PRELIMINARY ANALYSIS LETTER ITEM #2:
RACT Analysis for VOC Release to Tailing Cells and Evaporation Ponds

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REASONABLY AVAILABLE CONTROL TECHNOLOGY REPORT

Rev. 0 **Date: November 10, 2009**

PIÑON RIDGE MILL
Montrose County, Colorado

Submitted to:

Air Pollution Control Division
Colorado Department of Public Health and Environment

Prepared for:

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Project No. 83088
DCN: 83088.6.2-ALB09RP003

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Prepared for: **Energy Fuels Resources Corporation**
Lakewood, CO

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1.0 INTRODUCTION

This report evaluates Reasonably Available Control Technology (RACT) for reducing volatile organic compound (VOC) emissions from the Energy Fuels Resources Corporation (EFR) proposed Piñon Ridge Mill Site (Mill Site) located in Montrose County, Colorado. This RACT assessment was prepared in support of air permitting efforts in accordance with the Colorado Revised Statutes Regulations 3 and 7, verbal guidance from the Colorado Department of Public Health and Environment (CDPHE) Air Pollution Control Division (APCD), and the United States Environmental Protection Agency (USEPA) Control Technology Guideline (CTG) Series, Control of Volatile Organic Compound Emissions from Industrial Wastewater ("CTC Guideline"). This CTC Guideline contains emission control techniques and EPA guidance for a RACT assessment for industrial wastewaters generated in six specific industries. There is not a RACT guidance document specific to the uranium or vanadium industry, so it is considered as a general RACT guidance document for this project.

1.1 Basis for RACT Analysis

Pursuant to the Colorado Code of Regulations (CCR) 5 CCR-1001-5 Air Quality Control Commission Regulations (AQCC) Regulation 3.C.2.a, the facility would have to apply RACT for those regulated criteria pollutants for an area that is classified as non-attainment, or in attainment with a maintenance program. However, the area of the proposed Mill Site is in attainment and is not under a maintenance program for any regulated criteria pollutants. Therefore RACT is not triggered for the regulated criteria pollutants per AQCC Regulation 3.C.2.a. These regulated pollutants include particulate matter (PM_{10}/$PM_{2.5}$), volatile organic compounds (VOC), nitrogen oxides (NOx), sulfur oxides (SOx), and carbon monoxide (CO).

Pursuant to 5 CCR-1001-9 AQCC Regulation 7.V.A, the facility may not dispose of a VOC by evaporation or spillage unless RACT is utilized. Per discussion with the APCD, this regulation is considered to be applicable because the process results in VOC-containing liquids to be discharged to the evaporation ponds and tailings cells where it can then evaporate. Therefore, a RACT analysis specific to VOC reductions is required. This report provides an analysis of the effectiveness of control strategies for reducing VOC emissions from the process, the tailing cells, and evaporation ponds.

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1.2 RACT Analysis Approach

RACT is considered to be the lowest emission limitation that a particular source is capable of meeting by the application of control technology that is reasonably available, considering technological and economic feasibility. Accordingly, this RACT analysis includes identifying reasonably available control technologies and evaluating the economic and technological feasibility of those options. Since CDPHE does not have a cost-effectiveness threshold, the one-time (unannualized) capital cost of equipment will be considered.

The analysis also evaluated changes to the operational practices, materials used, management practices, and other environmental factors/consequences. A summary of the best options considered reasonable were concluded as the appropriate level for RACT.

Two control strategies applied for the reduction of VOC emissions are defined in the CTC guideline. The first control strategy is waste minimization through process modifications, modification of operating practices, preventive maintenance, recycling, or segregation of waste streams. These types of strategies were investigated and are detailed in Section 2 of this RACT assessment.

The second control strategy identified in the CTC guideline is to reduce the VOC content of the wastewater through treatment before the stream contacts ambient air. A more complete strategy for reducing the VOC content of the wastewater includes: (1) suppression of emissions from solutions entering the evaporation ponds or tailings cells by enclosing the evaporation ponds or tailings cells, (2) treatment of the organic and aqueous solutions to remove VOCs, and (3) treatment of residuals (organic phases or sludges). Various VOC treatment, capture, and control technologies were investigated and are discussed in detail in Section 3 of this RACT assessment.

Appendix A contains emission reduction calculations for each of the control technologies considered to be both technologically and economically feasible. Appendix B contains cost data references for these control technologies, however it should be noted that specific vendors have not been selected at this time, so equipment considered to be equivalent or manufactured by other vendors may be used.

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2.0 PROCESS UPGRADES AND WASTE MINIMIZATION

EFR designed the Piñon Ridge Mill based on input from former mill operators and discussions with vendors regarding currently available technology. This resulted in the incorporation of many technological improvements in the Piñon Ridge Mill design compared to the existing and former uranium/vanadium mills in the United States, which were largely constructed between 1950 and 1980. These improvements were especially notable in reducing air emissions and chemical and radiological exposures of mill workers. However, in calculating chemical consumption rates and associated costs, EFR relied primarily on historical records from other mill facilities. This resulted in an estimated consumption rate of 663 tons of kerosene per year for a 1,000 ton per day (tpd) mill. A comparison of the current technology proposed at the Piñon Ridge Mill to the older technology used in similar mills indicates that the kerosene consumption for the Piñon Ridge Mill will be 250 tons or less per year.

EFR proposes to include a number of conservation strategies and processing upgrades within its solvent extraction (SX) circuits where kerosene along with smaller amounts of other organics are used to extract and concentrate uranium and vanadium in separate circuits. These strategies and upgrades include the utilization of covered processing tanks, containment and treatment of solutions with high levels of organic entrainment, and high efficiency particle removal filters. These conservative processing approaches will reduce the amount of organics that the facility will consume, thereby reducing the potential for the generation of VOCs. Although not intended as a control device, the mixing of the raffinate with the tailings solution is expected to result in the permanent entrainment of some organics within the tailings cells that might otherwise evaporate as VOCs.

2.1 Solvent Extraction Covered Tank Option

Solvents containing VOCs are used in the uranium and vanadium SX circuits. The extraction mixer settler tanks contain an organic solution that is used to selectively remove the uranium or vanadium from acid solutions and concentrate them. The organic solution consists of kerosene (carrier) plus amine (collector) and alcohol (phase control). Similarly, a caustic solution is used in the scrubber mixer settler tanks and stripper mixer settler tanks to strip the products from the organic carrier. The stripped organic solution is pumped back to the barren organic tank for reuse in the extraction circuit.

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Traditionally the solvent extraction process tanks were not covered and organic solutions were exposed to airflow, causing accelerated evaporation. EFR will utilize enclosed mixer settler tanks, which are designed as covered processing tanks. These state-of-the-art mixer settler tanks would reduce VOC emissions by over 90%. Although the covered tanks will reduce VOC emissions by 90%, the tanks are occasionally uncovered for maintenance or cleaning purposes and therefore, a more conservative covered tank parameter (75%) is applied for emission calculation purposes. Emission reduction calculations are shown in Appendix A.

The covers for the uranium mixer tanks will cost $96,525 and will reduce VOC emissions by 46.8 tpy. Covers for the vanadium mixer tanks will cost $154,028 and will reduce VOC emissions by 62.3 tpy. Associated vendor cost data is provided in Appendix B, although equivalent equipment from another vendor may be used. The decrease in VOC emissions with the covers is 109.1 tons per year. This results in a cost of $2,297 per ton of VOC reduced. This technology is both technologically feasible and economically feasible and should be considered RACT for this process.

2.2 Solvent Extraction Covered Tank With Water Locks

Water locks are a proprietary cover sealing system that would reduce VOC emissions by an additional 5% over mixer settler tanks with covers alone. This would result in a reduction of VOC emissions by approximately 7.3 tpy. Total costs for covered mixer settler tanks were estimated to be $4,641,300, while covered mixer settler tanks with water locks would be approximately 50% higher or $6,961,950. Additionally, water locks are considered proprietary technology, offered by a specific vendor, and delivery schedule was estimated to be 50% longer than the covered tank option. Since the cost for water locks is estimated to be $317,897 per ton of VOC reduced, water locks were not considered economically feasible.

2.3 Crud Centrifuge and Raffinate Buffer Tank

When the solvent extraction system is operating at steady state, the organic solution will effectively extract the metal ores from the aqueous solution. However, if the organic and aqueous solutions become emulsified as a result of high levels of suspended solids in the aqueous solution, then the two solutions can not separate efficiently and an emulsified layer forms between the upper organic phase and the lower aqueous phase. Historically, facilities would “dump” the emulsified solution or “crud” when this type of

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upset condition occurred. The dumped solution would be directed to evaporation ponds and the process tanks were then refilled with new organic makeup solution.

EFR added a crud centrifuge to its processing system to allow for treatment and recovery of the organic compounds from emulsified solutions. When emulsification occurs, the organic will be drained off the raffinate settler and then the emulsified material (a.k.a., crud) will be drained off and pumped to the crud centrifuge where the emulsification is separated into aqueous and organic phases (which are recycled in the processing system) and suspended solids (which are wasted to the tailings cell).

The vanadium SX circuit is especially susceptible to a second type of organic loss when a portion of the organic solution becomes entrained in the aqueous solution. Organic entrainment can be identified by the presence of finely-sized bubbles in the aqueous solution coming from the raffinate settlers. To prevent excessive loss of the organic, EFR proposes to add a holding tank (raffinate buffer tank) to collect the solvent extraction waste solutions (i.e., raffinate) when these conditions occur. The contents of the raffinate buffer tank would be stored for a period of time, which would allow the two phases to separate with the organic floating to the top of the aqueous solution. The organic material would then be skimmed off and recycled. Emulsified material, if present, would be sent to the crud centrifuge for further separation. This would substantially reduce the potential amount of organic solution that would otherwise be sent to the evaporation ponds.

The tank would hold 103,000 gallons of raffinate, large enough to contain the combined flow (385 gpm) from the two vanadium raffinate settlers for four hours. The raffinate buffer tank, including a pump to redirect the raffinate, would cost approximately $423,400. The crud centrifuge will cost approximately $353,100. The use of a raffinate buffer tank would reduce emissions from the evaporation ponds and tailings cells by an estimated 139 tons for each major upset episode. Major upsets are not anticipated to occur more than once or twice per year, although smaller upset conditions may occur. The centrifuge system is oversized at 20 gpm and is designed to empty the contents of the raffinate buffer tank every four days. Emission reduction calculations are shown in Appendix A. Assuming two major upsets occur each year, this equates to a cost per ton for VOC reduction of $2,783 per ton of VOC. This is considered an economically feasible option.

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2.4 High Efficiency Pressure Leaf Filters

As described in Section 2.2, much of the organic solution loss at similar facilities was attributable to upset conditions in the solvent extraction process that would result in dumping the contents of mixer settlers into the evaporation ponds. Because this is affected by the amount of suspended solids in the pregnant solution which can mix with the kerosene and form an emulsification (crud), more efficient filtering has been evaluated.

EFR anticipates fewer problems with organic solution contamination because they will utilize pressure leaf filters, which are high efficiency particle removal filters located prior to both the vanadium and uranium circuits. In comparison, most uranium mill facilities use older technology sand filters. The pressure leaf filters are expected to alleviate many of the upset conditions in the organic extraction processes and will allow the organic solution to continue to be recycled as designed through the process. These filters are expected to reduce the amount of organic makeup solution that the facility would introduce to the system, thereby reducing the potential for organic losses.

Costs for the pressure leaf filters are estimated to be $1,685,300. In comparison, the lower technology sand filters would cost $351,600 for a difference in cost of $1,333,700. It is not yet known what the VOC emission reduction would be from the application of modern pressure leaf filters versus sand filters, as only a few of the older uranium mills used pressure leaf filters and, to the best of our knowledge, they have not been used in mills with vanadium circuits. However, the facility estimates that the pressure leaf filters would reduce the amount of new organic solution entering the process by at least 25 tpy and possibly much more, since higher quality filters would reduce suspended solids in solution thereby allowing the extraction to be less susceptible to emulsification upset issues. Since the reduction of organics is only assumed at this time, the economic feasibility was not assessed. Regardless of economic feasibility, the pressure leaf filter technology will be implemented.

2.5 Tailings Entrainment

In an effort to minimize water consumption at the Piñon Ridge Mill, EFR elected to utilize most (i.e., about 72%) of the vanadium raffinate stream to mix with the tailings pulp (i.e., solid waste from the leaching process) to allow it to be more easily pumped to the tailings cell. In the tailings cell, the solids settle out of solution and the clarified water

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is recovered and recycled back to the mill for use. Although some of the organics would volatize in the tailings cell, some would be expected to adsorb or absorb onto to the tailings solids and some would remain entrained within the saturated portion of the deposited tailings. At this time, it would be difficult to estimate how much of the organic material would remain in the tailings, as raffinate was not used historically for this purpose on a routine basis at other uranium mills.

The tailings cells are lined at their base and sides with multiple synthetic and geosynthetic liners. Once a tailings cell is filled, it is dewatered to the extent practicable and covered with a thick radon soil barrier and a vegetated evapotranspiration cover. Therefore, any residual organic material in the tailings would remain permanently encapsulated within the tailings repository.

2.6 Review of Process Chemistry

Since the solvent extraction process requires specific chemical reactions and proven methods, a change in the organic solution to reduce VOC losses would not be a practical option. The organic makeup solution, composed mostly of kerosene is relatively benign, since it does not contain hazardous air pollutants. Therefore a change in the process chemistry to reduce or remove the potential for VOC emissions is not achievable at this time and would not be considered technologically feasible.

2.7 Emission Reductions and Economic Feasibility

The facility estimates that annual kerosene usage would be reduced from 663 tons per year (tpy) to 250 tpy by incorporating feasible process upgrades and waste minimization practices discussed above. As shown in the emission calculations provided in Appendix A, the annual process VOC emissions are anticipated to be approximately 36 tpy. By mass balance approach, this would yield 214 tpy fugitive VOC emissions from the tailings cells and evaporation ponds versus 145 tpy VOC from the process and 518 tpy fugitive VOC emissions without incorporating these upgrades. The total cost for all of the upgrades considered technologically and economically feasible is $2,712,353.

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3.0 CONTROL TECHNOLOGY ASSESSMENT

In addition to process upgrades for waste minimization, an evaluation of process controls that could be used to remove the VOC from the raffinate (i.e., effluent solution) was conducted. This included review of the RACT/BACT/LAER Clearinghouse (RBLC) and CTC guidance for wastewater controls. This section describes the control technologies identified and their feasibility.

3.1 Review of RACT/BACT/LAER Clearinghouse

A review was conducted of the RBLC found on the USEPA technology transfer network (TTN) website (http://cfpub.epa.gov/RBLC/htm/bl02.cfm?lang=eg). The review was extensive using several search options. However, no similar uranium or vanadium processing facilities or process source types were found. Therefore, no feasible control options are considered to be recognized through the RBLC.

3.2 Review of Process Control Technologies

Several VOC treatment, capture, and control technologies were investigated and are discussed in these subsections. Existing RACT options for control of VOCs include carbon adsorbers, concentrators, condensers, flares, thermal and catalytic incinerators and scrubbers. However, these control technologies are typically used to control air streams and are technologically infeasible for direct add-on control of the process effluent without first removing the VOC out of solution into an air stream. The following wastewater control technologies can be used on fugitive wastewater sources.

3.2.1 Steam Stripping

As defined in the CTC Guideline, steam stripping is a proven technology that involves the fractional distillation of wastewater to remove organic compounds. The basic operating principle of steam stripping is the direct contact of the wastewater solution with steam. A feed tank, which is covered and typically vented to an onsite control device collects and conditions the wastewater fed to the steam stripper. Feed tanks are typically sized to provide a hydraulic retention time of 48-hours. After the wastewater is collected and conditioned, it is pumped through the feed/bottoms heat exchanger and into the top of the steam stripping column. Steam is sparged directly into the stripper at the bottom of the column and as the wastewater flows down the column, it contacts the steam countercurrently. Latent heat is transferred from the steam to the organic compounds in the wastewater, vaporizing them into the vapor stream. A condenser

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system is used to recover the organics and recovered VOCs can be pumped to storage and recycled back into the process.

Specific characteristics of the raffinate from uranium and vanadium processing would make steam stripping technologically infeasible. This includes the fact that not only does the raffinate stream contain suspended solids, but it may also contain emulsified crud not suitable for use in a steam stripping column. Additionally, the raffinate would require extensive pretreatment due to its low pH (4.4 standard units). Therefore, this control technology would not be considered technologically feasible.

3.2.2 Air Stripping

Air stripping is another control technology that may be applied to wastewater collection systems. The general principle of an air stripper is by forcing large volumes of air through the organic-laden wastewater, the air water interface is increased, resulting in the transfer rate of the organic compounds into the vapor phase. This technology works most efficiently with highly volatile compounds. Organics in the vapor phase are treated with add-on control devices, such as a carbon adsorber. However, the main component of the organic solutions used in the process is kerosene. Kerosene has low volatility and would not rapidly enter into the vapor phase, causing this control technology to be highly inefficient. Therefore, this control technology would not be considered technologically feasible.

3.2.3 Biological Organic Compound Destruction

A third control technology is biological organic compound destruction technology. Biological waste treatment is normally accomplished through the use of aeration basins. Microorganisms require oxygen to carry out the biodegradation of VOC that results in energy and biomass production. This control technology is very sensitive to environmental factors since living organisms are used. Due to the fact that the raffinate has high metal concentrations and a low pH, this type of control would not be technologically feasible.

3.2.4 Chemical Oxidization

A fourth control technology is chemical oxidation, which involves a chemical reaction between the organic compounds and an oxidant, such as ozone, hydrogen peroxide, etc. Kerosene would not be highly reactive to an oxidation process and other

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constituents in the raffinate would likely react much faster, causing unknown reactions and emissions, this technology is not considered technologically feasible.

3.2.5 Adsorption

A fifth control technology is adsorption, which takes advantage of compound affinities for a solid sorbant medium. Activated carbon or polymeric resins are often used as a medium and the volatile compounds are adsorbed onto the solid sorbent medium as they are contacted by wastewater. Polymeric resins are typically used with polar compounds and kerosene is non polar. Non polar compounds, such as kerosene, can be adsorbed onto the surface of activated carbon. Activated carbon is used with non polar compounds however, the ability to desorb (remove) the organic compounds is difficult and the carbon could become easily contaminated by other compounds, suspended solids, and emulsified materials. Therefore, this technology would not be considered technologically feasible.

3.2.6 Membrane Separation

A sixth control technology is membrane separation, such as ultrafiltration and reverse osmosis. These types of separation processes work well on either high molecular weight (> 2,000 g/mole) compounds or those without suspended particulates. Due to the low molecular weight of kerosene and presence of suspended particulates, this technology would not be considered technologically feasible.

3.2.7 Liquid-Liquid Extraction

A seventh control technology is liquid-liquid extraction. The basis of this process is similar to the solvent extraction process, where a compound may be removed from the solution. Since the raffinate is a mixture or aqueous acids, suspended solids, emulsified materials, and organics, this process would not be considered technologically feasible.

3.3 Economic Feasibility

Since no add-on control technologies are known to be technologically feasible, no additional economic feasibility assessment is required.

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4.0 SUMMARY CONCLUSIONS

4.1 RACT Findings and Conclusions

Several processing upgrades and waste minimization techniques were identified for this RACT assessment. These include the following options that will be implemented:

- Covered uranium and vanadium SX tanks;
- A crud centrifuge and raffinate buffer tank;
- High efficiency pressure leaf filters;
- Tailings entrainment.

Covered uranium and vanadium SX tanks would reduce VOC emissions from the process by approximately 90% during normal operation and by approximately 75% overall considering the tanks may be occasionally opened. The reduction in VOC emissions with the covers is estimated to be 109 tons per year. This option is considered both technologically feasible and economically feasible.

The raffinate buffer tank and crud centrifuge would be used, respectively, to collect the solvent extraction solution during an upset condition and recover the organic solution from emulsified and entrained mixtures. This technique alone would reduce the amount of kerosene added to the system by approximately 279 tons per year, given two major upset conditions, and therefore by direct mass balance, would reduce the annual VOC emissions from the evaporation ponds by 279 tons per year. This option is considered both technologically feasible and economically feasible.

Pressure leaf filters are high efficiency particle removal filters. These filters, used in place of typical sand filters, are designed to effectively remove suspended solids and contaminants from aqueous solutions to minimize the potential for emulsification during the SX process. Use of these filters is estimated to reduce the amount of kerosene added to the organic makeup solution by 25 tons or more per year. This option is considered both technologically feasible and economically feasible.

EFR also anticipates that some of the residual organics in the raffinate will not evaporate, but rather be permanently entrained with the tailings cells, which will be capped at the time of closure.

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Other options have been reviewed for this RACT assessment, but other options were considered to be technologically infeasible.

The process upgrades and waste minimization measures EFR proposes to take will significantly reduce the potential losses of organic compounds thus reducing the amount of organic solution going to the evaporation ponds. These measures are in accordance with the level of measures considered to meet RACT based on technological and economical feasibility. Therefore, the remaining organic solutions entering the evaporation ponds, and resulting evaporative emissions, should be considered a fugitive source of emissions.

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5.0 STANDARDS AND REFERENCES

USEPA, 2009. RACT/BACT/LAER Clearinghouse.
http://cfpub.epa.gov/RBLC/htm/bl02.cfm?lang=eg

USEPA, CTG Guideline Series, Control of Volatile Organic Compound Emissions from Industrial Wastewater, Draft Document, EPA-453 / D-93-056, September 1992.

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APPENDIX A
Emission Calculations for Reduction of VOC

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ENERGY FUELS PIÑON RIDGE MILL ANNUAL KEROSENE USAGE REDUCTION

Original annual Kerosene estimate of 663 tons per year based on historical data from other mills

a. Historically many other mills did not have covered tanks - Find difference in covered tanks vs uncovered
b. Historically, other mills would have upset conditions due to solids in the solution - thus raising the amount of kerosene needed from steady state
c. Historically, other mills used sand filter system rather than pressure filter systems

a. Reduction in Kerosene usage due to tanks being covered:

Uncovered:
Uranium SX VOC Emissions:

Source ID	Emission Source	Chemical Species (i)	Mol Wt. (Species i) (lb/lbmol)	Partial Pressure (psia)	Bath Surface Area (ft^2)	Temp. (^oR)	Gas Constant R (psia-$ft^3/^oR$-lbmol)	Air Speed Across Liq. Surface (mph)	Gas Phase Mass Transfer Coeff. (ft/s)	Covered Process Tank Parameter	Agitated Tank Factor	VOC Emissions (lb/yr)	VOC Emissions (ton/yr)
420-MSS-01	Uranium Mixer Settler Tank A1	Kerosene	170	0.019	210	529.67	10.73	1.7	0.003137	**0**	1.1	12986.93	6.49
420-MSS-02	Uranium Mixer Settler Tank A2	Kerosene	170	0.019	210	529.67	10.73	1.7	0.003137	**0**	1.1	12986.93	6.49
420-MSS-03	Uranium Mixer Settler Tank A3	Kerosene	170	0.019	210	529.67	10.73	1.7	0.003137	**0**	1.1	12986.93	6.49
420-MSS-04	Uranium Mixer Settler Tank A4	Kerosene	170	0.019	210	529.67	10.73	1.7	0.003137	**0**	1.1	12986.93	6.49
430-MSS-01	Uranium Mixer Settler Tank B1	Kerosene	170	0.019	210	529.67	10.73	1.7	0.003137	**0**	1.1	12986.93	6.49
430-MSS-02	Uranium Mixer Settler Tank B2	Kerosene	170	0.019	210	529.67	10.73	1.7	0.003137	**0**	1.1	12986.93	6.49
430-MSS-03	Uranium Mixer Settler Tank B3	Kerosene	170	0.019	210	529.67	10.73	1.7	0.003137	**0**	1.1	12986.93	6.49
430-MSS-04	Uranium Mixer Settler Tank B4	Kerosene	170	0.019	210	529.67	10.73	1.7	0.003137	**0**	1.1	12986.93	6.49
440-MSS-01	Uranium Scrubber Mixer Settler	Kerosene	170	0.019	112.5	529.67	10.73	1.7	0.003137	**0**	1.1	6957.28	3.48
440-MSS-02	Uranium Stripper Mixer Settler #1	Kerosene	170	0.019	112.5	529.67	10.73	1.7	0.003137	**0**	1.1	6957.28	3.48
440-MSS-03	Uranium Stripper Mixer Settler #2	Kerosene	170	0.019	112.5	529.67	10.73	1.7	0.003137	**0**	1.1	6957.28	3.48
												TOTAL:	**62.38**

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ENERGY FUELS PIÑON RIDGE MILL ANNUAL KEROSENE USAGE REDUCTION

Uncovered:
Vanadium SX VOC Emissions:

Source ID	Emission Source	Chemical Species (i)	Mol Wt. (Species i) (lb/lbmol)	Partial Pressure (psia)	Bath Surface Area (ft^2)	Temp. (^oR)	Gas Constant R (psia-$ft^3/^oR$-lbmol)	Air Speed Across Liq. Surface (mph)	Gas Phase Mass Transfer Coeff. (ft/s)	Covered Process Tank Parameter	Agitated Tank Factor	VOC Emissions (lb/yr)	VOC Emissions (ton/yr)
620-MSS-01	Vanadium Mixer Settler Tank A1	Kerosene	170	0.019	220.5	529.67	10.73	1.7	0.003137	**0**	1.1	13636.28	6.82
620-MSS-02	Vanadium Mixer Settler Tank A2	Kerosene	170	0.019	220.5	529.67	10.73	1.7	0.003137	**0**	1.1	13636.28	6.82
620-MSS-03	Vanadium Mixer Settler Tank A3	Kerosene	170	0.019	220.5	529.67	10.73	1.7	0.003137	**0**	1.1	13636.28	6.82
620-MSS-04	Vanadium Mixer Settler Tank A4	Kerosene	170	0.019	220.5	529.67	10.73	1.7	0.003137	**0**	1.1	13636.28	6.82
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630-MSS-01	Vanadium Mixer Settler Tank B1	Kerosene	170	0.019	220.5	529.67	10.73	1.7	0.003137	**0**	1.1	13636.28	6.82
630-MSS-02	Vanadium Mixer Settler Tank B2	Kerosene	170	0.019	220.5	529.67	10.73	1.7	0.003137	**0**	1.1	13636.28	6.82
630-MSS-03	Vanadium Mixer Settler Tank B3	Kerosene	170	0.019	220.5	529.67	10.73	1.7	0.003137	**0**	1.1	13636.28	6.82
630-MSS-04	Vanadium Mixer Settler Tank B4	Kerosene	170	0.019	220.5	529.67	10.73	1.7	0.003137	**0**	1.1	13636.28	6.82
630-MSS-05	Vanadium Mixer Settler Tank B5	Kerosene	170	0.019	220.5	529.67	10.73	1.7	0.003137	**0**	1.1	13636.28	6.82
640-MSS-01	Vanadium Scrubber Mixer Settler	Kerosene	170	0.019	120	529.67	10.73	1.7	0.003137	**0**	1.1	7421.10	3.71
640-MSS-02	Vanadium Stripper Mixer Settler #1	Kerosene	170	0.019	120	529.67	10.73	1.7	0.003137	**0**	1.1	7421.10	3.71
640-MSS-03	Vanadium Stripper Mixer Settler #2	Kerosene	170	0.019	120	529.67	10.73	1.7	0.003137	**0**	1.1	7421.10	3.71
640-MSS-04	Vanadium Stripper Mixer Settler #3	Kerosene	170	0.019	120	529.67	10.73	1.7	0.003137	**0**	1.1	7421.10	3.71
												TOTAL:	**83.02**

Note: Emissions from covered tanks in original APEN submittal and on page 4 and 5 of this attachment

Uncovered - Covered	**109**	**tpy**	(145.41 - 36.35)tpy

So, from being uncovered, an additional 109 tons per year of kerosene would be needed.

Now, Annual Kerosene usage:	**554**	**tpy**	(663 - 109)tpy

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ENERGY FUELS PIÑON RIDGE MILL ANNUAL KEROSENE USAGE REDUCTION

b. Kerosene usage reduction due to upset buffer tank:

Assume two major upsets from steady state conditions would occur and those upsets would get sent to the evaporation ponds rather than cleaned and reused.

Energy Fuels Pinon Ridge Mill will contain an upset buffer tank of approximately 103,000 gallons. A conservative estimate is that 40% of the SX solution would be organic.

Upset tank size (gal)	% Organic in SX Solution	Density of Kerosene (lb/gal)	Reduction in Kerosene due to one upset (tpy)
103,000	40%	6.76	139

Reduction in Kerosene from two major upset conditions going to the buffer tank: 279 tpy

New Pinon Ridge Mill estimate for annual Kerosene usage:	**275**	**tpy**	(554 - 279)tpy

Note: Solution in the buffer tank from an upset condition would be cleaned by using the crud centrifuge system and recycled back into the process at a later time.

c. Kerosene usage reduction due the use of pressure filters in the SX systems:

Pressure filters are used in both the Uranium and Vanadium SX circuits.
Historically, other mills utilized a different filtering system (sand filters) that is not as effective at removing particles.

An exact effectiveness of the pressure filters over the sand filters is not known. Thus, it was estimated that the pressure filters would decrease the annual Kerosene usage by a minimum of 25 tons per year

New Pinon Ridge Mill estimate for annual Kerosene usage:	**250**	**tpy**	(275 - 25)tpy

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ENERGY FUELS PIÑON RIDGE MILL KEROSENE EMISSION CALCULATIONS

Annual Kerosene Use (tpy)	Non-Fugitive Kerosene Total (tpy)	Fugitive VOC Total to Tailings/Evap Ponds (tpy)
250	**36.39**	**213.61**

All Emissions are Uncontrolled.

Uranium SX VOC Emissions:

Source ID	Emission Source	Chemical Species (i)	Mol Wt. (Species i) (lb/lbmol)	Partial Pressure (psia)	Bath Surface Area (ft^2)	Temp. (^oR)	Gas Constant R (psia-$ft^3/^oR$-lbmol)	Air Speed Across Liq. Surface (mph)	Gas Phase Mass Transfer Coeff. (ft/s)	Covered Process Tank Parameter	Agitated Tank Factor	VOC Emissions (lb/yr)	VOC Emissions (ton/yr)
420-MSS-01	Uranium Mixer Settler Tank A1	Kerosene	170	0.019	210	529.67	10.73	1.7	0.0031368	**0.75**	1.1	3246.7328	1.623
420-MSS-02	Uranium Mixer Settler Tank A2	Kerosene	170	0.019	210	529.67	10.73	1.7	0.0031368	**0.75**	1.1	3246.7328	1.623
420-MSS-03	Uranium Mixer Settler Tank A3	Kerosene	170	0.019	210	529.67	10.73	1.7	0.0031368	**0.75**	1.1	3246.7328	1.623
420-MSS-04	Uranium Mixer Settler Tank A4	Kerosene	170	0.019	210	529.67	10.73	1.7	0.0031368	**0.75**	1.1	3246.7328	1.623
430-MSS-01	Uranium Mixer Settler Tank B1	Kerosene	170	0.019	210	529.67	10.73	1.7	0.0031368	**0.75**	1.1	3246.7328	1.623
430-MSS-02	Uranium Mixer Settler Tank B2	Kerosene	170	0.019	210	529.67	10.73	1.7	0.0031368	**0.75**	1.1	3246.7328	1.623
430-MSS-03	Uranium Mixer Settler Tank B3	Kerosene	170	0.019	210	529.67	10.73	1.7	0.0031368	**0.75**	1.1	3246.7328	1.623
430-MSS-04	Uranium Mixer Settler Tank B4	Kerosene	170	0.019	210	529.67	10.73	1.7	0.0031368	**0.75**	1.1	3246.7328	1.623
440-MSS-01	Uranium Scrubber Mixer Settler	Kerosene	170	0.019	112.5	529.67	10.73	1.7	0.0031368	**0.75**	1.1	1739.3211	0.870
440-MSS-02	Uranium Stripper Mixer Settler #1	Kerosene	170	0.019	112.5	529.67	10.73	1.7	0.0031368	**0.75**	1.1	1739.3211	0.870
440-MSS-03	Uranium Stripper Mixer Settler #2	Kerosene	170	0.019	112.5	529.67	10.73	1.7	0.0031368	**0.75**	1.1	1739.3211	0.870
												TOTAL:	**15.60**

Uranium SX Organic Process Tanks:

Source ID	Emission Source	Chemical Species[2]	Capacity (gal)	Length (ft.)	Dia (ft.)	Annual Throughput (gal.)[1]	VOC Emissions (ton/yr)
440-TKH-01	Uranium SX Loaded Organic Tank	Kerosene	64298	19	24	202222	0.00856
440-TKH-02	Uramium SX Barren Organic Tank	Kerosene	64298	19	24	202222	0.00856
						TOTAL:	**0.02**

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ENERGY FUELS PIÑON RIDGE MILL KEROSENE EMISSION CALCULATIONS

Vanadium SX VOC Emissions:

Source ID	Emission Source	Chemical Species (i)	Mol Wt. (Species i) (lb/lbmol)	Partial Pressure (psia)	Bath Surface Area (ft^2)	Temp. (^oR)	Gas Constant R (psia-$ft^3/^oR$-lbmol)	Air Speed Across Liq. Surface (mph)	Gas Phase Mass Transfer Coeff. (ft/s)	Covered Process Tank Parameter	Agitated Tank Factor	VOC Emissions (lb/yr)	VOC Emissions (ton/yr)
620-MSS-01	Vanadium Mixer Settler Tank A1	Kerosene	170	0.019	220.5	529.67	10.73	1.7	0.0031368	**0.75**	1.1	3409.0694	1.705
620-MSS-02	Vanadium Mixer Settler Tank A2	Kerosene	170	0.019	220.5	529.67	10.73	1.7	0.0031368	**0.75**	1.1	3409.0694	1.705
620-MSS-03	Vanadium Mixer Settler Tank A3	Kerosene	170	0.019	220.5	529.67	10.73	1.7	0.0031368	**0.75**	1.1	3409.0694	1.705
620-MSS-04	Vanadium Mixer Settler Tank A4	Kerosene	170	0.019	220.5	529.67	10.73	1.7	0.0031368	**0.75**	1.1	3409.0694	1.705
620-MSS-05	Vanadium Mixer Settler Tank A5	Kerosene	170	0.019	220.5	529.67	10.73	1.7	0.0031368	**0.75**	1.1	3409.0694	1.705
630-MSS-01	Vanadium Mixer Settler Tank B1	Kerosene	170	0.019	220.5	529.67	10.73	1.7	0.0031368	**0.75**	1.1	3409.0694	1.705
630-MSS-02	Vanadium Mixer Settler Tank B2	Kerosene	170	0.019	220.5	529.67	10.73	1.7	0.0031368	**0.75**	1.1	3409.0694	1.705
630-MSS-03	Vanadium Mixer Settler Tank B3	Kerosene	170	0.019	220.5	529.67	10.73	1.7	0.0031368	**0.75**	1.1	3409.0694	1.705
630-MSS-04	Vanadium Mixer Settler Tank B4	Kerosene	170	0.019	220.5	529.67	10.73	1.7	0.0031368	**0.75**	1.1	3409.0694	1.705
630-MSS-05	Vanadium Mixer Settler Tank B5	Kerosene	170	0.019	220.5	529.67	10.73	1.7	0.0031368	**0.75**	1.1	3409.0694	1.705
640-MSS-01	Vanadium Scrubber Mixer Settler	Kerosene	170	0.019	120	529.67	10.73	1.7	0.0031368	**0.75**	1.1	1855.2759	0.928
640-MSS-02	Vanadium Stripper Mixer Settler #1	Kerosene	170	0.019	120	529.67	10.73	1.7	0.0031368	**0.75**	1.1	1855.2759	0.928
640-MSS-03	Vanadium Stripper Mixer Settler #2	Kerosene	170	0.019	120	529.67	10.73	1.7	0.0031368	**0.75**	1.1	1855.2759	0.928
640-MSS-04	Vanadium Stripper Mixer Settler #3	Kerosene	170	0.019	120	529.67	10.73	1.7	0.0031368	**0.75**	1.1	1855.2759	0.928
												TOTAL:	**20.76**

Vanadium SX Organic Process Tanks:

Source ID	Emission Source	Chemical Species[2]	Capacity (gal)	Length (ft.)	Dia (ft.)	Annual Throughput (gal.)[1]	VOC Emissions (ton/yr)
640-TKH-01	Vanadium SX Loaded Organic Tank	Kerosene	64298	19	24	202222	0.00856
640-TKH-02	Vanadium SX Barren Organic Tank	Kerosene	64298	19	24	202222	0.00856
						TOTAL:	**0.02**

Storage Tanks:

Source ID	Emission Source	Chemical Species[2]	Capacity (gal)	Length (ft.)	Dia (ft.)	Annual Throughput (gal.)[1]	VOC Emissions (ton/yr)	
860-TKH-01	Kerosene Tank	Kerosene	38071	20	18	202222	0.00597	*APEN exempt
860-TKH-02	Organic Make-Up Tank	Kerosene	5875	10	10	202222	0.002845	*APEN exempt

Notes:

1. Although annual throughput was revised to 74,000 gallons/year, the TANKS program was not used to recalculate emission values with the new throughput. The emission values with the higher throughput are more conservative and are only a small portion of the overall total; thus, the higher emission values were kept.
2. Since trimethylamine and isodecanol are not listed compounds in the TANKS 4.09d model, the contents of the organic make-up tank are assumed to be 100% kerosene.

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APPENDIX B
Vendor Information and Cost Estimates

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