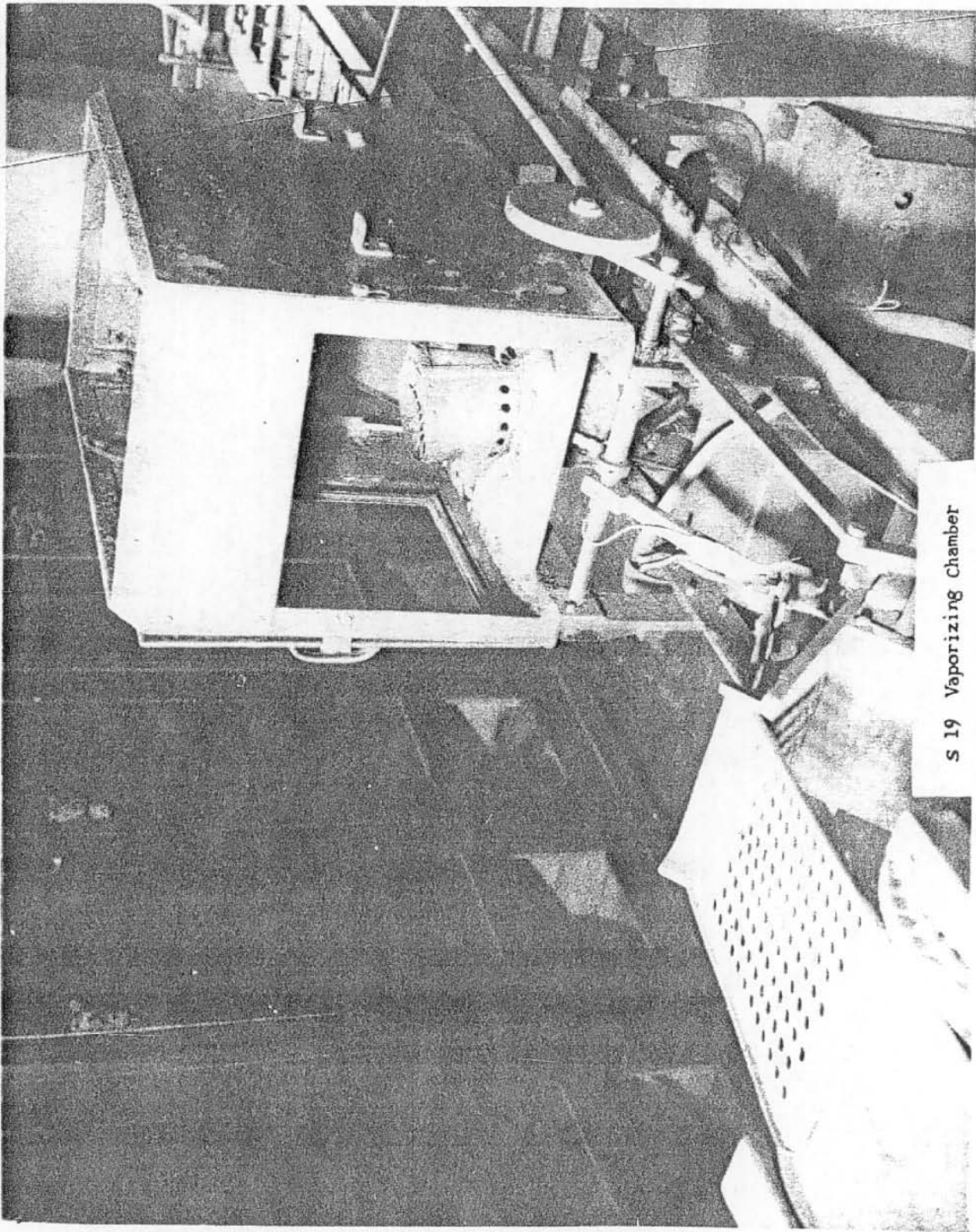


s 15 Automatic Alloy Sprayer





S 16 Forming Recks



S 19 Vaporizing Chamber