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HW-44097

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REACTOR GAS LOSS ANALYSIS

INTRODUCTION

Reactor gas costs have increased substantially each year since 1952 when the total cost was \$108,000. In 1953, 1954, and 1955 the gross annual cost of reactor gas was \$126,000, \$348,000 and \$606,000 respectively and are reported in Figure 1. These continued increases in reactor gas cost indicate the need for an analysis of gas usage and formulation of a program to reduce gas consumption. To provide basic information for such a program, a critical review has been made of the reactor gas system and gas consumption figures for the past four years.

SUMMARY AND CONCLUSIONS

The results of an analysis of reactor gas usage since 1952 are summarized in Table II from which the following major conclusions were obtained:

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1. Annual reactor gas cost has increased 560 per cent since 1952 while gas consumption has increased 450 per cent. The discrepancy between these figures is due to the increased usage of helium which is approximately five times as expensive as carbon dioxide. See Figure 2.
2. The addition of the C, EW, and KE Reactors has increased the amount of gas usage of which the major portion is justified in the form of increased production.
3. The use of helium purges for production gains following cold startups has contributed greatly to the increased gas usage. Early in 1954, this procedure was justified by resulting in production gains equivalent to seven times the value of the helium used.
4. Increased helium concentration in the atmosphere of the B, D, DR, F, and H Reactors has increased gas consumption due to the fact that leakage rates are a function of the density of the gas. Increased helium concentrations are necessary to limit graphite temperatures at high reactor power levels.
5. Miscellaneous leaks and other unjustified losses account for a large portion of the increased gas usage which, if reduced, could result in substantial savings.

Thus, a significant portion of the increases in reactor gas consumption over the last few years can be accounted for and justified in terms of production. This does not mean that the gas has been always used efficiently, or that increased consumption due to high leak rates is always justified.

RECOMMENDATIONS

A preliminary analysis has been carried out to determine the sources of normal gas losses and the remedies which may be utilized to reduce these losses. The following are general recommendations resulting from the study. These recommendations which should receive extensive follow-up on an individual reactor basis are:

1. It is recommended that the design for operational charge-discharge include an improved method for sealing the openings around the process tubes on both the front and rear faces of the reactor.
2. Split, replacable bellows boots may be installed in substantially less time than is required to install the conventional type boots. It is recommended that these split boots be used in the future, and that an effort be made to locate and reduce the number of leaking bellows on both the front and rear faces of the reactors. A study should be made at each reactor to determine the feasibility of installing these boots on non-leaking bellows as discussed elsewhere in this report.
3. An immediate program should be conducted to repair or replace defective neoprene gas seals on the biological shields.

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4. Purging efficiencies should be increased by application of one of the possible methods which are mentioned in the discussion. It is recommended that the Process Sub-Section, in cooperation with the Operations Sub-Section, continue to explore the possibilities in this area.
5. A significant amount of the total gas losses can be traced to losses occurring at the 115 Buildings or losses, apparently in transit, from the helium tank cars. It is recommended that these losses be reduced by bringing up to date operational and administrative procedures and by making an investigation of the tank car losses.
6. It is recommended that an increased effort be made at each reactor to periodically check all joints, connections, and other possible sources of leaks in the 105, 110, and 115 Buildings.

DISCUSSION

PAST GAS USAGE

Presented below is a summary of the yearly gas losses since 1952 (See Figure 3):

TABLE I

REACTOR GAS COST

(Expressed as a per cent of the total 1952 cost)

	<u>1953</u>	<u>1954</u>	<u>1955</u>
Helium start-ups	-	89%	147%
K Reactors	-	8%	91%
C Reactors	15%	29%	28%
Leakage due to increased helium concentration at B, D, DR, F, and H.	-	-	30%
1952 cost	100%	100%	100%
Total accounted for loss	115%	226%	396%
Unaccounted for loss	2%	96%	165%
Total loss	117%	322%	561%

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REACTOR GAS CONSUMPTION

(Expressed as a per cent of the total 1952 consumption)

	<u>1953</u>	<u>1954</u>	<u>1955</u>
Helium start-ups	-	38%	64%
K Reactors	-	4%	61%
C Reactor	22%	25%	27%
Leakage due to increased helium concentrations at B, D, DR, F, and H.	6%	7%	17%
1952 consumption	100%	100%	100%
Total accounted for loss	128%	174%	269%
Total unaccounted for loss	13%	111%	181%
Total loss	141%	285%	450%

Increases in the gas loss that can be accounted for and justified include:

1. Helium start-up losses. The use of helium for achieving production gains during reactor start-ups was initiated in 1954 and was justified at that time by showing that the value of the increased production was about seven times the value of the helium expended for this purpose.
2. Normal operating losses at KW, KE, and C Reactors. These losses are justified directly in terms of increased production.
3. Leakage due to increased helium concentration in the reactor atmosphere at B, D, DR, F, and H Reactors. The helium concentration in the reactor atmosphere must be increased to control graphite temperatures at increased power levels. This results in a higher leakage rate due to the decrease in the density of the gas atmosphere.

Thus, out of the 1955 gas cost which was 561 per cent of the 1952 figure used as a base, only 165 per cent cannot be directly accounted for and justified in terms of increased production.

The individual reactor usage of helium for helium start-ups is illustrated in Figure 4. The utilization efficiency of each reactor is indicated by the average helium usage per start-up. C Reactor, which does not ordinarily use helium start-ups, would be expected to have a high helium utilization efficiency because it normally operates at a relatively high helium concentration and has greater reactivity control in the horizontal rods requiring, therefore, less helium per start-up than the other reactors. DR Reactor has a relatively high helium utilization efficiency primarily because of the increased reactivity control afforded by the Poison Column Control Facility.

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F Reactor would be expected to use more helium than the average during helium start-ups because it normally runs at a very low helium concentration.

The increased number of reactor start-ups wherein the reactor must be purged to obtain a relatively air-free atmosphere, the use of gas purging during operation to control reactivity, and the use of carbon dioxide as a reactivity control to enhance the possibility of scram recoveries have undoubtedly accounted for some of the increased gas usage. However, sufficient information is not available to determine the amount of gas used for these purposes.

Increasing power levels have produced two effects: 1) higher temperatures which cause reactor components to expand thereby increasing the possibility as well as the severity of leaks in the system, and 2) increased graphite temperatures which must be controlled by increasing the helium concentration in the reactor atmosphere. Losses incurred at increased helium concentrations are more expensive (helium is approximately five times as expensive as carbon dioxide) and greater in magnitude because leakage is inversely proportional to the square root of the gas density. Present thinking by Pile Technology indicates that graphite temperature limits will be raised to 6500C providing the atmosphere is maintained at 95 to 100 per cent helium. This will tend to increase the consumption and cost due to leakage.

The increased number of tube leaks has accounted for some of the increase in gas usage because: 1) At a time when there is excess moisture in the reactor, the gas recirculation rate is increased so that the moisture can be removed at a more rapid rate. In order for the gas recirculation rate to be increased, the gas pressure must be raised which in turn increases the usage since the leakage rate is a function of the pressure. 2) Helium concentrations are increased during a period of leak testing utilizing the helium leak detector apparatus. The increased frequency of leak testing using these higher helium concentrations has undoubtedly accounted for an increase in usage since leakage is a function of the helium concentration.

The possibility of increased gas loss due to leakage from VSR and HSR channels following the Ball 3X installation and HSR revisions was investigated. No apparent increase in loss could be directly attributed to this work although it is probable that some losses now are occurring at these points.

SOURCES AND REMEDIES

Major Modifications

It appears to be inevitable that the gas losses will remain at a high value or increase further as the severity of reactor operation increases. Increasing power levels, increasing the amount of gas used for reactivity control, increasing the concentration of helium in the reactor atmosphere, and the deterioration of the gas system components will all contribute to an increase in gas losses.

Gas losses can be divided into two general categories: a) necessary losses and b) unnecessary losses. The unnecessary losses include all losses due to leakage from faulty gas system components. The items discussed elsewhere in this report include many of the corrective measures that should be taken to

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reduce these losses. However, it is evident that these measures, many of which are uneconomical, will not provide a large scale reduction in the reactor gas loss rates.

In order to provide for a large decrease in gas losses due to leakage, some basic changes should be made to the gas system. The measures currently being taken as well as those recommended in other parts of this document are temporary in nature. Since the most common, and probably the greatest, source of leakage is the gunbarrel bellows on the rear face of the reactor, modifications to the gas system should be initiated at this point. The most opportune time to carry out such a modification would be concurrent with the installation of operational charge-discharge facilities. This design can include an improved method for sealing the area around process tubes on both the front and rear faces. This is probably the only method by which a substantial reduction in gas losses due to leakage can be accomplished.

Poison Column Control

Following the installation of the Project 60-558 Poison Column Control Facilities at all reactors, some reduction can be expected in the amount of helium used during reactor start-ups. The amount of reduction will vary according to the lengths of outages and individual reactor conditions. However, on the basis of DR Reactor experience, which operated with the benefit of the Poison Column Facility during 1955, reductions in helium start-up usage by as much as 70 per cent may be achieved at other reactors through the use of this equipment.

Replaceable Bellows Boots

Leaking process tube bellows are probably the greatest source of gas loss from the reactor. There are 4000 potentially leaking bellows on each reactor, a great many of which are known to be leaking. A quickly installed neoprene boot has been developed by Pile Technology for use on leaking bellows. It is estimated that one of these split boots can be installed in fifteen minutes. Installation of a conventional boot requires the removal and replacement of the nozzle and gunbarrel flange, and may require up to two hours for a complete installation. In January, 1956, B Reactor replaced twelve leaking boots with conventional type boots at a rate of five boots per shift.

If ten leaking bellows are found after five hours of searching, and boots are installed by two men in two hours, the cost, assuming shutdown time at \$10,000 per day, is approximately \$3,000. The normal gas losses due to leakage (currently about 450,000 cubic feet per month with a 30 per cent helium concentration) must be reduced by approximately three per cent for a one year pay-off period. If no additional shutdown time is used, approximately 100 boots can be installed for a maintenance cost of \$150. Therefore, it is recommended that every effort be made to install the split, replaceable boots on as many leaking bellows as possible using as little downtime as possible. This could be done simultaneously with other rear elevator work such as the tube removal program.

A study should be made by the Operations Sub-Section on the feasibility of installing these boots on a mass basis. There is a possibility that the installations could be made randomly, concurrently with other rear elevator work,

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without trying to locate leaking bellows. The justification of this method would depend on the number of bellows that are leaking, the severity of the leaks, the manpower situation, the speed with which an installation can be accomplished, and the time that would be required to locate the leaks.

Neoprene Seals

The estimated cost for complete replacement of the neoprene seals on the rear face at B Reactor during the CG-558 outage is \$4400. The normal gas losses due to leakage will have to be reduced approximately six per cent for a one year pay-off period. However, since the neoprene seals will undoubtedly need replacement or repairs within the next few years anyway, it would be justifiable to do it during this outage as a preventative maintenance item. It is recommended that the seals on all reactors, which are substantially deteriorated, be replaced or repaired during the CG-558 outages. Liquid neoprene was used to seal a leak in a rear face neoprene seal at B Reactor during the outage of March 26, 1956. If it is found that this is a satisfactory method of sealing small leaks, the liquid neoprene should be used for that purpose at all reactors.

Purging

Efforts to reduce the gas consumption on start-ups should include: 1) the determination of the optimum helium concentration for start-up production gains by varying the helium concentration and evaluating the resultant gains, 2) maintaining closer control over the gas composition to insure that the specified helium concentration is not exceeded, and 3) the determination of the best gas purging techniques.

Presented here are three possible methods of increasing purge efficiency. The first two items are outlines and present the conditions to be met for the proposed tests. The third item illustrates the advantages of running all or part of a purity purge prior to a helium start-up with helium. These and other possible methods will be evaluated by the Reactor Operations Engineering Unit.

1. A test of this type will help determine the best gas addition rate which will minimize channeling effects. This is assuming that a continuous gas addition lends itself to channeling effects and that an intermittent addition and mixing procedure will reduce these losses. To analyze the results of this test, some curves can be drawn for the test conditions which will show 100 per cent efficiency and the experimental points obtained can then be compared. A procedure similar to the following may be used for this test:
 - a. Establish the beginning gas concentration.
 - b. Add 2000 cubic feet of helium.
 - c. Recirculate the gas until equilibrium is reached. Take orsat analyses at five minute intervals and record the required time to reach equilibrium. Equilibrium is reached when two consecutive orsat analyses give the same value.
 - d. Determine the gas concentration at this equilibrium condition.

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- e. Add 4000 cubic feet of helium.
 - f. Recirculate the gas until equilibrium is reached. Take orsat analyses at five minute intervals to determine the time at which equilibrium is reached.
 - g. Determine the gas concentration at this equilibrium condition.
 - h. Repeat at increments of 2000 cubic feet until the desired start-up concentration is reached.
2. There is some evidence that a helium purge in which the gas is introduced at the top of the reactor would have a greater efficiency than does the present method. To determine a possible purge efficiency increase obtained by using this method the following conditions must be met: Arrangements should be made for the introduction of helium, during a helium purge, at the top of the reactor and as near the front as possible. Two purges, run under identical conditions should be made; one conventional and the other purging from the top. The gas usage can be measured and an indication of the relative efficiency obtained. Identical conditions include purging from the same concentration to the same concentration in both instances. Naturally, this test should be run on the same reactor and changes in leak conditions kept to a minimum.
3. A gain can sometimes be realized by varying the purity purge procedure. An example was worked out empirically using two different methods. The first method utilized the batch purging technique and consisted of lowering the air concentrations to 10 per cent by purging in carbon dioxide and then raising the helium concentration to 60 per cent. This method required 16,000 cubic feet of carbon dioxide and 20,000 cubic feet of helium at a cost of \$600. The second method utilized the same batch purging procedure and the same initial conditions. The air was reduced to 10 per cent and the helium increased to over 60 per cent simultaneously by purging only helium. This method required 16,000 cubic feet of helium at a cost of \$430. Thus, there was a difference of \$170 plus the conservation of 4000 cubic feet of helium and 16000 cubic feet of carbon dioxide.

Alternate purity purge methods may be varied to fit different conditions. The Area Engineer and/or Physicist will have to work out the method for each set of conditions.

Reactor Leaks

There are several sources of gas leaks on the reactors. In addition to gun-barrel bellows leaks and neoprene seal leaks, which are discussed elsewhere, sources include 105 Building vent valves, experimental test holes, Ball 3X hoppers, safety rod seals, and ball valves on the bottom of C, KE, and KW Reactors. These points should be leak tested periodically. The 105 Building vent valves, Ball 3X hoppers, and test holes should be leak tested once a month. Front and rear gunbarrel bellows and neoprene seals should be leak tested as often as the need arises. The installation of sample lines to the rod seals would make it possible to detect leaks at these points during reactor operation. Studies should be made at C, KE, and KW Reactors to determine the losses occurring at the Ball 3X ball valves on the bottom of the unit and the best

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methods for minimizing these losses, such as installing a new type valve or sealing off the entire ball return duct. Where possible, leak testing should be done during reactor operation.

115 Building Procedures

Gas is lost in the 115 Building due to inefficient valving, leakage, and pop-off valve actuation. To reduce these losses procedures and instructions for 115 Building operation should be rewritten and brought up to date. Those especially important include valving sequences, transfer procedures, and flow meter instructions.

Frequency of soap testing components of the gas system should be reviewed. It is recommended that all joints and connections outside of radiation zones be soap tested at least once per week. Components in radiation zones should be soap tested once per month.

All thermometers, pressure gauges, and instrumentation should be calibrated periodically to assure reasonable efficiency in operation and inventorying.

Accurate records of gas inventories and deliveries should be obtained and forwarded to the Operations clerk. The Operations Sub-Section should review the forms used at the different reactors and establish standard forms. An effort should be made to assure that accurate records are obtained since these will give an indication of the efficiency of gas wing operations.

By following these recommendations the 115-110 Building losses can be minimized and more accurate gas usage data can be obtained.

Storage and Transfer Losses

High pressure storage tank losses, which include losses in high pressure storage and losses in transfer from high to low pressure storage, account for a significant amount of the reactor gas losses. The actual amount of loss occurring here varies with the number of transfers, capability of the operators, and the condition of the storage tanks and piping. The loss may be as much as 5 per cent of the total gas loss. Areas which have the gas flow meters have an automatic makeup between high and low pressure storage. This prevents over-pressurization of the low pressure tanks which minimizes the possibility of blowing the pressure relief valves. It is expected that transfer losses will decrease after the new automatic high to low pressure make-up installation is complete in all areas.

Tank Car Losses

Approximately 3 to 15 per cent of the charged gas losses have been traced to differences between the amount of gas charged to a reactor and the amount actually used by the reactor during a given month. In other words, the reactors are being charged for gas that is not received. A randomly picked helium tank car was investigated at 100-B, 100-K, and 100-D areas. The average pressure on this car was approximately 2495 psi at 56°F whereas the pressure stated on the invoice was 2707 psi. By correcting the actual pressure to 70°F which

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corresponds to the temperature stated on the tank car invoice, it is noted that there was a drop in pressure of 5.6 per cent. This indicates there was an apparent loss of 5.6 per cent, or 12,400 cubic feet, at a cost of \$330. The measured amount of gas received from this car was 212,000 cubic feet whereas 221,400 cubic feet was charged. This is a loss of 4.4 per cent, or 9,400 cubic feet, at a cost of \$251.

The discrepancy between 4.4 per cent loss and 5.6 per cent loss can probably be explained by slightly inaccurate pressure gauges and thermometers at 100-B Area. The 100-B Area unloading of two of the five tanks was the basis of the average pressure of 2707 psi, but B, K, and D Areas all received approximately the same amount from the different tanks which indicated that the pressure was nearly constant. The amount of helium left in the tank car because of the minimum pressure requirement of 5 psi is insignificant.

The Bureau of Mines will soon issue a booklet containing miscellaneous information on tank cars and helium in general. Upon receipt of this information a study should be made to determine the reasons and remedies for these tank car losses. Also, information in this booklet will give an indication of the practicality of establishing some curves showing volume, pressure, temperature relationships which would simplify the unloading procedure and give a better indication of the losses encountered at this point.

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TABLE II

YEAR	TOTAL USAGE 1000 CU. FT.	HELIUM USAGE 1000 CU. FT.	CO ₂ USAGE 1000 CU. FT.	K REACTORS USAGE 1000 CU. FT.	C REACTOR NORMAL (1) USAGE 1000 CU. FT.	HE STARTUP USAGE 1000 CU. FT.	USAGE DUE TO INCREASED HELIUM CONCENTRATION AT B, D, DE, F AND H (2)
1952	2453	1953	9060	360	---	---	---
1953	31020	11790	11230	2058	---	---	506
1954	35,510	15,510	16900	333	2366	3590	686
1955	41,400	18,170	22970	563	3461	5900	1,556

YEAR	TOTAL COST DOLLARS	K REACTOR COST DOLLARS	C REACTOR COST DOLLARS	HE STARTUP COST DOLLARS	COST OF INCREASED USAGE DUE TO INCREASED HELIUM CONCENTRATION AT B, D, DE, F AND H (2)
1952	\$108,000	---	\$2,779	---	---
1953	\$126,000	---	\$17,000	---	---
1954	\$144,000	\$8,500	\$11,600	\$26,000	\$100
1955	\$165,000	\$99,000	\$30,300	\$159,000	\$32,700

1. K Reactor normal usage is based on the 1952 usage taking into consideration increasing helium concentrations in 1953 and 1955.

2. B, D, DE, F, and H usage due to increased helium concentration is due to the increased difficulty of the reactor atmosphere at higher helium concentrations. The residual difference between the cost and consumption values under this heading can be explained by considering the price changes of helium and carbon dioxide during this period, i.e., carbon dioxide unit cost decreased whereas helium unit cost increased.

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FIGURE 1

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FIGURE 2

TOTAL REACTOR GAS CONSUMPTION

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GAS CONSUMPTION (CUBIC FEET)

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AVERAGE HELIUM USAGE PER STARTUP - CUBIC FEET

SECRET

NUMBER OF HELIUM STARTUPS 1955

FIGURE 4

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