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PROCESS IMPROVEMENT TRANSITION AUTHORIZATION
IP-20-I
INCREASED GRAPHITE TEMPERATURE LIMITS AND
USE OF NITROGEN IN THE K REACTORS

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PROCESS IMPROVEMENT TRANSITION AUTHORIZATION IP-20-I
INCREASED GRAPHITE TEMPERATURE LIMITS AND
USE OF NITROGEN IN THE K REACTORS

I. OBJECTIVE

The objectives of this Process Improvement Transition Authorization for KE and KW reactors are to authorize a flat 700 C graphite temperature limit in the bulk of the graphite, with a conditional 850 C limit in the 0.130 coring zone only, and in conjunction therewith to provide for routine use of nitrogen instead of carbon dioxide in the reactor atmosphere. These temperatures as quoted apply to filler blocks in the vicinity of normal channels, and are maximum limits.

This PITA is essentially an extension of an existing production test² at KE, and supersedes a companion production test currently in effect at KW. Test and monitor programs are specified from which information will be obtained on which to base process standards authorization of this type of operation.

II. BACKGROUND SUMMARY

Operation with a relaxed temperature limit was authorized for both KE and KW reactors on May 20, 1960, by Production Test IP-312-A.¹ The temperature limit specification was approximately 50 C higher at any particular concentration of carbon dioxide than allowed by process standards, with a maximum of 700 C at 100 per cent helium. KW reactor has continued operation under this authorization to the present. KE operated under this authorization until October, 1960, at which time nitrogen was substituted for carbon dioxide, and the graphite temperature limit was revised to a flat 700 C at all proportions of nitrogen and helium. These changes were authorized by Production Test IP-385-AC.² The reactivity and operational physics aspects of nitrogen usage have been summarized in reference 3.

During October, 1961, the rod pattern at KE reactor was revised to skew the flux upstream and reduce rupture potential. A front-to-rear thermocouple stringer was installed in channel 2781-KE during January, 1962,⁴ to permit graphite temperature monitoring in the front portion of the 0.130 graphite coring zone, which extends in a band across the front of the reactor and along the sides. This stringer included three couples in the 0.130 coring zone, as well as in the other coring zones of the reactor. The temperature gradient in this zone was found to be quite steep with a maximum temperature as read on the stringer of 920 C about one foot from the in-reactor face of the zone. Extrapolating to the in-reactor face, and correcting for the difference in temperature between a front-to-rear stringer and a filler block in the vicinity and for the higher filler block temperature near an uncooled channel, it is estimated that a normal filler block temperature near the in-reactor face of the 0.130 coring zone could approach 850 C.

Graphite temperatures in the comparable zone at KW reactor are undoubtedly lower than at KE reactor since the outboard rod pattern has been retained at KW, and the flux is not particularly skewed toward the front. Temperatures in the front portion of the 0.130 zone may still be significantly higher than in the balance of the stack, however.

Figure 1 shows a temperature distribution, front to rear, as seen on the front-to-rear stringer at KE. Figure 2 shows the coring pattern for the K Reactors in a plan view cross section at layer 61 (tube row 28).

To date, no deleterious effects upon either reactor has been detected⁷ as a result of these tests. There are areas of concern, however, which have not been fully resolved by the tests run to date. These areas are:

1. Effects of higher temperature in the 0.130 zone on graphite distortion and burnout rates.
2. Ability to minimize the rate of air in-leakage when nitrogen concentration is no longer meaningful as a measure thereof.
3. Effects of higher nitrogen concentrations upon external corrosion rates of process tubes and of gunbarrel and other carbon steel surfaces at the rear of the reactor during "wet" operation.

Definitive answers to these questions must be obtained before adequate process standards thereon can be written.

III. BASIS AND JUSTIFICATION

The basic aim of this program is to accomplish higher permissible graphite temperatures without compromising reactor life. Higher temperatures are desirable for two reasons:

1. To avoid power level limitations from graphite temperatures following completion of the K flow increase project.⁵
2. To gain additional reactivity by virtue of higher graphite temperatures.

It is estimated that power levels may be limited by up to 400 MW during the cold inlet water temperature months by the present graphite temperature limits in the process standards. It is assumed that the AEC administrative limit will be raised to permit bulk limited operation.

The higher graphite temperatures permitted herein represent an additional block of reactivity (estimated at about 60 cmk)³ which can be utilized in various ways to effect cost savings and/or increased production.² It can be used to reduce the amount of spike enrichment; to achieve better power distribution control through compensation for the reactivity changes due to fuel exposure changes; or to permit more efficient front-to-rear flattening.

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The quantitative economic gain that can be obtained by this program depends on how the additional reactivity is used. It is not within the scope of this document to specify the most efficient use of the additional reactivity; rather, it is the purpose to authorize the increased temperature limit and specify how it is to be accomplished without affecting reactor life.

The use of nitrogen in place of carbon dioxide is a necessary adjunct to this program because of possible excessive stack oxidation rates by carbon dioxide at higher concentrations, and particularly at the higher temperatures experienced in the 0.130 coring zone. Also some savings in gas costs can be effected with the use of nitrogen. The concentration of helium will, on the average, be less with nitrogen than with carbon dioxide, thus reducing the rate of helium loss.

A higher graphite temperature limit is permitted in the 0.130 zone because it is a relatively small portion of the stack, and only a portion of this zone will normally be in excess of the 700 C specified for the balance of the stack. Some relaxation of the graphite temperature limit in the 0.130 zone above that specified for the bulk of the stack is necessary even for KW reactor if the full benefit of the relaxation for the bulk of the stack is to be achieved. If, in addition, there is to be flexibility for rupture potential control, additional leeway must be provided. It is also anticipated that upstream flux shifts will result from the addition of mixers for minimizing internal process tube corrosion.

There is the risk of higher burnout rates in the 0.130 zone from the effects of higher temperature on the rate of reaction of graphite with water vapor. Also, the higher temperatures permitted coupled with and caused by higher fluxes may alter the rate of contraction in this zone in a fashion to adversely affect process tube distortion. For these reasons, the 850 C limit specified herein is conditional and will be reduced if evidence of unacceptable burnout rates or contraction rates are found.

IV. DISCUSSION

The areas which need further assessment are:

1. Ability to monitor temperatures in 0.130 coring zone across the front of the reactor.
2. Effects of the higher temperatures upon graphite distortion rates and upon the rate of water vapor burnout in the 0.130 zone.
3. Adequacy of ability to measure the rate of air in-leakage and, hence, minimize same.
4. Effects of higher concentrations of nitrogen upon process tube external corrosion rates, and on the corrosion of gunbarrels and other carbon steel surfaces at the rear of the reactor.

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A. Relation Between Front-to-Rear and Side-to-Side Thermocouple Stringer Temperatures

It is in order to provide some explanation on the significance of the various temperatures discussed herein. In a typical cell, sketched below, the maximum temperature will normally occur in the filler layer at the most remote point from the surrounding cooled process tubes.

It is this temperature which is referred to as the normal filler block temperature. If one of the channels is uncooled, as sketched below, then maximum graphite temperature will occur in the uncooled channel.

There will be a difference between this temperature and the filler block temperature in the vicinity; in addition, the filler block temperature will be higher than usual for two reasons. The heat normally transferred to the previously cooled channel must now be dissipated to other tubes in the vicinity, and the rate of heat generation in the graphite is somewhat higher due to enhanced powers in the surrounding normal process channels.

Thus, when a front-to-rear thermocouple train installed in an empty process channel is used to monitor graphite temperatures, the temperatures as read from the stringer do not directly reflect the maximum temperatures in the main portion of the zone being monitored, and corrections must be applied thereto. Corrections need not be applied to the side-to-side thermocouples, however, since these are installed in side-to-side channels. They are located in the region of interest and do not entail removal of a process tube from service.

B. Temperature Monitoring in the 0.130 Graphite Coring Zone

The temperature of interest in the front 0.130 zone cannot be directly measured since the original filler block thermocouples in this zone have failed, and none of the side-to-side stringers pass through this zone. It is proposed to monitor temperatures in this zone using two front-to-rear stringers in each reactor

coupled with flux traverses and calculation techniques. The correction factor from a front-to-rear stringer temperature to a filler block in a normal environment will be established. It is then hoped to develop a correlation between the front-to-rear stringer temperatures near a side-to-side thermocouple and 0.130 zone stringer temperatures as affected by local flux level and gas composition. Given this correlation and the correction factors between the two types of stringers, it will then be possible to infer 0.130 zone normal temperatures from other side-to-side temperatures and a flux traverse in the vicinity thereof.

This method will depend upon availability of flux traverses using non-poisonous splines.

C. Monitoring for Air In-Leakage and Total Burnout Rate

Oxygen reacts rapidly and quantitatively with the graphite stack. Thus, measurement of the oxygen concentration in the inlet gas stream will not reflect any air in-leakage at the front, top, side, or bottom faces of the reactor. At reactors using a helium-carbon dioxide atmosphere, the equilibrium concentration level of nitrogen coupled with the rate of gas loss for the reactor has been used as a measure of the amount of air in-leakage.

When nitrogen is deliberately added to the reactor atmosphere, then its concentration can no longer be used for this purpose. Argon is an inert component of air and can be used for the same purpose in reactors using a nitrogen-helium atmosphere. Furthermore, since argon is activated in the reactor and decays with a 1.3 MEV gamma and a half life of 1.8 hours, it should be possible to infer the argon concentration and hence the status of air in-leakage from the gas system activity. It is proposed to use this method as a primary tool for knowledge of overall air in-leakage. Production Test IP-502-E authorizes the necessary procedure for calibrating⁶ the activity meter in terms of argon concentration. This test should be conducted at each K reactor as soon as possible.

Some argon is added to the gas system as an impurity in the nitrogen make-up gas. The concentration of argon from this source is primarily a function of the nitrogen concentration in the reactor atmosphere. A correction will be supplied for application to the observed argon concentration as determined from the activity meter.

When CO_2 is not deliberately added to the gas system, neither it nor CO can be present except as a result of reaction of oxygen or water vapor with the graphite moderator. The combined concentrations of CO and CO_2 with the gas loss rate thus provide a measure of the total rate of burnout which is occurring. When used in conjunction with the total rate of air in-leakage as determined

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from the argon concentration, it may be possible to gain useful information on the rate of burnout due to reaction with water vapor.

Limiting concentrations are specified for both the argon concentration and the sum of CO and CO₂ concentrations in section V-E. Guidance and interpretations of the limits are also given.

D. Effects of Higher Temperatures in the 0.130 Coring Zone

It is probable that somewhat higher peak temperatures exist in the front portions of the 0.130 zone and the forward part of the side 0.130 zone than in the balance of the stack, even with relatively symmetrical flux distribution. This phenomenon becomes more marked as the flux is skewed upstream. Such is the case at KE where the rod pattern has been changed to skew the flux upstream and reduce the rupture potential. It is anticipated that the flux will be additionally skewed upstream with the use of mixer elements for additional process tube life. Thus, in order to permit practical achievements of the 700 C limit specified for the bulk of the stack, it is necessary to permit higher temperatures in the 0.130 zone.

Two possible adverse effects can result from the 850 C limit permitted herein. One of these is a sufficient increase in the rate of reaction of water vapor in the inlet gas with the graphite in the 0.130 zone to provide high burnout rates from this source. The other is a possible increase in the contraction rate.

The possibility of high burnout rates is real at the temperature levels proposed. However, the rates are limited due to the low amount of water vapor normally present in the inlet gas at the K reactors. At a gas flow rate of 700 cfm and an inlet dew point of -20 F, a burnout of 20 pounds of graphite per day would result if all input water vapor reacted with the stack. Assuming a uniform burnout pattern in the in-reactor two feet of the 0.130 zone, the corresponding rate of burnout would be about 8%/KOD. Inlet dew points at the K's are normally lower than -20 F.

Such a burnout rate is not acceptable but does not represent a run-away situation.

The contraction rate at the K's in-reactor side of the 0.130 zone is approximately one-half that of the central zone graphite. A significant increase in this rate would be undesirable, not per se, but because of the possible effect upon the process tube curvature. The outer edge of the 0.130 zone corresponds roughly with the highest point in the stack, and a sufficient increase in contraction rate at the in-reactor end could lead to metal sticking problems. Actually, any such problem is more to be feared from an increase in flux level than from an increase in temperature.

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Because of these adverse effects, the temperature limit specified herein is conditional upon a lack of significant burnout attributable to water vapor and upon lack of evidence of a significant increase in the contraction rate of the 0.130 zone.

Water vapor burnout would be inferred from a rising concentration of CO and CO₂, coupled with a lack of evidence of increased air in-leakage and also with an increasing inlet dew point. Primary reliance, however, would be placed in the oxidation samples exposed in bare channels. If evidence such as is outlined above is apparent for a significant period of time, the current set of samples would be discharged and the burnout rate determined. If significant burnout rates are measured, then the new set of samples would be removed after 20 to 30 days exposure and examined for confirmation of the rates measured on the first set. It would, of course, be necessary to assure during the second set that essentially no air in-leakage occurred to confirm that the high rates were due to water vapor burnout.

E. Effects Upon Corrosion Rate

Nitrogen, under the influence of temperature and radiation in the reactor, may react with atmosphere impurities to form various oxides of nitrogen or ammonia. It does not seem likely that both would occur. Evidence to date is that the formation of ammonia is favored. A number of samples of dryer condensate collected both at KE and KW and at B and F reactors have been analyzed for nitrate-ion (NO₃⁻) and ammonia content. In essentially all cases, the nitrate-ion was present in amounts less than 1 ppm. Ammonia, on the other hand, was abundantly evident. Samples from both K's indicated approximately 10 grams of NH₃ per liter; from the older areas, less than 1 gram per liter was noted. The odor of NH₃ was generally apparent, and frequently the samples were blue or green in color. The color was due to the complex ion formed with copper and ammonia. The considerable difference in ammonia concentration between the K's and the older reactors is tentatively felt to be due to higher water collection rates and hence more dilution from the old reactors.

Formation of either NH₃ or oxides of nitrogen could be deleterious in the event of very wet operation, when liquid water might be present in the stack or the rear plenum area. Either of the above would tend to be absorbed in the liquid forming basic or acidic solutions, depending on which is present. Either would accentuate the external corrosion rate of process tubes from the graphite-aluminum couples since the solution would be more conductive. Acidic solutions would likely accentuate corrosion of the gunbarrels and other carbon steel components; basic solutions (associated with NH₃) are anticipated to affect gunbarrel corrosion rates, but may affect corrosion product adherence and thus gunbarrel sticking. NH₃ will, of course, present a corrosion problem to any copper or copper base components.

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This is not a wholly new problem introduced by the switchover to nitrogen. Nitrogen is and always has been present to some degree in reactor atmosphere. The problem resolves itself to one of what happens with an increase in the concentration of nitrogen. Experience to date indicates that serious problems will not occur with a dry reactor. Whether or not the corrosion problems associated with wet operation will be appreciably increased when coupled with an increase of N_2 concentration by a factor of 10 cannot be evaluated at this time.

Sooner or later a definite answer to this aspect of the corrosion problem--operation "wet" with high nitrogen--must be determined; ultimately, this can only be done by test operation of a reactor under these conditions. However, because of the potential risks involved, it may not be prudent to run such a test at the K's, the most efficient and productive of the operating reactors. Therefore, if there is reason to believe a period of prolonged "wet" operation is imminent, a review of the advisability of continued operation with nitrogen shall be conducted. A return to carbon dioxide may be authorized by a supplement to this PITA.

The effects of the higher 0.130 coring zone temperatures upon the nitriding and/or hydriding of zirconium should be reviewed prior to the installation of zirconium tubes. Upon installation of the first zirconium process tubes, continuation of this PITA must be authorized by a supplement to the PITA.

V. DETAILS OF PROGRAM

A. Nitrogen Switchover

This is complete at KE. The procedure for switchover at KW shall be supplied by Operational Physics. Neither reactor shall re-introduce CO_2 to the reactor system once the switchover to nitrogen is complete, for the duration of this PITA. The temperature limits specified herein are not applicable until the concentration of CO_2 is less than five per cent. Until the switchover is complete, the temperature limits as specified in Production Test IP-312-A shall be binding at KW.¹

B. Temperature Limits

The temperature of filler blocks shall not exceed 850 C in the 0.130 coring zone, and shall not exceed 700 C elsewhere. Exceptions are:

1. Within one lattice unit of an uncooled channel or an enriched charge, the filler block temperatures may be as high as 900 C in the 0.130 coring zone or 750 C in the balance of the stack.
2. For 48 hours following a hot startup or 72 hours after a cold startup, the filler block temperatures may be as high as 800 C in portions of the stack other than the 0.130 coring zone. No special relaxation at startup is allowed in the 0.130 coring zone.
3. Following the startup period, the filler block temperatures exclusive of the 0.130 zone may be as high as 750 C (800 C within one lattice unit of an enriched charge or uncooled channel) for up to 24 hours. This is not to be used to extend

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the period of startup temperature relaxation.

4. Until more definitely established, a front-to-rear graphite stringer temperature may be assumed to be 100 C higher than filler block temperature within one lattice unit thereof.
5. The minimum temperature limits as specified in Process Standard B-040, Figure, 1, shall apply.

These temperatures are summarized in Table I below:

TABLE I

Summary of Temperature Limits

<u>Location</u>	<u>Normal</u>		<u>Non-Standard Allowance*</u>		<u>Emergency Overrun</u>		<u>Startup Allowance</u>		<u>Max. Allowable At Any Time</u>	
	<u>0.130 zone</u>	<u>bal.</u>	<u>0.130 zone</u>	<u>bal.</u>	<u>0.130 zone</u>	<u>bal.</u>	<u>0.130 zone</u>	<u>bal.***</u>	<u>0.130 zone</u>	<u>bal.</u>
As read on side-to-side stringer	850 C	700 C	900 C	750 C		750 C**		800 C	900 C	800 C
As read on front-to-rear stringer	---	---	1000 C	850 C	No special allowance	850 C**	No special allowance	900 C	1000 C	900 C
Filler block	850 C	700 C	900 C	750 C		750 C**		800 C	900 C	800 C

Changes in these temperature limits may be authorized only by supplement to this PITA. Verbal approval may be obtained, but must be followed up by a written supplement.

C. Temperature Monitoring

Means for temperature measurement in the 0.130 coring zone at the front of the reactor are non-existent. Such few original couples as were installed during construction have failed, and none of the side-to-side replaceable stringers penetrates this zone. A front-to-rear stringer installed in channel 2871 at KE has shown significantly higher temperatures in this zone than the bulk of the stack--sufficiently so that a special limit has been specified for this zone. It is thus important to be able to monitor temperatures in this zone.

*Within one lattice unit of an enriched charge or uncooled channel.

**An additional 50° allowable for up to 24 hours maximum within one lattice unit of an uncooled channel or enriched charge.

***For 48 hours after hot startup, 72 hours after a cold startup.

The approach of using several front-to-rear stringers could be used; in the interest of conserving the number of channels removed from service, an alternate method is proposed.

Two front-to-rear stringers shall be installed at each K reactor.

By virtue of flux traverses taken in conjunction with stringer temperature traverses, the relation between side stringer temperatures in the 0.060 or 0.030 zones can be correlated with the 0.130 zone temperatures for a particular gas composition and flux distribution. Upon accumulation of sufficient data, it may eventually be possible to utilize only the side-to-side couples, flux traverses, and gas composition data to determine 0.130 zone temperatures. This will depend upon development of reliable means of separately correcting for gas conductivity charges and flux distribution charges. For the present, it is specified that the front-to-rear stringers be used so that the gas conductivity effect is included and corrections are made only for flux distribution changes. It is assumed for this method that flux traverses can be obtained using non-poisonous splines.

With the data from the two front-to-rear stringers and periodic flux traverses taken near these two and five other tubes as selected, it should be possible to monitor temperatures in the 0.130 zone adequately. One front-to-rear stringer is already installed at KE in channel 2871. The second should be installed in channel 4270, 4271, 4370, or 4371. At KW, one should be installed in channel 2971, 2970, 2871, or 2870; the second should be installed in channel 4270, 4271, 4370, or 4371. Flux traverses for the front-to-rear stringers shall be taken within two lattice units of the stringers. The other flux traverses shall be taken within two lattice units of the #5 and #11 couples on side-to-side stringers in layer #90 (RS-6, 7, and 8); and couples #5, #8, and #11 in layer 48 stringers (RS-1, 2, and 3).

The minimum frequency of flux traverses shall be as follows:

1. Next to front-to-rear stringers:
 - a. Within three days after startup from a minimum outage, provided equilibrium operation has been achieved, and
 - b. Following a change in N_2 concentration of five per cent that has held stable for 24 hours, as based on the last N_2 concentration that has held stable for 24 hours, and
 - c. On a minimum frequency of at least once per week during equilibrium operation.
2. Other locations as specified above:
 - a. As above specified in 1-a, 1-b, and 1-c for the front-to-rear stringer for the first operating period that this process is instituted.

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- b. As in 1-a above for the front-to-rear stringers for the subsequent two operating periods.
- c. Subsequently as specified by the process engineer or process physicist, but in any case, upon significant flux shifts and with a minimum frequency of once every two months.

The flux traverse information collected above will be useful for other purposes to the process physicist.

Supplemental data needed in coordination with the flux traverses include stringer temperatures, tube powers, rod positions, and gas composition as specified by the process engineer who shall supply forms for recording the data.

For each central zone temperature used above, a limit for that couple shall be calculated corresponding to the 0.130 zone temperature limit and shall be specified to operating personnel for control purposes, unless such temperature exceeds 700 C. The process engineer and physicist shall be responsible for evaluating this data and specifying control temperatures as outlined above. They shall attempt to develop calculation methods that will permit reduction to one front-to-rear stringer per reactor.

It is very desirable for the front-to-rear stringers to be installed at the earliest possible date. Bare wire stringers using ceramic bead insulators can be used; however, installation and removal of this design stringer is difficult and costly in outage time at best. It is anticipated that sheathed couple stringers would be considerably less difficult to install and remove. Because of long lead times involved in procurement of the sheathed couples, three months is allowed by this PITTA for installation of the front-to-rear stringers. However, it is not advisable that the 0.130 zone be permitted to continue longer than this with no temperature monitoring at all with the elevated 0.130 zone temperature allowed by this PITTA. Therefore, it is specified that if after two months it is apparent that the above schedule cannot be substantially met, one front-to-rear stringer of the bare wire design shall be installed in channel 2871-KW (2870, 2971, or 2970 may be substituted) within one month.

The location of front-to-rear stringer couples in the stack shall be specified by the process engineer at each reactor. It is strongly recommended that inconel sheathed couples be used.

The side-to-side RS-1, 6, and 9 stringers shall be replaced if inoperable as defined by process standards or if couples 5, 8, or 11 on any of the stringers are inoperable. The replacement should be accomplished within three months. The additional side-to-side stringers shall be replaced within four months if inoperable as defined by

process standards, or if couple #3 on any of them is inoperable.

D. Graphite Distortion

Vertical height traverses shall continue to be made in the Y-2 hole at each reactor on the frequency specified in Process Standard G-010.

E. Gas Atmosphere Composition Monitoring and Controls

The gas chromatograph shall be in continuous operation with reasonable prospects that it will remain so. The calibration of the thermal conductivity analyzer for helium concentration shall be adjusted as necessary to compensate for the use of nitrogen. The gas flow rate meter calibration shall be corrected for the different densities obtained with He-N₂ mixtures.

The Beckman O₂ analyzer shall be maintained operable and in calibration at both reactors, as shall the orsat equipment.

As soon as possible, the test to calibrate the gas activity meter in terms of argon concentration shall be conducted, and in any case, no later than one month after approval of this PITA. Mass spectrograph samples shall be taken on a minimum frequency of once per week during equilibrium operation.

Composition control shall be as follows:

1. Helium and Nitrogen

He and N may be used in any proportions provided the temperature limits are not violated.

2. Air In-Leakage Control

The concentration of oxygen in the reactor gas at startup shall not exceed two per cent. During the 48 hours after startup, concentration of O₂ shall show a downward trend. Following this period and assuming successful calibration, a primary measurement for total air leakage shall be the gas activity meter. At all times following the startup period, the activity meter shall show a downward trend except when argon concentrations less than the following schedule are indicated by the activity meter:

<u>Gas Loss Rate (Cfd)</u>	<u>Percent Argon</u>
0 - 10,000	0.036
10,000 - 20,000	0.024
20,000 - 30,000	0.012
More than 30,000	0.006

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If a downward trend is not apparent when above these concentrations, corrective action, as appropriate, shall be taken without undue delay to reduce the rate of air in-leakage. Normally, a downward trend should be apparent within four hours.

Because some argon is present as an impurity in the nitrogen make-up gas, the per cent concentration of argon as indicated by the activity meter may be adjusted downward by the per cent nitrogen in the atmosphere multiplied by 300×10^{-6} . As an example, suppose the argon concentration indicated by the activity meter is 0.03 per cent and there is 40 per cent nitrogen in the reactor atmosphere; the adjusted argon concentration would be:

$$0.03\% - 40 \times 300 \times 10^{-6} = 0.03 - 0.012 = 0.018\%$$

The oxygen concentration as indicated by the Beckman oxygen analyzer shall be less than 0.02 per cent following 48 hours after startup. The gas chromatograph does not indicate oxygen directly, but the combined concentration of oxygen and argon. Normally, the difference between the chromatograph oxygen per cent and the argon concentration indicated by the activity meter shall not exceed 0.02 per cent following 48 hours after startup.

All of the above methods indicate but do not control the air in-leakage. To control air in-leakage, it is specified that the difference in pressure between the rear, bottom of the reactor and the rear face air pressure, and the corresponding ΔP for the front face shall both be maintained positive.

3. Total Burnout Control

With the elimination of CO_2 as a reactor atmosphere constituent, the presence of either CO or CO_2 in the atmosphere can only indicate moderator oxidation. In a similar fashion to argon, the sum of concentrations of CO and CO_2 in combination with the gas loss rate is an indication of the total rate of moderator burnout. Also, in combination with rate of air in-leakage, this approach may provide information on water vapor reaction rates, and on interpretation of burnout rates as shown by oxidation samples. This method of control has yet to be proven, but it is an objective of this PITA to evaluate its effectiveness. The sum of concentrations of CO and CO_2 shall normally be maintained less than the following schedule, or shall be on a downward trend during equilibrium operation.

Gas Loss Rate (Cfd)	Percent CO_2 plus Percent CO
0 - 10,000	6
10,000 - 20,000	3
20,000 - 30,000	2
More than 30,000	1

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This schedule corresponds to a maximum total burnout rate of 20 pounds of graphite per day, approximately eight times that which could result from oxygen burnout based on the argon concentration limits. It represents an unacceptable rate of burnout; operation should normally be well within the above limits. If the above limits are exceeded during normal equilibrium operation, the following sequence of action is recommended:

- a. Review the evidence for air in-leakage. If the limits specified for control of air in-leakage are being exceeded, take corrective action.
- b. If air in-leakage requirements are being met, or if not and corrective action does not establish a downward trend in the combined concentrations of CO-CO₂ within 12 hours, there is reason to suspect water vapor burnout. This being the case, consideration should be given to reduction of graphite temperatures, particularly in the front 0.130 coring zone if these are higher than central zone graphite temperatures, and to changing dryers if the inlet dew point is in excess of -20 F.

4. Moisture Content

The inlet dew points together with the gas flow rate indicates the water vapor input to the front of the reactor. Because of the high temperatures allowed in the 0.130 zone, the inlet dew point is an important monitor, as well as for other reasons. The inlet dew point shall normally be maintained at less than -20 F. Because of the previous requirements and because the continuous dew point analyzers do not indicate dew points of less than -10 F, manual dew points shall be taken with a minimum frequency of once a shift.

F. Oxidation Sample Monitoring Program

Oxidation samples shall continue to be exposed in channels 188C-KW and 3066-KE. The maximum residence time is specified to be three months, or until the first minimum outage occurring thereafter. If there is cause to believe that water vapor burnout rates are significant, samples may be discharged at shorter residence times.

Samples will be placed to provide adequate coverage with special attention to the front 0.130 coring zone and the 0.060 zone just downstream therefrom.

G. Corrosion Monitoring Program

It is not possible at this time to detail a full corrosion monitoring program. Sampling of the dryer condensate at each reactor should be continued on an every other time basis during dry operation; that is,

a sample should be taken of the condensate on one regeneration, skip the next time, take one the next time, etc. During wet operation, at least one sample should be taken per operating period while wet.

The procedure previously used for sampling should be continued. Process Technology will supply the sample containers and arrange for their analysis.

One of the principal questions involved is the effect upon external process tube corrosion. To this end, it is specified that upon the occurrence of a tube leak toward the rear of the stack, two process tubes in the immediate vicinity of the leak shall be removed after one operating period of approximately 20 to 30 operating days and examined for signs of external corrosion.

Apart from these programs, efforts will be directed toward developing analysis methods for nitrogenous compounds directly from the gas stream. If feasible, such analyses would be applied to more fully understand the results of condensate analyses and to verify the extent to which such compounds are removed in the dryers.

H. Revisions to the Monitoring Programs

The monitoring programs as outlined in parts V, C through G, may be altered upon approval of the Manager, KE-KW Reactors Operation, and the Manager, Process Technology Sub-Section.

VI. COSTS

Direct costs of graphite stringer fabrication and installation, and of tube removal for stringers and the corrosion program shall be borne by the Processing Operation at the reactor involved. Costs of oxidation sample fabrication, installation of corrosion monitoring programs, and of data evaluation shall be borne by Process Technology funds.

Estimated Production Losses

KE

KW

A. Outage Time

1. Removal of process tubes and subsequent re-installation at four hours per front-to-rear stringer channel, six hours for the two tubes authorized in the corrosion monitoring program.	10 hrs.	14 hrs.
2. Installation of front-to-rear stringers at four hours per stringer.	8 hrs.	8 hrs.

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Estimated Production Losses (cont.)

KE

KW

A. Outage Time (cont.)

3. Oxidation sample removal at one hour per changeout.	6 hrs.*	6 hrs.*
4. Contingencies	4 hrs.	4 hrs.
5. Total authorized outage time for this PITA.	28 hrs.	32 hrs.

B. Loss of Production Channels

1. Production loss from three tubes per reactor for one year.	1800 MWD	1800 MWD
2. Reactivity cost.	3 cmk per tube	

VII. SCHEDULE

1. Duration of PITA.	1 year, 6 months from approval.
2. Argon-activity meter calibration test completed.	1 month from approval.
3. Installation of front-to-rear stringers.	3 months from approval.
4. Installation of RS-1, RS-6, R-9 as required.	3 months from approval.
5. Detail corrosion program and initiate tests.	3 months from approval.
6. Evaluate effectiveness of 0.130 zone temperature monitoring program and issue recommendation thereon.	9 months from approval.
7. Complete evaluation of data and final report.	1 year, 3 months from approval.
8. Issue revised process standards as per final report recommendations.	1 year, 6 months from approval.

*At three months residence, it is anticipated that four changeouts would be accomplished at each reactor. Outage time is authorized for an additional two changeouts to cover the possible need for short-term samples.

VIII. HAZARDS

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Reactor Safety

None

Reactor Life

The possibility of accelerated external process tube corrosion above and beyond that normally encountered in wet operation cannot be discounted. The principal problem here is the possibility that the acceleration in the number of leaks appearing could virtually preclude operation, with ramifications on the zirconium tube installation schedule. Also, the possibility of enhanced gunbarrel sticking could affect the life of zirconium tubes. It is for this reason that a review for advisability of continued nitrogen usage is called upon for indications that a period of prolonged "wet" operation will occur.

Significant burnout rates from water vapor may occur at the high temperature limit authorized for the 0.130 graphite coring zone; also, significant increases in the contraction rate of the inboard side of front 0.130 zone with adverse effects on process tube distortion. Monitoring programs have been specified to detect such effects. If unacceptable levels on either are detected, the temperature limit will be lowered. There is no reason to believe such effects would be so rapid as to result in significant damage before they are detected and corrective action taken.

The higher 0.130 zone temperature may have adverse effects upon the nitriding and/or hydriding of zirconium tubes. For this reason, continuation of the PITA upon installation of the first zirconium process tubes must be authorized by a supplement to the PITA.

IX. REACTOR PROCESS STANDARDS⁸

Process Standards B-010 and C-040 are affected as follows:

B-010

1. Nitrogen is to be used in place of CO₂ in the reactor atmosphere. The upper limit of four per cent on nitrogen is suspended for the duration of this PITA.
2. The normal maximum O₂ content as measured by the Beckman oxygen analyzer should not exceed 0.02 per cent (formerly 0.05).
3. Mass spectrograph gas sampling frequencies based on nitrogen percentages are suspended.

C-040

The minimum temperatures specified in C-040 remain in force as does the 580 C limit in the vicinity of an uncooled process tube. All other temperature limitations and allowances are superseded by the limits specified in this PITA. Within these limits, the limiting rate of rise temperature specified in C-040.05 is applicable.

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All other provisions of the process standards remain in force.

X. RESPONSIBILITIES

KE and KW Processing shall be responsible for production continuity and safety of the reactor, for scheduling as specified, for compliance with limits stated herein, for obtaining dryer condensate samples, and for recording data in connection with the temperature monitoring program.

Process Technology shall be responsible for conducting the argon calibration production test, specification of location of front-to-rear stringer thermocouples, specification of activity-meter calibration for argon, for evaluation of temperature monitoring data, and for recommendations on a permanent 0.130 zone temperature monitoring procedure. Process Technology shall also be responsible for evaluating the effectiveness of air in-leakage control, the value of CO-CO₂ concentration for total burnout control and effectiveness for monitoring water vapor burnout, and for issuance of revised process standards based upon recommendations from Process and Reactor Development. If it should become necessary, Process Technology shall conduct the review of advisability for continuing on nitrogen if a period of extended wet operation is in view.

Process and Reactor Development shall be responsible for evaluating corrosion monitoring data and overall effects of higher temperature on the graphite, for evaluating the effects of this program upon the zirconium tubes, and for issuing a final report on this PITA to serve as a basis for revised process standards.

Operational Physics shall be responsible for specifying the procedure of changing over to nitrogen at KW reactor.

Process Engineering Unit
Process Technology Sub-Section
Research and Engineering Section
IRRADIATION PROCESSING DEPARTMENT

RE Baars:md

Reviewed and concurred with:

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FIGURE - I
FRONT TO REAR STRINGER TEMPERATURES
2871 - KE
(Data taken 5/22/62)

Note: See Section IV - A for explanation of relation between front-to-rear and side-to-side Stringer Temperatures

FIGURE - 2
K REACTOR GRAPHITE CORING ZONES-LAYER 61

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