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ENVIRONMENTAL MANAGEMENT

BECHTEL JACOBS COMPANY LLC
OAK RIDGE ENVIRONMENTAL MANAGEMENT CLEANUP CONTRACT
WITH THE UNITED STATES DEPARTMENT OF ENERGY

BJCF-4 (10/08) Rev. 4

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BJC/OR-3252

K-311-1/K-310-3 Purge Cascade Process Description, Oak Ridge Environmental Management Accelerated Cleanup Project, Oak Ridge, Tennessee

This document is approved for public release per review by:

A.F. McBride/ATR 3/25/2010

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BJC/OR-3252

K-311-1/K-310-3 Purge Cascade Process Description Oak Ridge Environmental Management Accelerated Cleanup Project, Oak Ridge, Tennessee

Date Issued—May 2009

Prepared for the
U.S. Department of Energy
Office of Environmental Management

BECHTEL JACOBS COMPANY LLC
managing the
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East Tennessee Technology Park
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under contract DE-AC05-98OR22700
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U.S. DEPARTMENT OF ENERGY

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APPROVALS

K-311-1/K-310-3 Purge Cascade Process Description, Oak Ridge Environmental Management Accelerated Cleanup Project, Oak Ridge, Tennessee	BJC/OR-3252
	May 2009

USQD Review Determination	☒ USQD ☐ UCD ☐ CAT X ☐ Exempt (Select Criteria below.) USQD/UCD/CAT X No.: PSW-ET-1625/1627-0792
Exemption Criteria	☐ (1) Non-Intent Change ☐ (2) DOE-Approved Document ☐ (3) Clearly no impact on Nuclear Facilities ☐ (4) Chief Financial Officer, Internal Audit, Labor Relations, Legal, Public Affairs, or Project Controls Organization Document
USQD Preparer:	Name ______ Date 5/14/09
Exhibit L Mandatory Contractor Document	☐ No ☐ Yes (Requires review by the Proforma Change Control Board.)
PCCB Reviewer:	Name ______ Date ______

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ACRONYMS

AGAs	Acoustic Gas Analyzers
cfm	cubic feet per minute
D&D	decontamination & decommissioning
FY	fiscal year
MLIS	molecular laser isotope separation
ORGDP	Oak Ridge Gaseous Diffusion Plant
rpm	revolutions per minute

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1. INTRODUCTION

1.1 HISTORY OF THE K-311-1 UNIT

K-311-1 was constructed along with the rest of the K-25 Building in the 1943-1945 timeframe. K-311-1 was equipped with Size 3 converters and Size 38 Allis Chalmers™ single-stage centrifugal compressors driven by 3600 rpm electric motors, and the unit operated as the "bottom" unit flow-wise in K-25. The depleted flow from the bottom stage in K-311-1 passed through booster compressors and flowed to the K-601 Building where the depleted or "tails" material was removed. In 1948, after the K-27 Building was completed, the decision was made to operate K-27 and K-25 in series rather than operate the two buildings as separate entities. To facilitate this operation, concrete bases were poured and two sets of booster compressors were installed in the extreme West end of the K-311-1 cell floor. These compressors were enclosed in heated housings and consisted of Size 38 compressors. One pair was to boost the 'B' flow between K-25 and K-27, and one pair was to boost the 'A' flow between the buildings. Each station operated with one compressor on-stream and the other in standby. (Reference 9) Each station also was equipped with a Size 2 after-cooler located in the discharge stream downstream of the junction of the on-stream and standby compressors.

Additional gaseous diffusion capacity was added at Oak Ridge as K-29, K-31, and K-33 were constructed and placed in service in the early 1950s. As a result of the additional process equipment added by these buildings, in-leakage of light gases to the cascade including light gases introduced into the cascade as a result of purging operations threatened to exceed the capacity of the existing K-312 Purge Cascade facilities in the K-25 Building. As a result, in 1954 K-311-1 was converted to a side purge cascade to remove light gases from the process gas stream as the stream entered K-25 from K-27. Low molecular weight gas in-leakage in K-33, K-31, K-29, and K-27 was removed by the K-311-1 Side Purge Facility and a relatively pure stream of UF_6 then passed from K-311-1 into the upstream cells in K-25. In-leakage of light gases in the K-25 Building continued to be removed by the K-312 Purge Facilities.

K-311-1 operated as a Side Purge Cascade from 1954 until the K-25 Building was shut down in 1964; at that time K-311-1 became the Oak Ridge Gaseous Diffusion Plant (ORGDP) Top (and only) Purge Cascade. The adjacent K-310-3 Unit was operated along with K-311-1 as the top purge cascade and K-310-2 was also operated at times to supplement cells in the K311-1/K-310-3 Purge Cascade. K-311-1 was shut down on February 14, 1977, after the newer, larger capacity K-402-9 Purge Cascade was placed in operation. K-310-3 continued to operate until the K-402-8 Coolant Removal Unit was placed in service, and K-310-3 was shut down on March 14, 1978.

Since the K-311-1 and K-310-3 units continued to operate after K-25 shutdown, removal of equipment such as valves and piping for other projects did not occur in this area. As a result, these two units have not been exposed to atmospheric wet air over the years as much of the remainder of K-25 has been exposed. Any deposits or residual gases contained in K-311-1 or K-310-3 are not likely to be fully hydrolyzed.

™ Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors.

1.2 PURPOSE OF PURGE CASCADE

The gaseous diffusion process takes advantage of the small difference in molecular weights between $^{235}UF_6$ (molecular weight 349) and $^{238}UF_6$ (molecular weight 352) to separate the two isotopes. A compressor is employed to compress the process gas stream and the gas then flows into a converter containing porous barrier tubes with holes roughly the size of the mean free paths of the molecules. As the gas stream flows through the barrier tubes, process pressures are set up to ensure that approximately one-half of the gas flows through holes in the barrier walls and one-half continues through the tubes and exits the end of the tubes. Since lighter molecules of the desired $^{235}UF_6$ move slightly faster than the heavier $^{238}UF_6$ molecules, the $^{235}UF_6$ molecules are slightly more likely to strike the barrier tube walls and thus slightly more likely to pass through the walls of the barrier than are the heavier molecules. As a result, the gas flow through the barrier walls is slightly "enriched" in the lighter isotope, and the gas flow that exits the end of the tubes is slightly "depleted" in the lighter isotope. The actual separation factor is proportional to the square root of the ratio of the molecular weights of the two isotopes, and since the molecular weights of the two isotopes of uranium are nearly equal, the separation factor is quite small and the separation process must be repeated thousands of times in order to produce desired final assays of the lighter isotope. The lighter isotope gradually moves upstream in the gaseous diffusion process and the desired product is removed near the 'top' of the process.

During normal gaseous diffusion operations, light gases such as nitrogen (MW 28), oxygen (MW 32), Refrigerant-114 (MW 171), and other gases of similar molecular weights are intentionally introduced into the process and can also be introduced into the process during operational upsets. Since these gases are much lower molecular weight than either of the uranium isotopes in the process, the separation factor between the UF_6 and light gases is much greater than between the two isotopes. As a result, the light gases are rapidly separated from the process gas stream and move quickly upstream along with the enriched flow of UF_6. The light gases continue to move upstream until the top of the separating cascade is reached, and at that point, the light gases will concentrate or form a "bubble", and if not removed, the top of the cascade will reach essentially 100% lights, and no product withdrawal can occur.

The purge cascade is required to remove the light gases that enter the cascade in order to ensure that process gas can be removed in product withdrawal. The purge cascade must consist of a number of cells that will contain the "bubble" of lights, including cells that can process both lights and process gas, and a number of cells that can process light gases and remove residual traces of UF_6 to allow the light gases to be vented to atmosphere.

Since compressors that are designed to pump UF_6, a very dense and heavy gas, do not pump light gases well, special compressors must be used to pump the light gases and provide the necessary pressure differential across the barrier to separate residual UF_6 from the light gases. In the K-312 Purge Cascade, constructed as part of the K-25 Building, specially designed reciprocating pumps were employed to pump the UF_6/light gas mixtures and the light gases. Cells containing these pumps were employed to contain enough UF_6 to ensure that product withdrawal cells contained essentially pure UF_6 necessary for withdrawal, and to pump the light gases to effect the removal of residual UF_6 before passing the light gases through chemical traps to atmosphere.

K-311-1 was originally constructed as a Side Purge cascade intended to remove the light gases from the process gas flow from K-27 and to provide a relatively pure stream of UF_6 to supply K-25 cells. K-311-1 employed specially designed high-speed centrifugal compressors to pump light gases rather than the reciprocating pumps used in K-312. Four standard 3600 rpm "low speed" cells were employed to contain the UF_6 and to separate the UF_6/lights until the UF_6 concentration was approximately 5%, and three 9000 rpm "high-speed" cells were designed to provide sufficient pressure drop across the barrier in order to remove the residual UF_6 down to the low parts-per-million range. The flow of light gases then passed through chemical traps to atmosphere.

1.3 EQUIPMENT DESCRIPTION

As constructed as a UF_6 separation unit in the K-25 Building, K-311-1 contained 9 cells of Size 3 converters and Size 38 Allis Chalmers™ centrifugal compressors driven by 3600 rpm electric motors. These cells were numbered in order of up-flow 3, 5, 7, 9, 10, 8, 6, 4, and 2. Since the adjacent unit, K-310-3, contained Size 2 equipment, there was an intersectional cell at K-311-1 on the west end of the cell platform where cell 1 would normally be located. There were two size 38 compressors on the cell platform near cell 3 that boosted the depleted 'B' down-flow from K-311-1 to tails withdrawal, originally located in K-601. As discussed in the history section above, in 1948 two groups of two each size 38 booster compressors were added on the west end of the cell floor to facilitate operation of K-27 and K-25 in series.

1.3.1 Cell Equipment

K-311-1 was converted to a Side Purge cascade in 1954. The cell equipment in cells 3 and 2 was removed to make room for the purge flow piping to atmosphere. The equipment in cells 5, 7, 9, and 10 was left intact, and as part of the purge cascade these cells are referred to as "low speed cells". The 3600 rpm low speed cells continued to be equipped with size 38 compressors with shrouded monel™ impellers.

"High speed" cells 8, 6, and 4 received high speed compressors with modified size 38 casings, new aluminum impellers without shrouds and 2.5-to-1 speed increasers driven by 3600 rpm electric motors that delivered 9000 rpm to the compressor impeller. These cells also received converters with new barrier matched to the characteristics of the high speed compressors. Interstage coolers supplied by removing stage 6A coolers from cells in other areas of K-25 were added on the outlet of all 'A' compressors to remove the additional heat of compression generated by the higher speed compressors. Inverse recycle lines were removed from the high speed cells and bottom recycle lines with control valves were installed to provide a recycle to the bottom stage high speed compressors to prevent overheating. (Reference 1)

1.3.2 Booster Compressors

The booster compressors located near cell 5 on the cell platform were converted to "Feed boosters" to boost the flow to K-311-1, and the 'A' compressors in the west end of the cell floor were modified by installing high speed compressors and speed increasers identical to those in the high speed cells and became the "Tops Boosters" to boost the flow from the top high speed cell A-outlet through a metering station, chemical traps, either air jets or pumps, and on to atmosphere. Coolers were also added to both tops booster discharges, and the heated housing surrounding this set of boosters was removed. The 'B' flow from K-311-1, cell 5 was routed from the cell 5 'B' outlet to the 'A' inlet of K-310-3 cell 1, the next upstream cell from K-311-1. The K-310-3 cell 1 'B' outlet flow then passed through the 'B' compressors in the west end of the cell floor back to K-27. The 'B' compressors functioned as 'B' boosters and were essentially unchanged, including the continued presence of a heated enclosure.

1.3.3 Metering Station

A metering station was constructed on the west end of the cell platform downstream of the tops booster to meter and control the flow of light gases to atmosphere. One section of the metering station was automatically controlled and the other section was manually controlled by the operator. The normal purge flow was automatically controlled and in the event the lights up-flow was too much for the normal purge orifice and control to handle, the operator used a manual controller on the operating floor to open the "emergency purge" valve until lights up-flow had decreased to the point where the normal purge could regain control.

1.3.4 Alumina Traps

Eighteen five-inch diameter geometrically safe alumina traps were constructed on the west end of the cell platform near the metering station as six groups of three traps. These traps were located downstream of the metering station. Flow from the alumina traps passed to either a pair of air jets (one 2-1/2-inch diameter and one 3-inch diameter) or a pair of 110 cfm Kinney™ vacuum pumps on the west end of the cell platform and then to atmosphere. The air jet or Kinney™ pump discharge passed vertically through the operating floor where a centrifugal Buffalo™ blower diluted the flow as it passed to atmosphere through a discharge pipe through the wall and above the roof.

1.3.5 Coolant Systems

The coolant systems of the low speed cells were unchanged; each low speed cell had its own liquid recirculating (C-816/B-437) coolant system. Coolant flow was through the recirculating pump, through the process gas coolers located in the converters, through the water cooled coolant cooler located in the basement, and back to the recirculating pump (Reference 2).

Each high speed cell was equipped with two coolant systems. The 'B' system was similar to the low speed cell coolant system and served the coolers located in the converters. The 'A' system was added as a separate system to serve the interstage coolers on the discharge of each high speed 'A' compressor. Both coolant systems on the high speed cells consisted of a recirculating pump, process gas coolers, and a water cooled coolant cooler located in the basement of K-311-1.

The K-311-1 coolant systems were served by the coolant storage tank in the basement of K-310-1.

1.3.6 Lube Oil Systems

Both low speed and high speed cell compressor and motor bearings were served by the same lube oil system that was originally installed in K-311-1 that does not differ from other lube oil systems in other Size 3 units throughout the K-25 Building (Reference 3). Each of the speed increasers in the high speed cells and tops boosters was served with its own self-contained lube oil system. There was an oil reservoir in the bottom of each speed increaser, and the oil was pumped by a gear pump through the speed increaser gears and bearings, through a filter, an oil cooler, and back to the reservoir. The speed increasers used Code BG oil instead of the Code BE used in cell lube oil systems.

The high speed compressors were notoriously bad oil leakers and a waste oil vacuum system was installed to salvage the oil. A pickup block was installed in each high speed compressor in the low area between the load and thrust bearings. The pickup block was connected by plastic tubing to a common header that connected to a knockout drum located in the basement near the lube oil drain drum. An air jet provided a vacuum on this line, and the air jet exhausted at the east end of the unit. The contents of the knockout drum were periodically pumped back to the lube oil drain drum.

1.3.7 Seal Systems

There was one seal system for each cell in K-311-1 and one seal system for each pair of boosters. (Reference 4) The seal systems were manually controlled and the seal piping, seal exhaust pumps, and seal control systems were identical to other units in K-25.

1.3.8 Datum Systems

Datum systems in K-311-1 were the same as the rest of K-25 except there was a separate unit automatic "high" datum system for cells 5, 7, and 9, and a unit automatic "low" datum for cells 4, 6, 8, and 10. Each cell had its own "cell datum" system as did the rest of K-25. (Reference 6)

1.3.9 Instrumentation and Control Systems

Three distinct systems were installed in K-311-1 to control the lights/UF_6 front and the purge rate. Each system was intended to measure the density of the gas stream in the top low speed cell. The top low speed cell was generally cell 10, and under normal operations the top stage in that cell contained approximately 5% UF_6 and 95% light gases.

Two Acoustic Gas Analyzers (AGAs) were installed. (Reference 5) These instruments measured the density of the gas mixture by measuring the speed of sound in the gas. Since the speed of sound in a gas varies with gas density, this parameter can be used to determine density.

An ammeter controller was installed on cell 10. The higher the density of a gas stream, the more power is required to pump the gas. This device was intended to measure the gas mixture density by measuring the process motor amperage.

A fluid composition analyzer was installed to measure density using a capillary flow technique.

Although all three methods measured density and that measurement could be used to control the purge cascade flows, the superior performance of the AGA resulted in abandoning the ammeter controller and the fluid composition analyzer. The AGA was successfully used for the life of the K-311-1 Purge Cascade.

Two space recorders were installed to measure UF_6 concentrations in the purge gas stream. The space recorders, which measured parts-per-million quantities of UF_6 using an ionization chamber, or "signal can", were used to monitor the purge flow to atmosphere and automatically closed the top purge valve in the event pre-set limits were exceeded.

A special line recorder designed to measure fluorine concentration in UF_6 was installed in K-311-1 to provide real-time fluorine analysis.

1.3.10 Other Equipment and Systems

Since the K-311-1 purge cascade separated UF_6 and light gases by the gaseous diffusion process, the other equipment and systems such as cell pressure measurement, power and auxiliary transformers, process piping and valves, and process seals were identical to other Size 3 units within the K-25 Building.

1.4 SIDE PURGE PROCESS FLOW DESCRIPTION

Operating as the side purge cascade from 1954 until K-25 shutdown in 1964, K-311-1 received the A up-flow from the top cell in K-27[1]. This flow is shown schematically in Figure 1. The flow entered the unit through the tie line at the southwest corner of K-311-1, then to the feed booster station immediately south of cell 5 on the cell platform. One of the feed boosters was normally operating with one in standby. The flow passed through the operating feed booster, into the feed header, and normally entered the K-311-1

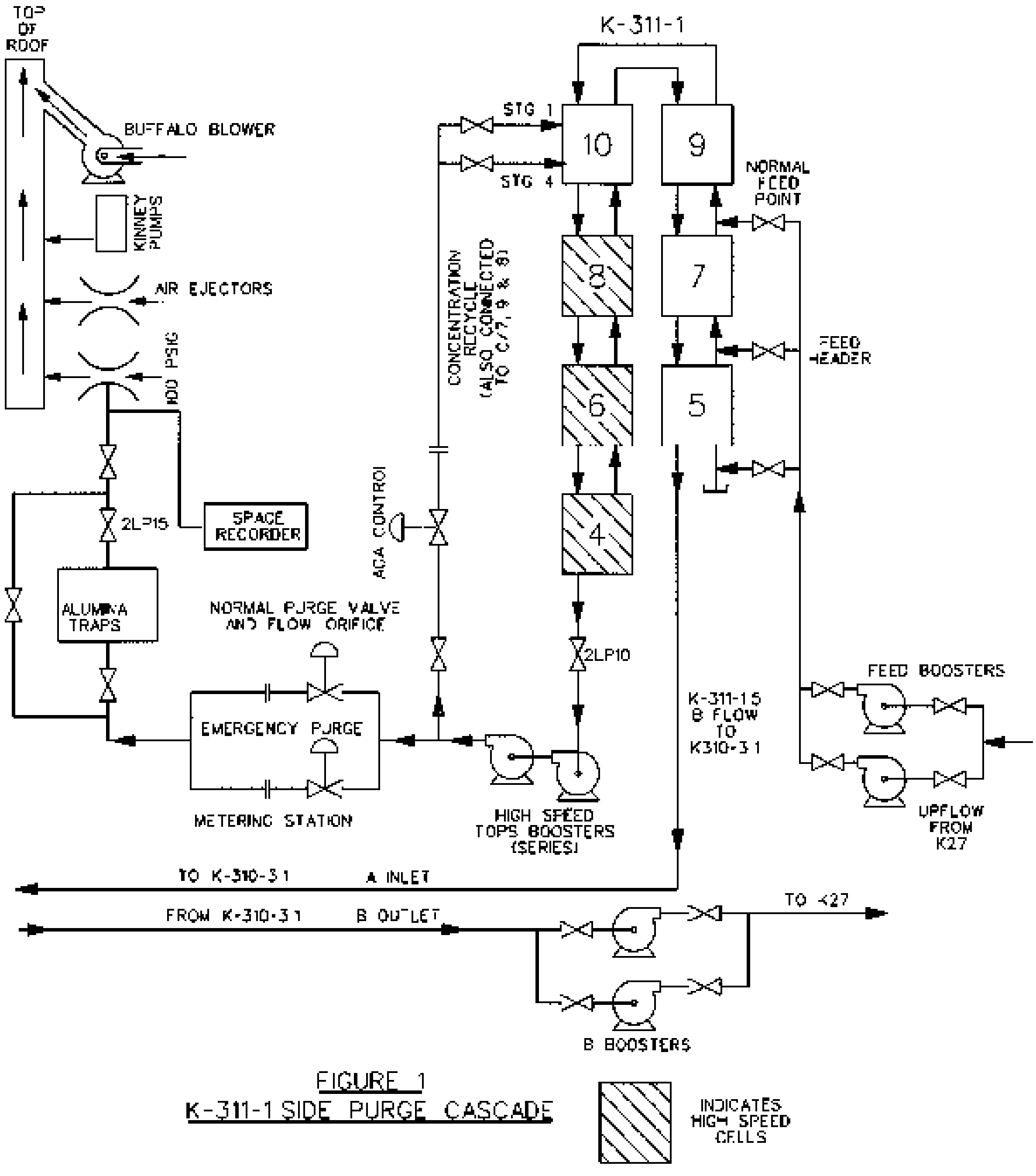

Fig. 1. K-311-1 Side Purge Cascade.

low speed cells between cell 7 and cell 9. In this configuration, cells 5 and 7 served as "stripper cells" and cells 9 and 10 served as "enricher cells". The feed stream at this point contained approximately 5% lights.

The two stripper cells served to strip out the lights and at the bottom of cell 5, the process gas stream was essentially pure UF_6, and this flow was routed to the next upstream unit, K-310-3, and entered the cell 1 'A' inlet. The 'B' flow from K-310-3, cell 1, was routed through the operating 'B' booster (one booster maintained in standby) back to the top operating cell in K-27.

Since the flow entered K-311-1 through the feed header, there was no 'A' flow into the 'A' inlet of cell 5; the 'A' inlet of that cell remained closed.

Intermediate molecular weight compounds such as Refrigerant-114 with a molecular weight of 171, that entered the cascade from K-29, K-31, and K-33, were separated in the process stream and flowed upstream toward the top of the cascade. In the K-311-1 Side Purge Cascade, the intermediate molecular weight compounds entered the low speed cells and exited through the cell 5 'B' outlet and continued to travel up the cascade to be removed in a coolant removal facility in K-312. In 1957, modifications were made to the adjacent K-310-3 unit to assist in the removal of R-114. Two 5-inch diameter sodium fluoride traps were installed on the K-311-1 Operating Floor, and a 2-inch line was installed from K-310-3 cells 2, 4, 6, and 8 to the sodium fluoride traps. As a coolant removal unit, K-310-3 operated most of the time isolated with no flow into or out of the unit except a small flow from the top stage of the top cell, through the line to the sodium fluoride traps, to the jet and to atmosphere. As the unit operated in this manner with a small flow from the unit to the sodium fluoride traps, pressures in the lower portion of the unit, cells 1 and 3, decreased. Periodically, the inlet and outlet valves in cell 1 were opened and coolant that had accumulated in K-311-1 was transferred into K-310-3. A more detailed description of the K-310-3 as a coolant removal unit is provided in the post-K-25 Shutdown section below "Operation of K-310-3 as the Coolant Removal Unit".

From K-311-1, upstream to the top of the K-25 cascade, light gases that entered the process were removed at K-312, the Top Purge.

The two K-311-1 enricher cells served to separate the lights and process gas until, at the top of cell 10, the UF_6 concentration was approximately 5% and the remainder was light gases. At this point, the low density of the gas mixture resulted in the low speed compressors losing compression ratio and with very little compression ratio and thus very little pressure differential across the barrier, separation of the UF_6 and lights essentially ceased.

The flow then entered cell 8, the bottom high speed cell. The high speed compressors re-established compression ratio of the gas mixture, pressure differential was re-established across the barrier, and as the gas mixture passed through the high speed cells, the UF_6 was separated from the light gases, and at the top stage of the top high speed cell, UF_6 concentration was in the parts-per-million range.

From the top high speed cell the gas flow passed through the two tops boosters operating in series. This boosted the pressure before the flow entered the metering station. Just prior to the metering station, a portion of the purge gas flow was diverted and recycled through the "concentration recycle" valve back to the top operating low speed cell. The position of the concentration recycle valve was controlled by the AGA based on the density of the gas stream in the top operating low speed cell.

The purge gas flow that was not recycled flowed to the metering station. The metering station consisted of two parallel flow orifices and control valves. One orifice and valve combination, the normal purge valve, was used during normal purge flow operations, and the second orifice and valve combination, the "emergency" purge was manually loaded and was used by the operator when the normal purge valve and orifice coupled with the concentration recycle valve was not able to handle the total lights up-flow.

The design of the concentration recycle valve and the normal purge valve ensured that under routine operations as lights up-flow increased and decreased within certain levels, the overall purge flow through the high speed cells remained constant. If the AGA sensed an increase in lights up-flow through a decrease in gas density in the top operating low speed cell, the AGA would close the concentration recycle valve to the extent necessary to direct a greater percentage of the flow through the normal purge valve and orifice until the excess lights had been removed and proper gas density and thus gas concentrations in the top operating low speed cell had been re-established.

If up-flow of light gases exceeded normal purge and concentration recycle ability to remove the gases the concentration recycle valve would close 100% and the AGA would exhibit an audible and visible alarm. When the operator saw that the concentration recycle valve was 100% closed and gas density in the top low speed cell was continuing to decrease, the emergency purge would be used. The operator would manually open the emergency purge valve to the extent necessary to remove the excess light gases until the concentration recycle began to open and once again the AGA could control the process.

From the metering station the purge flow passed into the inlet of the onstream bank of alumina traps to remove any residual uranium. From the trap outlet, the flow entered either the air jet inlet or the Kinney™ pump inlet and then entered the exhaust header. The exhaust header traveled vertically from the jet or pump exhaust through the operating floor where the Buffalo blower discharge diluted the flow. The exhaust header then passed through the wall and discharged vertically above the roof line.

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[1] *The side purge process flow description is written describing flows with K-311-1 located flow-wise immediately upstream from K-27. The side purge cascade could be located in various configurations flow-wise within the K-25 Building, and this flexibility was necessary as additional buildings were added at Oak Ridge. Regardless of the side purge location within the cell configuration, flows as described are representative of K-311-1 operations. The flow description is also written describing all four low speed and all three high speed cells onstream. Due to maintenance schedules and process failures, the purge cascade at times operated with less than a full complement of cells. K-311-1 could operate successfully at reduced capacities with as few as one high speed cell and two low speed cells.*

The concentration recycle header is shown schematically discharging to either stage 4 or stage 1 of cell 10. The normal discharge point was cell 10 stage 4. The concentration recycle could also be valved to stages 1 and 4 of low speed cells 9 and 7, and to stage 1 of high speed cell 8.

2. TOP PURGE PROCESS FLOW DESCRIPTION FOLLOWING K-25 SHUTDOWN

2.1 OPERATIONS IMMEDIATELY FOLLOWING K-25 SHUTDOWN

The K-25 and K-27 Buildings were shut down in April, May, and June 1964, and the K-312 Purge Cascade was shutdown on June 9, 1964. The only two running units in K-25 were K-311-1 and K-310-3. K-311-1 became the top purge cascade for the ORGDP, and K-310-3 served as the R-114 removal unit.

With the shutdown of K-25 and K-27, the flows to the purge cascade were as follows and are shown schematically in Figure 2. The enriched flow from the top cell in K-29 passed through an 'A' booster located in K-29, through the tie line to K-25, and entered K-311-1 feed booster that discharged between low speed cells 7 and 9. The 'B' flow from the 'B' outlet of K-311-1 cell 5 passed through the 'B' boosters back to the top operating cell in K-29.

Periodically the 'B' flow from the 'B' outlet of K-311-1 cell 5 was redirected into the 'A' inlet of K-310-3 cell 1, the coolant removal unit.

It was assumed that as top purge and coolant removal unit, K-311-1 and K-310-3 would be capable of removing light and intermediate molecular weight gases. Purge cascade operations in this configuration successfully removed light gases such as oxygen and nitrogen, but almost immediately major problems with intermediate molecular weight compounds, particularly Refrigerant-114 were encountered. .The K-310-3 unit operating as a coolant removal unit equipped with the two 5-inch diameter sodium fluoride traps that were installed in 1957 could not handle the rate of up-flow of R-114 and excessive levels of coolant accumulated in K-311-1 and K-29. It quickly became clear that modifications were necessary to allow K-311-1 to function as the ORGDP top purge cascade.

K-29, K-31, and K-33 were constructed with axial flow compressors rather than the centrifugal compressors employed in K-25 and K-27. Although the axial flow compressors were more efficient than centrifugal compressors, they were much more sensitive to excess light gases, and tended to surge and fail if operated on elevated light gas concentrations for extended periods. For that reason it was recognized that additional cells containing centrifugal compressors should be operated between the axial buildings and the K-311-1 Top Purge Cascade.

On July 24, 1964, K-310-2 was restarted and placed on-stream between K-29 and K-311-1 to provide additional cells in which to store the excess R-114. This is shown schematically in Figure 3. Preparations also began to provide additional coolant removal capacity for K-310-3 . Over the next few months, three 12-inch diameter annular sodium fluoride traps were installed in addition to the two existing 5-inch diameter sodium fluoride traps on the operating floor of K-311-1 (Reference 11). The outlet of the sodium fluoride traps was connected to an air jet and the exhaust mixed with the K-311-1 jet exhaust and exited the building. A space recorder monitored the flow from the traps to the air jet.

2.2 OPERATION OF K-310-3 AS THE COOLANT REMOVAL UNIT

In late calendar year 1964 and early 1965, the capacity expansion of the K-310-3 coolant removal unit was completed and was successful in that the full upflow of R-114 in the ORGDP cascade could now be removed in K-310-3. As a coolant removal unit, the unit operated most of the time isolated with no flow into or out of the unit except a small flow from the top stage of the top cell, through the line to the sodium fluoride traps, to the jet and to atmosphere. As the unit operated in this manner with a small flow from the unit to the sodium fluoride traps, pressures in the lower portion of the unit, cells 1 and 3, decreased.

With K-310-3 isolated, flows from K-29 entered K-310-2 and then on to K-311-1 as described previously as shown in Figure 3. As K-311-1/K-310-3/K310-2 operated in this configuration, K-310-3 operation was commonly referred to as a "pigtail" cascade. R-114 up-flow from K-29 reached K-311-1 and "peaked" since there was essentially no outlet for intermediate molecular weight compounds. Periodically, the 'B' outlet flow from K-311-1 cell 5 would be redirected into the K-310-3 cell 1 'A' inlet by opening valves including the K-310-3, cell 1 'A' inlet. While the flow was set up in this manner, the 'B' flow from K-310-3 cell 1 was returned to K-310-2. This configuration was maintained for an hour or two or until the "peak" of R-114 was reduced by the migration of the R-114 into K-310-3, "filling" K-310-3 with additional UF_6 and R-114. K-310-3 was then isolated once again by closing the cell 1 'A' inlet and 'B' outlet valves, and the only flow from K-310-3 once again was the small flow from the top stage in the top cell to the sodium fluoride traps.

Since K-310-3 consisted of eight cells, none of which were high speed cells, the separation of UF_6 and lights in that unit was incomplete. As it operated isolated, the gas concentration in the bottom cells was essentially pure UF_6, and the gas concentrations in the top stages of the top cell were from 2-5% UF_6, but also a substantial concentration of R-114, 10-20%, was present. The remaining gases were nitrogen, oxygen, and other intermediate molecular weight compounds. By removing a small flow from the top cell and passing that flow through sodium fluoride traps, R-114 in-leakage to the cascade was removed.

Sodium fluoride traps were used in K-310-3 operations since the relatively high concentration of uranium in the stream from the top cell required the ability to return the uranium to the process. The annular sodium fluoride traps were operated in series, and the smaller diameter backup traps operated on the outlet of the on-stream annular traps to remove any carryover of UF_6. When the inlet trap became saturated or "loaded", the trap was removed from service, heated, and a stream of fluorine was passed through the trap. This operation resulted in the trapped uranium being regenerated as UF_6 and the gas was returned to the K-311-1 low speed cells.

A gas chromatograph, a laboratory instrument that was capable of measuring R-114 and other intermediate molecular weight compounds in UF_6 was installed in K-311-1 and used to determine when the K-310-3 unit should be valved to K-311-1 to reduce R-114 concentration.

K-310-2, K-310-3, and K-311-1 continued operating with K-311-1 as the top purge, K-310-2 as additional cells between K-29 and K-311-1, and K-310-3 as the coolant removal unit (Reference 8). K-310-3 functioned well enough as a coolant removal unit that K-310-2 was returned to shutdown status. The exact shutdown date of K-310-2 has not been found, but the last operations log book entry for a failure in that unit was September 22, 1965. The unit was likely shutdown shortly after that date, since it is unlikely that there were no further failures in that unit if it continued to operate.

K-311-1 continued to operate as the top purge and K-310-3 continued to operate as the R-114 coolant removal unit until replaced by K-402-9 and K-402-8, respectively. The K-311-1 and K-310-3 "pigtail" operation is shown schematically in Figure 2. K-311-1 was shutdown on February 14, 1977, and K-310-3 was shutdown on March 14, 1978. The operations log book entry for March 14, 1978, following shutdown stated "nothing running in K-310-3 but varmints."

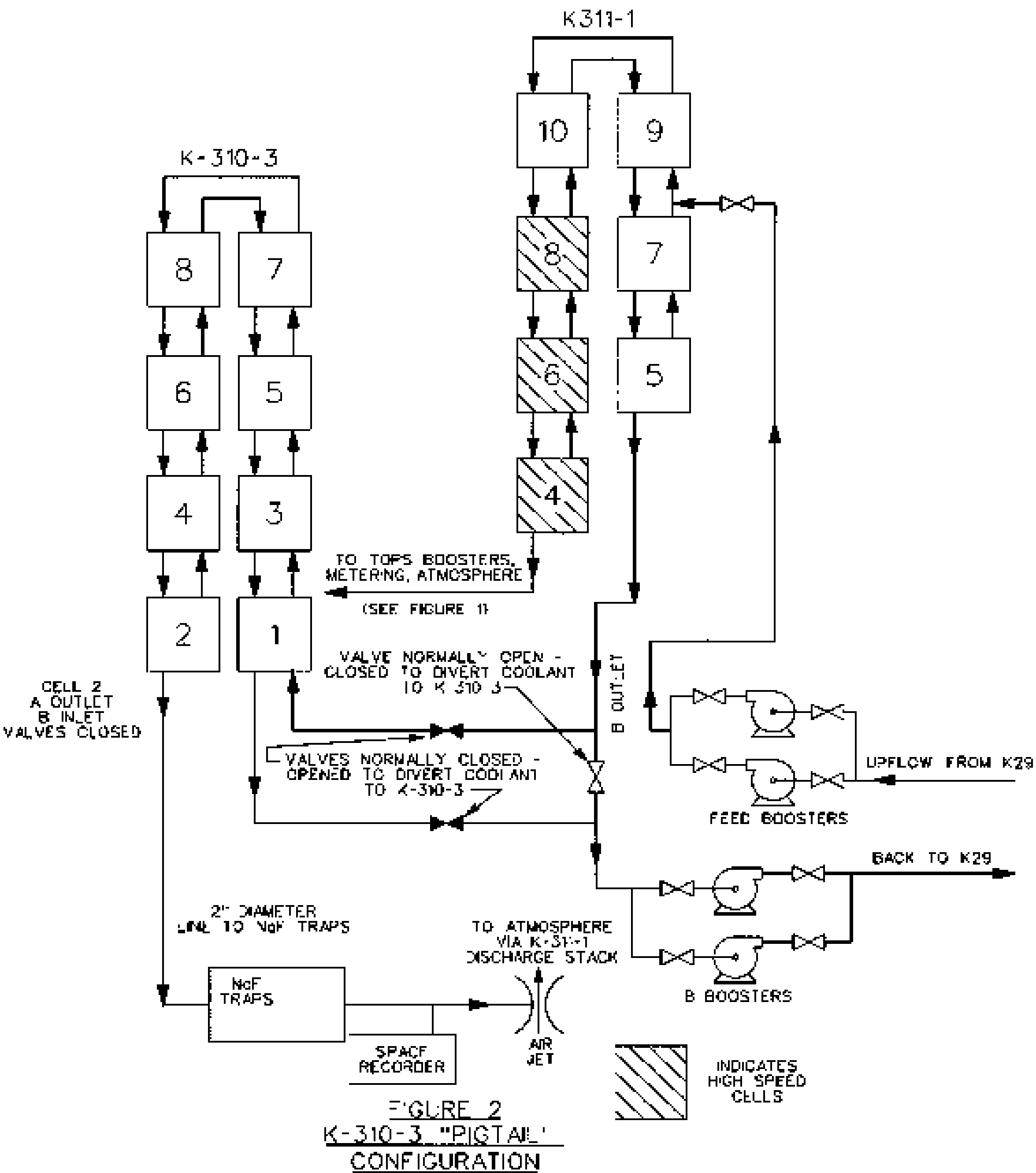

Fig. 2. K-310-3 "PIGTAIL" Final Configuration.

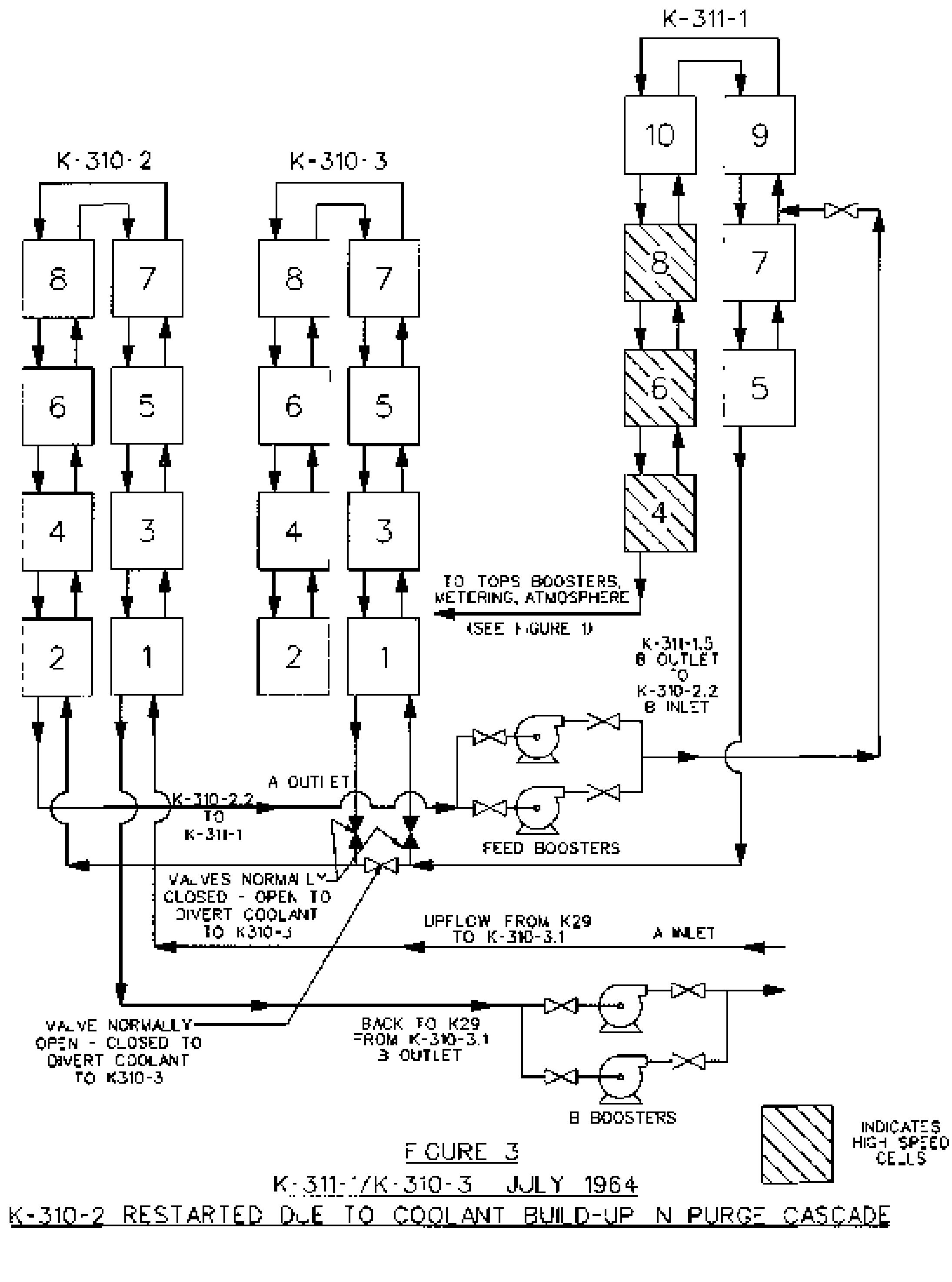

Fig. 3. K-310-2 Restarted due to coolant build-up in purge cascade.

3. K-311-1 AND K-310-3 OPERATIONAL ISSUES AND MODIFICATIONS

3.1 SIDE PURGE IMPELLER PROBLEMS

Shortly after start-up of K-311-1 as a side purge, failures of the high speed aluminum impellers began to occur. The first log entry (Reference 12, p. 57) was February 4, 1955, and documented the failure of the 6A impeller in K-311-1.4. The impeller split apart, was thrown through the discharge pipe into the after-cooler resulting in large air and coolant leaks. The incident knocked out the high speed cells and tops boosters. This failure was followed by additional similar failures, and investigation revealed that the cast aluminum impellers were operating at high discharge temperatures and were undergoing an alloy change during this "heat treatment" and splitting apart at the keyway where the impeller attached to the compressor shaft. This problem was solved by switching to a forged aluminum impeller. All high speed impellers were changed to forged impellers and, although the high speed compressors remained high maintenance items, the forged impellers were operated successfully for the remaining life of the facility.

3.2 TECHNETIUM PLUGGING

Following shutdown of K-25 and K-27 and conversion of K-311-1/K-310-3 to the top purge configuration, plugging problems that could not be alleviated through chemical treatments began to emerge in K-311-1. Operating log book entries beginning in March 1966 (Reference 12, page 116) documented plugging problems in both the high and low speed cells that could not be fully removed by chemical treatment. A June 23, 1966, log entry documented difficulty in troubleshooting K-311-1, cell 10, a low speed cell. Two days later the log documented "still treating, no improvement". Plugging problems continued to be documented and the issue turned out to be technetium plugging. Evidently, once K-311-1 and K-310-3 were converted to the top purge and connected directly to the top of K-29, technetium from K-29 moved into K-311-1/K-310-3 and caused plugging and operational problems. Similar problems were documented for the remainder of the operating life of the K-311-1/K-310-3 Purge Cascade.

A February 25, 1977, log entry (Reference 12, p. 139) documents that lines for technetium traps were installed in stage 6 of K-310-3.6 in an effort to remove technetium from the gas stream. These traps were probably MgF_2 chemical traps. On this date, K-310-3 was operating as the coolant removal unit to support K-402-9, and technetium plugging problems were beginning to surface in the new purge cascade.

The presence of technetium in K-311-1 and K-310-3 is well documented and must be addressed as these units are scheduled for D&D.

3.3 MODIFICATIONS IN RESPONSE TO 1971 PURGE CASCADE INCIDENT

On August 24, 1971, a mis-valving occurred in K-311-1, cell 8 that introduced massive quantities of wet air into K-311-1, K-29, and the top units in K-31 (Reference 12, p. 125). This resulted in barrier plugging throughout K-311-1 and K-310-3, and it was more than a month before the situation was stabilized. During this period, there were repeated seal and compressor failures throughout K-311-1 and K-310-3, some of which introduced not only wet air, but oil into process compressors, piping, and converters. During recovery from this incident, it was discovered that much equipment in K-311-1 was in need of updating and that instrumentation and control systems required modernization. Several modifications were implemented including replacing the single stage air jets with two-stage jets, installation of individual stage ammeters for the high speed cells, installation of motor operators on valves required for

K-311-1/K-310-3 operations, adding schematic cell and process layouts in the control area, adding eight instrument panels, adding a 'B' booster panel, and converting the open control area into an air conditioned control room (Reference 10).

4. INTERFACES WITH OTHER PROCESSES

4.1 MOLECULAR LASER ISOTOPE SEPARATION LABORATORY

A laboratory to support molecular laser isotope separation (MLIS) research was constructed in the basement of K-310-2 in the mid-1970s. The laboratory included a scale mounted steam chest with a 12A UF_6 cylinder containing 450 pounds, and used a carrier gas with the UF_6. Three K-310-2 cells were modified to serve as multi-stage centrifugal pumps to move the gas. Cells 3, 5, and 7 were modified by removing the converters and installing piping from the discharge of each compressor to the suction of the next compressor. Each cell then functioned as a 12-stage compressor. Interstage coolers were installed at various locations in the cells. The cells as modified were:

K-310-2.3 Even stages of compressors received full diameter monel™ impellers from K-303-4
Stages 1 and 3 received Cooper Bessemer™ aluminum impellers from K-402-1
Remaining odd compressors retained existing cut down monel™ impellers
Stages 1 and 7 received interstage coolers
K-310-2.5 This cell was equipped exactly as Cell 3.
K-310-2.7 Even stages received full diameter impellers
Odd stages retained existing cut down monel™ impellers
Stages 1, 5, and 9 received interstage coolers

Flow from the basement laboratory was pumped by the cells in a recirculating loop. Seal in-leakage that accumulated and the inventory of UF_6 and carrier gas were evacuated as required through the K-310-2 odd 'A' cell bypass line to the unit 'A' bypass line in front of K-310-2, through the tie line to K-29, where it was discharged to the suction of the K-29 'A' booster. This scheme provided a desired surge volume of approximately 5000 cubic feet and provided a very low pressure at the 'A' booster suction. There do not appear to have been any direct ties to either K-310-3 or K-311-1; the flow was routed to K-29 and then to the purge cascade through normal purge up-flow (Reference 7).

4.2 K-1423 TOLL ENRICHING FACILITY VENT

In an effort to curb gaseous UF_6 emissions from the cold traps used in the K-1423 Toll Enrichment Facility to purge cylinder pigtails and piping, changes were made in the early 1980s to route purge gas from K-1423 to the operating gaseous diffusion cascade (Reference 8). Approximately 900 feet of 4-inch diameter nickel-plated schedule 40 piping was installed from K-1423 into K-25 between K-302-4 and K-302-5, west to above the truck alley, and then turned 90 degrees and ran south approximately 9-feet above the operating floor to the K-311-1/K-310-3/K-310-2 area. There, the new line was tied into a 3-inch "waste" line to K-27. The new 4-inch line was steam-traced and insulated with 1-1/2-inch thick calcium silicate insulation.

This project was completed during the 4th quarter of fiscal year (FY) 1982 (Reference 13), and from that time until ORGDP was shut down, K-1423 purge gas was vented to the operating cascade. It is important to note that this tie was made after K-311-1 and K-310-3 were shut down and replaced by K-402-9 and K-402-8; it must be addressed during East Side K-25 decontamination & decommissioning (D&D).

5. REFERENCES

1. K/PC-644, Procedure 325.3, *K-311-1 Side Purge*, January 9, 1963

2. K/PC-644, Procedure 305.1, *Purge Cascade Coolant System*, January 1976

3. K/PC-644, Procedure 315.1, *Purge Cascade Lube Oil System*, January 1976

4. K/PC-644, Procedure 315.5, *Purge Cascade Seal Systems*, June 1976

5. K/PC-644, Procedure 325.1, *Operation of the Acoustic Gas Analyzer (AGA)*, June 1974

6. K/PC-644, Procedure 325.6, *Purge Cascade Datum System*, January 1976

7. K/GD-1786, *Laser Isotope Separation Laboratory Description (U)*, D. A. Bodey, March 1978

8. Engineering Drawing, *K-1423/K-27 Evacuation Tie Line Piping Plan*, P1E-53259A, Revision 4

9. Engineering Drawing, *K-25 and K-27 Series Operations*, D-AWP-7850, June 10, 1948

10. K-1902, *ORGDP Quarterly Report, 2nd Quarter 1972, October 1, 1971—December 31, 1971, p. 18.*

11. Engineering Drawing P-31247, *NaF Trap, Coolant Removal*, December 1964 (microfiche)

12. *Operations History Data Base Compiled from Operating Log Entries*

13. K-1945, *ORGDP Quarterly Report, 4th Quarter 1982, July 1, 1982—September 30, 1982, p. 46.*

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