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HYDRAULIC PERFORMANCE OF A MULTISTAGE ARRAY OF ADVANCED CENTRIFUGAL CONTACTORS

by

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ABSTRACT

The hydraulic characteristics of an advanced design centrifugal contactor array have been determined at the Savannah River Laboratory (SRL). The advanced design utilizes couette mixing (Taylor vortices) in the annulus between the rotating and stationary bowls. Excellent phase separation over a wide range of flow conditions was obtained. Interfaces within an entire eight-stage array were controlled with a single weir air pressure.

INTRODUCTION

Centrifugal contactors are analagous in their operation to mixer-settlers. They are stage-wise liquid-liquid contacting devices with the force of gravity being replaced by centrifugal force. (Slide 1)

Because the residence time requirement for settling in a centrifugal field is not as great as for gravity settling, several advantages relating to the resulting smaller stage volume are immediately apparent. These include reduced solvent degradation from decrease in exposure time, simple accountability, ease of flushing, rapid startup, and improved nuclear safety. (Slide 2)

BACKGROUND

Centrifugal contactors were developed at SRL during the early 1960s for replacement of large mixer-settlers.[1] The long residence times in the mixer-settlers then in use allowed the solvent to become degraded through prolonged contact with the highly radioactive solutions. These centrifugal contactors have been used in the first cycle of the Purex solvent extraction process at Savannah River Plant (SRP) since 1966 with excellent results. Figure 1 (Slide 3) is a schematic of the Purex process, showing where centrifugal contactors are presently used. Figure 2 (Slide 4) shows a cut-away drawing of the type of contactor now used in the Purex process. (Slides 3 & 4)

Recently, Argonne National Laboratory (ANL) developed an improved design based on the original SRP concept.[2] Figure 3 provides a cut-away view of the advanced contactor. In this design, mixing is accomplished through Taylor vortices induced by couette flow in the annulus between the rotating bowl and the stationary housing rather than with a paddle mixer as in the currently installed SRP contactors. This concept greatly simplifies shaft design and permits the rotating bowl to be easily removed if needed during maintenance. In addition, the new design uses commercially available motorized milling machine spindles as drive motors to reduce fabrication and maintenance costs. (Slide 5)

Because the improved design concept offered significant advantages for fuel reprocessing applications, the Consolidated Fuel Reprocessing Program at the Oak Ridge National Laboratory (ORNL) supported development work at ANL that resulted in conceptual designs for two specific applications. Design, fabrication, and testing of multistage arrays of the contactors were done at SRL with ORNL funding.

The advanced design results in several mechanical benefits. These include simpler and less expensive fabrication and maintenance than the older design centrifugal contactors. In addition, commerically available components are used in fabrication wherever possible. (Slide 6)

OPERATION

In operation, the immiscible liquids (aqueous and organic) flow into the side of the stationary housing. The two liquids then flow downward in the annular space between the stationary housing and the rotating bowl. Taylor vortices are set up in the annulus, causing droplet break-up of the dispersed phase. From the annulus, the coarse emulsion flows into the bottom of the rotating bowl. Inside the bowl, centrifugal force causes the heavier liquid to be forced to the outside of the bowl and the lighter to move to the inside. The lighter liquid flows over a weir and into a collector ring from which it then flows to the next stage in series. The heavier liquid flows under and over a series of weirs designed to maintain the interface in the rotor through air pressure in the weir space.

MULTISTAGE ARRANGEMENT

The individual contactors were connected in series as shown in Figure 4. Just as in a mixer-settler bank, flow was countercurrent between stages and cocurrent within a stage. The "U" shaped arrangement provided for a compact array and permitted all fluid connections to be made on one end of the assembly. In a plant situation, the array could be linear or any other convenient shape, as long as the interstage flows provide series operation. (Slide 7)

OPERATING ENVELOPE

An operating envelope for these machines may be defined as the minimum and maximum weir air pressures that maintain less than 1% phase cross-contamination as a function of flow rates. This envelope is a function of rotor speed and organic/aqueous ratio. Figure 5 shows a typical operating envelope for an 8-stage array of advanced centrifugal contactors. it may be seen from this envelope that this design permits a wide variation in flow rates with a single air pressure setting. (Slide 8)

TEST PROGRAM

The centrifugal contactors described in this paper were designed for a conventional Purex flowsheet. For determination of the operating envelopes, the organic to aqueous ratio was fixed at 1.4:1. The total throughput to the device and the rotational speed of the separator bowl were varied over wide ranges.

Initial or scouting runs were made with 3N nitric acid as the aqueous phase and n-paraffin (a mixture of C-12 through C-14 straight-chain hydrocarbons) as the organic phase. Following the scouting runs, the organic phase was changed to 30% TBP in n-paraffin. At most of the flow rates studied, less than 1% phase cross-contamination was observed, over a wide range of control air pressures. It was found that the edges of the operating envelope were very sharp, i.e. inside the envelope the contamination was essentially undetectable and outside the envelope, contamination was observed in the 10 to 40% range.

CONCLUSIONS

It was found that a single air pressure could be used to control the entire multistage array of centrifugal contactors. Excellent phase separation was attained over a wide range of flow rates, up to and including three times the nominal design rate. It was concluded that this contactor design provided a wide latitude in operation, and by proper sizing of the weirs and by careful air pressure control, a wide range of hydraulic conditions may be handled quite easily.

ACKNOWLEDGEMENT

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REFERENCES

1. D. S. Webster, A. S. Jennings, A. A. Kishbaugh, and H. K. Bethmann, Performance of Centrifugal Mixer-Settlers in the Reprocessing of Nuclear Fuel, AIChE Chem. Eng. Prog. Symp. Ser., Nuclear Engineering--Part XX, No. 94, Vol 65, pp. 70-77 (1969).

2. G. J. Bernstein, D. E. Grosvenor, J. F. Lenc, and N. M. Levitz, "A High-Capacity Annular Centrifugal Contactor," Nuclear Technology, Vol. 20, p. 200 (1973).

SLIDE 1 **CENTRIFUGAL CONTACTOR**

- LIQUID-LIQUID EXTRACTION EQUIPMENT
- CENTRIFUGAL FORCE USED FOR PHASE SEPARATION

SLIDE 2 **PROCESSING BENEFITS**

- REDUCED SOLVENT DEGRADATION
- SIMPLE ACCOUNTABILITY
- EASE OF FLUSHING
- QUICK STARTUP

SLIDE 3 FIGURE 1

PUREX PROCESS

SLIDE 4 FIGURE 2

SRP CONTACTOR

SLIDE 5 FIGURE 3

ADVANCED CONTACTOR

SLIDE 6 **MECHANICAL BENEFITS**

- SIMPLE COMPONENT REPLACEMENT
- LOWER FABRICATION COST
- COMMERCIALLY AVAILABLE COMPONENTS

SLIDE 7 FIGURE 4

FLOW PATTERN

SLIDE 8 FIGURE 5

OPERATING ENVELOPE

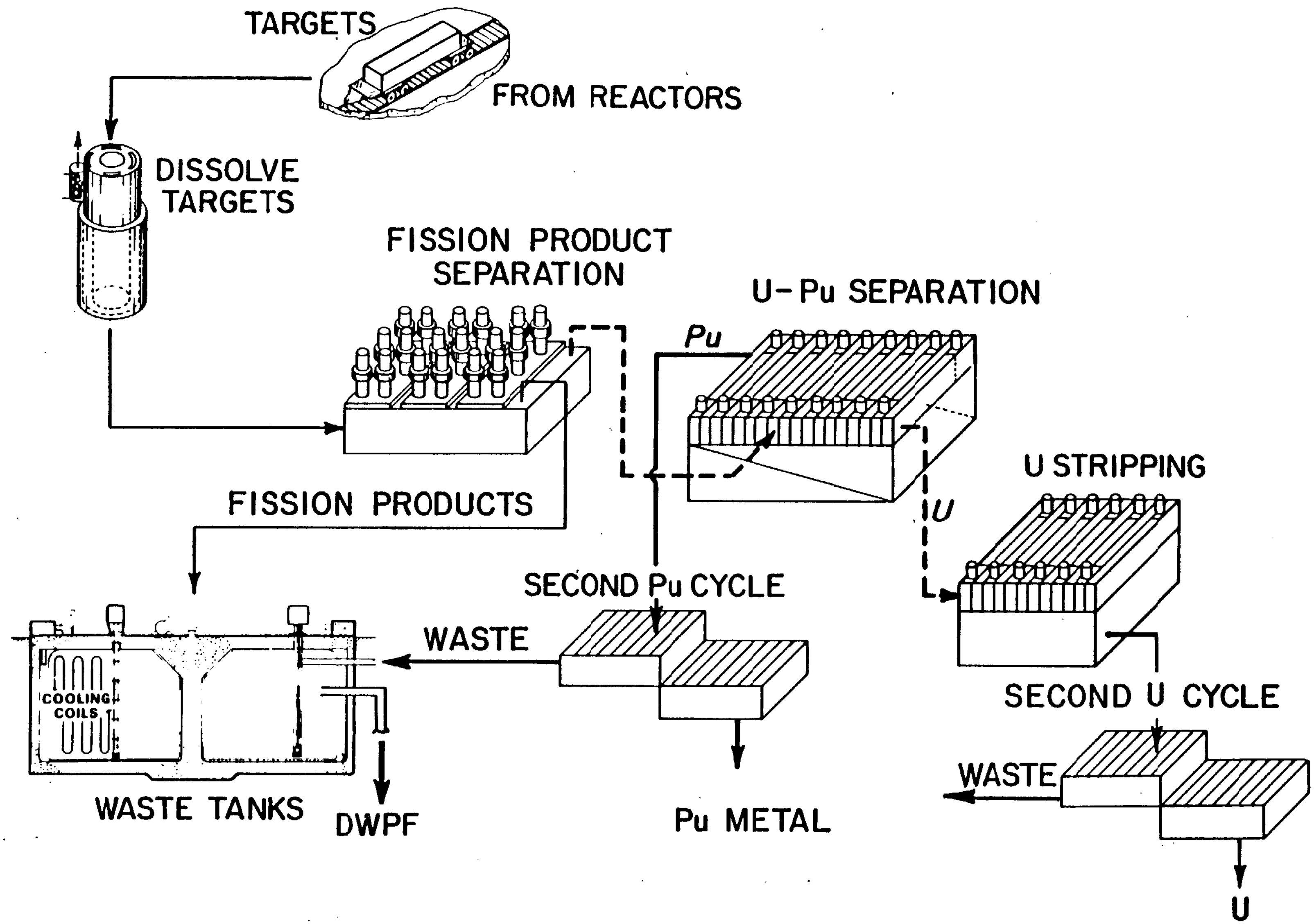

FIGURE 1. Purex Process

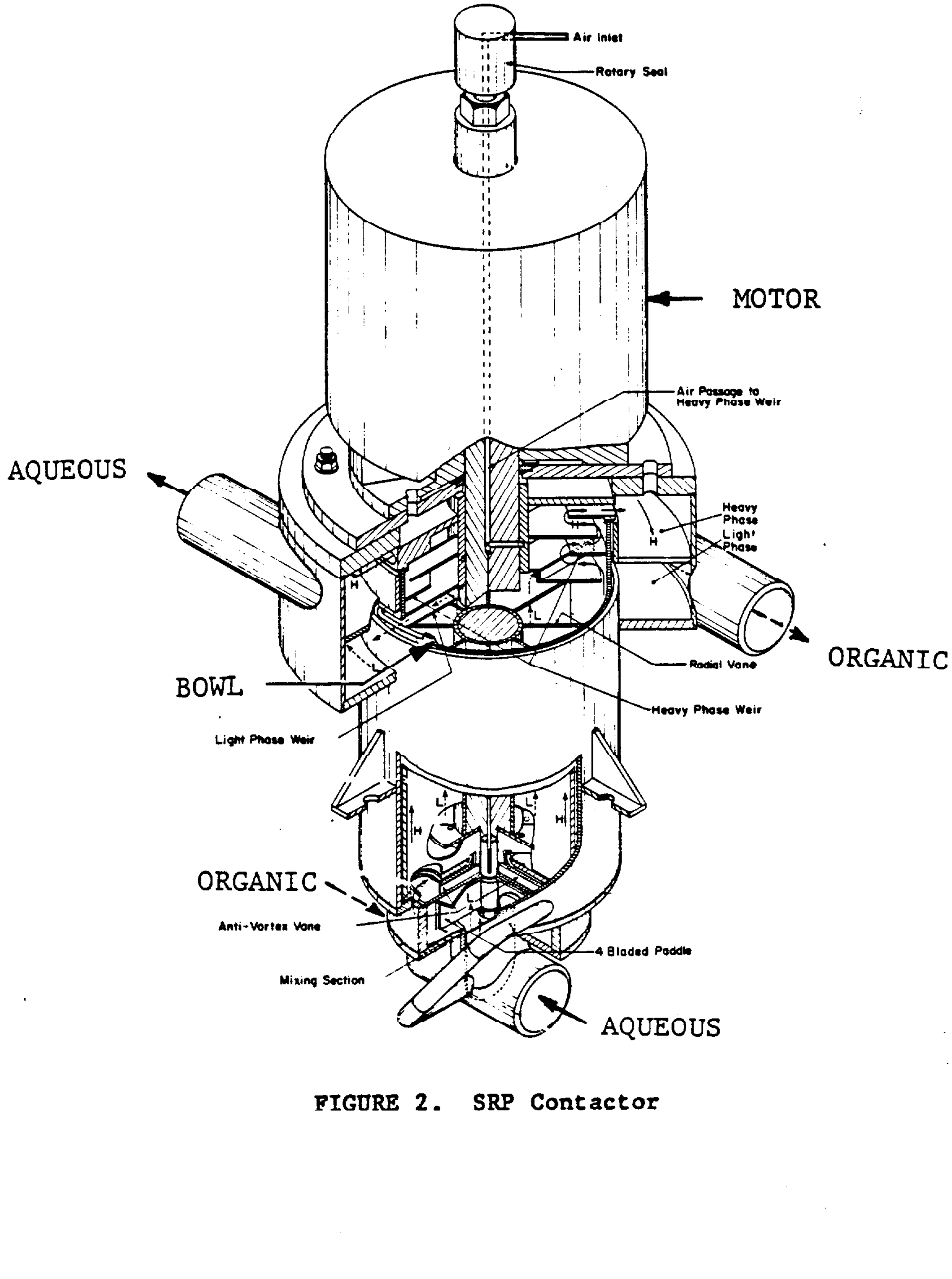

FIGURE 2. SRP Contactor

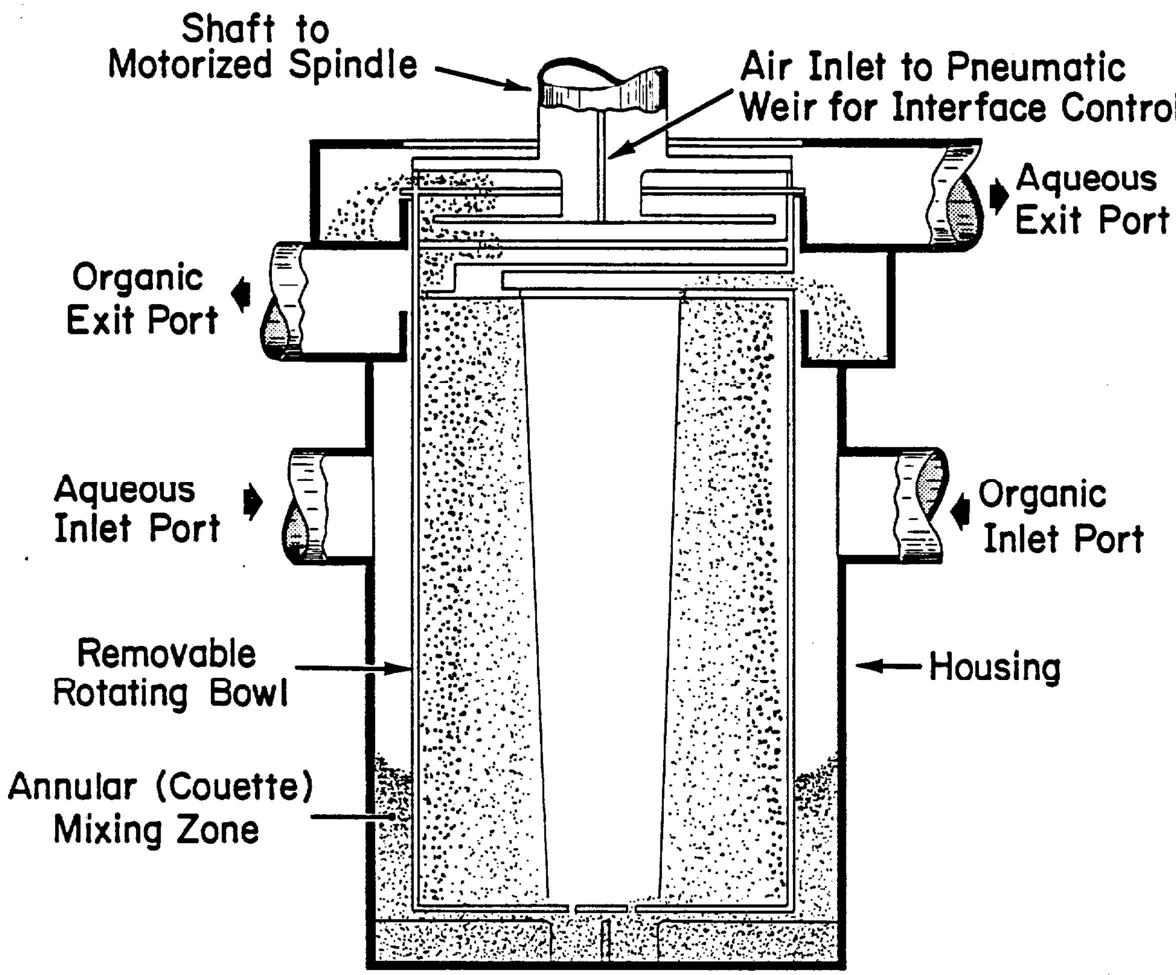

FIGURE 3. Advanced Contactor

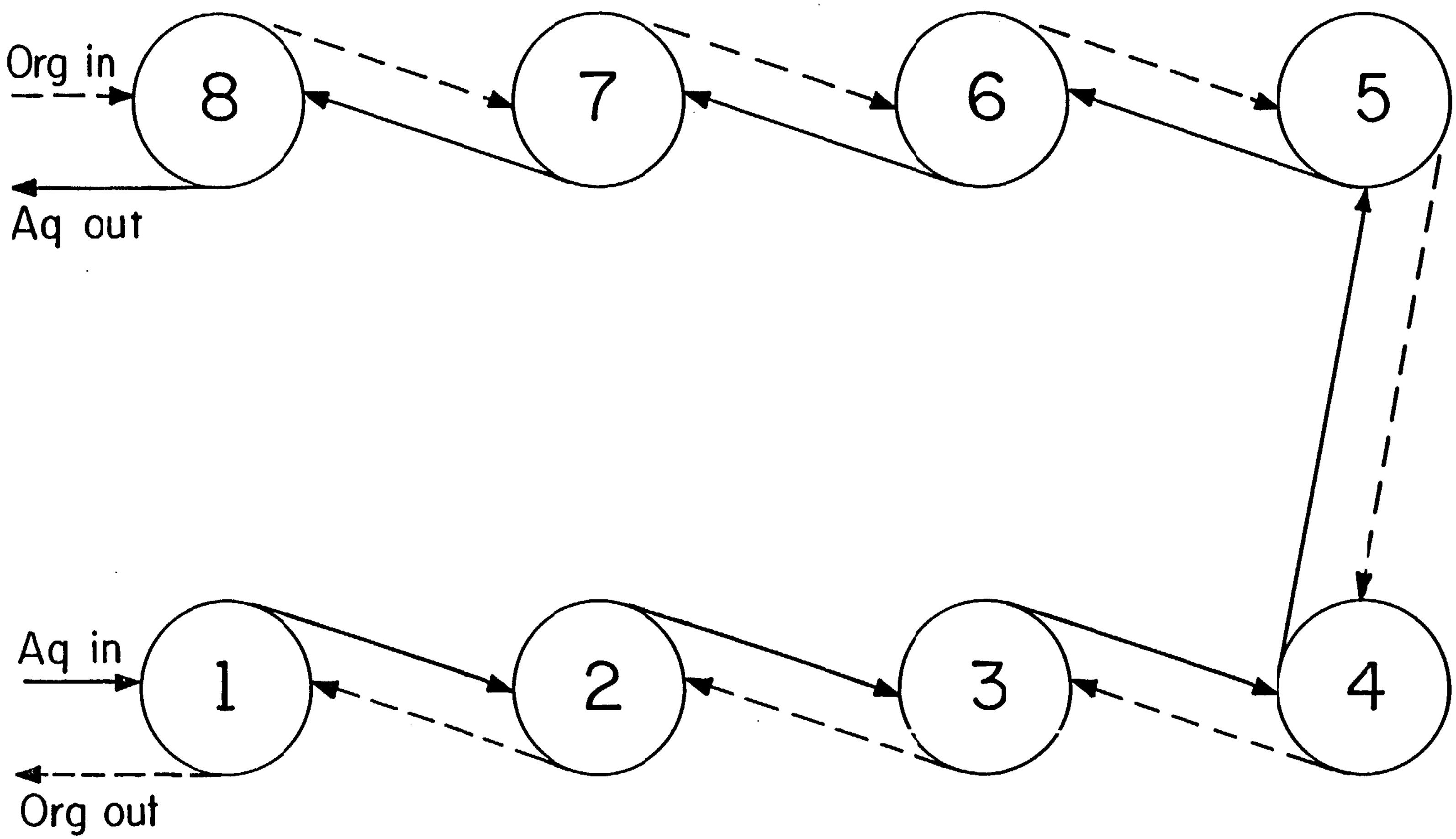

FIGURE 4. Flow Pattern

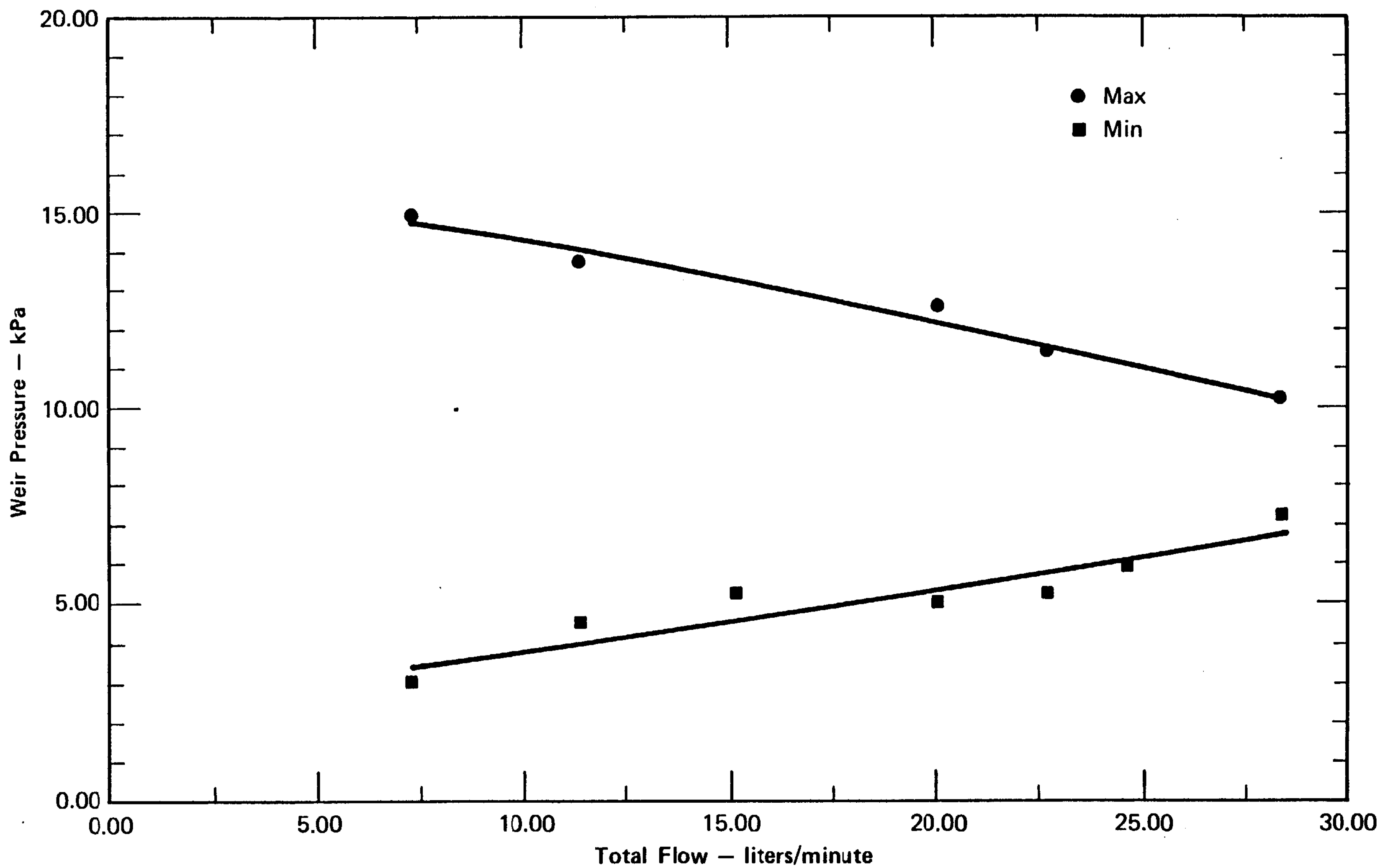

FIGURE 5. Operating Envelope