AIR PURGE APPLIED TO SUBSTANTIALLY MITIGATE STACK RELEASE LEVELS RESULTING FROM BWR FUEL LEAK

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Abstract

An airflow injection device was developed to prevent untreated effluent from leaking past a defective isolation valve. The device was used to control the leakage and this prevented a potential forced outage to repair the leaking valve. The cost of a unit forced outage was estimated to be approximately $1,600,000 which is based upon the cost of replacement power.

Introduction

The problem encountered at the Brunswick Nuclear Plant was due to three conditions that influenced each other to result is extraordinarily high stack release rates. The first condition was a fuel leak of a magnitude that caused radiation levels of the offgas to increase dramatically. The second condition was the piping arrangement in the Augmented Offgas (AOG) System. The pipe from the 30 minute hold-up line and pre-filter which contained the untreated effluent entered the AOG System in an area that is in close proximity to the AOG bypass valve. The third condition that contributed to extremely high release rates was a very small leak past the seat of the AOG bypass valve.

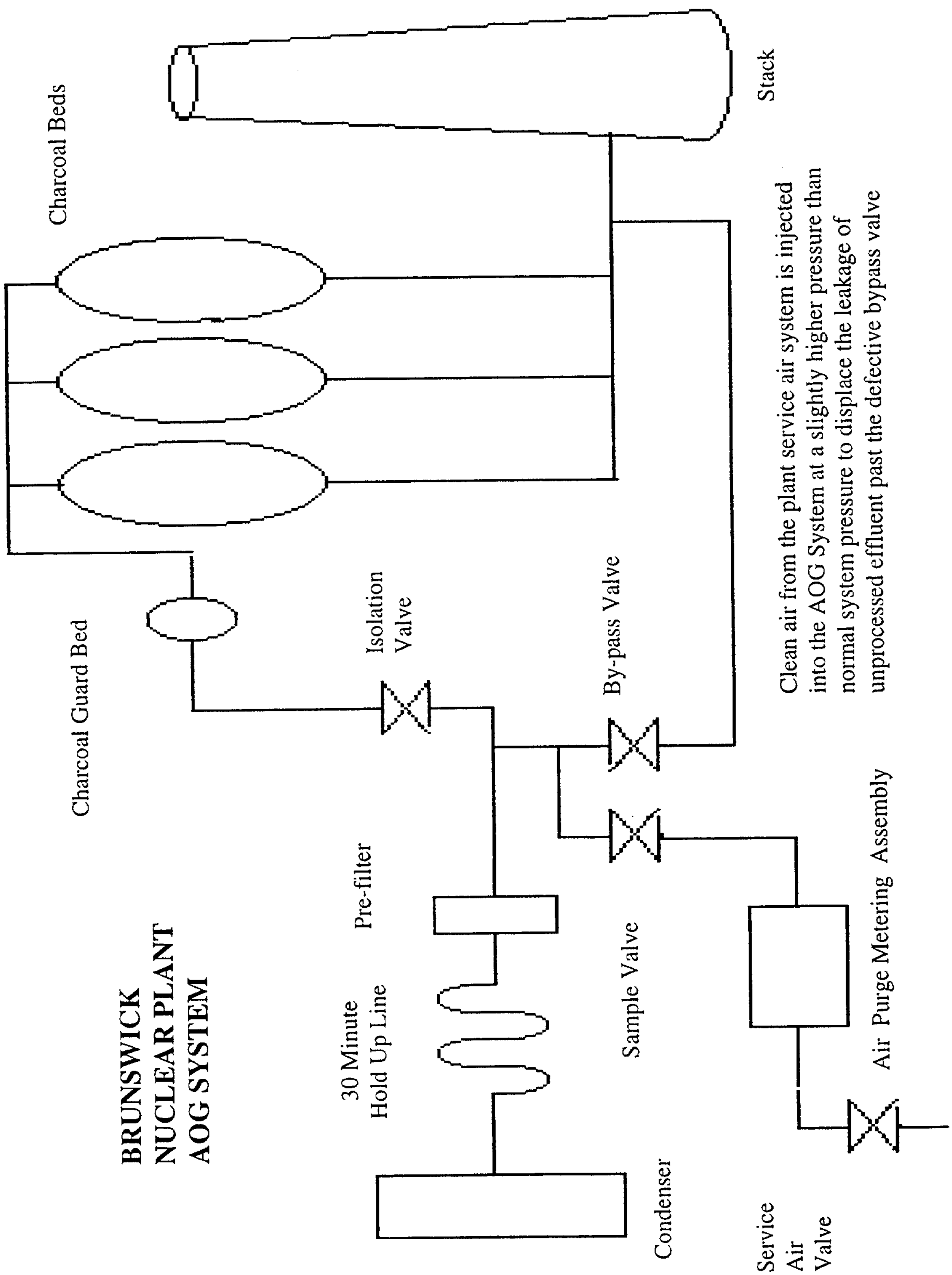
AOG System Design & Operation

The AOG system is designed with a long portion of piping (30 minute hold-up line) as well as several charcoal filtration units that further hold up the effluent that is discharged from the condenser through the Steam Jet Air Ejectors. After the effluent is treated in the AOG System an elevated release is made from the stack.

Under abnormal AOG operating conditions, the effluent by-passes the AOG processing. Conditions such as high moisture content of the effluent, high hydrogen content, or high radiation levels at the Steam Jet Air ejectors will cause an automatic by-pass of the system. The AOG by-pass valve opens and the AOG system is simultaneously isolated. See the schematic on the following page for additional information on the operation of the AOG System.

BWR Fuel Leakage

The Brunswick Nuclear Plant has periodically experienced fuel leaks in both reactors. Leaks have resulted from foreign material in the core which had become logged against fuel rods and as a result of normal cooling flow the fuel rods were damaged. The fuel leak in this instance resulted from 2 leaking fuel bundles. Noble gas activity measured at the plant stack had increased from approximately 10 uCi/sec to 300 uCi/sec. The increase in stack release levels occurred very rapidly. The increase was a step function.


BRUNSWICK NUCLEAR PLANT AOG SYSTEM
Charcoal Beds
Stack
Charcoal Guard Bed
Isolation Valve
By-pass Valve
Clean air from the plant service air system is injected into the AOG System at a slightly higher pressure than normal system pressure to displace the leakage of unprocessed effluent past the defective bypass valve
Pre-filter
30 Minute Hold Up Line
Sample Valve
Air Purge Metering Assembly
Condenser
Service Air Valve

Consequences of Elevated Stack Release Levels

The foremost consequence of an elevated stack release is an increased release of effluent to the environment. There is also an immediate financial impact to the plant in the form of increased insurance rates. Rates for insurance of nuclear power plants are based upon an equation that considers many factors of operation. One of these factors is the amount of gaseous effluent that is released from the plant. The lower the ranking that a plant has, the higher the insurance premium. It was projected, based upon the release being experienced with the fuel leak, that Brunswick Nuclear Plant would rank very close the bottom of all US Plants in the category of gaseous releases.

Considerations for Correcting the High Off-Gas Conditions

The first consideration was to attempt to seat the isolation valve. Assuming the problem may be caused by the valve not seating properly, the valve was cycled and adjusted in an attempt to stop the leakage flow. These attempts did not result in any increase in AOG flow rates.

The next consideration for correcting this problem was to replace the valve. This was quickly ruled out as a possible solution to the problem because the plant would have to be taken off line. The plant would have to be taken off-line because there is no way to isolate the line in which the valve is located. Attempting to remove the valve on-line could have resulted in a ground release. In addition, due to increased radiation levels, exposure considerations made replacement on-line impractical.

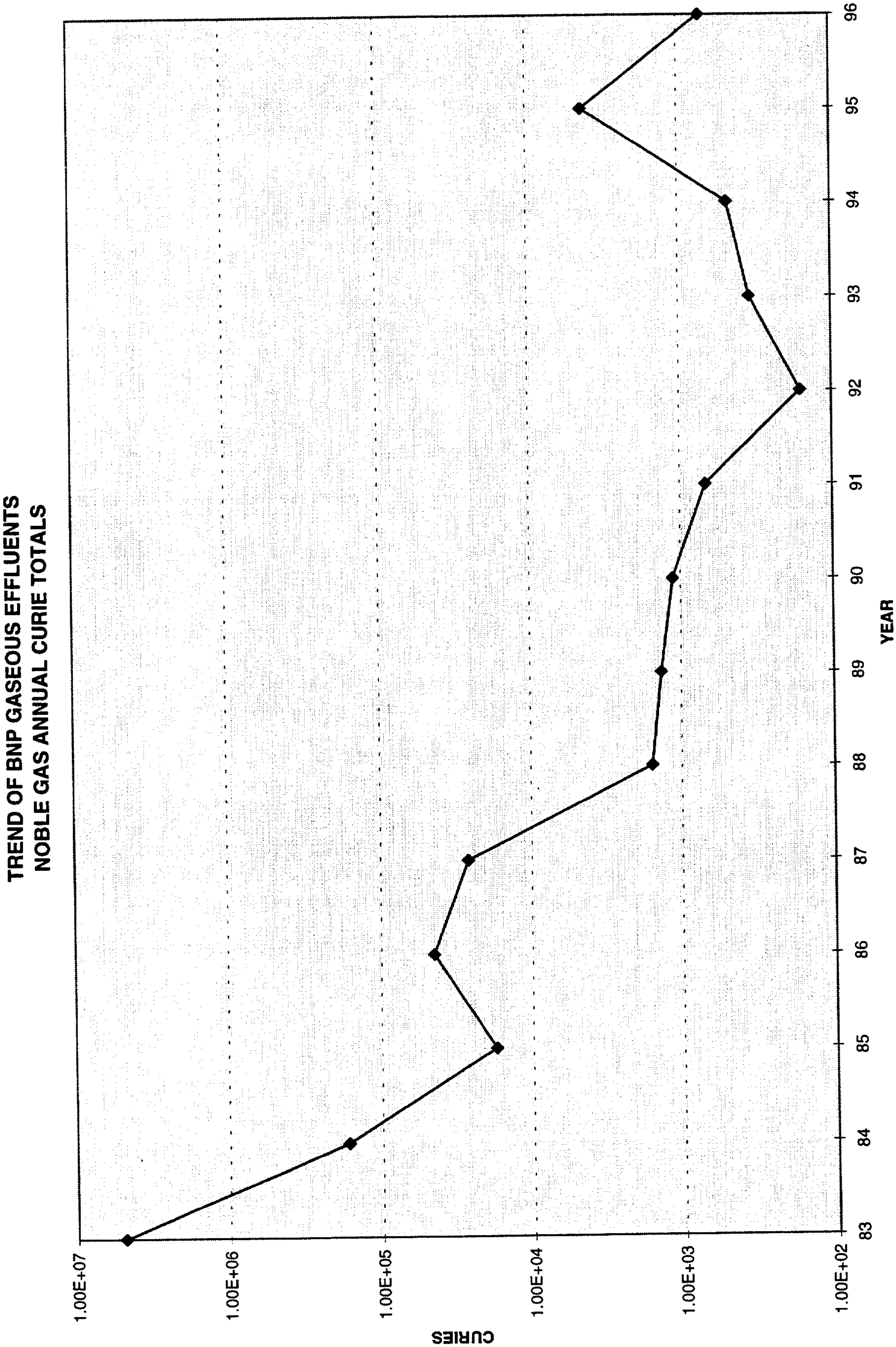
Consideration was given to develop an off normal line-up to cross tie the AOG System from U2 into the U1 system. This was ruled out because the combined off-gas flow approached the maximum flow limit to one AOG train. If the high flow by-pass were jumpered out, the hold-up time for the charcoal bed would be exceeded and the efficiency would be diminished. In addition, operating at flows greater than 150 cfm would be in excess of rates specified in the Final Safety Analysis Report for the plant.

Development of the Injection and Purge Concept

After reviewing the apparent options it was concluded that none of them provided a feasible solution to the problem. The air purge concept was formulated during discussions of a technique applied during underwater construction in the Mississippi River. The water is murky from the silt that is washed into the water. Clean water is pumped into the river in the construction area. A "bubble" of clean water permits divers to see in areas that they otherwise would not be able to.

It was reasoned that the approach used to work in the muddy water of the Mississippi River may be applied to shielding the leaking AOG By-pass valve. Since the flow rates are low in the AOG System it was postulated that a stream of clean air injected through a test connection at a slightly higher pressure than the normal system operating pressure would displace the effluent that was leaking past the valve seat. The clean air would leak past the valve seat into the pipe going to the stack and also force the effluent through the AOG system. It was expected the effluent would be processed such that releases would be equivalent to the condition prior to the development of the by-pass valve leak.

Since the concept was not proven in actual application it was decided a test be run to validate the effectiveness of the method. There are sample valves upstream and downstream of the leaking by-pass valve. The leak was confirmed by taking a sample downstream of the valve which indicated activity levels identical to levels of unprocessed effluent. The upstream valve would serve as an injection point for the clean air. A leakage flow rate was estimated based upon the quantity of untreated effluent that would be required to mix with gases from other plant locations and result in the higher activity levels at the stack. Noble gas annual curie totals released from BNP are provided in the graph, Trend of BNP Gaseous Effluents Noble Gas Annual Curie Totals, on the next page. Based upon a mass balance of the six isotopes that are released from the AOG system, it was determined that the leakage through the by-pass valve was approximately 14 to 17 cfm.


TREND OF BNP GASEOUS EFFLUENTS
NOBLE GAS ANNUAL CURIE TOTALS
CURIES
1.00E+07
1.00E+06
1.00E+05
1.00E+04
1.00E+03
1.00E+02
YEAR
83
84
85
86
87
88
89
90
91
92
93
94
95
96

A small manifold was fabricated from 3/8" tubing, valves, a pressure regulator, and a flow meter. When the manifold was bench tested a maximum flow of 11 cfm was obtained using the plant service air system (90 psig) reduced to .5 psig. This was determined to be representative and the manifold was installed in the plant on a test basis to evaluate the actual affect on stack release levels. The results of the test are provided in the graph, Response During Test of Air Purge Concept are provided on the next page.

Design Considerations

The primary design consideration was that the manifold operate safely while unattended. The manifold would require provisions for isolating on loss of flow into the system to prevent a ground release from the sample valve. The manifold must maintain a steady flow rate and be designed to prevent an excess flow condition. Flow rates above 150 cfm would cause the by-pass valve to open, releasing the entire AOG effluent, untreated from the stack. The manifold would also need the capability to be adjusted to minimize the stack release rate and keep the flow through the AOG as low a possible to minimize the potential for an excess flow by-pass of the AOG System.

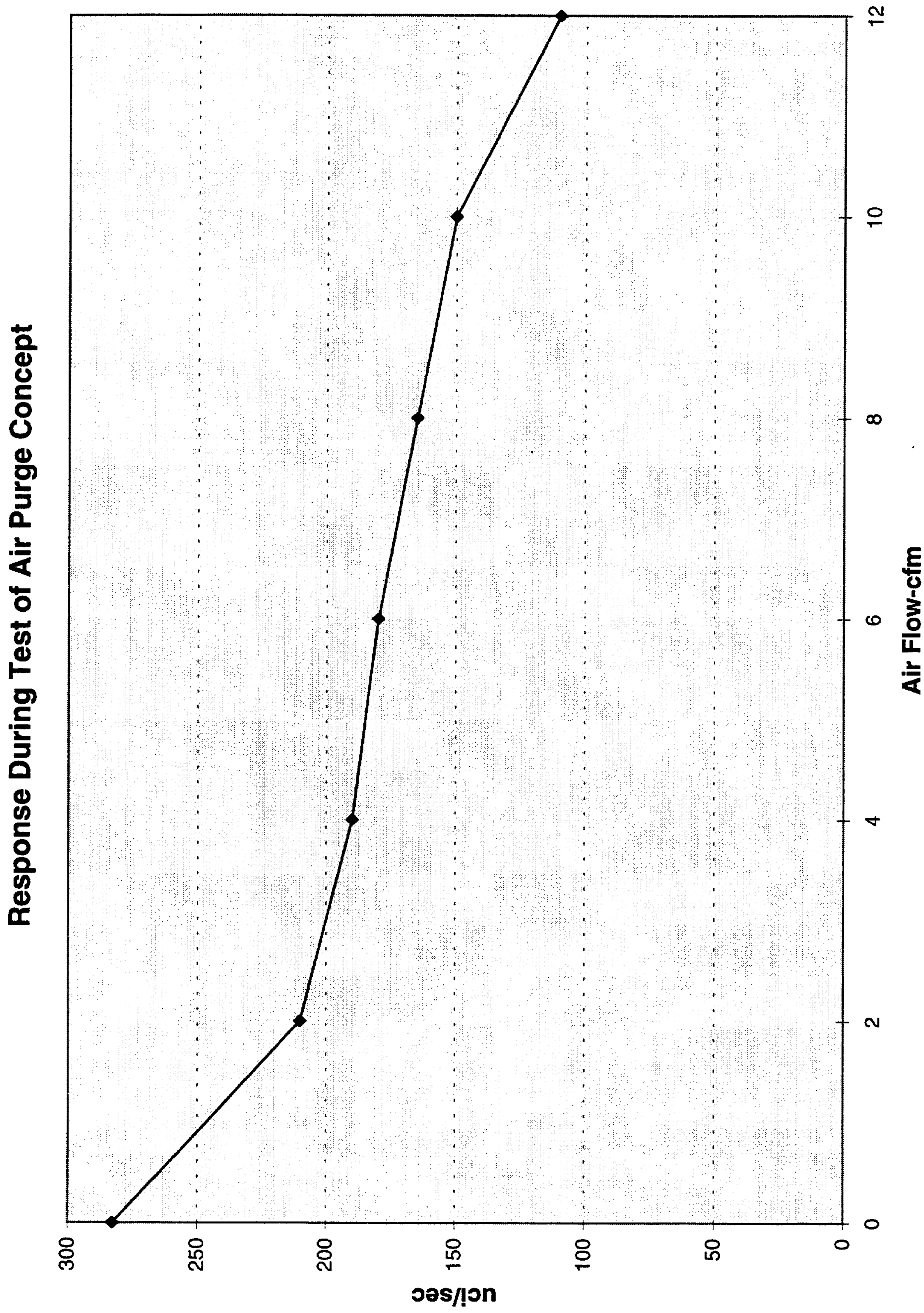
The manifold assembly was designed with the following features to address the design considerations:

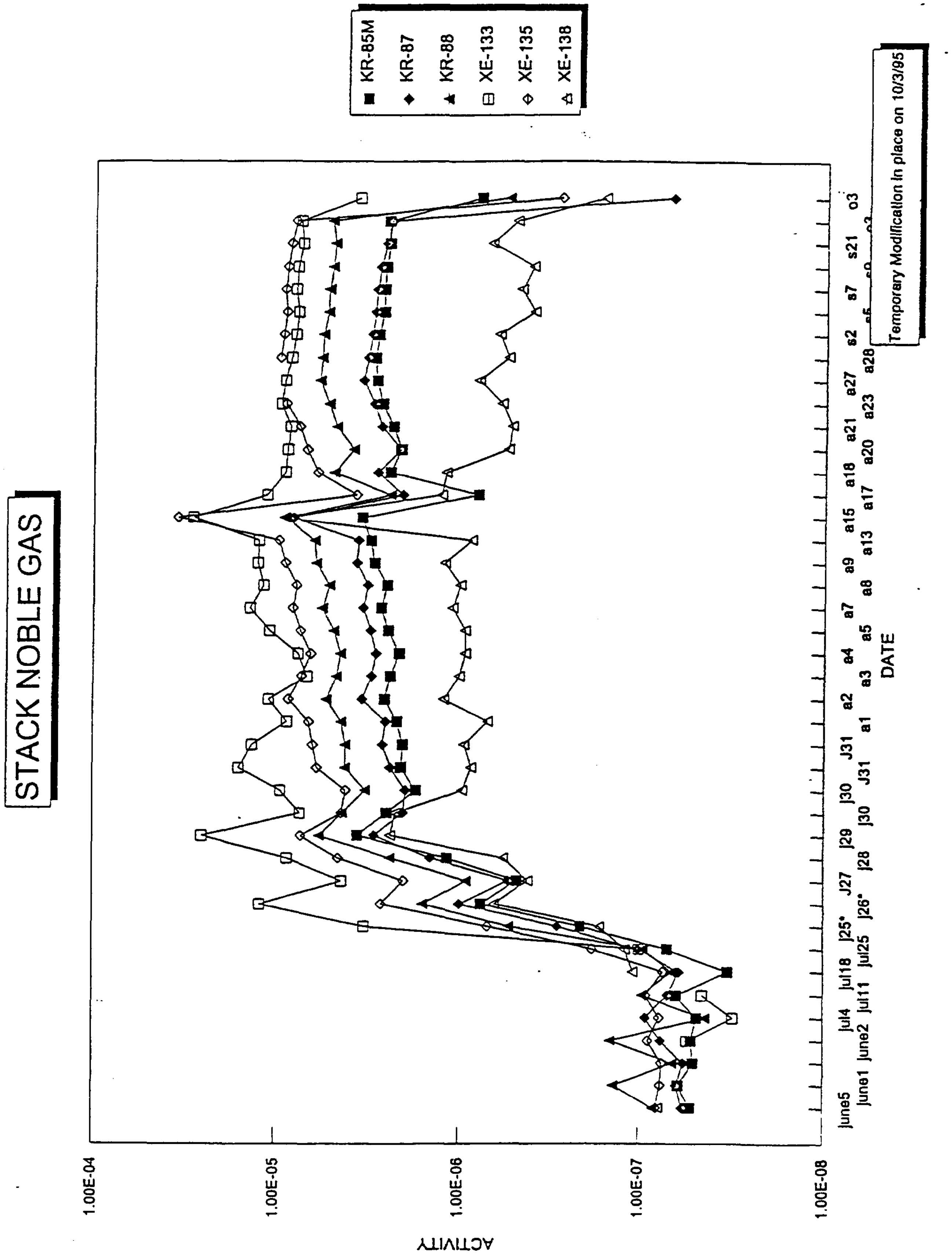
1. A check valve was installed at the inlet of the sample valve to provide isolation capability in the event there was a loss of clean air flow.
2. A steady flow rate was assured by installing a throttling valve upstream of the pressure regulator that would limit flow to approximately 17 cfm.
3. A flow meter provided accurate measurement of the flow rate.
4. Another throttling valve was installed downstream of the pressure regulator to enable the injection flow to be adjusted to minimize activity levels out of the stack and overall AOG flow.
5. A check valve was installed at the outlet of the plant service air valve to provide additional protection of back flow of effluent into the Service Air System in the event of a loss of service air.

Implementation and Results

The Air Purge was installed in October 1995. Stack release levels were immediately reduced from 300 uci/sec to approximately 35 uci/sec. The 1995 projected annual release was 7800 curies if the modification was not installed. With the modification installed, the 1995 annual total release was 4400 curies. During January of 1996 this modification prevented an additional 1133 curies from being released. There is also a substantial reduction of the 3-year average release rates: projected totals are 1144 curies/year vs. 2058 curies/year.

The graph, Stack Noble Gas, plots the noble gas isotopes over the period the fuel leak developed and the installation of the air purge. The affect of the air purge can be easily seen.


Response During Test of Air Purge Concept
uci/sec
300
250
200
150
100
50
0
Air Flow-cfm
0
2
4
6
8
10
12


STACK NOBLE GAS
KR-85M
KR-87
KR-88
XE-133
XE-135
XE-138
Temporary Modification in place on 10/3/95
ACTIVITY
1.00E-04
1.00E-05
1.00E-06
1.00E-07
1.00E-08
DATE