# United States Patent [19]

**Veach et al.**

[11] **3,908,123**

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[54] **EXTRACTION ELECTRODE GEOMETRY FOR A CALUTRON**


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[52] **U.S. Cl.** ..... **250/298;** 250/281

[51] **Int. Cl.²** ..... **H01J 39/34**

[58] **Field of Search** ..... 250/298, 299, 300, 398, 250/423, 424, 281, 282; 313/359, 360



[56] **References Cited**

UNITED STATES PATENTS

3,096,456 7/1963 Shelton et al. ..... 313/359

3,610,923 11/1971 Bell et al. ..... 250/298



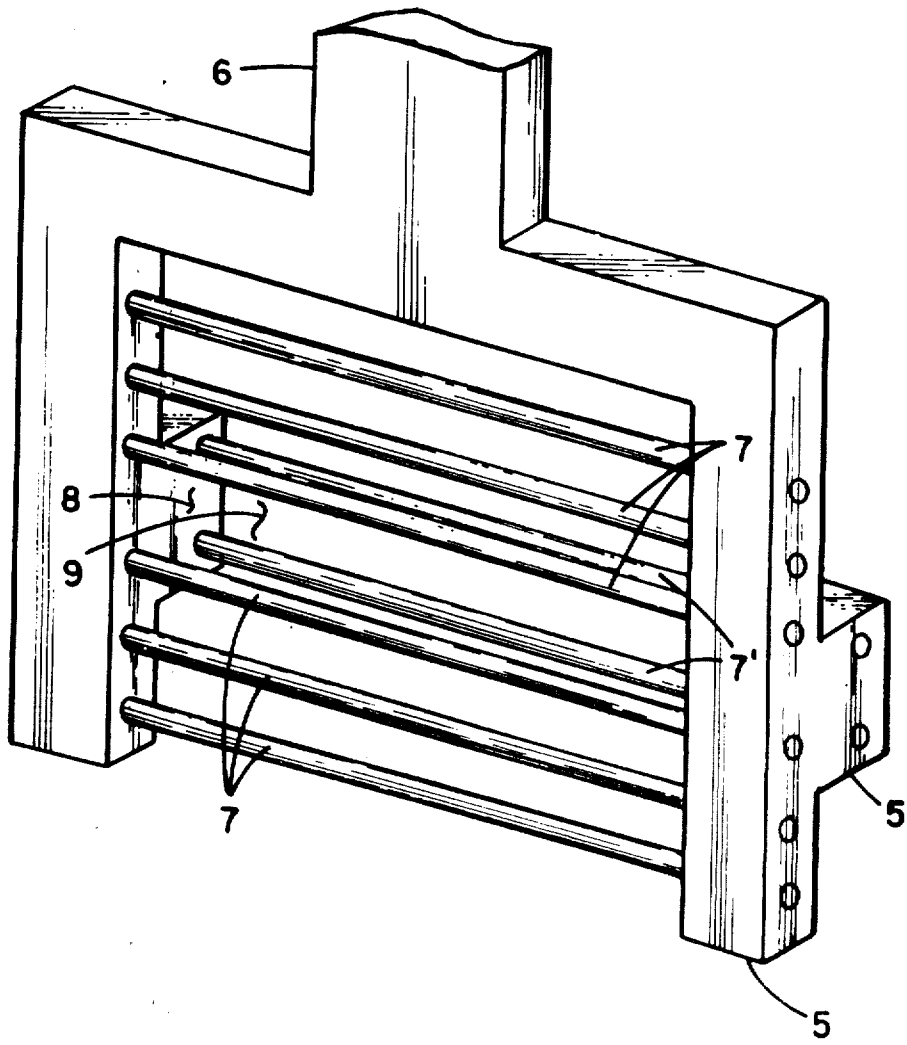
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[57] **ABSTRACT**

The present invention relates to an improved geometry for the extraction electrode and the ground electrode utilized in the operation of a calutron. The improved electrodes are constructed in a partial-picture-frame fashion with the slits of both electrodes formed by two tungsten elongated rods. Additional rods are used to establish equipotential surfaces over the rest of the front of the ion source.


**2 Claims, 3 Drawing Figures**



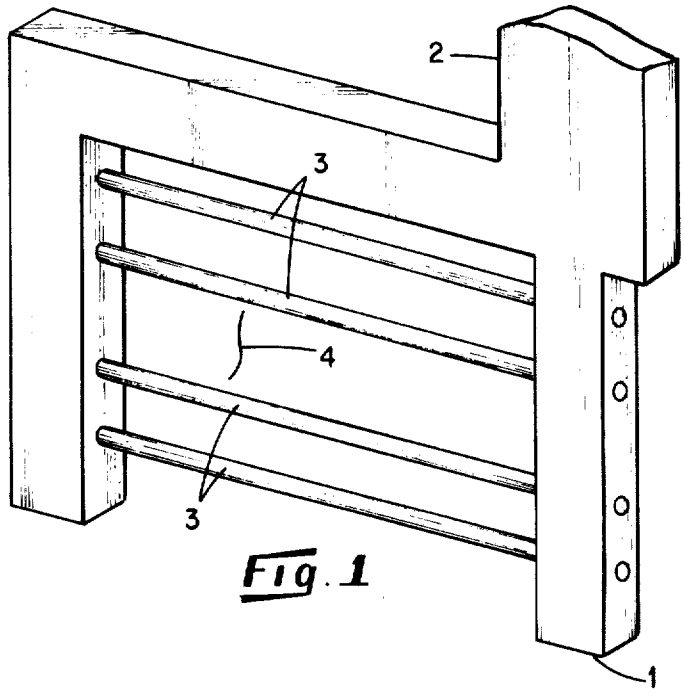



Fig. 1

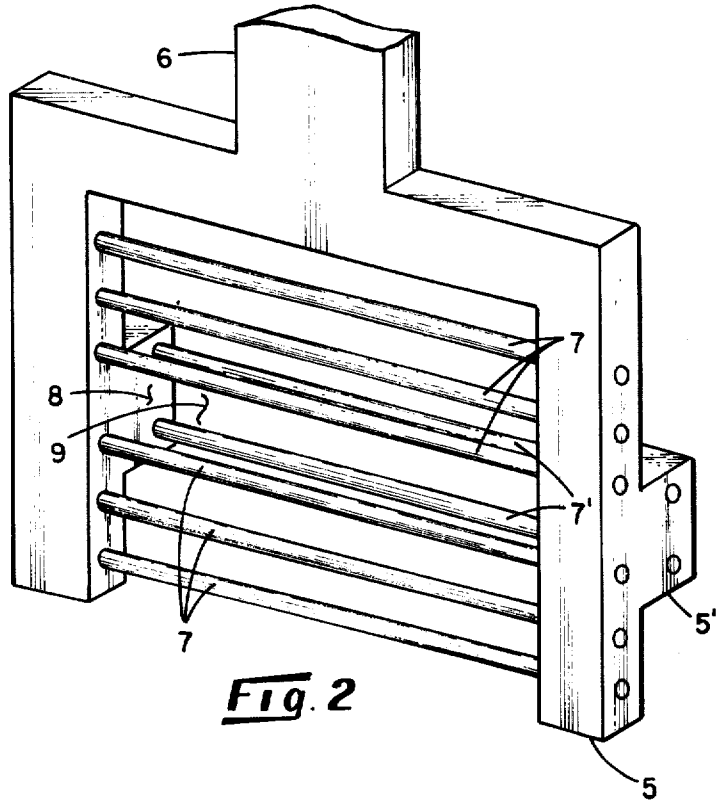



Fig. 2

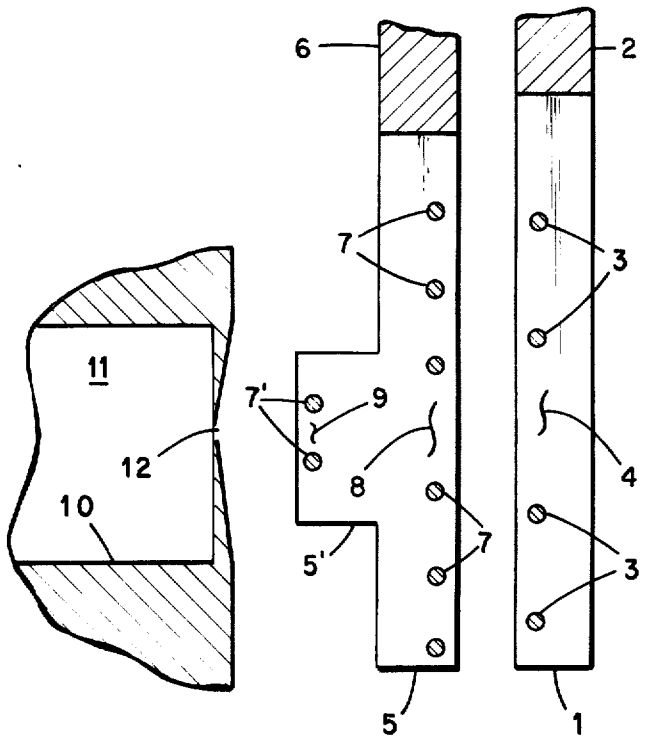



Fig. 3

# EXTRACTION ELECTRODE GEOMETRY FOR A CALUTRON

## BACKGROUND OF THE INVENTION

This invention was made in the course of, or under, a contract with the United States Atomic Energy Commission.

In all prior charge particle acceleration systems the source electrode geometry (which influences the formation of equipotential surfaces) has been critically shaped in order to achieve acceptable ion or electron beam focus. In the calutron (electromagnetic) separation of isotopes at the Oak Ridge National Laboratory, it has long been desirable to bring about a reduction of the un-ionized charge materials (neutrals) in the immediate vicinity of the source and electrodes. The reasons behind this objective are as follows:

1. The total useful output from a source is lowered because charge exchange of the primary beam occurs with the neutral atoms that make up the high pressure region existing in the electrode system.

2. High neutral particle densities in this region contribute to contamination by scattering the primary beam.

3. An optimized electric field gradient cannot be achieved in a high-pressure region due to high voltage breakdown. This is especially detrimental when charge feed is of a reactive nature (the vapors are easily ionized, such as those of rubidium, potassium, lithium, cerium, etc.). When high voltage breakdown occurs with these elements, sustained electron drains to the ion source literally melt source components.

Thus, there exists a need for an improved calutron extraction electrode geometry such that the calutron can be operated in a more efficient manner to produce an increased ion output therefrom than that which is possible with prior-art calutrons and at the same time providing for more stable operation of the calutron. This need has been met by the present invention in a manner to be described hereinbelow.

## SUMMARY OF THE INVENTION

It is the object of the present invention to provide an improved extraction electrode geometry for a calutron wherein a substantial reduction of un-ionized charge materials in the immediate vicinity of the source and electrodes is effected to provide an increased ion output therefrom and more stable calutron operation.

The above object has been accomplished in the present invention by replacing the conventional negative extraction electrode and the ground extraction electrode of a calutron with new electrodes constructed in a partial-picture-frame fashion with slits of both electrodes formed by two tungsten rods. Additional parallel, spaced-apart rods are also provided in each of the electrodes for the purpose of establishing equipotential surfaces over the rest of the front of the calutron ion source. The use of these tungsten rods substantially reduces the neutral particle density in the source region such that in the operation of the calutron the total useful output therefrom is substantially increased.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an oblique front view of the new ground extraction electrode.

FIG. 2 is an oblique front view of the new negative extraction electrode.



FIG. 3 is a cross-sectional view of the new extraction electrodes in relation to the calutron ion source exit slit.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

Only the necessary portions of the improved extraction electrode geometry and its relation to the calutron ion source are shown in the drawings for an understanding of the present invention. It should be understood that the improved extraction geometry of the present invention may be utilized in a complete calutron system such as disclosed in U.S. Pat. No. 2,709,222 to E. O. Lawrence, to which reference is made. It should also be understood that the necessary charge vapor for the ion source of the present invention is supplied thereto in a conventional manner. One means for heating the charge material for use in the ion source is disclosed in U.S. Pat. No. 3,115,575 to W. A. Bell et al., to which reference is made.

Referring now to the drawings, the ground electrode of the present invention is illustrated in FIG. **1**. Parallelly mounted in a graphite frame are a plurality of spaced-apart elongated metal rods **3** which may be three thirty-seconds inch in diameter 7 inches long and may be constructed from tungsten, for example. The frame **1** is open at the bottom thereof and is provided with an upper extension **2**, only partially shown, which is utilized for mounting this electrode in front of the negative electrode in spaced relation thereto as schematically shown in FIG. **3**. The space **4** between a pair of the rods **3** serves as the ground electrode aperture or slit through which the ions are withdrawn from the calutron ion source.

The negative electrode of the present invention is illustrated in FIG. **2** of the drawings. Parallelly mounted in a graphite frame **5** are a plurality of spaced-apart elongated metal rods **7**. The frame **5** is open at the bottom thereof, as shown. The rods **7** may be three thirty-seconds inch in diameter by 7 inches long and may also be constructed from tungsten, for example. The frame **5** is provided with an upper extension **6**, only partially shown, which is utilized for mounting this electrode between the ground electrode **1** and the calutron ion source **10** in spaced relation therebetween as schematically shown in FIG. **3**. The frame **5** is also provided with a pair of flanges **5'** in which are mounted a pair of elongated rods **7'**. The space **9** between the rods **7'** which is in line-of-sight with the space **8** between a pair of electrodes **7**, as more clearly seen in FIG. **3**, defines a slit or aperture for the negative electrode which is in alignment with the slit **4** of the ground electrode, and ions from the calutron ion source **10** are withdrawn by the electrodes **5** and **1** from the arc chamber **11** through its exit aperture or slit **12** which is in alignment with the respective slits **9**, **8**, and **4** of the electrodes **5** and **1**. The ions thus withdrawn from the calutron ion source **10** are electromagnetically separated by the calutron magnetic field, which is perpendicular to the plane of the paper in FIG. **3**, before they are received by respective collection pockets of the calutron receiver, not shown, in a conventional manner as described in the prior art mentioned hereinabove. It should be understood that the negative electrode **5** is connected to a source of negative voltage and the electrode **1** is connected to ground in a conventional manner.

An important feature of the tungsten-rod electrodes of the present invention is that they reduce the area which is available for the collection of reactive elements. Such collected materials are well known from past experience to be liberated by heat from beams and high voltage breakdown (sparking), thus causing $\vec{E} \times \vec{H}$ drains to avalanche in the source electrode region. This problem of avalanching drain has long been objectionable in source operation because of the "off" time associated with the high drain condition. Additionally, contamination in the separated isotopes is increased due to this type of sparking and high voltage "kickoff." In extreme drain conditions, the source voltage is lowered because the drains exceed the limits of the power supply.

The use of tungsten rods in the extraction electrodes, as described above, substantially reduces the neutral particle density in the source region wherein in the operation of the calutron the total useful ion output therefrom is substantially increased, which can be seen from the operating data which will now be described.

The present tungsten-rod extraction electrodes were initially tried for silicon isotope separation. The charge material used in the separation was $SiS_2$ (silicon disulfide). In a 241-hour comparison involving 14 different runs, the average total silicon output for the standard electrodes was 18.88 milliamperes as compared with 38.39 milliamperes for the tungsten-rod electrodes. This was an increase of 203% over the output from the standard-electrode runs.

The most impressive difference in the performance of the two electrode geometries was illustrated in the rubidium separation. Rubidium is second only to cesium in having the lowest ionization potential of the stable elements. Drain problems and high voltage "kickoff" are unpleasantly common and contribute greatly to the contamination of the separated isotopes in prior-art calutrons. The rubidium vapors are absorbed by the graphite source parts and the conventional graphite electrodes. Heat and sparking liberate the rubidium into the electrode region to elevate the pressure, and drains are high in conventional calutron operation. The output (weighted average) of eight calutrons used in standard prior-art rubidium separations was determined to be 9.96 milliamperes. When the new electrode system was installed on an ion source, the average ion output during 154 hours of run time was 38.96 milliamperes, an increase of almost 400%.

All of the sources utilized in the rubidium separation were then equipped with the present new type of electrode. After thousands of operating hours in eight separators, the average rubidium ion output was 9.94 milliamperes using standard electrodes and 28.79 milliamperes after the sources were equipped with the new-type electrodes. An ion output increase of 290% over the standard electrode system was thus obtained for the rubidium series.

The increase in output achieved in the present invention is attributed largely to decreasing the pressure in the source and electrode slit region, as evidenced by the following argument. Any ion from the source that experiences a charge exchange event will be registered as a portion of the metered source drain but will not be monitored at the receiver as collected output. Therefore, if ions were being lost by this process, the ratio of the collected output to source drain in the standard electrode system should be smaller in value than for the new electrode geometry. This ratio for the old geometry was 0.152 as compared to 0.288 for the present new system. Thus, the ratio for the present tungsten-rod electrode system was almost twice (1.91) the value derived from the standard electrode system.

The increase in ion output is somewhat higher than would be expected from the preceding charge exchange process alone. At high pressure ($5 \times 10^{-5}$ torr) an annular glow around each of the tungsten rods is visible. The axis of the rods is parallel to the magnetic field, and with the electric field gradient there is an electron trap which the primary beam must pass through. This added source of electrons for beam neutralization could also have been partially responsible for the increase in collected current, since improved neutralization would reduce the amount of ion loss in a radial direction to the 90° baffles because of space charge effects. This effect could also possibly be used to explain why the electrode geometrical shape is not required to be as critical as current theory predicts.

Another point in favor of the present invention is that the "down time" because of drain problems and high voltage "kickoff" is reduced by the use of the present new electrode geometry. Electrical timers were used to read when the high voltage was not on during the run; likewise electrical counters recorded the number of times the high voltage was kicked out during the run. The new electrode system showed a high-voltage down time of only 1.5% and the high voltage "kicked off" at the rate of 4.67 times per hour during this same time period. With the standard electrode geometry, the down time was 5.2% and the high voltage "kicked off" an average of 36 times per hour. In each instance, high voltage cycling is detrimental to isotopic purity.

The new extraction electrode geometry is presently being utilized in a high purity $^{122}Te$ run and its use will soon be scheduled in a second-pass tin run. It should be understood that the new electrode geometry of the present invention is not restricted for use in separation runs involving the above-mentioned charge materials, but will be substantially equally effective for use with all types of charge materials including particularly those of a reactive nature such as potassium, lithium, cerium, etc.

This invention has been described by way of illustration rather than by limitation and it should be apparent that it is equally applicable in fields other than those described.

What is claimed is:

**1.** In a calutron system including an ion source chamber provided with a side chamber cover having a narrow elongated ion exit slit, said chamber adapted to receive a vaporized charge material therein, means for producing an arc discharge which is associated with and passes through said chamber by means of arc defining slots for ionizing the charge material within said chamber, a magnetic field for effecting charge separation of the ions as they pass from said ion source exit slit, the improvement comprising an improved extraction electrode geometry including a negatively biased graphite accelerating electrode mounted adjacent to and parallel with said ion source chamber cover, said negative electrode being in the form of a first bottom-opened picture frame provided with a first plurality of spaced-apart metal rods mounted in parallel relation in the vertical legs of said frame, said frame being provided with a pair of flanges extending rearwardly from

about the center of said frame's vertical legs, a pair of spaced-apart metal rods mounted between and to said flanges, said pair of rods defining an ion exit slit in alignment with said ion source cover exit slit and in alignment with a slit formed between two of said first plurality of metal rods; and a graphite ground electrode mounted adjacent to and parallel with said negative electrode, said ground electrode being in the form of a second bottom-opened picture frame provided with a second plurality of spaced-apart metal rods mounted in parallel relation in the vertical legs of said second frame with two of said second plurality of rods defining an ion exit slit in alignment with all of said previously mentioned exit slits, whereby during operation of said calutron all of said metal rods except those used for providing said ion exit slits are utilized to establish equipotential surfaces over the rest of the front of said ion source for effecting a substantial reduction of un-ionized charge materials thereabout, thereby providing an increased ion output from said ion source and more stable calutron operation.

2. The calutron set forth in claim 1, wherein all of said metal rods are tungsten.

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