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**ALTERNATIVES FOR SODIUM-POTASSIUM
ALLOY TREATMENT**

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SUMMARY

Sodium-potassium alloy (NaK) is currently treated at the Y-12 Plant by open burning. Due to uncertainties with future permits for this process, alternative treatment methods were investigated, revealing that two treatment processes are feasible.

One process reacts the NaK with water in a highly concentrated molten caustic solution (sodium and potassium hydroxide). The final waste is caustic that may be used elsewhere in the plant. This process has two safety concerns. Hot corrosive materials used throughout the process present handling difficulties. Also, the process must be carefully controlled (temperature and water content) to avoid explosive NaK reactions.

To avoid these problems, a second process was developed that dissolves NaK in a mixture of propylene glycol and water at room temperature. While this process is safer, it generates more waste than the caustic process. However, the waste may possibly be used as a carbon food source in biological waste treatment operations at the Y-12 Plant.

Experiments were conducted to demonstrate both processes, and they showed that both processes are feasible alternatives for NaK treatment. Process flow sheets with mass balances were generated for both processes and compared. While the caustic process generates less waste, the propylene glycol process is safer in several ways (temperature, material handling, and reaction control). The authors recommend that the propylene glycol alternative be pursued further as an alternative for NaK treatment.

In order to optimize this process for a larger scale, several experiments should be conducted. The amount of NaK dissolved in propylene glycol and subsequent waste generated should be optimized. The offgas processes should be optimized. The viability of using this waste as a carbon food source at one of the Y-12 Plant treatment facilities should be investigated. Finally, if the state accepts this process as an alternative, design and construction of a pilot-scale treatment system should begin.

INTRODUCTION

Sodium-potassium alloy (NaK) is used as a coolant in a skull caster furnace at the Y-12 Plant. The furnace is scheduled to be shut down by the end of 1993, leaving ~250 gal of NaK for treatment. In the past, NaK has been treated by open burning; however, the permit with the state of Tennessee expires in November 1993 and will not allow for the treatment of the total NaK waste. The Y-12 Plant Development Division has been asked to develop a low-cost, small scale treatment alternative. This project was planned to have two phases. The first phase was to demonstrate the feasibility of treatment alternatives. The second phase was to demonstrate and optimize the process on a pilot scale. This report documents the results of the first phase. The information gathered from this investigation will be used to compare other alternatives. Also, it may be used in negotiations with state authorities to extend the open burning permit.

BACKGROUND

NaK is a silver-colored liquid metal alloy used as a coolant in a skull caster furnace at the Y-12 Plant. Similar to liquid sodium, NaK is very reactive with oxygen, water, and hydrocarbons. For example, when contacted with water, NaK reacts instantly, creating sparks, flames, splattering, and/or explosions (depending on the reaction conditions). Hydrogen gas, which is also quite flammable, evolves from the reaction. NaK is also harmful when contacted with skin. Typically, NaK is handled under an inert atmosphere, such as nitrogen or argon, and is stored under a layer of mineral oil to prevent reactions.

By the end of 1993, the skull caster furnace, which is the only source of NaK waste, should be out of service. At this time, ~250 gal of NaK will have to be treated. The current treatment process is open-air burning. The permit for this process from the Tennessee Department of Environment and Conservation (TDEC) will expire in November 1993. The permit only allows for the burning of a total of 20 gal of NaK (for the entire life of the permit). Unless a request to the state to allow open burning for the rest of the NaK is successful, an alternate treatment method is needed. Waste Management asked the Y-12 Plant Development Division to develop a process that would be safe and cost effective for the required amount of NaK.

PRESENTATION OF EXPERIMENTAL WORK

PROCESS DESCRIPTIONS

Two similar processes were developed and evaluated simultaneously. The first process reacts NaK (78% potassium by weight) with water using sodium and potassium hydroxide as a diluent to minimize the hazards of the reaction. The reaction is as follows:

(Although NaK_2 is the correct formula for the alloy, it is commonly referred to as "NaK". In this report, "NaK" will be used except in chemical equations.)

The final products of this reaction are caustic (KOH and NaOH), which may be recycled through the process, and hydrogen. Due to the relatively high concentration of caustic used and produced (70 to 80 wt % caustic), the reactants and products must be heated to maintain fluidity. The molten corrosive solutions and explosive hydrogen gas are the chief hazards of this process.

The second process uses propylene glycol as a reactant/diluent. Like water and most alcohols, propylene glycol also reacts with NaK, but at a more controllable rate. In this process, hydrogen gas is generated in the same quantities as in the caustic process. The final liquid product is a relatively safe-to-handle mixture of propylene glycol and caustic, which could possibly be used as a food source in the bioreactors of the Y-12 Plant.

EXPERIMENTAL SETUP

Initially, the processes were tested in beaker scoping studies, which varied in size and purpose and will be discussed in detail in later sections. To test both processes on a larger scale under an inert atmosphere, the setup shown in Figure 1 was used. Propylene glycol is shown in the figure, but caustic may be used as well.

The setup consisted of a 1-L glass reactor with mixing from an overhead mixer. The process was designed to safely control the amount of NaK fed to the reaction vessel. The desired amount of NaK (usually less than 5 mL) was fed with argon from its storage container to a glass separator funnel. After the feed line from the storage container was closed, the NaK was added drop by drop, with argon, from the separator funnel to the reaction vessel.

The funnel contained 5 to 10 mL of mineral oil or propylene glycol to help feed the NaK, depending on the nature of the experiment. Mineral oil, rather than propylene glycol, is commonly used in NaK storage and containment. Because mineral oil is lighter and insoluble in water, it tended to surround the NaK in the reactor, creating an unreactive emulsion. Propylene glycol did not have this problem. However, propylene glycol is heavier than and mildly reactive with NaK, creating clogging problems when feeding. On a larger scale, feeding NaK is not a problem. Such a process would use a gravity feed of NaK in greater quantities with relatively small amounts of mineral oil (from storage).

Argon was used to maintain an inert atmosphere and to feed the NaK. The argon also purged the hydrogen gas created during the reaction. The exiting purge line was fed through a bubbler (about 100 mL of water, propylene glycol, or mineral oil in a 250-mL Erlenmeyer flask) to dissolve any vaporized caustic or organic. The setup also safely dissipated hydrogen into the hood.

Figure 1-NaK reactor setup

Before experiments began, a Health and Safety Readiness Review was conducted to independently evaluate the safety of this setup. The process was approved, with the caution that the development of this project beyond this laboratory scale should be closely followed. If and when the experimental configuration is appreciably altered or expanded, another review will be required. In addition to this, a safety evaluation for the process was conducted by the Development Compliance Assistance Group, which was approved by Facility Safety.

THE CAUSTIC PROCESS

In the caustic process, regulation of the reaction requires about 70 wt % caustic. As the caustic concentration increases, the reaction is milder because of dilution of the reactants. At high concentrations, the caustic is solid at room temperature and must be heated or diluted with additional water. As the NaK reacts, the caustic concentration increases and heat evolves. As a result, the operating temperatures are usually well above 90°C. NaK becomes spontaneously combustible at 115°C under a normal atmosphere; therefore, even under an inert atmosphere, temperatures were usually kept below this level. Experiments concentrated on finding a feasible caustic concentration and temperature for this process.

Initial beaker experiments were conducted to find a workable caustic concentration. One hundred grams of solid caustic (78 g of KOH and 22 g of NaOH) were measured into a glass beaker with 10 g of water. The mixture was heated until it was completely liquid at 140°C and then cooled until crystals formed at 120°C. Ten more grams of water were added and the process was repeated. The process continued over a range of concentrations and temperatures, as shown in Table 1.

Table 1. Freezing points of caustic solutions

Total Weight (g)	Water Weight (g)	% Water	Temperature Completely Fluid (°C)	Freezing Point (°C)
110	10	9.1	140	120
120	20	16.5	130	105
130	30	23.1	110	80
135	35	25.9	90	60

Another beaker experiment (in a hood under normal atmospheric conditions) was performed with 20 wt % water in caustic. One hundred grams of caustic and 25 g of water were measured into a 1-L thick-walled glass beaker. The stirred mixture was heated until the caustic was liquid at 130°C then cooled until crystals formed at 116°C. The molten caustic was again heated to 125°C. To observe the reaction above the temperature at which NaK becomes combustible, a small drop of NaK was added. The NaK immediately reacted, creating shooting sparks and a small flame. Ten grams of water were added (to make 26 wt % water) and the temperature was lowered to 97°C. Small drops of NaK were added again, creating sparks. The reaction was slightly less vigorous than the first reaction but still hazardous. The solution was then transferred to a 100-mL beaker. A drop of NaK with a dark (presumably oxide) coating was added. After a noticeable delay (~30 s), the coating dissipated. When the drop became shiny, it caught fire and

emitted sparks. These experiments established 23 wt % water as a lower water concentration limit and emphasized the necessity of depleting oxygen from the system. With the absence of oxygen, the NaK becomes far less reactive and hazardous.

The system was then tested on a larger scale with the system shown in Figure 1. Initially, a stoichiometric mix of KOH and NaOH with 25 wt % water (184 g of NaOH, 516 g of KOH, and 300 g of water) was added to the reactor. The mixture was heated with an electric heating mantle to above 120°C to completely liquify the solution then cooled to 110°C. The heating mantle was then removed to observe the NaK addition more clearly. At 106°C, 0.5 mL of NaK was fed to the reactor with 8 mL of propylene glycol. The reaction created a great amount of smoke that filled the reactor and turned the solution light brown. The color and smoke were believed to be due to the presence of propylene glycol. These results were not seen during the beaker caustic studies. No sparks, flames, or significant temperature increases were observed. Successive additions of 1 mL, then 2 mL of NaK, each with 5 mL of propylene glycol, followed. The temperature for these additions were 103°C and 93°C, respectively. Again, except for a great deal of smoke, no hazardous effects were observed. At this point, the experiment was halted because the NaK feed line became clogged.

These experiments demonstrated the basic feasibility of the caustic process. However, because of its inherent hazards, especially caustic handling and high temperatures, work focused on the propylene glycol process.

THE PROPYLENE GLYCOL PROCESS

During a literature review, the authors discovered that one method for treatment of very small quantities of NaK is by reaction with and dissolution in alcohol.¹ Alcohol has also been used in the nuclear industry for the safe cleaning of sodium-wetted reactors and components.² The general reaction is

This reaction is very similar to the water based reaction, with an organic group (R) replacing one of water's hydrogen atoms. The rate for alcohols is considerably slower than that for water. In general, the heavier the organic group, the slower the reaction. The K^+RO^- and Na^+RO^- compounds are referred to as potassium and sodium alcoholates. Studies were begun to find an alcohol that reacted safely with the NaK at room temperature and produced an acceptable waste product.

Because of to their availability, first beaker scoping studies were done with methanol (CH_3OH) and isopropanol ($\text{C}_3\text{H}_7\text{OH}$). NaK was added drop by drop to 10 mL of the chosen alcohol in a 1-L glass beaker at room temperature in an open hood. As expected, methanol was more reactive than isopropanol. The NaK dissolved in about 30 s in methanol and in 5 min in isopropanol. No sparks or flames were observed. Due to the mildness of the reaction, water was added to observe its effect. Experiments were conducted with 100-mL solutions of both alcohols in 0 to 90 vol % water. As expected, reactivity increased as the water concentration increased. At higher water concentrations, sparks and flames formed on the surface of the solution. Also, the reactivity (and sparks) increased dramatically with stirring.

Although these experiments were successful in finding a less reactive solvent, several concerns were raised. Most alcohols, including the preceding two, are flammable. Using them in a process that may generate sparks and flames is risky. Also, the alcoholates are very alkaline organic salts.

Solution pH from the beaker experiments reached 13.6, even when relatively small portions of NaK were reacted. Although the Y-12 Plant treatment facilities could possibly handle such wastes, secondary waste treatment is not yet determined for either process. At this point, investigations turned to propylene glycol.

Propylene glycol ($\text{CH}_3\text{CHOHCH}_2\text{OH}$) is a dihydric alcohol with two potentially reactive hydroxyl groups on two separate carbons. It is nonflammable (flash point of 210°F). Propylene glycol is used at the Y-12 Plant both as a machining coolant and as a carbon food source for biodenitrification at the West End Treatment Facility (WETF). Although thorough investigations should be conducted, an alkaline solution of propylene glycol (below 40 wt % in water) can potentially be consumed by the microorganisms at WETF.

Beaker experiments in an open hood were conducted to qualitatively determine the reactivity of propylene glycol with NaK. Solutions with 10, 20, 30, 40, 50, and 100 vol % propylene glycol in water were prepared. One hundred milliliters of each solution were measured into 250-mL beakers, and NaK was added drop by drop without mixing. Small sparks and a flame were observed as NaK dissolved instantly in the 10% solution. From 20 to 40%, only singular small sparks were observed as the NaK was added. In these solutions, NaK dissolved slowly with noticeable fizzing. For the 50% and 100% solutions, no flames or sparks occurred, even when the solutions were mixed. The NaK eventually dissolved after several minutes.

Experiments continued under an argon atmosphere with the same setup as was used with caustic process (Figure 1). The main objective of the experiments was to determine the solubility of the NaK in propylene glycol/water solutions. From experimental data with methanol and sodium metal³, 12 wt % of NaK was expected to dissolve in the solution.

One liter of 50 vol % propylene glycol (in water) was measured into the reactor. NaK was added drop by drop with 100% propylene glycol (used to flush the NaK through the lines). The solution was mixed constantly and the temperature monitored. Table 2 shows the addition amounts, temperatures, and observations. It also shows the approximate wt % of sodium and potassium ions in the final solution, assuming that all of the sodium and potassium remained in the reactor and that none vaporized. At the end of this experiment the bubbler solution remained clear, indicating that no sodium or potassium had been entrained in the offgas. The experiment was interrupted when the authors observed the undissolved NaK in the reactor.

To examine the solution more closely, a 70-mL sample was pulled from the bottom. It had a light-brown tint and a pH of 13.6. A small amount of undissolved NaK appeared to be trapped in oil (probably mineral oil residue from earlier experiments).

To dissolve the NaK, the reactor, with the remaining solution, was heated. At 77°C , the NaK still did not dissolve. To drain the reactor for cleaning, 500 mL were pulled from the bottom, which caused the NaK on the surface to smoke and dissolve, probably the result of air pulled into the reactor as it was drained. The 500-mL solution appeared to be free of oil or undissolved NaK, so it was saved for further experiments.

After this experiment, the reactor was cleaned to remove any oily residue. The 500-mL solution was returned to the reactor, and NaK was once again added under an argon atmosphere. The addition amounts and observations are shown in Table 3.

The final solution was very dark brown (almost black) yet still clear, without any visible suspended solids. The calculated concentration of sodium and potassium ions was 3.46 wt % (~ 4.2 vol %). The water in the bubbler had a light-brown tint, indicating that some of the solution had

Table 2. Initial NaK solubility experiment

Vol. of NaK added (mL)	Vol of propylene glycol added with NaK (mL)	Initial Temp (°C)	Max. Temp. after NaK added	Wt % of Na ⁺ & K ⁺ ions	Observations
0.2	10	22.2	22.4	0.01	Instant dissolution of NaK, no sparks or flames
0.2	5	22.3	22.3	0.03	Same
0.5	8		22.6	0.07	Tan tint to solution
0.6	8	22.4	24.1	0.12	Lots of smoke; dissipated after ~1 min.
1	10	23.9	23.8	0.20	Same
2	10		24.7	0.36	Did not dissolve as readily
1.5	15		25.6	0.47	Same
4	10		24.9	0.77	Undissolved NaK observed on the surface

Table 3. NaK solubility experiment

Volume of NaK (ml)	Volume of propylene glycol added with NaK (ml)	Wt % of Na ⁺ & K ⁺ ions	Observations
0	0	0.77	Solution from end of experiment described in Table 2
1	5	0.90	Reacts quickly; no sparks or flames
0	2	0.89	Propylene glycol only to flush residual NaK from lines
2	6	1.20	Some NaK splattered on sides of reactor
0	5	1.19	Propylene glycol flush
2	5	1.49	Reacts quickly; brown tint to solution
0	3	1.48	Propylene glycol flush
3	5	1.93	Reacts fine; Temp - 26°C
4	5	2.50	Temp - 29.1°C; Lots of smoke; Backpressure almost pulls water from bubbler into reactor; Increase argon flow to correct problem
3	5	2.92	Temp - 31.2°F; No problems
4	5	3.47	Temp - 32.8°C; Some NaK splattered in reactor; single spark was observed.
0	1	3.46	Propylene glycol flush

vaporized (or had been entrained in the hydrogen offgas) and dissolved in the bubbler. The assumption that all of the sodium and potassium remained in the bubbler was not valid for this experiment. For this reason, the calculated wt % of sodium and potassium ions in solution was higher than actual value. One hundred milliliters of this solution and the water solution used in the bubbler were analyzed for sodium and potassium concentration and organic content. A blank solution of 50% propylene glycol in water was analyzed at the same time. The results, shown in Table 4, were used as the basis for the process flow sheet (see "Discussion of Results").

The remaining solution (466 mL) was used to determine if more NaK could be dissolved. In the reactor under argon, a total of 8 mL of NaK was added in 3 approximately equal portions (with ~20 mL propylene glycol). During the first addition, the temperature rose from room temperature to 40.6°C. During the second addition, a spark was observed and the temperature rose suddenly to 49°C. The solution was allowed to cool to 34.4°C before the third addition. After the third addition, the temperature increased again to 49°C. At this point the total concentration of sodium and potassium ions in solution was, at most, 3.8 wt %. This experiment demonstrates the increasing hazards as the solution became concentrated.

Table 4. Results of NaK solubility experiment

	50% Prop. Glycol Soln	Final Solution	Bubbler Solution
Potassium Conc. (mg/L)	<30	>10000	4300
Sodium Conc. (mg/L)	<30	9530	614
Total Organic Carbon (mg/L)	303000	36000	1100

The authors conducted several beaker experiments in an open hood to try to reach a maximum concentration of NaK in propylene glycol. They also investigated the effect of varying propylene glycol concentration. Although these experiments are cruder than those with the reactor, they required less time and material. These experiments could be done in smaller volumes, requiring less NaK to reach saturation. One hundred milliliters of 40, 60, and 80 vol % propylene glycol solutions were measured into 600-mL beakers. NaK was added drop by drop with a pipet. A plastic dish with a hole was used to cover the beakers to contain sparking and splattering. Because the great amount of offgas was not contained and the final product was usually solid at room temperature, the final waste concentrations were difficult to approximate or measure. The results from these experiments are only qualitative.

During the test with the 40 vol % solution, NaK was added very slowly, 0.5 mL to 1 mL at a time. A total of 50 mL of NaK were added. After 5 to 6 mL of NaK were added, the solution was expected to turn dark brown; however, it became light brown but did not grow very dark until the last 10 mL were added. Excessive smoke was generated during the experiment. The temperature was not measured during the NaK addition. After all 50 mL were added, the temperature was 117°C. The final volume was ~50 mL. As the solution cooled, it quickly solidified.

The 60 vol % solution behaved similarly. After 18.4 mL of NaK had been added, the solution was dark brown and cloudy and looked very similar to the final 40 vol % solution. At this point, the temperature was 175°C. After 34 mL of NaK had been added, the solution was very viscous and the NaK took considerably longer to react. After a total of 40 mL of NaK had been added, the solution sustained a flame for an abnormally long time (over 30 s). The final solution was black, viscous, and oily and solidified upon returning to room temperature.

The 80 vol % solution was unexpectedly reactive. In earlier beaker studies, as propylene glycol concentration increased, reactivity decreased, but not for this case. The first 3 mL were added quickly, creating flames and turning the solution very dark brown. As the experiment continued, the NaK for some unknown reason was more reactive with the solution than with the two earlier solutions. After 19 mL had been added, the volume of the solution was slightly less than 100 mL and the temperature was 54°F. After 2 mL more were added, the NaK stopped reacting and formed a nonreactive layer on the surface. The NaK appeared to be trapped in an emulsion, yet no oil had been added to the solution. The maximum solubility of NaK appeared to have been reached for this concentration of propylene glycol. More experiments should be done to understand NaK dissolution in higher concentrations (if this information is deemed necessary).

DISCUSSION OF RESULTS

Both processes are feasible for a larger scale. Although the systems differs in operating parameters and final waste forms, both processes are very similar. A selection should be based on a close comparison of the two.

Two flow sheets were developed to compare processes and evaluate costs. The basis for both flow sheets was the treatment of 5 gal of NaK in 4 h. This scale was selected to compare with the current open burn permit which allows for burning of 5 gal of NaK "at a time", a phrase that is loosely defined.

THE CAUSTIC PROCESS

Figure 2 shows the caustic process flow sheet. The preceding experiments were used as a basis, assuming a final water concentration of 30 wt %. The heat of reaction shown was calculated from tabulated values⁴, assuming that the NaK reacts solely with water. (Theoretically, the NaK will react with the caustic but generally at much higher temperatures.) Another assumption is that little caustic is vaporized in the reactor and that all that is vaporized is dissolved in the bubbler.

The initial caustic solution is 260 kg of caustic, 35% water. The final waste, including the bubbler solution, is a total of 358 kg of caustic, 46% water. Assuming that the waste is not too contaminated with other materials, 198 kg may be used in the NaK dissolving tank and added to 62 kg of fresh caustic to continue the process. The rest of the waste (160 kg) should be relatively clean caustic that may be used in waste treatment operations. The relatively small amount of waste is the greatest benefit of this process; however, the largest drawback is safety. Throughout the process, hot corrosive materials must be handled, requiring careful execution of the process and special equipment (heated tanks, steam-traced lines, etc.). The temperature and amount of water in contact with the NaK must also be carefully controlled to prevent explosive reactions.

THE PROPYLENE GLYCOL PROCESS

Figure 3 shows the flow sheet for the propylene glycol process. The final waste from the reactor is 341 L of 60 wt % propylene glycol [360,000 ppm total organic carbon (TOC)] with 34,280 ppm potassium, and 9530 ppm sodium. The bubbler waste, as shown, has the composition of 4300 ppm potassium, 614 ppm sodium, and 1100 ppm TOC (~0.2% propylene glycol). These compositions were found from the data in Table 4 and a subsequent mass balance for potassium. The mass balance calculations were based on the following assumptions.

1. The amount of undissolved NaK described in Table 2 was negligible when compared with the overall amount of NaK dissolved.
2. The bubbler solution used for additions in Table 4 had a final volume of 100 mL, which is a good estimate that has little effect on the overall mass balance.
3. All of the vaporized material dissolved in the bubbler (a good assumption based on observations).

This composition is not necessarily optimal. As demonstrated in beaker experiments, the waste could be more concentrated. However, as the waste becomes concentrated, it becomes more combustible and viscous. As the dissolved NaK concentration increases, the waste becomes a solid (at room temperature), alkaline substance that has the same handling difficulties associated

Fig. 2 Caustic process alternative.

Fig. 3 Propylene glycol process alternative.

with the caustic process; therefore, the endpoint represented by the composition noted was chosen.

The waste from this process is an organic caustic solution. This waste may likely be used as a food source in the Y-12 Plant waste treatment facilities. Before being added to a bioreactor, the waste should be neutralized to reduce pH effects and diluted to less than 25% propylene glycol. Above this concentration, propylene glycol is toxic to microorganisms, but below this concentration it is an excellent food source. A second concern is that the waste might raise sodium discharge levels from the treatment facility. High discharge concentrations of sodium can create toxicity problems. Because NaK is 23 wt % sodium, any waste generated from any process will have sodium. As shown in the flow sheet, the total amount generated from this process is about 7000 gal with 6300 ppm sodium over 10 weeks or longer. This relatively small amount will be diluted to reduce the propylene glycol concentration and further mixed with other wastes. Because of this dilution, the sodium discharge level should not be adversely affected.

The heat from the reaction of water with NaK is used on this flow sheet. It is a worst case value. NaK may actually react with water, propylene glycol, or both. From theory and observation of NaK reactions separately with water and propylene glycol, one would think that NaK reacted solely with water. The reaction rate for NaK-water reaction is generally higher than that of alcohols. The heat of reaction (calculated from tabulated heats of formation⁵) for the water reaction is also higher: 276 kcal/mol for water reaction vs 122 kcal/mol for propylene glycol reaction. These calculated values are consistent with those determined experimentally for NaK reaction with water and methanol⁶. However, the experiments conducted with propylene glycol/water mixtures indicate that some of the NaK reacted with the glycol. The brownish color that was observed indicates sodium and potassium ions that would not be present in a mixture of sodium and potassium hydroxides and propylene glycol.

COMPARISON OF PROCESSES

As was shown earlier, the two processes were demonstrated to be feasible. Table 5 shows a comparison of the mass balances of the processes. In many respects, the processes are alike. Both react NaK with water, which is somehow diluted, in a controlled manner under an inert atmosphere. Both generate at the same rate hydrogen offgas which must be handled carefully.

Table 5. Process mass balances

	Caustic Process	Propylene Glycol Process
Basis: amount of NaK treated	5 gal (16.3 kg)	5 gal (16.3 kg)
Amount of waste generated	105 liters (158 kg)	537 liters (548 kg)
Composition of waste	46 wt % water 40 wt % KOH 14 wt % NaOH	38 wt % propylene glycol 23,338 ppm K 6,276 ppm Na
Rate of hydrogen offgas	22.4 L/min	22.4 L/min

The differences are waste generated and operating temperature. As shown in the process flow sheets, the propylene glycol will produce approximately 5 times more waste than the caustic process. In this comparison, it is important to note that this will not be an on-going process. Only a limited amount of NaK (~ 250 gal) will be treated. When compared with the overall amount of aqueous waste generated at the Y-12 Plant, the difference in waste generated is insignificant. To maintain fluidity, the caustic process must be kept above 90°C. As a result, hot caustic solutions must be managed carefully. Special safety precautions, as well as heated tanks and piping, are required. The propylene glycol process may be operated at room temperature with fewer safety precautions; therefore, it is the preferred process.

COST ESTIMATE

Y-12 Plant Engineering made a rough cost estimate of the cost of the propylene glycol process for use in discussions of alternatives with TDEC. This estimate was made quickly with limited cost information from vendors and engineering experience. It was assumed that the treatment facility would be built from scratch and not from existing facilities. In actuality, either existing facilities or a temporary structure will be used, which would lower construction and overhead. The total project cost was \$363,030. The actual equipment cost was \$90,000. The project sizing cost study is included in the appendix.

CONCLUSIONS AND RECOMMENDATIONS

Two alternative processes for NaK treatment were shown to be feasible. The caustic process generates less waste overall but has serious safety concerns. Temperature, water concentration, and caustic handling must be carefully controlled throughout the process. Hot corrosive material used and generated in the process must be managed carefully. The propylene glycol process operates at room temperature and is considerably safer than the caustic process. It does produce more waste, but this amount is insignificant when compared with overall Y-12 Plant waste generation. The authors recommend that this process be pursued as a likely alternative for NaK treatment.

Work should be done to optimize this process on a larger scale. Experiments should be conducted to optimize the amount and composition of the final waste. The feasibility of using this waste as a carbon food source in biological treatment should be studied. The offgas processes (bubbler and flare) need to be further investigated and optimized (to reduce the waste generated). Also, the use of nitrogen, a less expensive inert gas than argon, should be investigated. Finally, depending on the State's position on NaK treatment, design and construction of a pilot unit should begin.

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PROJECT SIZING COST STUDY

Project Name: NaK DISPOSAL-PROPYLENE GLYCOL ALTERNATIVE
 Category: NONE

Estimator: Jerry Kern

SITE: Y-12; SOURCE: Y-12

Step 1. COST DRIVERS

SEE ASSUMPTIONS AND SCOPE OF WORK (SEE PAGE 2)

TOTAL COST DRIVERS

\$90,000

Step 2. CONSTRUCTION COST FACTORS

Rule of
Thumb, % Total
Add - On

7.1 Mob. & Demob., Shop Support, Clean up	3.00%	2,700
7.2 Health Physics	1.00%	900
7.4 Training / Safety	5.00%	4,500
7.5 Material Tax	3.00%	2,700
Subtotal Cost Factors		<u>10,800</u>

Subtotal Direct Construction

100,800

7.6 Construction Indirects	26.00%	28,208
7.7 MMES Overhead	6.71%	<u>8,522</u>
Total Field Construction		<u>135,530</u>

7.3 MK-F Salaried Field Support	14.10%	19,110
7.7 MK-F Construction Management	14.00%	<u>18,974</u>
subtotal		<u>38,084</u>
7.8 MMES Overhead	6.71%	<u>2,555</u>
Subtotal MK-F		<u>40,639</u>

TOTAL CONSTRUCTION

176,170

Step 3. TITLE I & II DESIGN

8.1 MMES Overhead on A/E Design

16.00%	28,187
6.71%	<u>1,891</u>
	<u>30,078</u>

Step 4 MMES SUPPORT FACTORS

9.1 Title III Engineering	10.00%	17,617
9.2 A/E Support	6.00%	10,570
9.3 Construction Support	6.00%	10,570
9.4 Systems Engineering	0.00%	0
9.5 FFA Compliance	5.00%	8,808
9.6 MMES Overhead	31.74%	<u>15,097</u>
SUBTOTAL		<u>62,663</u>

Subtotal Less Contingency

288,911

Step 5. CONTINGENCY

TOTAL PROJECT COST w/o additional escalation

25.00%	<u>67,228</u>
	<u>338,139</u>

Step 6. ESCALATION beyond time of Cost Driver

8.00% 28,891

Step 7. TOTAL PROJECT COST with additional escalation

383,030

Total Project Cost with esc. / Direct Construction Cost

4.03

ASSUMPTIONS

1. No contaminated earth work
2. No unusual environmental conditions
3. Project construction completion FY 94/4
4. Project is expense funded
5. Duration of disposal project is 50 days

SCOPE

DESCRIPTION	TOTAL DOLLARS
1. 20'Wx100'L GRAVEL ROADS	\$1,200
2. 20' x 40' x 8" CONCRETE PAD	\$6,000
3. 300 LF OF SECURITY FENCE AND GATES	\$4,000
4. SITE TRAILER FOR 3 MONTHS	\$800
5. 1000 GAL. NITROGEN TANK	\$10,000
6. 100 LF OF 3" DIA S.S. NITROGEN PIPING	\$6,000
7. 500 GAL. S.S. TANK, VALVES, ETC.	\$6,000
8. ELECTRICAL POWER, 300'RUN-100A SERVICE	\$3,200
9. 300 LF OF 2" WATER LINE, VALVES, ETC.	\$6,000
10. DECHLORINATION STATION	\$1,000
11. 100 LF OF 1" DIA S.S. PIPE AND FITTINGS	\$1,400
12. BUBBLER STATION	\$22,100
13. HYDROGEN OFFGAS FLARE STATION	\$7,500
14. 800 GAL POLY TANK	\$2,500
15. REMOVAL OF EQUIPMENT	\$7,600
16. MISC MATERIALS	\$7,300
FPSC TOTAL	\$80,000

Fixed price sub w^t

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