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ANL/NE-15/3

Evaluation of Argonne 9-cm and 10-cm Annular Centrifugal Contactors for SHINE Solution Processing

Nuclear Engineering Division

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Evaluation of Argonne 9-cm and 10-cm Annular Centrifugal Contactors for SHINE Solution Processing

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EVALUATION OF ARGONNE 9-CM AND 10-CM ANNULAR CENTRIFUGAL CONTACTORS FOR SHINE SOLUTION PROCESSING

1 INTRODUCTION

Work is in progress to evaluate the SHINE Medical Technologies process for producing Mo-99 for medical use from the fission of dissolved low-enriched uranium (LEU). This report addresses the use of Argonne annular centrifugal contactors for periodic treatment of the process solution.

In a letter report from FY 2013 [1], Pereira and Vandegrift compared the throughput and physical footprint for the two contactor options available from CINC Industries: the V-02 and V-05, which have rotor diameters of 5 cm and 12.7 cm, respectively. They suggested that an intermediately sized “Goldilocks” contactor might provide a better balance between throughput and footprint to meet the processing needs for the uranium extraction (UREX) processing of the SHINE solution to remove undesired fission products. Included with the submission of this letter report are the assembly drawings for two Argonne-design contactors that are in this intermediate range—9-cm and 10-cm rotors, respectively.

The 9-cm contactor (drawing number CE-D6973A, stamped February 15, 1978) was designed as a single-stage unit and built and tested in the late 1970s along with other size units, both smaller and larger. In subsequent years, a significant effort to developed annular centrifugal contactors was undertaken to support work at Hanford implementing the transuranic extraction (TRUEX) process. These contactors had a 10-cm rotor diameter and were fully designed as multistage units with four stages per assembly (drawing number CMT-E1104, stamped March 14, 1990). From a technology readiness perspective, these 10-cm units are much farther ahead in the design progression and, therefore, would require significantly less re-working to make them ready for UREX deployment (see Figure 1). Additionally, the overall maximum throughput of ~12 L/min is similar to that of the 9-cm unit (10 L/min), and the former could be efficiently operated over much of the same range of throughput. As a result, only the 10-cm units are considered here, though drawings are provided for the 9-cm unit for reference.

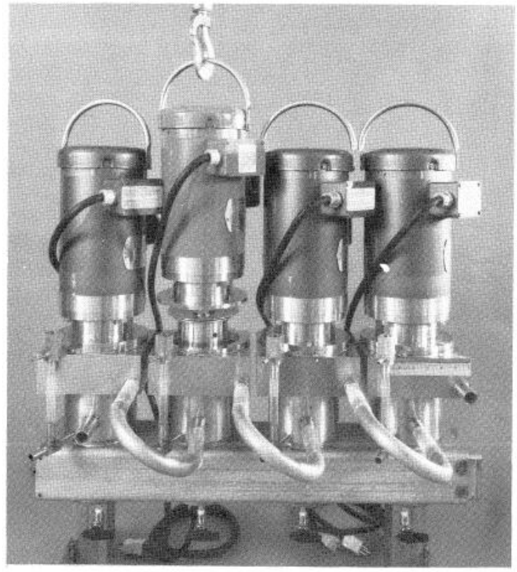

FIGURE 1 Photograph of Argonne 10-cm Four-Stage Contactor Unit

2 ESTIMATES OF FOOTPRINT, THROUGHPUT, AND HOLDUP

While it will be possible to develop a complete input set for the Argonne-developed ROTOR model to give more accurate estimations of the contactor throughput for the given process and to aid in designing the final configuration, at this stage we must use estimates from experimental observation in actual fabricated units for total throughput. Because estimation of phase holdup is unfortunately not recorded, we only report here best estimates from the contactor dimensions and the limited test information available.

2.1 PHYSICAL FOOTPRINT

The 9-cm contactor, as designed, is only a single stage. Therefore, the exact dimensions of multistage configurations are unknown but can be reasonably estimated to be similar to those of the multistage 10-cm units. The length of a 4-stage, 10-cm assembly is approximately 0.864 m (34 in.). For the desired contactor bank of 32 stages, the total length would thus be 6.91 m (23 ft). If a special two-pack end stage unit is designed such that only 30 stages are used, the length is slightly less, 6.5 m (21.2 ft). Given the depth of the contactor support frame (61 cm, 24 in.), the total floor space required for the bank of contactors would be either 4.2 m^2 (32 stages) or 4.0 m^2 (30 stages). This is only 25% more than the estimated footprint of the V-2 contactors (with aligned interstage lines) and only 30% of the space needed by the V-5 contactors.

2.2 THROUGHPUT

The maximum total throughput for the 10-cm contactors is reported as 10 L/min for a nominal rotor speed of 1800 rpm (note that the same values are reported for the 9-cm units). In general, the unit would be able to operate with excellent efficiency at flow rates as low as ~2-3 L/min (25% of maximum) and, with minor design changes, at even somewhat lower rate. If a nominal throughput of 5 L/min is assumed, the feed flow rate would be 1.35 L/min, leading to a total processing time of 192 min for 260 L of solution. For comparison to the V-5 at 10 L/min, the required processing time for hot feed will thus be twice as long.

2.3 HOLDUP

The total liquid holdup for the each 10-cm contactor stage is an estimated 1.8 L. Thus, compared to the CINC V-5 contactors, which have a holdup of 3.3 L, the total in process phase volumes for 30 stages is estimated to be 21 L of organic phase and 35 L of aqueous phase with corresponding fractions of the hold-up in each section based on the relative number of stages in the section (see Table 3 of Ref. 1). Assuming that the total inventory of solvent required is three times the total holdup, 63 L of solvent would be needed.

More precise estimates of per-phase holdup can be obtained once a ROTOR model is set up to predict the operation of the 10-cm design for the current process solutions.

2.4 SUMMARY

These estimates are summarized in Table 1 and can be compared to corresponding values for the V-2 and V-5 contactors in the previous report [1].

TABLE 1 Summary of Estimates for Argonne 10-cm Contactor

Characteristic	4-Stage		30 Stages[a]	
Footprint	0.5	m^2	4.0	m^2
Height	1.0	m	1.0	m
Length	0.9	m	6.5	m
Max. Throughput	~12	L/min		
Rotor Speed	1800	rpm		
Processing Time (260 L of feed @ 5 L/min total flow)			192	min
Total Holdup	1.8	L	56	L
Aqueous			35	L
Organic			21	L
Req. Solvent Inventory			63	L

[a] A 30-stage bank assumes 7 four packs and 1 two pack and includes interstage spacing.

3 ADDITIONAL POINTS TO CONSIDER

While the throughput is governed by rotor radius and rotation speed, the footprint is more strongly dependent on the actual configuration (aligned versus perpendicular interstage piping). The Argonne contactors are designed as multistage units (assembly of four stages in the case of the 10-cm unit) and are thus, generally, more conserving of linear space limitations. That said, CINC has built several custom configurations, including the bank of V-05 and V-10 contactors in use at Savannah River Site's (SRS's) Modular CSSX Unit (MCU), which comes as a multistage skid assembly with perpendicular orientation and U-tube interstage connections (see Figure 2). In this U-tube connected configuration, rotor-rotor spacing is limited by the minimum bend radius of the interstage piping material. With stainless steel piping, this configuration will be larger than if a flexible hose were used (stainless braided hose has been used at SRS along with corrugated flexible hose[1] in some cases in the MCU setup). From estimates based on drawings of the MCU bank of contactors obtained from SRS, it appears that the V-05 contactor spacing is 34.5 cm (13.6 in.)—compared to 20 cm (8 in.) in the case of the Argonne 10-cm contactors—giving a total length of 10.4 m for a bank of 30 stages. Given a depth of approximately 1.4 m, the area is roughly 14.6 m^2. Thus, it appears that rotor-rotor spacing for a custom CINC multistage bank, while more compact than a bank of individual units in series, still has greater space requirements than the Argonne multistage units. Thus, the use of Argonne

FIGURE 2 Contactor Skid Used in the Modular CSSX Unit (MCU) at SRS. CINC V-10 Units Used in the Extraction Section (7 stages) are in the Right Foreground, and CINC V-05 Units Used in Other Sections (total of 11 stages) are at the Far Left

1 Argonne designs always use smooth interstage piping/tubing to ensure unimpeded interstage flow.

10-cm multistage units results in a "savings" of approximately 4 m of shielded cell length—6.5 m versus 10.4 m. Obviously, design of a customized multistage bank of CINC contactors would also add some cost.

Additionally, the design of the CINC contactors can be tailored to give slight performance improvements for the desired operating conditions (e.g., decrease in annular gap size or use of different mixing vane configurations to increase mixing efficiency in low flow conditions). Even so, proper sizing of contactors to the designed process conditions can ensure that operation is efficient in each section, and that the equipment footprint is reduced to minimize costly shielded-cell floor space.

In terms of design modifications that would be required for the present application, the Argonne units do not include all features needed for hot cell operation, though the necessary external modifications could be easily added. CINC has a V-05 unit (though no similar V-02 unit) designed specifically for hot cell operation (designated "HHC"), which also includes the option for clean-in-place operation if required, but we do not think use of this option is necessary and do not recommend it.

In the case of the CINC units, single-stage V-02 and V-05 units are currently available for hydraulic testing at Argonne. For the Argonne 10-cm unit, a lead test unit (either a single stage or a four pack) should be fabricated and tested to confirm hydraulic performance prior to delivery. Exterior details from a more recent 15-cm contactor design specifically developed for remote operations would also be added to the prototype for testing.

4 RECOMMENDATIONS AND PATH FORWARD

Given the sizable reduction in footprint and solution holdup for the Argonne 10-cm multistage contactors, if the estimated cost of their design and fabrication is competitive with the custom multi-stage CINC alternatives, updating and use of the Argonne design should be pursued.

While the physical drawings are available and provide a basis for the eventual design, they will need to be updated prior to fabrication. First, the drawings will need to be modified with additional design features as needed. Then, two and/or three-dimensional computer-aided design models will need to be generated to facilitate further design and ultimate fabrication. In particular, during testing of the 10-cm units, vibration issues with the frame structure necessitated use of somewhat over-sized motors with a larger shaft to compensate. Consequently, changes are needed to optimize the design given vibration considerations—modern computational capabilities for structural response can greatly speed this process once a three-dimensional model of the design is constructed. None of these design modifications is time consuming or expensive.

5 REFERENCE

1. Candido Pereira and George F. Vandegrift, *Centrifugal Contactor Operations for UREX Process Flowsheet*, ANL/CSE-13/27, Argonne National Laboratory, http://www.ipd.anl.gov/anlpubs/2013/10/76974.pdf (2013).

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