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SANITIZED VERSION OF PURGE CASCADE STUDIES AND TESTS (SEPTEMBER 1, 1971)

(SANITIZED VERSION OF CRD DOCUMENT # K-PC-612)

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K-PC-612

PURGE CASCADE STUDIES AND TESTS (U)

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PURGE CASCADE STUDIES AND TESTS(U)

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ABSTRACT

Results of recent tests conducted in the K-311-1 Purge Unit are presented. Process- and equipment-related problems are discussed in detail. Recommendations are itemized for improving the performance of the Purge Unit. Also listed are options to be considered for ensuring greater purging capacity and increased operational reliability. These options involve either major modifications to the present facility or new design and construction. A program for future testing is presented.

PURGE CASCADE STUDIES AND TESTS

INTRODUCTION

In May 1970, a work group was established to recommend the appropriate course of action to follow to assure adequate cascade purge now and in the future. To do so required developing studies and conducting a series of tests with particular emphasis on new methods for disposing of chlorine trifluoride (ClF_3) and Freon-114.

The major problem areas of the Purge Unit appear to be of two categories. Some are process-related; others are equipment-related. Process-related problems include the need for improved methods of disposing of potentially explosive accumulations of ClF_3 and Freon-114 and an evaluation of the true maximum purging capacity of the unit as related to purge rates anticipated under the Cascade Improvement Program (CIP). Equipment-related problems include the degree of plugging prevalent in the high-speed cells, the life expectancy of the high-speed pump impellers and speed increasers, and obsolescent automatic control instrumentation, specifically the Acoustic Gas Analyzer (AGA).

SUMMARY

TESTING RESULTS

The testing program resulted in the development of an operational procedure which is successful in rapidly disposing of high concentrations of ClF_3 totally within K-311-1. In essence, this procedure involves the introduction of a 60,000-scfd bleed of air into the Purge Unit to sweep the ClF_3 through the high-speed cells and thence to the atmospheric vent stack.

The preceding procedure was unsuccessful in disposing of Freon-114. The molecular weight of the Freon-114 is simply too high to permit passage through the barrier of the high-speed cells. The only method currently available is to concentrate the Freon-114 in the K-310-3 cells and then to evacuate concentrations of Freon-114 and UF_6 through sodium fluoride (NaF) traps. However, tests were conducted with the spare low-speed cell 5 as a small cascade within K-311-1 to demonstrate that this cell could achieve the separation obtained using the K-310-3 cells. Unfortunately, the cell 5 volume is too small to accommodate the rapid dumping of a large slug of Freon-114. What is needed to permit shutdown of K-310-3 is a system of equal or greater volume for temporary storage of large accumulations of Freon-114 that enter K-311-1. Some limited testing has indicated that, with the proper type of booster pump, the K-29 Surge Drums might serve this purpose.

REMAINING PROBLEM AREAS

As was evident during the tests, an enlargement of the NaF trapping system appears desirable. In the final analysis, the quantity of Freon-114 that can be exhausted to atmosphere is largely a function of the UF_6 sorption capacity of the traps and the Freon-114 concentration in the exit gas stream. This is approximately 20 lb of Freon-114 per day, based on a Freon-114 concentration of 3.5 mol percent and a gas flow rate through the traps of 1200 scfd. However, if a sizeable leak develops in a cascade gas cooler, the amount of Freon-114 which subsequently accumulates in K-311-1 and K-310-3 usually requires about a week to be disposed of via the NaF traps.

Many of the difficulties in maintaining effective operation of the Purge Unit are attributable to the deteriorated condition of the operating equipment, particularly the barrier and the pump impellers of the high-speed cells.

The condition which most adversely affects the operation of the Purge Unit is the barrier plugging prevalent in the high-speed cells. Much of the plugging is from wet air leaks within the unit itself. Leakage sources have been recurring seal failures and cracked expansion flanges.

The high-speed aluminum impellers are also a major source of concern. When these impellers were purchased in 1955, their anticipated useful life expectancy was approximately 15 years. By the end of this period, it was felt that prolonged operation at elevated temperatures would ultimately weaken the impellers by reducing the metal hardness and allowing creep to set in. This anticipated life span has now been exceeded. Hardness tests on impellers that have been removed for rebalancing show a definite reduction in hardness. Also of concern is the effect of plugged barrier in shifting the operating point of the high-speed compressors into the surge region. The fluctuating motor currents of a pump in surge translate into severe cyclic stresses which can induce metal fatigue in the impellers which have already been weakened by a reduction in hardness. It would seem that full value has been obtained from these impellers, and it would appear unwise to depend on them for the heavy purging anticipated when power is restored and all cascade equipment is operating.

RECOMMENDATIONS

When all cascade equipment is again in operation, the K-311-1 purge rate should return to the 20,000-scfd level, with slugs increasing the total rate at times to approximately 200,000 scfd. In its present condition, the Purge Unit would have difficulty coping with such purge loads. It appears appropriate, therefore, that consideration be given at this time to measures which will ensure that adequate purging capacity will be available when needed.

The recommendations stemming from the recent tests comprise two categories. The first consists of items which can be acted on now; the second is broader in scope, calling for major modifications to existing facilities or new design and construction.

Items which can be acted on now:

1. Convert the present high-pressure stripper cells to enriching cells equipped with *automatic proportional response* on the stage instrumentation in order to reduce spillover, or backup, of light contaminants into K-29.

2. To reduce venting of UF_6 to the atmosphere when purging slugs of fluorine or ClF_3, discontinue the practice of temporarily bypassing the alumina traps. To adsorb the UF_6, purge the slugs through two banks of traps emptied of alumina and then refilled with NaF pellets.

3. Eliminate the need for the K-310-3 unit by developing a high-compression ratio booster pumping system for stacking process gas rich in Freon-114 in the K-29 surge drums.

4. Install a degrader to break up the Freon-114 molecules into lower molecular weight constituents which can be purged through the high-speed cell barrier. Such a unit would support, rather than supplant, the NaF traps by adding to the overall Freon-114 disposal capacity of the Purge Unit.

5. Double the capacity of the existing NaF trapping facility by fabricating an additional annular-type trap and installing it along with the two annular-type traps recently removed from the abandoned K-1131 feed cylinder *burping* facility.

6. Reheat treat the high-speed aluminum alloy impellers to restore them to, or near, the original metal hardness.

7. Minimize the internal stresses in the high-speed impellers by reducing the operating speed by approximately 20%. This will require changing speed increaser gears.

8. Regain as much of the original barrier permeability as possible by rotating all of the high-speed converters through the Furnace Area for treatment.

9. Develop a simple and modern type of purge control system to back up, or replace, the obsolescent AGA. A simple pneumatic control responding to variations in the compression ratio across a selected stage pump or an electrical control responding to variations in the motor load of this same stage pump should be feasible.

10. Install a scrubber on the vent stack flow to remove fluorine, ClF_3, and other noxious atmospheric pollutants.

<u>Options to be evaluated which require either new design and construction or major modifications to present facility:</u>

1. Construct a new, larger, and more mechanically reliable Purge Unit using four cells of the standby K-502-3 unit. Subdivide these four 10-stage cells into eight 5-stage cells; retain the 0-size converter shells but retube them with modern T-4 type barrier, equip the high-speed cells with 2-stage centrifugal compressors; install purge controls in the K-29 Area Control Room.

2. Relocate the Purge Unit to a standby size 2 unit, either K-310-3 or K-402-9. Moving to K-310-3 would require less movement of controls and auxiliaries, much of which could be retained in K-311-1 and tied into the new location. Moving to K-402-9, however, would permit completing the shutdown of K-25 and would allow deactivating the K-25 recirculating water system. Also, the unit could be controlled from the K-29 ACR.

3. Replace the partially plugged size 3 high-speed cell converters in K-311-1 with larger size 2 converters from standby units. Indications are the size 2 converters can be fitted into the smaller K-311-1 cell enclosures. However, extensive modifications to the interstage piping will be necessary.

FUTURE TESTS

Future testing should include the following:

1. A test to determine the maximum purging capacity of the Purge Unit in its present condition in order to provide a comparison base for evaluating the effects of subsequent improvements.

2. Installation of automatic proportional response on one or more low-speed cells in order to gain experience on the best way of utilizing this type of stage control.

3. Evaluation of simple pneumatic or electric purge control systems to support or replace the obsolescent AGA.

4. Tests with a 3-in. OD jumper line which would bypass the low-speed cells to permit rapid bleed-off of a sudden flood of light contaminants which would otherwise reduce the compression ratio of the low-speed pumps to near unity and thus seriously impede purging.

5. A test with Rabbit Test Cell pumps to develop a booster for stacking accumulations of Freon-114 in the K-29 Surge Drums.

6. A retest for maximum purge capacity, particularly after treatment of high-speed converters in furnace stands for permeability recovery.

PRESENT PURGING METHODS

The principal contaminants which either leak into or are deliberately introduced to the cascade are nitrogen, oxygen, HF, Freon-114, fluorine, and ClF_3. Considerable details are involved in the present purge system, but the basic flow scheme is as shown in figure 1.

Contaminants are continuously removed, or purged, from the process stream by means of the K-311-1 Purge Unit situated flow-wise immediately atop K-29, but geographically in the K-25 building. The Purge Unit is comprised of four low-speed cells and three high-speed cells, with appropriate feed and tops boosters. One of the low-speed cells and one of the high-speed cells are considered as spare cells since they are not absolutely required to achieve the desired separation of contaminants from the UF_6. The upflow from K-29 is fed into the side of K-311-1 between the second and third low-speed cells. The two low-speed cells and the high-speed cells above this feed point function as enriching cells; the low-speed cells below the feed point function as stripper cells.

The cells in the upper part of the unit utilize high-speed compressors in order to compress and move the very low-density contaminants on to the ejectors which exhaust them to the atmosphere. The barrier of the high-speed cells is of a higher permeability than that employed in the low-speed cells. Low molecular weight gases pass freely through the high-speed cell barrier; heavier gases encounter resistance to passage pretty much in proportion to their molecular weight. As a consequence, UF_6 is rejected to the downflow and returned to the cascade in K-29.

Freon-114 [molecular weight (MW) 171] enters the process stream largely as a contaminant in the Paducah product feed material and from any leaks that may develop in ORGDP gas coolers. ClF_3 (MW 93) is bled to the cascade as the aftermath of cell unplugging operations.

All of the above contaminants progress up the cascade and eventually reach the K-311-1 Purge Unit. The fluorine is light enough to pass through the high-speed barrier and exhausts to the atmosphere along with the air and nitrogen. The Freon-114 and ClF_3, however, are too high in molecular weight. As a consequence, these contaminants tend to accumulate in the

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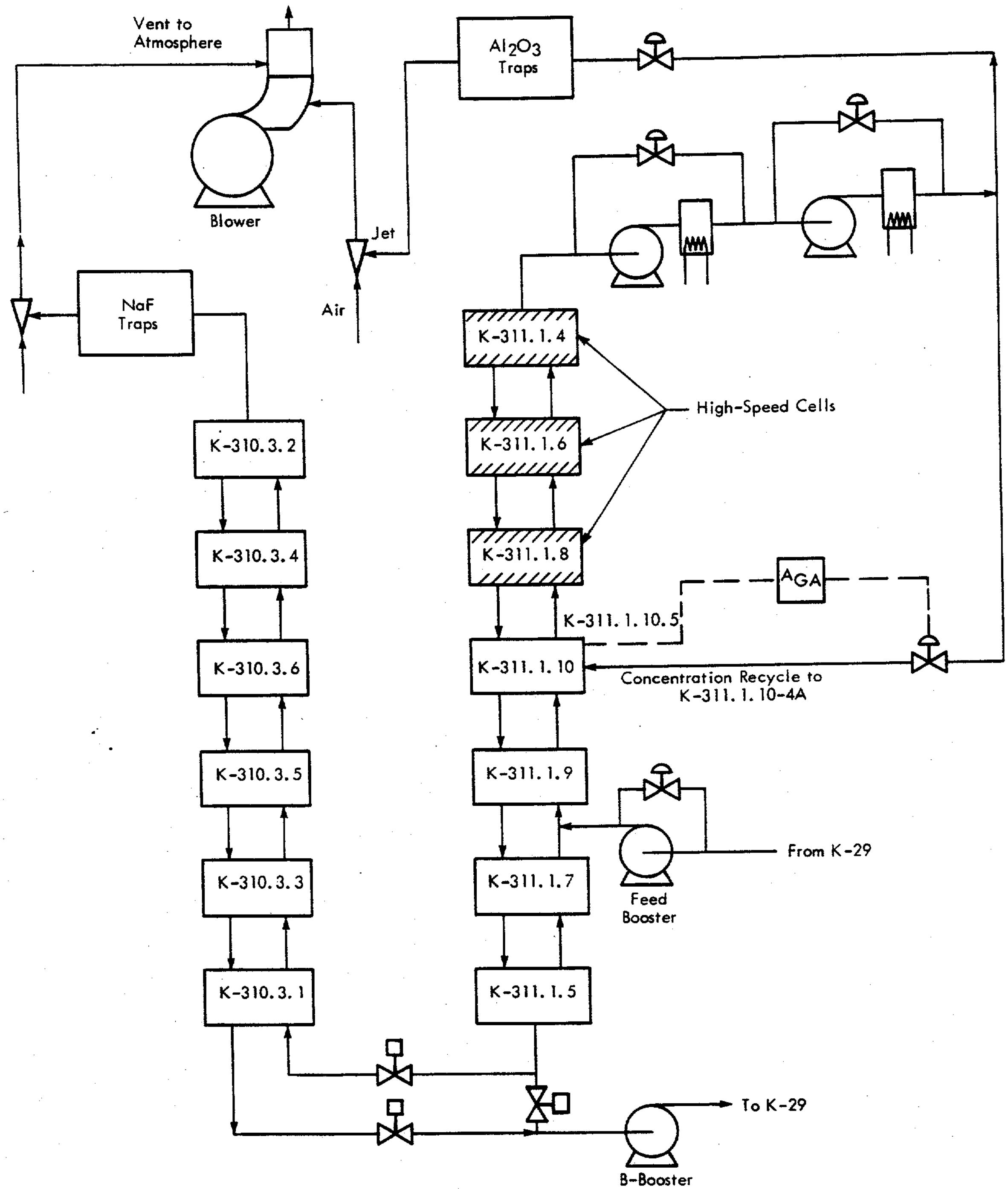

Figure 1

PRESENT PURGE ARRANGEMENT

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low-speed cells. If allowed to accumulate, a hazardous condition will develop since concentrations of 3.5 mol % Freon-114 and 8.0 mol % ClF_3 (or fluorine) are potentially explosive. Dangerous accumulations can build up rapidly in K-311-1 inasmuch as the cells in this unit are but one-fifteenth the size of the cells in K-29. Because of the combined effects of low operating pressure and small volume, the actual quantity of process gas in a Purge Unit cell is quite small. Surprisingly small amounts of Freon-114 and ClF_3 can reach dangerous proportions rather quickly. In actuality, at the low-speed cell 9 where these intermediate molecular weight contaminants reach their peak concentrations, the presence of only 1.25 lb of Freon-114 and 1.50 lb of ClF_3 is all that is required to attain the potentially explosive 3.5:8.0 ratio of volume concentrations.

To maintain safe levels of these contaminants in K-311-1, a side stream of process gas is periodically led from the Freon-114/ClF_3 peak point in K-311-1 to the isolated K-310-3 unit. The Freon-114 and residual ClF_3 constituents distribute themselves in the upper cells of K-310-3. Their removal is accomplished by evacuating a stream from the top cell of this unit through a NaF trapping system. The traps adsorb and retain any UF_6. Lights, Freon-114, and residual ClF_3 proceed to the jet exhauster on the Purge Unit vent stack for disposal to the atmosphere. Any excess of UF_6 at the bottom of K-310-3 is bled back to the cascade. UF_6 adsorbed in the NaF traps is later desorbed by heating the traps and returning the material to K-311-1 low-speed cells.

Expenditure for electrical power to operate K-310-3 for this purpose amounts to approximately $95,000 per year. Since there is no isotopic separation benefit from the cells in this unit, one of the objectives of the recent test program has been to see if Freon-114 and ClF_3 could be disposed of without K-310-3 in the hope this unit could be shut down. This would make 17,700 Mwhr/yr of power available for increased production in the lower units of the cascade.

CONTROL OF THE K-311-1 PURGE UNIT

The process control instrumentation is designed to automatically control the Purge Unit at purge rates up to about 24,000 scfd, which is the normal total upflow out of the top high-speed cell. Approximately 17,000 scfd is recycled back to maintain a 90% lights concentration between the high- and low-speed cells. This is accomplished by an AGA which provides a continuous measurement, at constant temperature, of the average molecular weight and specific heat ratio of the light contaminant/UF_6 gas mixture as sampled from stage 5 of cell 10.

The pneumatic output of the AGA system operates a control valve in the *concentration recycle* header to recycle sufficient flow to maintain the concentration at the desired level at the control point (stage 4 of cell 10). Thus, the AGA has first call on the total lights upflow stream and takes whatever is needed to maintain control. With proper instrumentation set up across the total flow orifice to maintain a 24,000-scfd constant flow, the remaining 7000-scfd portion of the total upflow is routed to the atmospheric vent stack by the output of the DBM across the total flow orifice driving open the *normal* purge control valve. To purge slugs of light contaminants which exceed the limit of the automatic control, it is necessary to open a control valve on the *emergency purge* system by manually loading air onto the diaphragm of the control valve.

PERFORMANCE OF THE K-311-1 PURGE CASCADE

Performance of the K-311-1 system with the normal flow arrangement, figure 1, has been examined and the results are shown in figure 2. The concentration gradients were determined with gas samples taken on each stage of the system and analyzed in the laboratory.

The K-311-1 performance study indicates that the separative capacity of K-311-1 system is too large to purge the intermediate molecular weight contaminants at the normal purge rate of 7000 scfd; however, the capacity cannot be reduced by eliminating stages below that capacity required to handle abnormally high purge rates. One approach to this problem is a variable capacity system, e.g., operate at reduced pressures normally and increase the pressures to increase capacity when needed. This can be done by installing *automatic proportional response* on the low-speed cells. With such an arrangement, as a slug of light contaminants moved into the Purge Unit, the instrumentation of the low-speed cells would respond by automatically raising cell pressures as the lights increased. This type of setup was a good feature in the control of the old K-304-5 Side Purge Unit.

REMOVAL OF INTERMEDIATE WEIGHT CONTAMINANTS

The work group has devised several methods and conducted tests toward removing the intermediate weight contaminants from the cascade without the use of the K-310-3 unit. Tests to date indicate that ClF_3 can be purged through the high-speed cells by a sweeping technique utilizing a high bleed of air. Adequate purging of Freon-114, however, has not been achieved without recourse to the NaF sorption traps.

As discussed in the preceding section under *Present Purging Methods* and as depicted in figure 1, the normal valving setup for K-311-1 introduces the feed, or cascade lights upflow, into the side of the Purge Unit between the stripper section and the enriching section.

Prior to testing, the K-311-1 unit was revalved from a side purge configuration consisting of stripper cells and enriching cells to a true tops purge operation consisting only of enriching cells, as shown in figure 3. This was beneficial since it permitted reducing the low-speed cell pressures by approximately 50%. In addition, the two stripper cells became superfluous to tops purge operation and therefore could be considered as spare cells. As such, these two cells were then available for subsequent tests directed towards disposing of ClF_3 and Freon-114 entirely from within K-311-1 rather than from K-310-3. Subsequently, low-speed

Figure 2
PRESENT PURGE ARRANGEMENT
Cells 5 and 7 Are Strippers

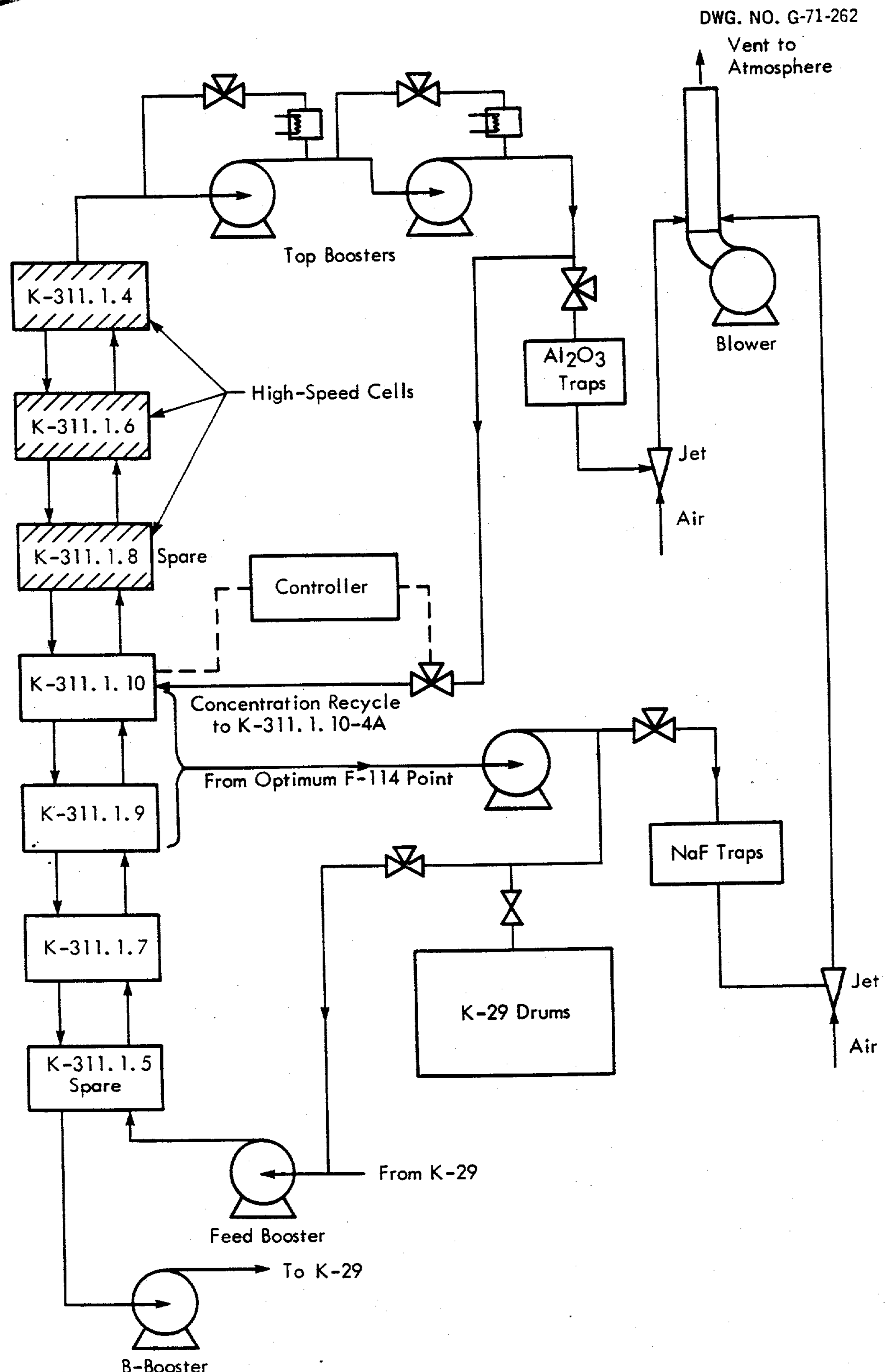

Figure 3

MODIFICATIONS TO PURGE FACILITY

cell 5 and high-speed cell 8 were shut down and bypassed because, at the current purge rate of 7000 scfd, they were not needed. New pressure tapers were set up and samples taken in order to determine the concentration gradients throughout the revised system as shown in figure 4. The top cell 4 was not sampled because sample lines were not available. Figure 4 shows that Freon-114 tends to *bundle up* while ClF_3 is apparently spread out.

An interesting sideline to the testing was noted when monthly power costs were compared throughout the duration of the tests. Figure 5 depicts the variations which occurred. A breakdown of the purge cascade power cost is not available; therefore, the power costs which are shown include the entire K-25 building. Except for possible seasonal changes, it is reasonable to assume that the remaining units within the K-25 building consume a constant amount of power each month. A major portion of the changes which occurred from month to month on figure 5 can be credited to the comments depicted on the figure. Expenditure for electrical power to operate K-310-3 amounts to approximately $95,000 per year. If K-310-3 can be shut down, the electrical power would then be available for increased production in the lower units of the cascade.

Also, it was demonstrated that the two series-operated top high-speed booster pumps were not required for normal operation. With the top boosters bypassed, a purge rate of 40,000 scfd could be maintained with no difficulty. Purging large slugs, however, would require use of the boosters.

Prior to this test work, the customary method for disposing of ClF_3 and Freon-114 has been to transfer the accumulations, along with some UF_6, into the adjacent K-310-3 unit. The objective in so doing was to *clear the tracks* of Freon-114 in K-311-1.

Tests were conducted to dispose of ClF_3 and Freon-114 within the K-311-1 Purge Unit itself so that K-310-3 could be shut down. To this end, several new approaches were tried.

Initially, the top low-speed cell pressures were raised and the AGA resonator shortened to increase the density of the process stream entering the high-speed cells. While this was successful in moving some ClF_3 and Freon-114 into the high-speed stages, these materials were ultimately rejected into the UF_6 downflow by the high-speed cell barrier.

Next, an *end run* approach was resorted to. From the peak point of concentration at cell 9, a side stream was fed into the suction of the 4A pump on the top high-speed cell. With this setup, only two stages of high-speed barrier had to be negotiated in order to reach the jet exhausters. Again, however, the high-speed barrier prevailed. Bulb samples showed no really significant concentrations of either ClF_3 or Freon-114 in the exit purge gas stream. Changing the connection to the 6B suction did little to improve results. Undoubtedly, the partially

[redacted]

Figure 4
TOP PURGE ARRANGEMENT
Feed Point at Bottom of Cell 7

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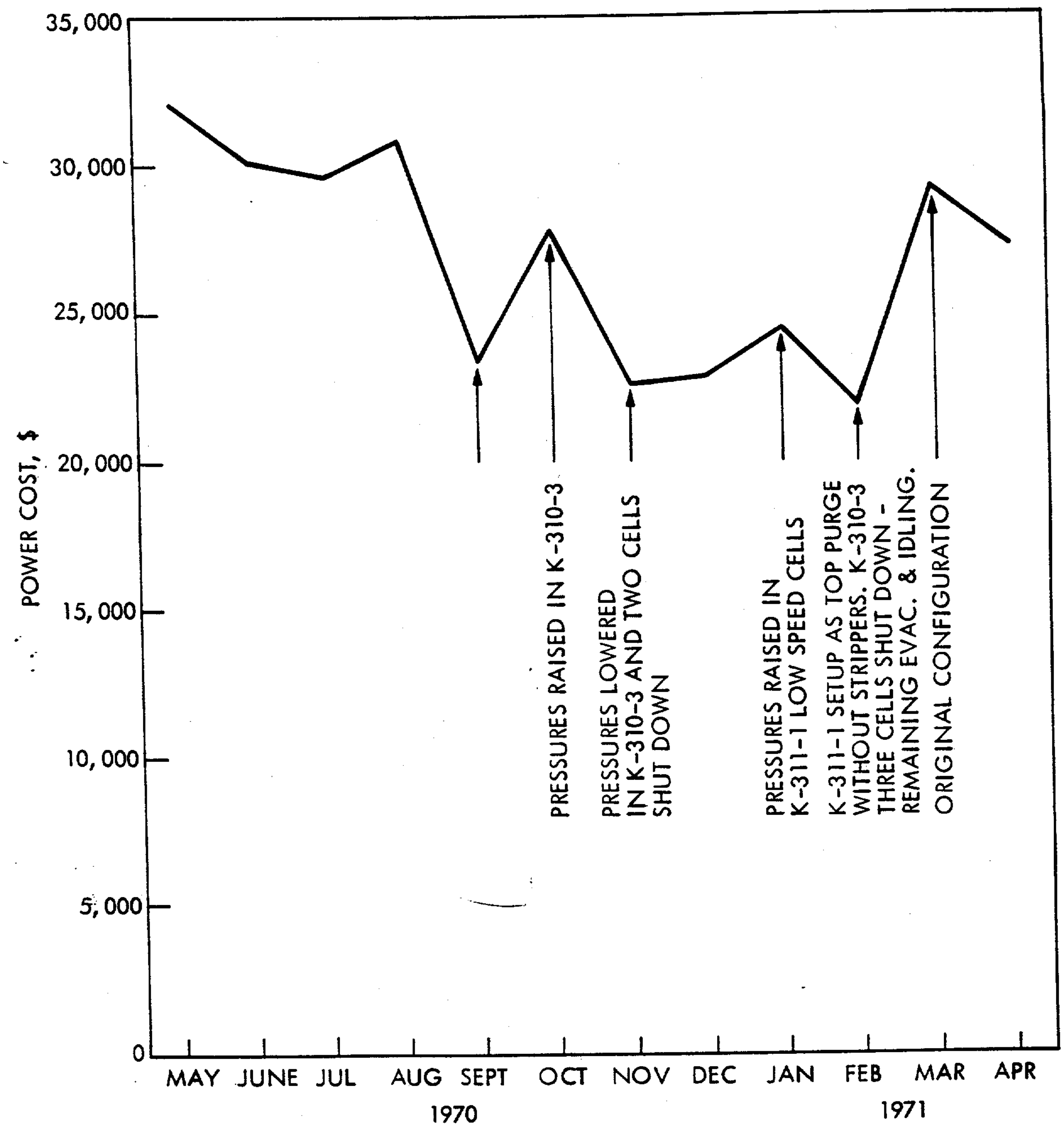

Figure 5

POWER USAGE IN THE K-25 BUILDING
INCLUDING THE PURGE CASCADE
$5.37/Mwhr

~~CONFIDENTIAL~~

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open direct recycle control valve on this cell was effective in negating the test. Since there is no B-downflow entering the top cell, the recycle valve must be open to keep the 6B pump from surging. Also, closing the valve will cause the high-speed cells to evacuate.

A different approach to the disposal problem involved introducing a 60,000-scfd bleed of diluent air or nitrogen into the system below cell 9 to sweep the ClF_3/Freon-114 concentrations through the high-speed cells. This technique proved to be very effective in getting rid of the ClF_3 but was not successful in moving the heavier Freon-114. One drawback to bleeding the diluent gas in at this point is that diluting the UF_6 process stream with lights causes a reduction in the compression ratio across the low-speed pumps. The sweeping procedure was therefore modified to leading a side stream from the top low-speed cell into the top high-speed cell, while at the same time, introducing the 60,000 scfd of diluent air at the top of cell 10. Within a several-hour period, ClF_3 concentrations of 8% and greater were reduced to an innocuous level.

Up to this point, testing had demonstrated that Freon-114 could not be moved through the high-speed cell barrier. Since K-311-1 was not equipped with a Freon-114 degrader, the only available and proven disposal system for Freon-114 was the NaF trapping facility. Rather than feed into the traps from K-310-3, however, the spare low-speed cell 5 in K-311-1 was set up as a small cascade within the Purge Unit. A side stream rich in Freon-114 was fed from the K-311-1 Freon-114 peak into the 1B pump suction, with UF_6 returning to the cascade via stage 1 CV. Sufficient separation of UF_6 and lights was achieved across the six stages of this cell so that the gas stream leaving stage 6 could be fed into the NaF traps without overloading the sorption traps with UF_6.

Since contaminant concentrations are subject to wide variations in K-311-1, it is difficult to quote or tabulate firm data on the gas composition entering and leaving cell 5. Some average values, however, serve to illustrate the performance of the six stages. Typically, the Freon-114/UF_6/lights ratio of the stream entering the cell was 10/40/50, and 3.5/6.5/90 upon leaving the top of the cell and before entering the NaF traps. To avoid premature loading of the traps, the UF_6 concentration entering the traps should not exceed 10%; employment of cell 5 as a small cascade was effective in maintaining the UF_6 below this level. In addition, raising the stage 6 high-side pressure provided the added benefit of a higher inlet pressure to improve the flow rate into the traps.

Bulb sampling of the outlet gas stream from the NaF traps produced some disconcerting results. The UF_6 concentrations ranged from several ppm to, at times, several thousand ppm. This erratic performance of the NaF traps prompted the dumping of the traps and refilling with fresh pellets. Extreme difficulty was experienced in removing the used pellets; their removal was finally effected by a combination of rodding and chiseling of the largely fused beds of pellets. The performance of the traps improved for a time with the change of pellets, but again fell off, apparently caused by inleakage of wet air past a failed bottom flange gasket. The pellets were again changed and the flanges welded closed to give a positive airtight closure. This seemed to alleviate the problem.

With cell 5 employed in the preceding manner, and assuming an inlet Freon-114 concentration of 3 to 4%, the Freon-114 disposal rate averaged 15 to 20 lb/day. This was comparable with Freon-114 disposal via K-310-3 but did not permit shutdown of K-310-3, because what was needed was some means of rapidly removing Freon-114 accumulations from K-311-1 in order to let safely pass upcoming slugs of fluorine and ClF_3.

Consideration was given at this time to making a rapid dump of Freon-114 rich inventory from K-311-1 into the K-29 Surge Drums and later evacuating the drums via the NaF traps. However, the operating pressure of cell 9 was too low to permit transfer of much inventory without a booster pump. A brief test was conducted using the top high-speed boosters to pump from cell 10 into the drums, but the test had to be terminated because of a coolant leak in the recycle cooler of the north booster. To date, further tests have not been conducted. The basic concept of utilizing the drums for temporary storage still appears to have merit, nevertheless, and would seem to be worth pursuing further when testing is resumed. However, because of the sensitivity of the high-speed boosters to UF_6, it might be worthwhile to investigate using two of the size 12 pumps of the Rabbit Test Cell in series for boosting the flow to the drums.

Finally, some discussion seems appropriate of the circumstances under which these tests were conducted. The very act of establishing and maintaining test conditions long enough to gain meaningful data was in itself a major problem in K-311-1. Since there is only one Purge Unit, any testing had to be subordinated to the exigencies of the cascade. Typically, large slugs of light contaminants or high levels of ClF_3 or Freon-114 often made it necessary to upset or undo a testing situation in order to take immediate action to dispose of these contaminants. Interruptions also resulted from the necessity to replace failed seals, impellers, speed increasers, or motors. Finally, because of the inherent lag between sampling and reporting of results, it was difficult to obtain an up-to-the-minute evaluation of the progress or outcome of a particular test. The gas chromatograph was useful in filling the void on sampling stages but was not adaptable to monitoring the exit gas streams from the NaF traps and alumina traps, analyses of which generally constituted the verification of the success or failure of a test.

EQUIPMENT-RELATED PROBLEMS

Many of the difficulties experienced in maintaining effective operation of the Purge Unit are traceable to the deteriorated condition of the operating equipment. Sixteen years of around-the-clock operation have resulted in considerable wear and tear. The effects have been sharply rising maintenance costs and significant reduction in the operational reliability and overall performance of the unit. Shown on the next page is a breakdown of equipment failures in K-311-1 during FY 1969, FY 1970, and for the first 9 months of FY 1971 (table 1).

Table 1

K-311-1 EQUIPMENT FAILURES

	Seals	Compressors	Motors	Speed Increasers
FY 1969	45	8	1	2
FY 1970	60	8	3	2
FY 1971*	75	13	5	4

*FY 1971 for first 9 months only.

Fifty-four of the 75 seal failures which have occurred during FY 1971 have been on the three high-speed cells. This means that 72% of the seal failures have occurred on less than 43% of the equipment. Also, it should be pointed out that pressure changes were necessary in the low-speed cells during several of the tests which were conducted, but the high-speed cell pressures were unchanged during these tests. Therefore, it seems reasonable to assume that the increased equipment failure rate was not a function of testing conditions, at least where the high-speed equipment was involved.

The increased number of equipment failures each year naturally results in additional maintenance cost each year. Figure 6 depicts the history of maintenance labor and material costs along with total gross cost from FY 1965 through the first 9 months of FY 1971. As can be seen, it would be difficult to predict maintenance labor and material costs from year to year since costs fluctuate widely.

With the present low level of activity in the cascade, the normal purge rate is correspondingly low, and purging requirements impose little strain on K-311-1. However, the situation will change when power is restored to the 1600-Mw level. With a return to the normal purge rates, 20,000 scfd and slugs of the magnitude experienced prior to the 1964 power reduction, the Purge Unit in its present condition will be severely taxed to fulfill adequately its job of purging the cascade of light contaminants. Slugs of the pre-1964 period were often in the range of 150,000 to 200,000 scfd, and there is serious doubt that K-311-1 will be able to dispose of them rapidly enough to avoid lights backing into the axial compressor cells. Such occurrences would result in shifts of inventory, interruptions to withdrawal of product, and expose the axial compressors to surge.

[redacted]

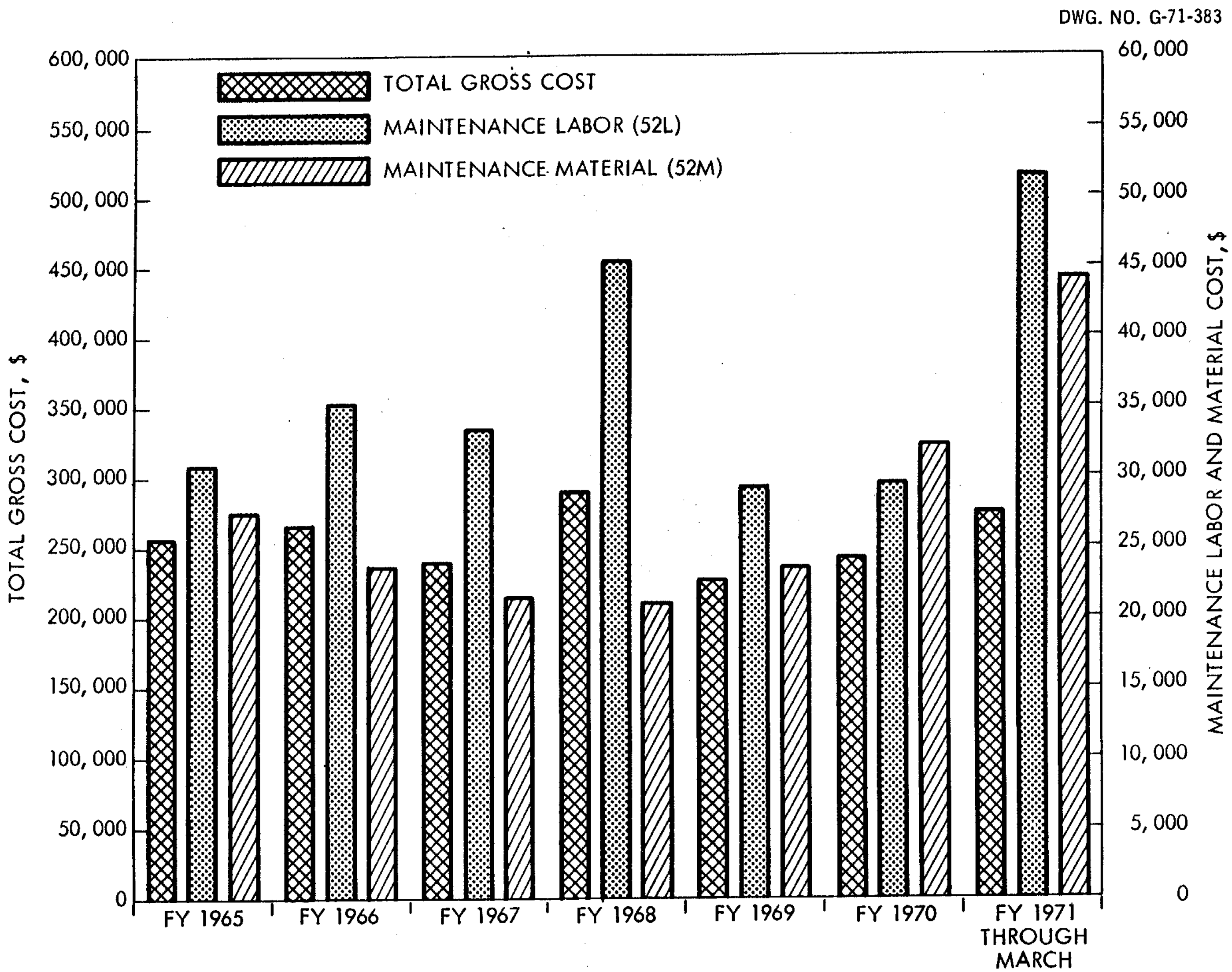

Figure 6
PURGE CASCADE COST

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HIGH-SPEED CELL CONVERTERS

The condition which most adversely affects the operation of the Purge Unit is the degree of barrier plugging prevalent in the high-speed cells.

Plugging has resulted principally from wet air leaks within the unit itself. Leakage sources have been recurring seal failures and cracked expansion flanges. In earlier days, massive quantities of wet air were introduced when pump casings were ruptured by fragmenting high-speed impellers of the pinned Monel-hub type.

Overall, the high-speed barrier situation is critical. There is no supply of tubes available for retubing fresh converters, and the Barrier Plant is no longer tooled to produce tubes of the required diameter and length. The half dozen spare converters on hand have all been in use at one time or other, and their barrier is in little better condition than the barrier in the installed stages.

HIGH-SPEED IMPELLERS

The high-speed aluminum impellers are a prime source of concern. At the time of installation, it was anticipated that these impellers would have a useful life expectancy of approximately 15 years. By the end of this period, it was felt that prolonged operation at elevated temperatures would ultimately cause a gradual reduction in metal hardness with onsetting creep. Development of excessive creep would expose the impellers to abrupt in-service failure with attendant extensive damage to other equipment such as pump casings, shafts, and speed increasers.

The expected 15-year life of these impellers has now been realized. Since it is not feasible to remove all of the impellers for inspection and metallurgical examination, no meaningful judgment can be made of their continued serviceability. However, hardness tests have been made on many impellers that have been removed from service for one reason or other. A definite trend in the direction of reduced hardness has been noted. Recently, with no prior indication of trouble, one of these impellers abruptly failed in service causing extensive damage to other equipment. Subsequent hardness measurements on sections of the failed impeller disclosed a considerable reduction in metal strength.

There is a strong possibility that plugged barrier can adversely affect the high-speed impellers. The effect of reduced permeability would be to shift the operating point of the compressors into the surge region. Within less than a year after start-up in 1954, this matter was of sufficient concern to prompt an investigation. Oscillograph photographs of the stage motor currents and voltages disclosed that all of the high-speed A compressors were operating either in or near surge, whereas the high-speed B compressors were either in the stable or near surge region. More recent measurements with a clip-on ammeter revealed that the situation has worsened to the point where all of the A pumps and a large number of the B pumps are operating in surge. The fluctuating or swinging motor currents of a pump in surge translate into severe cyclic stresses which could cause metal fatigue in the aluminum impellers. Surging would also cause a rise in operating temperature which could weaken the impellers by reducing metal hardness.

While there is no way of accurately measuring the extent to which these forces have affected the high-speed impellers, it may very well be that some impellers are nearing the point of sudden failure. At any rate, after more than 15 years of continuous service, it would seem that full value has been obtained from them. It would appear unwise to depend on these impellers for the heavy purging anticipated when power is restored.

CONTROL INSTRUMENTATION

The AGA controls the Purge Unit automatically by recycling a flow of light contaminants back to the control point. Essentially, this instrument provides a continuous measurement of the density of the process gas at the control point. A full range of calibration curves permit translating the signal into percentages of lights and UF_6.

While the AGA is very sensitive and reacts quickly to maintain the lights concentration at the desired level, the instrument is not without its drawbacks.

The two AGA's in K-311-1 are at the point of obsolescence. They have been in continuous service for 16 years in the Purge Unit, and were in use for some unknown period previously at Paducah. They are very complex electronic instruments and can be effectively maintained or repaired only by instrument mechanics who are well versed in them. In addition, spare parts for such old instruments are difficult to obtain.

Based on the above, it would appear advisable to consider other control systems. Apart from the major requirement that any new control system must first be able to control properly, the system should also be simple in makeup and of modern design. This would simplify repair problems and parts replacements.

Although no survey has been made of various control systems that might be substituted for the AGA, the system currently in use at Portsmouth looks attractive. Basically, the Portsmouth control incorporates a DBM/PBC combination to sense variations in compression ratio across a stage pump at the control point and uses the pneumatic output of the combination to drive a control valve. The arrangement, which apparently works well for Portsmouth, is a simple pneumatic rather than electronic system, and is comprised of modern type transmitters and controllers representative of current instrument technology.

The only shortcoming such a system would appear to have is that it would not provide a measurement of the lights and UF_6 concentration as does the AGA. Nevertheless, the pneumatic system appears attractive and very possibly some sort of calibration could be developed which would be translatable into actual concentrations of lights and UF_6. While it should be possible to learn to operate the Purge Unit without a continuous measurement and recording of the process gas composition, such information would be helpful, and development of a special calibration would seem worthwhile.

RECOMMENDATIONS

With current cascade operation at reduced power levels, the light contaminant upflow is but approximately 7000 scfd with occasional slugs in the 30,000- to 60,000-scfd range. These are modest purging requirements and are well within the capacity limits of the Purge Unit in its present condition. However, upon restoration of power to the 1600-Mw level, the purge rate should return to about 20,000 scfd, with slugs increasing the total rate at times to approximately 200,000 scfd. Primarily because of the present condition of the barrier in the high-speed cells, the Purge Unit would experience difficulty in disposing of such an increased level of light contaminants. It would seem timely, therefore, that consideration now be given to measures which will ensure that adequate purging capacity will be available when power is restored to the pre-1964 level.

As a result of tests conducted thus far, a number of recommendations are possible. These recommendations are divided into two categories. The first is comprised of items which can be acted on now for the improvement of the existing Purge Unit. The second is broader in concept and involves options for major design modifications to existing facilities, or completely new design and construction. Some of the recommendations in the first category, however, would also be applicable in the second.

Recommendations which could be acted on now, or in the near future, are as follows:

1. For Tops Purge operation and assuming that some modification can be made, the continued operation of cells 7 and 5 at high pressure for stripping purposes appears difficult to justify. At normal purge rates, operation without benefit of stripper cells does not seriously interfere with the withdrawal of top product. On the other hand, while some benefit may accrue to the use of these cells for stripping during purging of large slugs of light contaminants, the incidence of such slugs during a given 24-hour period is low. Meanwhile, during normal purging over the major portion of this 24-hour interval, considerable power is expended on the high-pressure stripper cells with little commensurate gain in lights separation being obtained.

   Two measures are recommended which would result in significant savings on power and would still serve to minimize backup of lights, or spillover, into the cascade immediately below the Purge Unit. First, dispense with stripper cells by changing the feed of lights upflow from side feed between cells 9 and 7 to the A-inlet at the bottom of the unit as shown in figure 3. Shut down cell 5 as a spare low-speed cell, reduce cell 7 stage pressures and convert it to enriching service. Secondly, install *automatic proportional response* on the stage control of the low-speed cells in order to minimize backup of lights during purging of large slugs. With the transmitter response keyed to changes in the differential pressure developed across the 1B stage pump, upflow of a slug of lights into a cell would cause the stage control valves to move in a closing direction in order to automatically raise the high-side pressure on each stage. The effect of the pressure increase would be to raise the density of the diluted process gas stream so that the low-speed compressors could regain the compression needed for maintaining lights upflow into the high-speed cells. This change would cost an estimated $3000 and should reduce operating costs by $45,000 per year.

2. When purging a slug of fluorine or ClF_3, the present practice is to bypass the alumina traps in order to avoid fluorination of the activated alumina and accompanying high temperature in the traps. While this protects the alumina, it allows venting of undesired quantities of UF_6 to the atmosphere. One possible way of avoiding this discharge of pollutants would be to charge two of the six banks of traps with NaF pellets and reserve these traps for service during purging of fluorine and ClF_3 slugs. However, in order to avoid HF accumulations which would impair the adsorption of the NaF pellets, it would be necessary to enclose the two banks of traps in a heated housing with the temperature controlled at 250°F. Based on the experience with this type of system as employed in the old K-312-1 Tops Purge Unit, the NaF pellets should last for several months before requiring dumping and recharging with fresh pellets. This change would cost an estimated $2500.

[redacted]

3. Shutting down the K-310-3 unit is not feasible until arrangements are made for an alternate system of comparable volume for temporary storage of Freon-114/UF_6 gases. The stored gases would be subsequently bled back into the cascade at a regulated rate and removed from K-311-1 via the NaF traps. Or, if the UF_6 concentration was below the 10 mol % maximum for admission to the NaF traps, the gases could be evacuated directly through the traps. In order to provide such a large storage volume, economically maintained, consideration should be given to the use of the K-29 Surge Drums. Additional volume, if desired, could be obtained by appropriating some of the surge drums from the shutdown K-25 units. To make effective use of surge drums, however, a high-compression booster pump would be needed in order to stack large volumes of gas in the drums. Since the gas to be pumped would be of an intermediate density, possibly two pumps in series would be required to obtain the needed overall compression ratio. The standby Rabbit Test Cell, built on the site of the abandoned cell 2 in K-311-1, would be an ideal location for establishing such a booster station. Stage motor power is already connected up and, if needed, a recirculating coolant system is existing. It would be relatively simple to tie two of the existing test cell stage pumps (high-speed size 12's) in series and connect the booster system into the Purge Unit process piping directly overhead. Other types of pumps could be tested in these same pump positions if the existing Rabbit pumps proved unsuited to the application. It is estimated that it would cost $2000 to make this test, which could lead to a $95,000 annual savings.

4. It would appear that any equipment or process that has the capability of facilitating the disposal of Freon-114 would be worth serious consideration as a Purge Unit adjunct. On this basis, an evaluation should be made of the applicability of a Freon-114 degrader to assist in disposing of this intermediate weight contaminant. While there have been conflicting reports on the performance of the degrader at the Portsmouth plant, the process is inherently an effective one. With proper choice of material and special attention to fabrication details, it would appear that a serviceable unit could be constructed at reasonable cost, using the latest Portsmouth design. It is estimated that this would cost $50,000, which amount has been included in the FY 1972 Equipment Budget.

5. Enlargement of the NaF trapping facility for Freon-114 disposal is suggested. The capacity of the existing system is barely adequate for disposing of the Freon-114 upflow which enters the cascade along with the Paducah product feed material. When a sizeable leak develops in an ORGDP cascade gas cooler, the amount of Freon-114 which subsequently accumulates in K-311-1 and K-310-3 usually requires about a week to be disposed of via the NaF traps. The capacity of the present system could be doubled by fabricating an additional annular-type trap and putting it in service along with the two annular traps recently removed from the abandoned K-1131 feed cylinder *burping* facility. The cost for this improvement is estimated to be $15,000.

6. As mentioned earlier, there are indications that the existing high-speed impellers are in a dangerously weakened condition, and replacement with new impellers would seem to be in order. The sudden disintegration of an impeller not only represents the loss of a valuable impeller, but produces a mechanical impact which causes extensive damage to other stage components such as pump casing, impeller shaft, expansion flanges, converter shell, stage control valve, and sometimes even the cast pump frame itself. Delivery on new impellers, however, would be approximately 1 year. In lieu of new impellers, or at least as a temporary expedient, there is the alternative of removing the present impellers from service and reheat treating to restore the aluminum alloy to, or near, its original hardness. Metallurgical Services has already demonstrated on samples removed from a softened failed impeller that the hardness can be restored successfully. Total cost for removing, reheat treating, and reinstalling the impellers is estimated to be $30,000.

7. By reducing the operating speed of the high-speed compressors approximately 20%, it should be possible to extend the service life of the aluminum impellers by lowering internal stresses. This would also reduce pump vibration and would likely have a salutary effect on the seal failure rate. Changeout of the speed increaser gears would be required to reduce the operating speed of the high-speed compressors. New gears would cost approximately $85,000.

8. Since permeability reductions in the high-speed barrier have such a deleterious effect on the performance of the Purge Unit, a major effort should be made to recover as much of the original permeability as possible. Specifically, a program should be started to rotate all of the high-speed converters through the Furnace Area.

This program would also provide quantitative data on the actual barrier permeability for each converter returned to K-311-1. This treatment is estimated to cost $16,000.

9. As detailed in the section on *Control Instrumentation*, consideration should be given to a less complex and more modern type of automatic control system to replace the obsolescent AGA. The control system now in use at Portsmouth looks attractive. In essence, the system consists of a simple DBM/PBC combination sensing variations in compression ratio across a stage pump at the control point, the output of the combination being used to drive a control valve in the concentration recycle header. To install such a control system would cost approximately $1000. Also worth considering is an Ammeter Controller as used on the old K-312-1 Tops Purge Unit. Instead of controlling off the total cell motor load, however, improved sensitivity would be obtained if the instrument was connected to a single stage pump motor, preferably a stage or two below the recycle control point. A control system of this type is estimated to cost $1500.

10. Finally, in order to conform with environmental antipollution requirements, a scrubber system should be designed and installed to remove fluorine, ClF_3, and other noxious substances in the purge gas stream prior to venting to atmosphere. The installed cost for a suitable scrubber is estimated to be $25,000.

The following recommendations are aimed at ensuring greater purging capacity and increased operational reliability, and involve major design modifications or completely new design and construction. While each recommendation has merit, each is not without some shortcomings. A detailed evaluation and comparison study would be required in order to make a judicious assessment of the relative worth of each approach:

1. Design and Construct a New Purge Unit

One alternative would be to construct a new Purge Unit of modern design and increased capacity in K-29, specifically on the site of the shutdown K-502-3 unit. Controls would be installed in the K-29 Area Control Room to minimize operator coverage. To the extent feasible, operating equipment and piping of the shutdown unit would be incorporated into the new design, but not all of the cells of the unit would be required for making a new Purge Unit. On the surface, it would appear that only the top four cells would be required, thus leaving six cells for possible use as add-on stages under the CIP. For purging purposes, however, the mechanical difficulties which have been experienced over the years with the present K-311-1 Purge Unit make it appear wise to split these four 10-stage K-29 cells in half, thus making eight 5-stage purge cells. With this arrangement, shutting a cell down for repairs would take only five stages instead of ten out of service and would reduce the effect of cell shutdown on purging capacity. Splitting 10-stage cells in half, however, would require additional motor-operated cell block valves, cell bypass lines and valves, plus Freon-114 condensers for four of the new 5-stage cells.

Of the eight 5-stage cells thus formed, four would be high speed and four would be low speed. Normally, three high-speed cells and three low-speed cells would be in operation, with one high-speed cell and one low-speed cell maintained in standby as spares. The high-speed cells would probably be equipped with 2-stage centrifugal rather than axial compressors since present axial compressors are not well suited to pumping light contaminants. Further, the new high-speed compressors would be of improved design and capacity over the existing K-311-1 units. As with the present high-speed cells, interstage coolers would be required on the discharge of each A compressor to avoid overheating the next upstream B compressor. To simplify alignment problems, the K-311-1 concept of a separate speed increaser unit mounted between pump and motor would be supplanted by motors equipped with integrally mounted gear boxes on the drive end. Retaining the existing 0-size converter shells would greatly minimize modifications to the interstage piping. There would be the added benefit that with purge cells of large volume, accumulations of Freon-114 and ClF_3 would not rise to hazardous concentration levels as rapidly as they presently do in the very small cells in K-311-1. The existing tube bundles are 9 ft long and are made up of LD (0.6-in.) barrier tubes. Since these bundles contain more surface area than required for purging applications, plugging of some of the tubes would be necessary. The Barrier Plant, however, no longer can make LD tubes. In constructing a new and modern type of Purge Unit, it would seem wise to utilize barrier of a type now being manufactured.

Finally, to permit off-stream ClF_3 treatments, the high-speed cells would be equipped with inverse recycle lines.

In summary, establishing the Purge Unit in K-29 would accomplish the following:

a. Permit shutdown of the K-311-1 and K-310-3 units.

b. Eliminate the operator coverage for these two units.

c. Allow taking the K-25 recirculating water system out of service.

d. Eliminate the K-25/K-29 tie line booster pumps (three boosters on the A upflow and one booster on the B downflow).

e. Provide the cascade with a modern purge unit of improved design and increased capacity.

2. <u>Relocating the Purge Unit to a Size 2 Unit Location</u>

Another alternative to consider is relocating the Purge Unit to a standby size 2 unit. This would avoid the problems associated with trying to squeeze size 2 converters into a size 3 cell. Other problems, however, would present themselves. For example, to convert a standard type of size 2 centrifugal cell into a high-speed type would necessitate replacement of the compressors with high-speed types. This would involve changing casings as well as pumps. Also, since the speed increasers occupy the space on the high-speed pumps normally occupied by the motors, special concrete bases would have to be poured for the motors. The 3-in.-OD nickel-lined concentration recycle line would need to be transferred from the K-311-1 unit or new pipe installed. Interstage coolers for cooling the discharge of the A compressors would have to be mounted above the high-speed cells and connected into the cell piping. This would in turn require, as in the case of the present K-311-1 unit, an additional coolant pump and coolant cooler on each high-speed cell to serve these added interstage coolers. The AGA sensing elements and sampling manifold also would have to be moved and relocated near the new control point.

Whether other things would be affected, however, would depend on the actual size 2 unit site selected. If K-310-3 were chosen, for instance, there would be no need to physically move the graphic panel and AGA control systems, the space recorder cubicles and sampling manifolds, the gas chromatographs, the NaF trapping system, the high-speed tops boosters, metering station, jet exhausters, or alumina traps. All of these are close enough to K-310-3 so that they could be retained in place and easily tied into the new purge unit location. Also, the cell block valves and bypass valves are all presently motorized.

If K-402-9 were selected as the new site, all of the above would need to be relocated, including the added interstage A pump coolers for the high-speed cells. Also to be considered is that the cells in this unit have been converted to two-stage Badger cluster configurations and, as such, are missing three B stage compressors, three stage control valves, and the cell inverse recycle lines. If this configuration is adaptable to purging operations, fewer high-speed compressors would be needed. If not adaptable, the missing control valves and compressors would have to be replaced and extensive revisions made to the cell interstage piping. Also, motorizing of the cell block and bypass valves would be required. On the other hand, utilization of K-402-9 would permit transferral of operations from the K-25 plant and would allow deactivating the recirculating water loop now serving the K-311-1 and K-310-3 units. The proximity of the K-402-9 unit to K-29 would permit installing the purge controls in the K-29 ACR so that only minimal operator coverage would be required for the Purge Unit.

3. <u>Installing Size 2 Converters in the High-Speed Cell</u>

An approach to consider for coping with the critical barrier situation in the high-speed cells would be to replace the partially plugged size 3 converters with larger size 2 converters from one of the standby K-27 or K-25 units.

There is the problem, however, of fitting the larger size 2 converters in the high-speed cell enclosures. A cursory check indicates that the larger converter shells (about 3 ft longer and 1½ ft greater diameter than size 3 shells) can likely be accommodated. However, considerable modification of the interstage piping will be necessary. Also, the converter supports will require altering to lower the centerline of the converters to the centerline of the A stage compressors, and the cell enclosure doorways will need enlarging to accommodate the size 2 units.

FUTURE TESTS

When testing is resumed, the work group recommends that the following be included in the test program:

1. A test should be made to determine the maximum purging capacity of the Purge Unit in its present condition in order to provide a comparison base for evaluating the effects of subsequent improvements. To avoid a large lights *bubble*, lights should be bled into the cascade at a number of separated sources well below the Purge Unit. The test should be made using both top boosters and all three air ejectors for maximum exhausting capacity.

2. Installation of automatic proportional response on at least one, but preferably three, low-speed cells should be made. The purpose of the tests would be to gain experience with the system in order to establish optimum stage pressures and proper set points for this type of stage control.

3. Installation of the Portsmouth-type DBM/PBC concentration recycle control as either a backup or replacement control system for the present AGA should be performed. These tests should also include an evaluation of an Ammeter Controller for this same application.

4. The sudden influx of a very large slug of lights will cause almost complete loss of compression in the low-speed pumps and will drastically reduce purging capacity when it is needed most. It is proposed that a test be made to see whether compression can be restored by bleeding the excess lights from near the bottom of the low-speed section to the A-bypass line entering the high-speed section. Such a jumper line, with a 2-in. manually loaded control valve, can quite readily be formed from an unused section of 3-in. OD concentration recycle line.

5. A test with two of the stage pumps on the adjoining Rabbit Test Cell should be made in order to develop a booster pump facility for stacking process gas rich in Freon-114 in the K-29 Surge Drums.

6. A retest for maximum purge capacity, particularly after treatment of high-speed converters in the furnace stands for permeability recovery, should be performed.

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