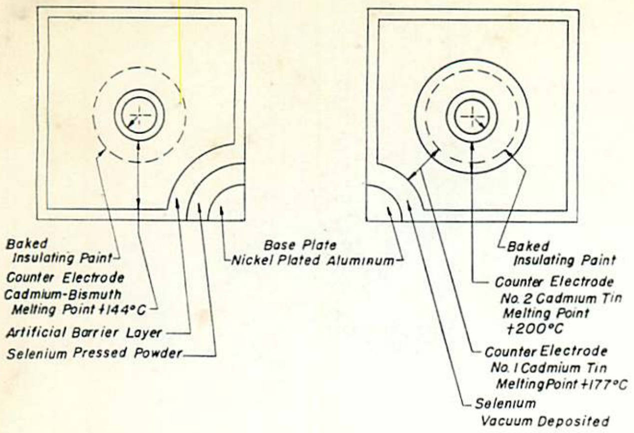

CELL COMPARISON. Left, Cell made by the pressed powder method. At the right, HCD Petti-Sel vacuum process cell.

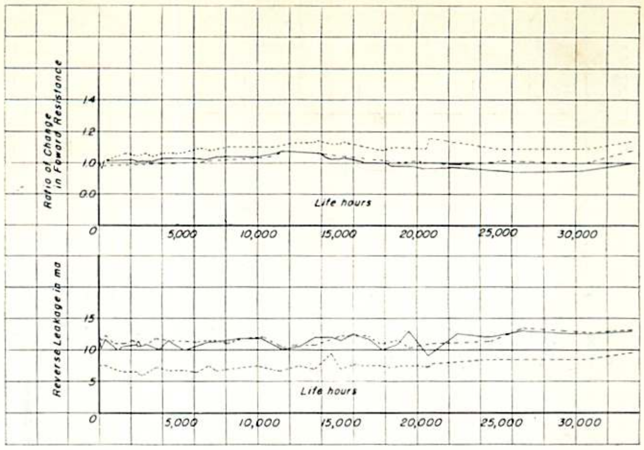

Fig. 1. Curves of three typical rectifiers of the type described showing ratio of change in forward voltage drop as related to initial voltage drop, and change in reverse leakage.

MANUFACTURING A NEW HIGH CURRENT DENSITY SELENIUM RECTIFIER

by JULIAN LOEBENSTEIN*

As a result of five years of intensive research developments by a prominent manufacturer** of West Germany into the art of selenium rectifier manufacture, a new and in many respects unique selenium cell is now being produced in the United States. It operates at much higher current density than heretofore considered standard and offers at the same time improved electrical properties and stable characteristics indicating a 100,000-hour life.

Selenium rectifiers, first made on a commercial scale in Germany, were brought to the United States a quarter of a century ago. In those days each cell—first known as a disc and later, when rectangular forms appeared, a plate—was rated as being able to operate at an alternating potential of eighteen volts. The product varied in quality and also in aging characteristics.

Originally the rectifier cell was made on an iron base plate. Although the iron base plate is still in use, the American market has in the main swung to the use of aluminum. At that time selenium was applied to the base plate by melting it and spreading it on the base plate. Then on top of the selenium there was placed a layer of cadmium bismuth alloy known as the counter electrode. Later the selenium was applied in the form of powder which was made to coalesce and adhere to the base by being placed in a press with heated platens. Still later the selenium was applied by vacuum methods.

Rectification takes place between the selenium and the counter electrode and the voltage which can be supplied is determined by the nature of the barrier formed at the junction of the selenium and the counter electrode. Much research and experiment was devoted to the problems of procuring greater uniformity, longer life and higher voltage.

INTRODUCTION OF LACQUER FILM

As experimentation proceeded it was found that by introducing a thin film of lacquer between the selenium and the counter electrode, the cells could be made to withstand higher voltages and before long standards were raised to 26 volts. Many stacks using cells at this rating have been in service for periods ranging to eight years and possibly longer. Cells rated at 33, 36 and some at 45 volts have also been developed.

In both the United States and in Europe, research was devoted to improving the methods of applying the selenium. In the United States effort was expended in the field of barrier layers with the goal of higher cell voltages. In Germany, on the other hand, the manufacturer's scientists believed that the barrier layer had certain inherent characteristics which had a tendency to cause a reduction in output voltage, or "aging," as the rectifier continued in use. As a result, their effort was channelled into improving the method of manufacture. The aim was a smaller cell for a given current rating without, at the same time, sacrificing efficiency, stability of output voltage or the long life of the rectifier.

In the process described, a metal base plate is used at the start, much as is the case with many other methods of manufacture. These base plates are put through a series of chemical and thermal treatments and then they are placed in a vacuum chamber. Here the selenium is carefully applied under automatically controlled conditions to insure a semiconducting layer of continual good quality. After being removed from the vacuum chamber, cells are placed on a conveyor line. They pass through a series of ovens and under an automatic spray gun which applies the counter electrode.

PROCESS ADVANTAGE

During the first stage of the processing, internal conversion takes place. This effects a crystalline modification of the selenium, thus yielding the best conducting properties. In the second stage, the internal structure of the counter electrode is improved as is its bond to the selenium. These changes constitute the advantage of the Siemens process.

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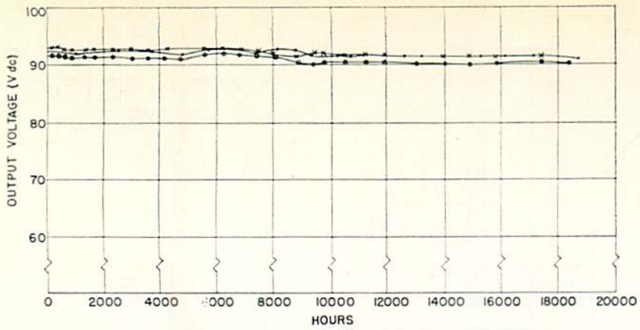

Fig. 2. Curves showing output voltages for three single-phase bridge rectifiers, input voltage 108v.

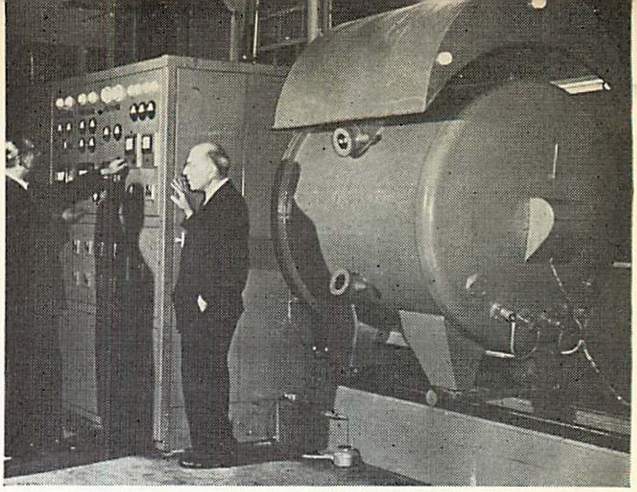

Fig. 4. Eric Waldkoetter, left, who came over from West Germany to install equipment used in the new selenium rectifier manufacturing process, makes an adjustment while the author observes. The vacuum chamber behind Mr. Loebenstein is a key production unit.

The counter electrode does not cover the area at the center of the cell where current is collected. In this area a different alloy at higher melting point is applied because greater resistance to heat is required.

After these operations, the cells are electroformed in the same manner as are cells made by any other process.

The long, stable life of German-type cells is shown in Figs. 1 and 2, which are typical curves for this new type of cell. Fig. 1 indicates the negligible drop in output voltage over a period of nearly 20,000 hours, while Fig. 2 shows the per cent change in the forward voltage drop over a period of more than 30,000 hours. The change does not exceed 17 per cent, and this per cent change in forward voltage drop in turn represents a negligible drop in the output voltage.

The significance of this small (17 per cent) change in the forward voltage drop can better be appreciated if this change is compared with the 100 per cent change which is often considered reasonable. This 100 per cent change is considered an arbitrary definition of stack aging and does not necessarily coincide with the end of useful life of the rectifier stack.

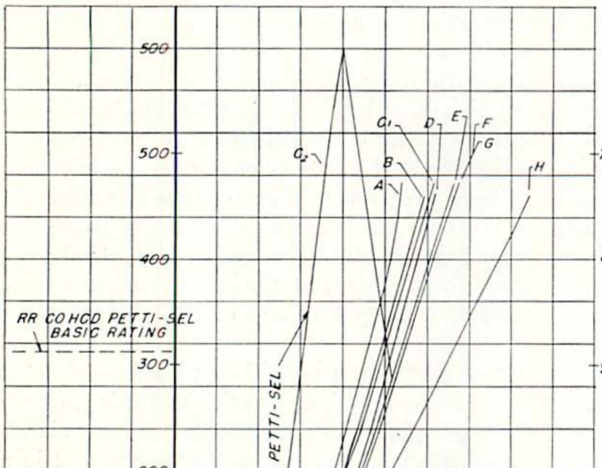

Fig. 3. Comparative voltage of HCD Petti-Sel (Curve C_2), as compared with other American cells made by the vacuum process.

With such stability of output voltage it may be concluded that the rectifier may well be rated at a probable life of 100,000 hours. But the remarkable achievement consists in the improvement of the electrical characteristics obtained simultaneously with the reduction in cell size for a given current rating. This improvement in electrical characteristics is shown in Fig. 3. From this it may be seen that operating at 320 ma/sq in. there is a forward drop in each cell of 0.75 volts, whereas the average American cell operating at half that current density; namely 160 ma/sq in., has a drop of almost one volt. It is expected that over a period of 100,000 hours this forward drop of 0.75 volts will not increase by more than 100 per cent. Conversely, this means that there is a smaller voltage drop in the cell for a given current, resulting in a lower energy loss and a correspondingly higher efficiency. Since the total rectifier area is smaller for the same current rating the rectifier reverse current will also be correspondingly reduced as will the energy losses resulting therefrom.

CELL SIZES

These new cells are available for electroplating and similar applications in sizes ranging from 4 x 4 in. to 8 x 16 in. Each of these are at present rated at approximately twice the current density of those made by other methods. For instance, a cell 4 x 4 in. can be used in place of a cell 5 x 6 in., and new developments may before long permit a still further reduction in cell size.

Rectifier stacks using cells in sizes 4 x 8 in. and up to 8 x 16 in. are assembled with a multiplicity of studs, one stud being supplied for each 4 x 4 in. area. Single powdered metal washers are used as cell separator or contact washers. These give higher conductivity than multiple washers; likewise, the powdered washers may be held to close tolerance so that surfaces are parallel and exactly the same distance apart in all washers of a given dimension. Thus, when a stack using a multiplicity of studs is assembled, it is certain that there will be no tilting or cocking of cells, because all distances will be equal and contact pressure will be the same. As a result, no hot spots will be developed.

The quality of the cells made by this process is the result

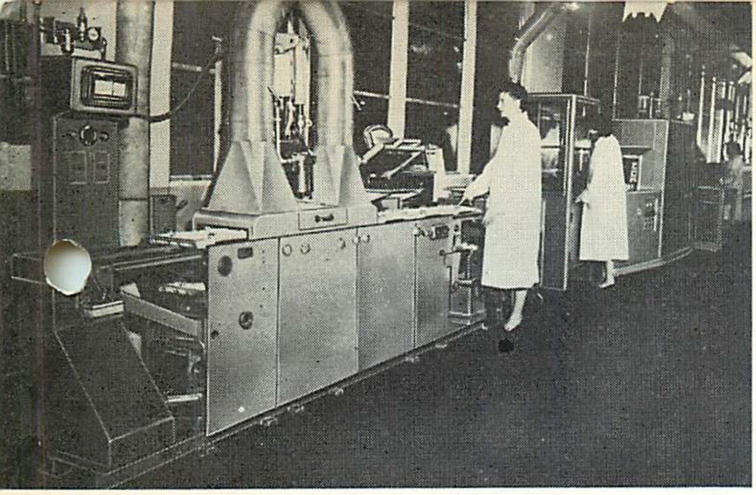

Fig. 5. White smocked, white gloved workers at stages of production line. The long machine at left is an automatic alloy applicator. The next step is spraying insulating paint for "dead centers" which keep rectifiers from shorting under the contact washer. The worker at far right is feeding cells into a thermal processing unit.

of almost completely automatic manufacture with time and temperature cycling mechanically and electronically controlled. Some of the units used in a 200-foot continuous production line are shown in Figs. 4 and 5. Even the counter electrode is applied with an automatic spray gun, shown in Fig. 5, assuring an even coating on the cells passing under the gun at a uniform speed on a conveyor belt. All the operations take place in an air conditioned room in which the temperature is closely controlled.

Fig. 6 shows the stacks, without the transformers and auxiliary equipment of a plating rectifier manufactured in Germany and installed in Hamilton, Ontario, Canada. It has a direct current rating of 9 volts and 10,000 amp. The stacks are fan cooled with air at a velocity, over the stacks, of 1100 lineal feet per minute. The use of air at this velocity permits the stacks to be used at current densities, in many cases, as high as three times their convention cooled rating. This is possible because of the inherent low losses in this new type of cell. It is thus possible to use the stacks to their highest potential, without sacrifice of enduring qualities.

In Europe these rectifiers have been applied to many diversified uses, some of which are shown in Figs. 7a and 7b.

*Radio Receptor Co., Inc., Brooklyn, N. Y., a subsidiary of General Instrument Corp. manufactures under brand name of HCD Petti-Sel.

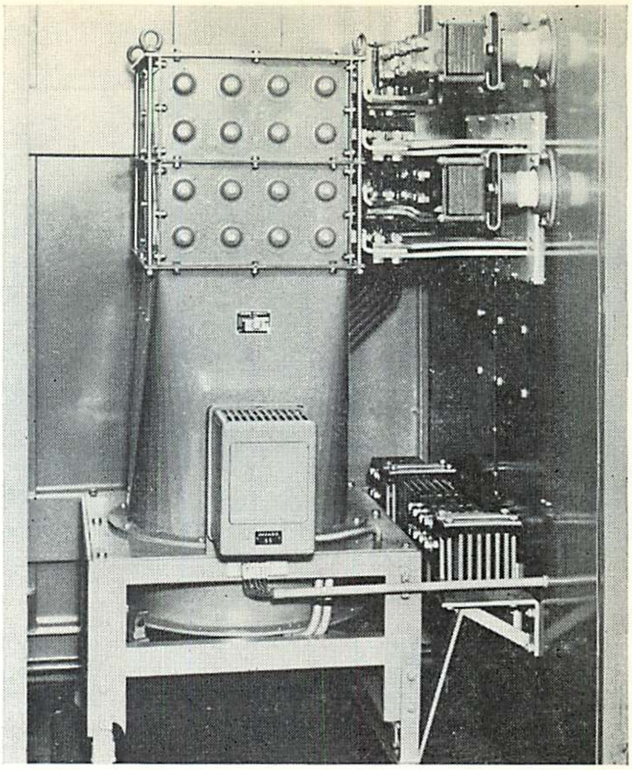

Fig 6

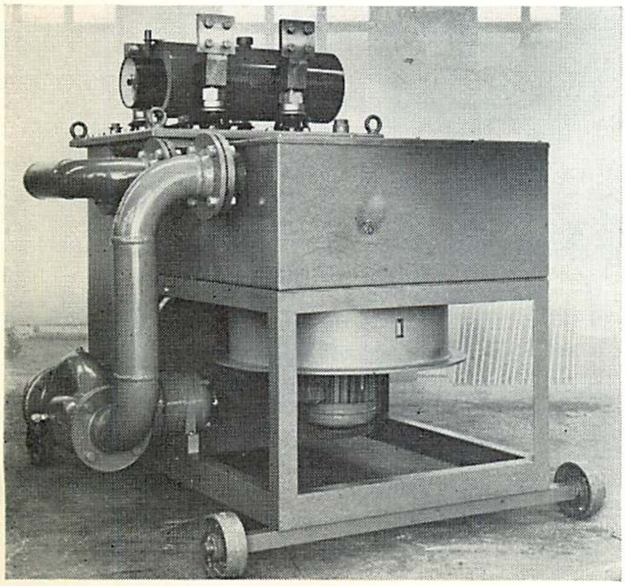

Fig. 7a

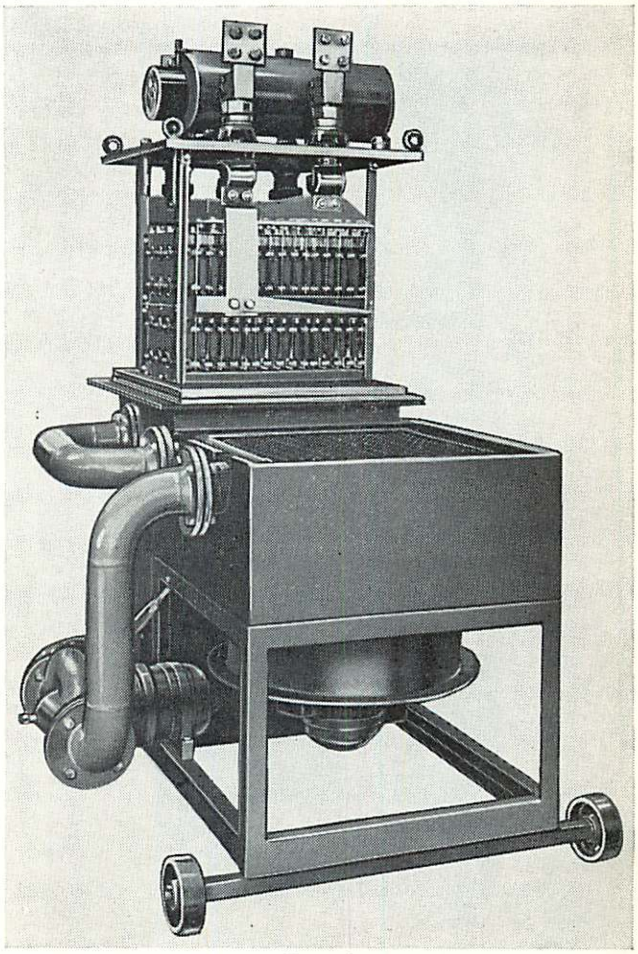

Fig. 7b

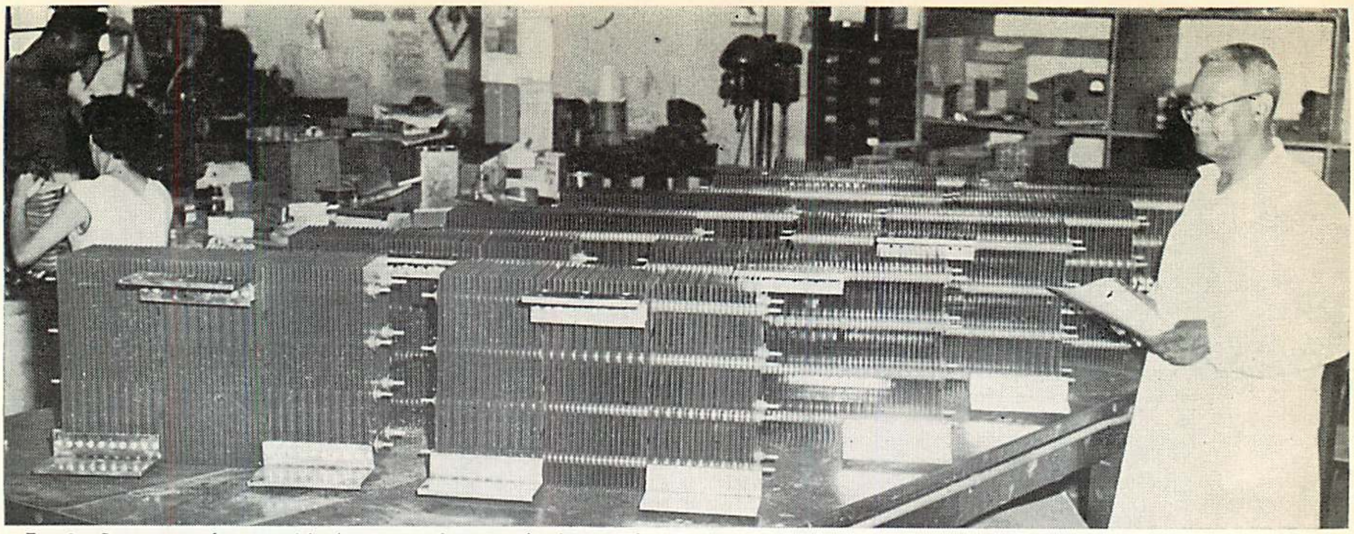

Fig. 8. Power rectifier assembly department foreman checks an order of selenium rectifiers being prepared for installation at an electroplating plant.

Fig. 8 shows a group of stacks now operating in equipment supplying a 50,000-amp, 9-v plating installation. Figs. 9 and 10 show other plating applications.

The equipment in Fig. 9, with 8-by-16-in. cells, will supply 1500 amp at 9 v.

Fig. 10 shows part of a unit to be used for electroplating in Formosa. The rectifiers will supply 500 amp at 12 v. Tests show a conversion efficiency of 77 per cent at full load with a temperature rise of 6C above ambient. It is operated with ac at 380 v input and uses a three-phase half-wave connection.

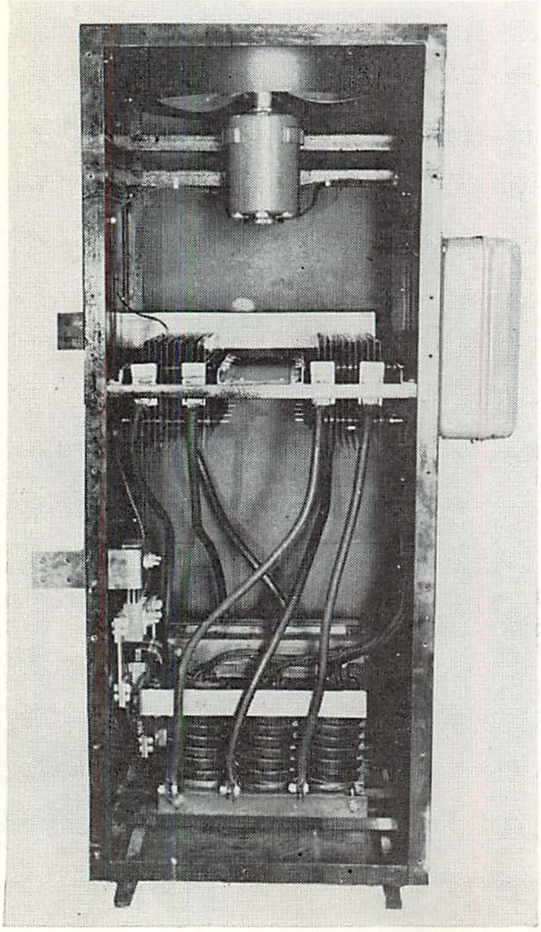

Fig. 9. Plating equipment whose 8 x 16-in. plates supply 1500 amp at 9 v.

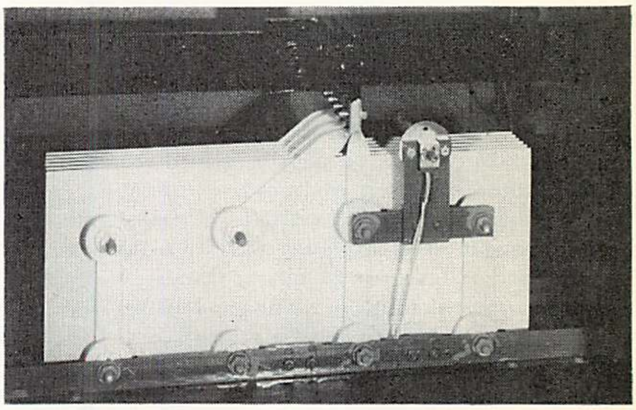

Fig. 10. Rectifier section of an electroplating unit to be used in Formosa. The plates, which can supply 500 amp at 12 v, are operated with ac at 380 v input and use a three-phase, half-wave connection.

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Mr. Loebenstein was graduated from Columbia University as an electrical engineer in 1912. In the years that followed he held a number of administrative positions, including that of captain in the Corps of Engineers during World War I. He was with Consolidated Edison of New York for 15 years as sales manager for gas appliances before he joined Radio Receptor 15 years ago.

During World War II, Mr. Loebenstein was production manager for Radio Receptor, itself a pioneer firm in the field of communications equipment. He took over as semiconductor sales manager in 1946.

Mr. Loebenstein is a member of the American Institute of Electrical Engineers and of the National Association of Corrosion Engineers. He was formerly section chairman of the semiconductor division of the National Electrical Manufacturers Association.

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