SHORT NOTE

New Proposal for a Gas Centrifuge with Desirable Counter-Current

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Modern date gas centrifuges used for the enrichment of uranium are of counter-current type, which promises better performance than other forms. The counter-current is generated either by source-sink distribution ("externally driven")¹, by the temperature difference between end plates ("thermally driven")², or by the existence of obstacles called scoups ("mechanically driven")³. The latter two can be collectively termed "internally driven". In this note, the author proposes a simple device by which the desired counter-current is established in a gas centrifuge.

Figure 1 shows schematically two kinds of centrifuges proposed here—for stripping and for enriching. Taking as example the case of a total enricher, the feed is injected by an external pump such as a molecular pump through a top slit located at about half way along the radius. The product is taken out through a bottom slit at the same radius, and the waste is rejected through a top slit near the periphery. If the temperatures of the top and the bottom end plates are equal, one half of the source or the sink flux bifurcates into the top and the bottom Ekman layers⁴. These Ekman layer flows are represented in the figure by the solid and the dashed horizontal lines. The part of the feed gas which flows in the top Ekman layer (short-circuit flow) does not undergo effective separating action, and its existence is nothing but harmful to the performance of the centrifuge. One type of counter-current centrifuge currently being tried in Japan is arranged to have a thermally-driven convection is superposed on the externally-driven current, tending to cancel this undesirable short-circuit flow⁵; this centrifuge might be termed "mixed".

For examining a typical thermally driven counter-current (top and the bottom end plates at different temperatures), the authors assumed that the centrifuge wall is ideally conducting⁶. Their assumption, however, is not realistic, since centrifuges are currently made of thin metals or of carbon fiber plate with low thermal conductivity.

More recently, Matsuda et al.⁷ have studied the case in which the sid-wall of the centrifuge is insulating and the end plates ideally conducting. They found that the temperature in the main inner flow differs from the case of ideally-conducting wall, and that the closed circulation in the side-wall boundary layer is inhibited. The inner axial flow profile, however, proved to be the same as in the case of ideally-conducting wall. Since it is the axial flow profile that is crucial

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for the separation efficiency, we can say that
the thermal boundary condition on the side-
wall does not have an important effect on the
separation efficiency.\(^8\)

The case of a centrifuge with insulated end plates and ideally conducting side-wall was studied by Matsuda et al.\(^9\) They found that the Ekman layer flow caused either by the temperature gradient on the side-wall or by the source-sink distribution on the end plates is definitely suppressed in comparison with that in the case of ideally conducting plates. The reason can be explained as follows; the horizontal motion of the gas element in the Ekman layer causes either compression or expansion of the element. The heat supplied to or taken away from the element by this work must be compensated by the end plates in order to permit the Ekman layer flow to proceed. While an ideally conducting wall would provide the means for this heat compensation, this should not be possible with insulating end plates. Thus, the Ekman layer flow in the latter case is strongly inhibited by the centrifugal buoyancy force. In order to overcome this buoyancy force and to produce a flow, a sharp temperature distribution on the side wall (for a thermally driven flow) or a large pressure difference between slits (for a source-sink flow) would be needed. This leads to the conclusion that the thermal boundary conditions on the end plates have an important effect on the flow in the gas centrifuge.

Based on the above result, we propose a new design of gas centrifuge in which the short-circuit flow is suppressed. This gas centrifuge would have a thermally insulated top plate and a conducting bottom plate. In this centrifuge, the horizontal flow in the top Ekman layer (that is to say the short-circuit flow) is distinctly inhibited in comparison with that in the bottom. It can be expected that, under ideal conditions, the short-circuit flux would be of the order of \(10^{-2}\) to \(10^{-3}\) of the flow in the bottom Ekman layer.

While the realization of a practical centrifuge of this concept should still require solution of a number of structural problems, we still believe that the proposed concept is a worthwhile target for centrifuge development through engineering effort. While the foregoing consideration has been limited to the case of end plate feeding and collecting, there is no reason why it could not be applied also to the case of scoop centrifuge.

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--- REFERENCES ---

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