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DESIGN OF A JET-ACTUATED VACUUM SYSTEM FOR USE IN THE COATED PARTICLE DEVELOPMENT LABORATORY, BUILDING 4508

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ABSTRACT

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A jet-actuated vacuum system has been designed to serve the microsphere producing operation in the Coated Particle Development Laboratory, which is located in Building 4508. This system is simple and inexpensive, and can easily be made critically safe by limiting equipment diameters to 4 in. or less and by maintaining an edge-to-edge spacing of at least 12 in. between adjacent items of equipment, all of which are located in the same plane.

The performance curve for the jet exhaustor, supplied by the manufacturer, shows that it can evacuate a closed system, with essentially zero inleakage, to a stable absolute pressure approaching 1 in. Hg; at loadings of 6.75 and 31 lb of air per hour, it will maintain absolute pressures of 3 in. and 10 in. Hg, respectively. Other similar information may be obtained from the curve.

Exhaust steam leaving the jet exhaustor is completely condensed, and the condensate is routed to "hot" waste; noncondensable gas, mainly air that is included in the jet exhaust, is vented to the building off-gas system.

In addition to the exhaustor, the system is comprised of a Pyrex vacuum accumulator, two shell-and-tube heat exchangers, and a vent pot. All the items of equipment are mounted in a single plane on the outside south wall of the sphere forming enclosure. An edge-to-edge spacing of at least 12 in. between adjacent items was maintained.

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1. INTRODUCTION

This report describes the design of a vacuum system for use with the sphere forming equipment in the Coated Particle Development Laboratory (CPDL). Such a system is needed in this operation for transferring recently formed microspheres from one vessel to another and also to aid in the sphere drying step.

Safety, from the standpoint of criticality, is a valid concern since, in the future, fissionable uranium (^{233}U or ^{235}U) may possibly be processed using the CPDL sphere forming equipment. Simplicity of equipment and economical installation and subsequent operation are always important factors to consider.

The system selected employs a steam jet exhauster that is similar to those installed recently in Buildings 4507 (ref. 1) and 3019. This exhauster is capable of producing a stable, closed vacuum at an absolute pressure approaching 1 in. Hg; at higher absolute pressures, it can exhaust significant amounts of air (e.g., 6.75 and 31 lb of air per hour at 3 in. and 10 in. Hg abs, respectively). This capability was considered to be more than adequate for estimated CPDL needs.²

The steam from the jet is exhausted to a shell-and-tube heat exchanger, where it is condensed and subcooled enroute to the hot waste header. Downstream from the heat exchanger, noncondensable gas, mostly air from the equipment being evacuated, is disengaged from the condensate and sent to the off-gas system for the building. Cooling water from the heat exchanger shell is routed to the process water drain, which is separate from the hot waste system.

The vacuum equipment, which is mounted on the outside south wall of the sphere forming enclosure, is designed to be critically safe by limiting the diameter of each item of equipment to 5 in. or less and by maintaining an edge-to-edge spacing of at least 12 in. We used 5-in.-diam heat exchangers in the actual installation, since they were readily available and since, at present, fissionable material is not being handled in the CPDL; however, smaller-diameter equipment can easily be substituted in the event that specific criticality review makes it necessary.

A schematic flowsheet of the system is shown in Fig. 1; a photograph of the installed equipment is shown in Fig. 2.

The design considerations of the steam jet exhauster, the heat exchanger, the vent pot, and the vacuum accumulator are discussed in detail below. A list of drawings (e.g., titles and numbers) prepared for this project is also included.

C. C. Haws, Unit Operations Section, is currently responsible for operating the CPDL Microsphere Forming Facility, and the author is indebted to him for many valuable suggestions made in the course of this design.

Fig. 1. Jet-Actuated Vacuum System for Coated Particle Development Laboratory.

PHOTO 87763R1

Fig. 2. Jet-Actuated Vacuum System as Installed in CPDL.

2. JET EXHAUSTER

The model 23A Penberthy jet exhauster selected for use in the CPDL is fabricated from type 316 stainless steel and has 1-in. suction and discharge connections and a 3/4-in. NPS steam connection. It will consume approximately 65 lb of 150-psig steam per hour during operation.³ A performance curve is presented in Fig. 3 and further details may be found in the manufacturer's literature.⁴

The jet costs less than \$200, delivered. It is simple in design and has no moving parts.

3. HEAT EXCHANGER

The exhaust steam coming from the jet must be condensed because: (1) it may be contaminated with thorium and/or uranium and, therefore, needs to be routed to the hot drain; and (2) it would be a nuisance, if not condensed and collected, even if uncontaminated. Although spray cooling of the exhaust steam by injecting a stream of cold water into the exhaust appeared to be a simple method for solving the problem, it was rejected because it would have increased the load on the tank farm evaporator unnecessarily. Therefore, exhaust steam will first be condensed, and then the condensate will be subcooled to 100°F by using two shell-and-tube heat exchangers in series.

Heat-transfer calculations of mixed condensing vapors and noncondensable gases are complicated since the rate of condensation is governed by the laws of diffusion of the vapor through a film of noncondensable gas. A simplified method shown in the Chemical Engineers Handbook⁵ was used to calculate the required heat-transfer area. These calculations indicated that a Ross SSCF 502 heat exchanger would be sufficiently large to handle the theoretical maximum hourly load of 113.5 lb of air mixed with 65 lb of steam that would result from operation of the vacuum system at an absolute pressure of 5 in. Hg. However, in order to avoid possible operating limitations because of inaccuracies resulting from the simplified calculational method, an available Ross SSCF 501-2 heat exchanger was added in series with, and downstream of, the first exchanger mentioned above. This safety factor will, in the minimum case, permit some reduction in the cooling-water waste load to a drain system that is already operating near its maximum capacity. Optimum operating conditions will properly be determined by actual experience with the installed system.

Alternatively, a more rigorous, but also more tedious, step-by-step method of calculation based on the work of Colburn,⁶ Colburn and Haugen,⁷ and Chilton and Colburn⁸ may be used to calculate heat-transfer area.⁹

The Ross SSCF 502 heat exchanger, 5 in. in diameter and 2 ft long, is made from type 316 stainless steel. It has 15-1/2 ft² of heat-transfer area and contains 80 tubes that are 3/8 in. OD and have a 22-BWG wall thickness.

Fig. 3. Performance Curve for Penberthy 23 A Steam Jet Exhauster.

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The Ross SSCF 501-2 heat exchanger is a shorter version of the SSCF 502 model; its dimensions are similar to those of the SSCF model 502 except that the tubes are only 14 in. long, with a corresponding total of 9 ft² of heat-transfer area.

4. VACUUM ACCUMULATOR

The vacuum accumulator is made from a 3-ft length of 4-in.-diam Pyrex glass pipe oriented so that its long axis is vertical. Glass was used to provide a visual check on the carry-over of solids or liquids; this feature will be especially convenient in the event that fissionable materials are processed, using this system. The accumulator will also provide the system with a surge capacity and tend to reduce fluctuations in the vacuum.

The 1-in.-diam inlet to the accumulator is also made of Pyrex pipe and enters normal to the accumulator approximately 8 in. from the top flange. It extends to the center of the accumulator, where its open end is directed downward to aid in deentraining the carry-over of solids or liquid. A 1/2-in. nominal pipe size poppet check valve was included in the inlet line to prevent accidental pressurization of the accumulator with steam. A 3/4-in. outlet provided with a ball valve is attached to the lower flange to permit emptying of the accumulator when necessary.

The constructional details of this item of equipment are shown on ORNL drawing M-10896-CD-050-D, "Vacuum Accumulator."

5. VENT POT

A vent pot, made from 4-in. NPS, sched 10S, type 304L stainless steel, is situated downstream from the heat exchangers. Its purpose is to permit disengagement of the entrained air from the condensate and to vent the air to the contaminated off-gas system.

Condensate leaves the bottom of the vessel through a nominal 1-in.-diam pipe loop seal that is designed to impose a back pressure that is equivalent to approximately 8 in. of water. This causes some condensate to be retained in the pot for additional cooling before leaving. By its design, the vent pot minimizes the possibility of uncondensed steam vapors leaving the system.

ORNL drawing M-10896-CD-051, "Vent Pot," gives the constructional details for this equipment item.

Because of the unavailability of 4-in.-diam, sched 10S, type 304L stainless steel pipe, which was specified for the pot body, 5-in.-diam pipe was substituted. The installation was such that the vessel made from the latter pipe can readily be replaced by one of a smaller diameter when the situation demands.

6. INSTRUMENTS

The process instrumentation for the system is simple and consists of devices for measuring temperature, pressure (including vacuum), and flow.

Thermocouples spot-welded to outside equipment surfaces will measure the temperature of the exhaust steam immediately downstream of the jet exhauster, each heat exchanger, and the vent pot. The temperatures of inlet and outlet cooling water will also be measured to provide a heat balance for the heat exchangers. Readout for the thermocouples will be done on the existing panel board either by an available instrument or by newly installed instruments in presently unused panel board space.

The vacuum gage for the accumulator can be obtained from the Stores Department; it will be mounted on the top flange of the vessel.

A pressure gage, which can also be obtained from the Stores Department, will be mounted on the steam supply header, downstream of the pressure reducer.

7. DRAWING LIST

The following four engineering drawings were made in the course of this work:

M-10896-CD-050-D	Vacuum Accumulator
M-10896-CD-051-D-Rev. 1	Vent Pot
M-10896-CD-052-D-Rev. 1	Equipment Layout and Piping
M-10896-CD-053-Rev. 1	Flowsheet for CPDL Vacuum System

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