Alternative Disposal Routes for Tar-decanter Sludge and Other Tar Wastes Using the AKJ Process

D. Deer, H. Hatters and F. Maddalena

The AKJ process is able to convert tar-decanter sludge into a pumpable fuel suitable for open hearths and blast furnaces.

The cokemaking industry in recent years has seen the classification of a number of tar-based coke plant wastes as being either toxic, hazardous or requiring special handling. Environmental regulatory agencies have placed increasingly stringent restrictions on the handling, storage and disposal of these waste products. Currently, tar-decanter sludge (TDS) is classified as a "listed" hazardous waste that must be recycled within the coke plant in an approved manner, or transported to an approved secure landfill. Other tar sludges are often considered troublesome for disposal because they require special handling.

The AKJ process is a patented process that is used to convert TDS and other tar wastes into a pumpable fuel that has multiple alternative uses within an integrated steel plant. Other waste materials, i.e., tar tank deposits, tank car deposits, terminal treatment sludge and coke plant waste pond material, have been successfully processed into beneficial liquid fuels. Old coke plant sites are now being investigated for the possible recovery of tar wastes for recycling as fuel. AKJ Industries currently has five operating plants within the United States, with several more scheduled for construction.

GENERAL

Bituminous coal is thermally pyrolyzed or distilled (by heating in the absence of air) to a temperature of between about 1,700 and 2,100°F in a coke oven to produce coke and a variety of liquid and gaseous by-products. The liquid by-products of coke include water, coal tar and crude light oil. The gaseous products include hydrogen, methane, ethylene, carbon monoxide, carbon dioxide, hydrogen sulfide, ammonia and nitrogen.

Until about the middle of the 19th century, the coal tar by-product of coke was regarded as a waste material. Since that time, uses have been found for many coal tar products. For example, some coal tars meet specifications that are required for roofing and road tars. Other coal tars have either been reduced in viscosity by dilution with solvents for use as fuel, or distilled to recover pitch and tar oils.

This paper was presented at the ISS 46th Ironmaking Conference held in March 1987 in Pittsburgh, PA.

COAL TAR SLUDGES

While uses for most of the coal tar by-products have been discovered, the coal tar sludges remain as waste products. The disposal of these materials is coming under close scrutiny by environmental regulatory agencies. In particular, a waste fraction known as TDS is of increasing importance since it has been classified as a "listed" hazardous waste by the U.S. Environmental Protection Agency. Basically, it is required that the coke plants (or mills) must dispose of this sludge either by internal recycling in the process (within the plant) or by hauling it to an approved secure landfill.

Generally, coal tar and flushing liquor from the gas collecting mains at the coke ovens are directed to the tar-decanter vessel for separating the tar phase from the ammoniacal flushing liquor. While the flushing liquor normally has a residence time of less than one hour in the vessel, the tar phase typically remains in the decanter for about 1.5 days. As the coal tar that is received from the ovens usually contains a small percentage (about 1 percent) of solid particles of coal/coke, the settling of this particulate material to the bottom of the vessel occurs during this period. These particles then agglomerate by binding with the dense coal tar/pitch to form a cementitiously bound solid waste product that is recognized as TDS. The liquid coal tar is decanted from the vessel and then pumped to a storage tank (frequently via a heated tar dehydrator). The sludge is removed by a continuous horizontal endless chain scraper or by periodic discharge from the base of the decanter. In the storage tank, the coal tar is kept heated to provide sufficiently low viscosity for pumping to suitable vessels.

GENERAL PROCESS DESCRIPTION

The general AKJ process (Figure 1) is comprised of a primary processing tank into which TDS or other tar wastes are added along with a prescribed amount

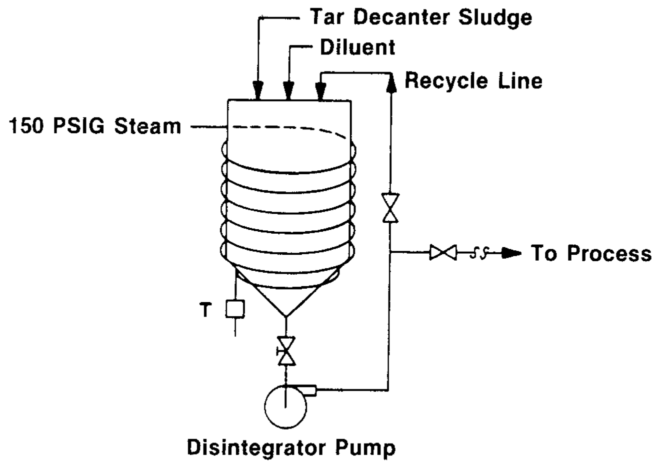

Fig. 1 — Schematic diagram of the AKJ process.

of diluent to bring the finished product to a specified viscosity. A chopper grinding pump reduces the sizing of the particulate matter and mixes the solution into a homogeneous liquid with a normal viscosity in the range of No. 6 oil. Table I shows the typical properties of the processed fuel. *This product can then be transferred to a fuel holding tank or further processed in a secondary processing tank to further reduce particulate sizing in cases of more critical fuel specifications.* The finished fuel can then be utilized as a neat product or it can be blended with other fuels for final use.

ALTERNATIVE USES OF THE AKJ PROCESS

The US Steel Division of USX is currently using the AKJ process at its three corporate coke plant locations, while LTV Steel is piloting the process at two of its coke plants. Each location uses the finished product in different applications to take economic advantage of the local conditions.

Use as an Open Hearth Fuel

USX's Geneva, UT, Works uses the processed TDS as an alternate fuel in its open hearth furnaces.

Table I — Typical Fuel Made from Coke Plant Tar-decanter Sludge

Btus	150,000 — 165,000/gallon
Lbs/gallons	10.5 — 11
Carbon value	80 — 85
Viscosity	250 SUS at 210°F
Sulfur	<3% Depends on base material
Moisture	>1%
Solids	Approximatley 30%
Solids sizing	70% — 90% thru 325 mesh

(Editor's note: The USX Geneva Works has been sold and is now operating under the name of Geneva Steel Company.) The finished product is neatly fed into the open hearth lances. The TDS is processed in the vicinity of the coke plant decanters, transported by a tanker truck and then unloaded into a separate fuel system at the open hearth which incorporates recirculation to eliminate any settling of solids. By utilizing this fuel, substantial economic savings are realized from the fuel value and the cost avoidance of the off-site disposal of the decanter sludge. Operation of the Geneva AKJ facility first began in August 1985. Plans are now in place to process tank sludges and tar materials in a large waste pond to further supplement fuel usage and eliminate future environmental problems.

Use as a Blast Furnace Fuel

USX's Gary, IN, Works uses the finished AKJ product as a blast furnace fuel. The economics associated with using this material as blast furnace fuel are very favorable due to the high Btu value and, more importantly, the high carbon value as a coke replacement. The AKJ fuel is blended with the overall tar fuel being fired on the blast furnaces. As with USX's Geneva Works, substantial fuel savings are realized. The Gary Works' AKJ plant became operational in January 1986. Tar tank sludge and terminal treatment sludge have also successfully been processed into liquid fuels and burned in the blast furnace. Ongoing tank cleanings and tank car cleanings are being utilized as fuel. Plans are also in place to remove material from a waste pond and process it into a fuel.

At USX's Geneva and Gary works, consideration was given to the high solids content of the finished fuel. Proper agitation has been installed in the fuel holding systems of both plants to prevent settling problems. Thus, they have had minimal problems in fuel handling.

Solids sizing is a major consideration in the design and operation of an appropriate fuel handling system. If adequate care is not taken, the settling of particulate materials can result in fuel lance and strainer pluggage. The AKJ process at these USX facilities incorporates an attrition mill in the process to further reduce solids sizing. Table II presents the results of particle size analyses that were conducted on samples of fuel produced from tar-decanter sludge at the Geneva facility.

One of the restrictions concerning the burning of fuel is its sulfur content. The sulfur content has been found to be acceptable to date. It must be realized, however, that this is dependent on the types of coal

Table II — Solids Mesh Sizing — Finished AKJ Open Hearth Fuel

Date	+ 100	− 100/ + 140	− 140/ + 200	− 200/ + 270	− 200/ + 325	− 325
8/22/85	1.56%	1.55%	1.96%	1.54%	0.61%	92.78%
8/29/85	0.22%	0.54%	1.06%	1.08%	0.51%	96.59%
9/3/85	0.18%	0.22%	0.37%	0.32%	0.16%	98.75%
9/9/85	2.00%	2.27%	2.94%	2.06%	0.38%	90.35%
9/13/85	0.24%	0.66%	1.20%	1.05%	0.43%	96.42%
9/20/85	0.44%	0.52%	0.74%	0.68%	0.38%	97.24%
10/14/85	2.00%	1.50%	1.70%	1.30%	0.80%	92.70%
Average	0.95%	1.03%	1.43%	1.15%	0.47%	94.97%

used in the cokemaking process and other sulfurous materials that may have been deposited in tar waste pits along with the TDS.

Use as a Coal Additive

Since February 1985, USX's Clairton, PA, Works has been using an AKJ processing plant to produce a liquid fuel material that is being sprayed on the coal at the conveyors going to the coal bunkers. The benefit in this use has been to decrease bulk density oil usage by between 60 percent and 75 percent. Other benefits include utilizing the Btu value and recovering tar and carbon values from the TDS. Tank cleanings and bio-plant treatment sludge have been processed and used extensively as a recycle material at the Clairton Works. Additionally, a successful trial has been run with sludge from a tar waste pond being made into a fuel, transported and fired in the blast furnace at the USX Edgar Thomson Works in Braddock, PA. Figure 2 presents a schematic representation of the overall materials flow for proposed processing operations in the Monongahela Valley which is located in Western Pennsylvania. The significance of this approach is to provide better overall economic savings by using multiple waste products as a large fuel source for the blast furnaces. As the price of fuel oil rises, this project becomes more economically advantageous.

In October 1985, LTV Steel Corporation began piloting the use of the AKJ process at its Chicago, IL, Works' coke plant to process TDS for recycling into the coal charge going to the coke ovens. Prior to the installation of the AKJ pilot facility, the TDS was added "batchwise" to the high volatile coal portion of the blend in the coal field just prior to processing. This prior practice was very problematic, since coal-handling facilities individually process the coals through a Bradford breaker and hammer mill before the blend is formulated. Pluggage of the handling equipment with masses of TDS that were coated with coal fines, and subsequent damage to the bearings and screens from overloading of units, was observed. Additionally, checks of bulk density (by the cone method and the back calculation of oven bulk density from individual oven charge weights) showed that 15 percent swings in the oven bulk density were periodically occurring due to the slugging of the TDS through the system. Since the battery at the Chicago plant is of 6 m design, the appearance of high uncontrolled bulk densities in the oven cannot be tolerated due to the nearly exponential effect that bulk density has upon lateral coking pressure. Some damage to the battery walls, which is likely to have been caused by the swings to high oven bulk density, was observed after the implementation of these practices. To insure against any further damage potential from this condition, it was decided to eliminate the surges in coal bulk density by finding a more uniform method for adding the TDS to the coal blend. The AKJ process, which produces a pumpable slurry from decanter sludge, offered a viable solution to this problem and was piloted.

Prior to the installation of the pilot facility at the Chicago Works in mid-1985, laboratory-scale tests were conducted to determine the expected effect of the AKJ-processed TDS on the coal bulk density. The

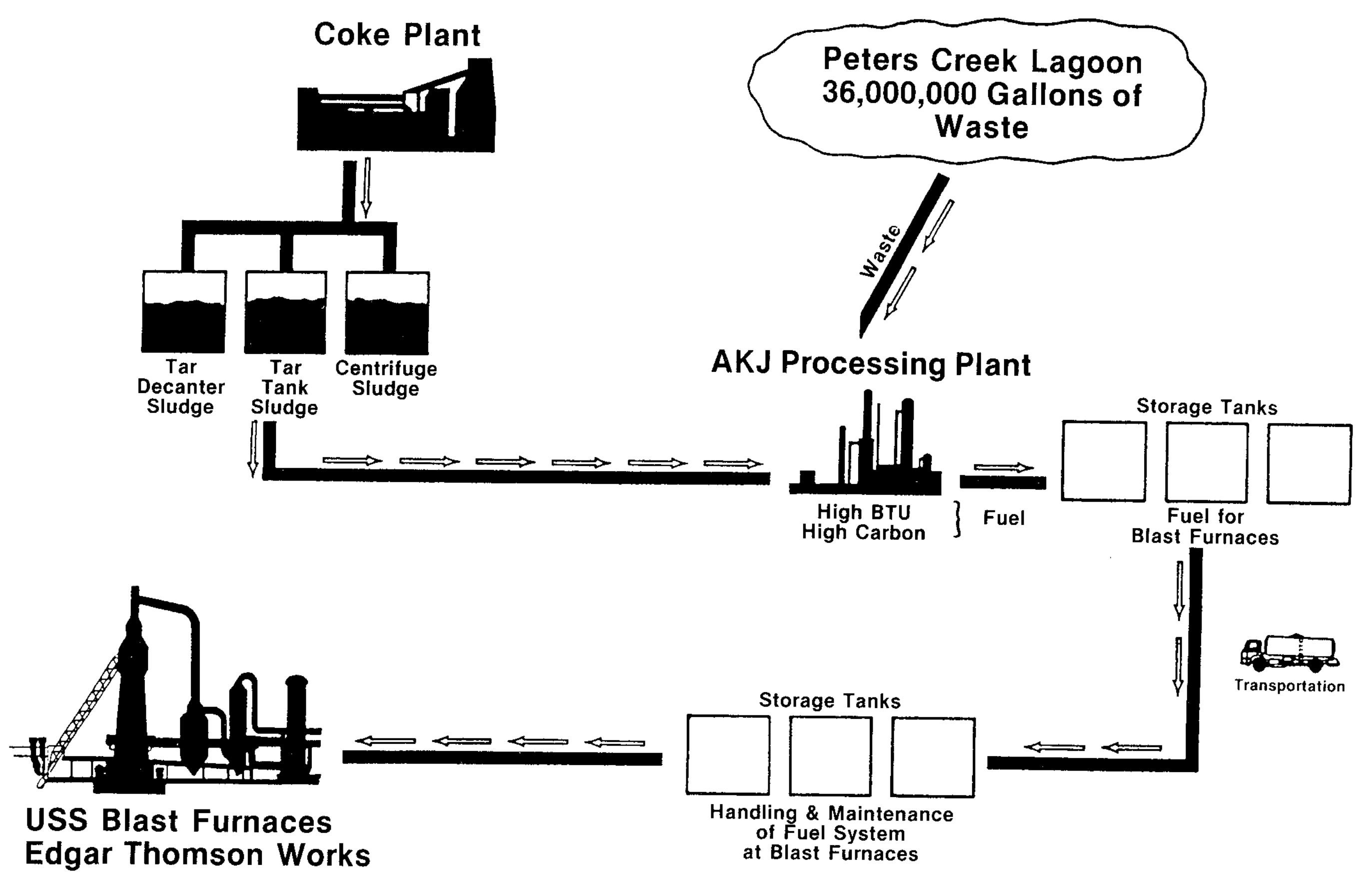

Fig. 2 — Schematic representation of the proposed Monongahela Valley processing operation.

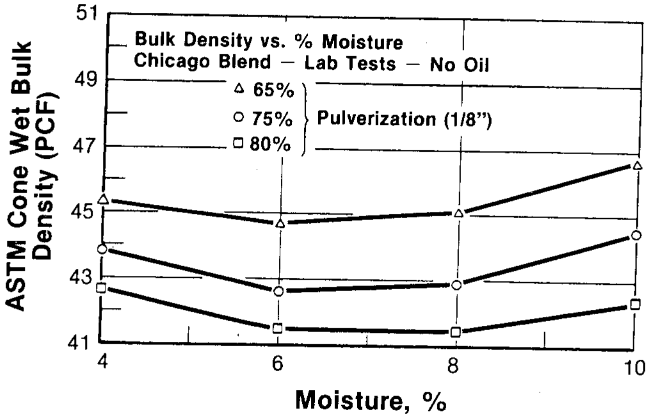

Fig. 3 — The effect of grind and moisture on bulk density (lab tests).

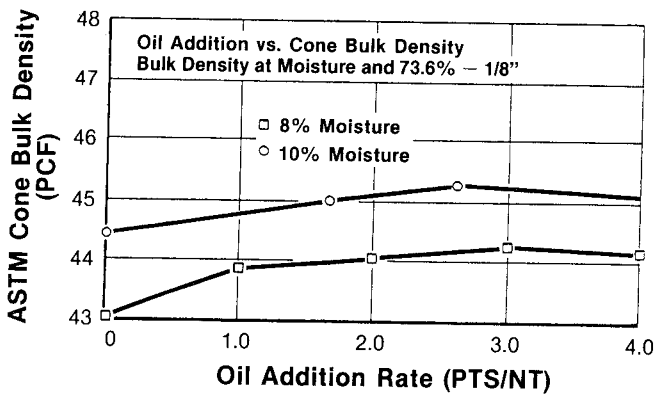

Fig. 4 — The effect of the AKJ oil addition rate on bulk density (lab tests).

results of the laboratory trials on the effects of grind and moisture, and the AKJ oil addition rate on bulk density are given in Figures 3 and 4, respectively. They show a marginal gain in bulk density with the use of the processed sludge. One of the main observations from these data is that above a usage rate of between 2.5 and 3 pints/NT coal processed, the bulk density-oil addition rate curve flattens out. Also, there is no major increase in bulk density for the normally projected range of processed sludge addition. After the startup of the AKJ processing unit in October 1985, the cone and oven bulk densities were closely observed. Tables III and IV compare cone and oven bulk density levels before and after implementation of the facilities, respectively. It is noted that the bulk density swings that were due to the previous coal handling practices have been substantially reduced. The expected increase in bulk density with processed sludge addition was not observed in the ovens, *which is most likely due to an inadequate mixing of the oil onto the coal blend.* However, the main

Table III — Bulk Density Variability Before the Uniform Addition of TDS

Period: 6/25/85 to 7/11/85

Statistic	Cone Wet Bulk Density (PCF)	Oven Wet Bulk Density (PCF)
$\bar{X}$	40.41	51.55
σ	0.62	1.21
n	60.00	60.00

Table IV — Bulk Density Variability — AKJ Oil Addition Trial Results

Period: 10/3/85 to 10/17/85
Oil addition levels: ≤6 pints/NT coal

Statistic	Cone Wet Bulk Density (PCF)	Oven Wet Bulk Density (PCF)
$\bar{X}$	40.39	50.44
σ	0.59	0.63
n	32.00	104.00

purpose of the pilot facility was demonstrated: the uniform addition of the processed sludge to the coal blend would aid in reducing the drastic swings in oven bulk density and thereby extend battery life by reducing surges in coking pressure.

RECYCLING TO A TAR PRODUCT

Although LTV Steel is utilizing the AKJ process for piloting the recycled TDS back into the coal charge for the ovens at its Chicago Works, a review of the local economics of sludge disposal resulted in the development of an alternative process scheme for the company's Warren, OH, Works' coke plant.

The normal tar product at the Warren plant averages about 2 percent quinoline insolubles (QI), which is substantially below the norm for LTV's coke plants. The quinoline insolubles in tar are composed of carbon particles from the cracking of tar droplets when they come in contact with the high temperatures existing in the oven, and the ultrafine coal/coke particles elutriated from the coal/coke bed into the gas collecting system. Since TDS basically consists of a mixture of heavy coal tar and decanted solid particles (carbonaceous matter), it was reasoned that the use of the AKJ process to reduce the viscosity of the tars in the sludge and deagglomerate the particulate materials would allow the production of a material that could be directly recycled into the tar decanter. The tar portion of the sludge, having had the viscosity reduced, would mix intimately with the production tar, while the solid particulate would also be incorporated into the tar and would report to the quinoline insoluble fraction.

A primary factor affecting the ability of the tar to incorporate the carbon particles is the size of the particulate matter. Thus, it was considered that if the normal AKJ process treatment was insufficient to keep the carbon particles in suspension in the tar, attrition mills or fluid energy mills could be added to the system to provide the necessary particle size reduction. In 1960, Bethlehem Steel Corporation reported using a ball mill to crush the TDS to an adequate size distribution for maintaining suspension in tar.[1] Based on our tar and sludge production records, it was calculated that the quinoline insoluble content of the production tar would increase by less than 1 percent.

In order to eliminate any potential problems downstream (in the tar customers' processing facilities), it was decided to use creosote as the diluent material with the AKJ process. Creosote, which is a normal constituent of crude coal tar, had previously been piloted by AKJ Industries and found to be an effective diluent for use with its process. Creosote is not the preferred solvent for use with TDS. However, since a higher percentage of creosote is generally necessary to effect dilution than the normal petroleum-based product in use at LTV's Chicago Works, it was deemed critical that no problem be experienced by the downstream tar distilleries. Therefore, creosote is the solvent used for this application.

Based on the foregoing analysis, it was decided that a pilot unit would be built for the recycling of deagglomerated TDS into the production decanters.

LABORATORY STUDIES

Prior to proceeding with the construction of the pilot facilities, laboratory tests were conducted in an attempt to determine whether an attrition mill would be required in the circuit. In these tests, pretreated TDS that was available from another plant was added in varying amounts ranging from 0 percent to 5 percent to production tar samples from LTV's Warren Works. The resultant samples were well mixed, and the quinoline insoluble solids were extracted from the resultant tar. The QI solids from these tests, as well as the solids from an extraction performed on the pure TDS, were examined microscopically to determine the relative amount and the top size of the solids present.

The TDS used in these tests was available in a pretreated form from another plant; this sludge was deemed to be similar to that discharged from the decanters at the Warren plant.

TREATED TAR SAMPLES

Table V lists the distribution of carbon forms present in the QI solids that were extracted from the specially treated tar samples from the Warren Works, along with the estimated top size of the largest coarse carbon form. Because of the very small quantity of sample that was available (the QI content ranged from 1.5 percent to 2.1 percent) for the sample preparation and microscopic examination, the values are relative. As expected, the data show that as the amount of sludge added to the tar increases, the amount of coarse carbon solids, i.e., coke cenospheres, coke, coal and roof carbon fragments, increases. There appears to be an anomaly in the data: there is a significant incremental change in the amount and top size of the coarse carbon solids between the 4 percent and 5 percent sludge addition levels. The estimated top size for the coarse carbon solids in the first four samples is about 200 mesh, whereas in the 5 percent sludge addition sample the coarse carbon solids are larger (about 60 mesh top size). Actually, this latter sample is indicative that the sludge used in the tests contained an amount of excessively large particulates.

Table V — Distribution of Carbon Forms in Treated Tar Samples from LTV's Warren Works

Sludge %	0	1	2	3	4	5
QI Wt %	1.49	1.57	N.A.	1.82	1.90	2.11
Aggregates of tar/pitch residues and extremely fine QI solids*	96.5	96.5	95.0	94.2	94.5	89.9
Coke cenospheres	2.8	3.3	3.8	4.4	4.1	7.4
Coke	0.2	–	–	0.4	0.3	0.3
Coal	0.5	0.2	1.2	0.8	0.8	2.2
Roof carbon fragments	–	TR	TR	0.2	0.3	0.2
Estimated top size microns/mesh**	75/200	<75/<200	75/200	50/250	75/200	250/60

*Fine carbon solids from cracking or incomplete combustion
**Top size for largest carbon form

FILTERED SLUDGE SOLIDS

Table VI shows the distribution of carbon forms found in the filtered sludge solids. These data show that the sample consists principally of coke cenospheres and coke particles. The remainder are tar/pitch aggregates, unaltered coal particles, pitch coke and roof carbon fragments with a top size of about 8 mesh (typical of TDS).

Table VI — Distribution of Carbon Forms in Sludge Solids — LTV's Warren Coke Plant

Carbon Forms	Volume, %
Coke cenospheres	60.0
Coke*	16.0
Tar/pitch aggregates	10.0
Coal	8.0
Pitch coke	4.5
Roof carbon fragments	1.5

*Consists of partially devolatilized coal particles, semicoke and high-temperature coke.

PILOT FACILITY

A schematic diagram for the AKJ process being piloted at LTV's Warren Works is given in Figure 5. In this system, dump boxes receive up to 4,500 pounds of sludge per day from the scraper discharge of three tar decanters. The dump boxes are transported to the AKJ process tank where the TDS is added "batchwise" to the heated diluent. The dump boxes are steam jacketed to improve the flowability of the sludge during dumping into the process tank. This also reduces the heat load during processing.

After adding the TDS to the solvent, the mixture (slurry) is recirculated through the disintegrator pump for several hours to guarantee that the TDS has been deagglomerated. During the recirculation phase, the temperature of the mixture is maintained

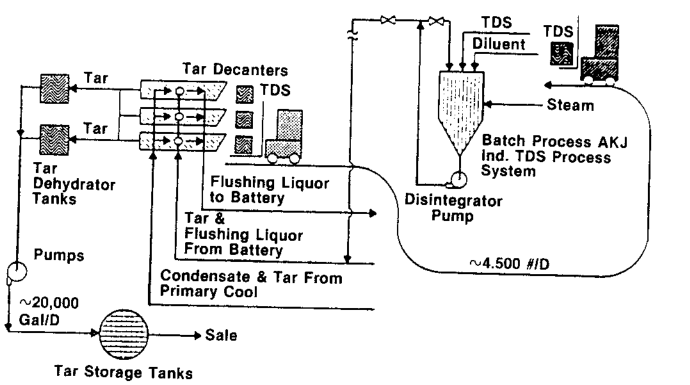

Fig. 5 — Schematic diagram of LTV Warren Works' sludge processing arrangement.

Table VII — Preliminary Trial Results — Production Tar — LTV's Warren Works

Period	Statistic	QI Content (%)	Moisture Content (%)	Specific Gravity
10/12 to 12/21	$\overline{X}$	1.89	5.1	1.181
(Base)	S	0.46	1.4	0.007
12/22 to 2/4	$\overline{X}$	2.44	3.5	1.196
(AKJ process)	S	0.29	0.7	0.002

at about between 75 and 80 °C to improve the action of the diluent in dissolving the tar portion of the sludge. The consistency of the resulting pumpable slurry varies somewhat with the solvent and concentration used (typically between 5 percent and 30 percent by volume) as well as the solids concentration of the TDS.

After recirculating the slurry for a nominal four-hour period, the mixture is added to the tar at the flushing liquor downcomer from the battery, and directed to the tar decanters for reprocessing. In the initial phases of the trials, no attrition mill was incorporated in the facility. However, later trials will utilize an attrition mill to maintain a maximum solids top size of 325 mesh.

TRIAL RESULTS

Startup of the AKJ process at the Warren Works was on December 22, 1986. In the initial phase of this project, an attrition mill was not utilized in the grinding circuit since the laboratory studies had given indications that the mill might not be required. After startup, the volume and consistency of the sludge generated at the decanters were carefully monitored to determine if the sludge was recycling at the decanters. Initially, there was no noticeable increase in the volume of sludge generated. However, after the system had been in service for about one month, a substantial increase in sludge volume was observed.

An analysis of the creosote-tar sludge slurry after processing revealed that the slurry consisted of two fractions: a tarry fraction (containing suspended solids between 200 and 325 mesh in size) having a QI content of 3 percent to 4 percent, and a solids fraction of heavily carbonized material (coke, coke cenospheres, roof carbon, etc.) of plus 200 mesh size. From a review of the results to date, it appears that the creosote is effective in dissolving the tar and tar aggregates in the sludge and separating them from the mass of coke particulate. However, *petrographic examinations of the particles that make up the tarry fractions as well as settling velocity calculations show that it will be necessary to pulverize the heavily carbonized forms to less than 325 mesh in order to guarantee that the solid particulate will remain in suspension during processing and storage.* For this reason, the process has recently been modified to include an attrition mill in the circuit. The modified system is currently being evaluated.

Data obtained during the preliminary trials show that the QI content of the production tar increased < 0.5 percent (Table VII). The increase in tar specific gravity is the normal increase for the increased push rate which occurred during the trial period.

CONCLUSION

Tar-decanter sludge and other tar-based coke plant wastes are coming under increased scrutiny by environmental regulatory agencies. Their disposal requires either internal recycling or disposal in an approved secure landfill. The AKJ process is versatile and has been used to develop multiple alternative routes for the economic recycling of TDS and other tar-based wastes. Economic benefits from the displacement of high-cost fuels have been shown, and pilot studies are being directed at reprocessing TDS for inclusion into the tar product.

Reference

1. H.B. Scharf, "Decanter Sludge Recovery Process at Sparrows Point," *Blast Furnace and Steel Plant,* May 1960, pp. 439-442.

APPENDIX — SETTLING VELOCITY CALCULATIONS

By Stokes Law:

$$U_t = gD_p^2(\varrho_p - \varrho)/18\mu$$

where:

- U_t = Settling velocity
- g = Gravitational constant
- D_p = Particle diameter
- ϱ_p = True particle density
- ϱ = Fluid density
- μ = Fluid viscosity

For typical conditions at decanters (90 °C):

- μ = 10.6 — 21.6 centipoise
- ϱ = 72.20 — 73.11 lbm/ft^3
- $\varrho_p \cong$ 121.68 lbm/ft^3

Particle Diameter Mesh (Micron)	Settling Velocity (ft/hr)
20 mesh (841)	165 — 333
35 mesh (500)	58 — 118
100 mesh (149)	5.2 — 10.5
200 mesh (74)	1.3 — 2.6
300 mesh (48)	0.5 — 1.1
325 mesh (44)	0.4 — 0.9
−325 mesh (20)	0.1 — 0.2

For a typical decanter, the residence time is 36 hours with a tar height of 10 feet; solids must be less than 325 mesh to remain in suspension.