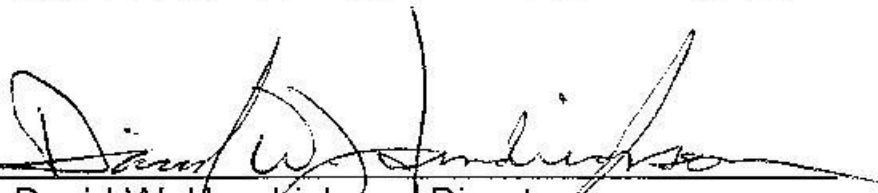


**BENCH SCALE TESTS  
TO SEPARATE MERCURY  
FROM WET-SCRUBBER SOLIDS  
FROM TACONITE PLANTS**

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## **Bench Scale Tests to Separate Mercury from Wet-Scrubber Solids from Taconite Plants**

### **Summary:**

Mercury emissions are a great concern. Initially the emphasis was on the reduction of elemental sources, such as switches, lights, thermometers, dental and medical waste. With those sources greatly diminished, the emphasis has switched to air emissions. The main effort has been in the area of coal-fired power plants, but taconite plants are coming under more scrutiny. Compared to the research on coal-fired power plants, relatively little research has been conducted on taconite plants. The work that has been conducted indicated that the solids in the wet-scrubbers associated with the taconite plants contain a relatively significant amount of mercury and iron units and that this mercury is being recycled back into the process along with the iron. The purpose of this test program was to look at conventional mineral processing steps on the bench scale to determine if the amount of mercury being recycled can be reduced, while at the same time recovering the iron units associated with the scrubber solids. Along with scrubber solids, some of the plants, Minorca, Hibbing Taconite and Keewatin Taconite, also recycle multiclone dust.

Sampling was conducted at Keewatin Taconite (KeeTac), Minntac, Minorca, Hibbing Taconite (Hibtac) and United Taconite (Utac). KeeTac discards all of their scrubber water, and, by permit, are not allowed to recover anything from the scrubber water. They do recycle about 44,700 long tons per year of multiclone dust, which contains about 369 grams of mercury. Some of that mercury is probably removed in a hydraulic classification step prior to the dust going back into the process. No additional beneficiation appears to be necessary. Minorca recycles their multiclone dust and discards a bleed stream of scrubber water. Magnetic separator tests on the scrubber water discard indicated low iron recovery (25%), with a mercury concentration of about 470 ng/g. Minorca's multiclone dust is low in mercury, about 10 ng/g, so there is no need to try to beneficiate that dust. Hibtac also recycles their multiclone dust at a rate of about 990 long tons per year per operating line. Along with that dust, about 174 grams of mercury is recycled. Neither magnetic separation nor hydraulic classification on the dust appeared to reject any significant amount of mercury while still recovering the iron units. When compared to the amount of mercury in the green balls, about 64,000 grams per year, the amount of mercury recycled with the dust is not significant. Hibtac sends their scrubber water to the process water sump in the concentrator, where it is distributed throughout the concentrator. The laboratory tests on Hibtac scrubber water solids indicate that the majority of the mercury is in the minus 8 micron fraction, and, therefore, should stay with the water and report to the tailings basin.

Minntac's scrubber water handling system is a bit more complex than the other plants. The scrubber discharge from each line is sent to a Step wise scrubber thickener, which handles all the scrubber discharge for each Step. So, added to the scrubber thickener is a classifier sand product. The scrubber thickener overflow goes to the pellet plant concentrate thickener, and the overflow from the concentrate thickener goes back to the concentrator. The scrubber thickener underflow goes to the reclaim thickener; the reclaim thickener overflow goes to the reservoir, and the reclaim underflow goes to the concentrate thickener. For two of the six sampling days, the three feeds and two discharges to the Step III scrubber thickener were sampled to obtain a balance around the thickener. Based on the sampling, Minntac scrubbers contain a significant amount of solids, about 4000 long tons per year, containing 7 to 9 pounds of mercury per year.

However, not all of that mercury is recycled. Up to 49 percent of the mercury entering the scrubber thickener reports to the overflow, which in all likelihood ends up in the concentrate thickener overflow and eventually in the tailings basin. Greater than 83 percent of the remaining mercury in the scrubber thickener underflow is in the minus 8 micron fractions. Since the scrubber thickener underflow must pass through two more thickeners before being recycled as pellet feed, it is probable that a significant portion of the minus 8 micron mercury is rejected to the overflows. Additional sampling will be necessary to confirm the above.

For Utac Line 2, there are two parallel scrubbers, one for each side of the machine. Each scrubber discharges under the water level in its own thickener. Also added to each thickener is make up water. The thickener overflows are recirculated to their respective scrubber, and the thickener underflows report to the pellet plant thickener. The combined scrubber thickener underflows send about 3000 long tons of iron and 8.8 pounds of mercury to the pellet plant thickener. With over 50 percent of the mercury in the scrubber thickener underflow being in the minus 10 micron fractions, it is probable that a significant amount of mercury reports to the pellet plant thickener overflow and, therefore, is not recycled. Additional testing will be needed to quantify the amount. Laboratory magnetic separator tests indicate that about 80 percent of the mercury in the scrubber thickener underflows can be rejected, while recovering about 63 percent of the iron. Because of the low percent solids in the thickener underflows, the volumetric loading of the magnetic separator will determine the number of separators needed. Continuous magnetic separator tests will be needed to determine the optimal volumetric loadings.

### **Introduction:**

Mercury in the environment has been a great concern for sometime. Initially the emphasis focused on the reduction of elemental mercury sources such as mercury switches, lights, thermometers, dental waste, medical waste, etc. Great strides have been made in reducing those sources of mercury. While these reductions have been very beneficial to the state, they have elevated the taconite industry from the fourth largest mercury emitter in 1990 to the second largest in 1995<sup>1</sup>. The largest source of atmospheric mercury remains coal fired power plants. While emissions from coal fired power plants have been and continue to be extensively studied, there is only a relatively small body of data on taconite plants. The two major sources of information on mercury in the taconite industry have been the Minnesota Department of Natural Resources Division of Lands and Minerals (DNR) and the University of Minnesota Duluth through its Coleraine Minerals Research Laboratory (CMRL). Their work has indicated that each of the six operating taconite plants is unique as far as mercury is concerned. A “snapshot” of mercury distributions around taconite concentrators<sup>2</sup> in 2003 indicated mercury contents in the crude ranging from a low of 9.44 ppb to a high of 27.90 ppb. The mercury in plant concentrates ranged from 6.19 to 16.10 ppb. There appeared to be no relationship between mercury in the crude and mercury in the concentrate. In general, it appears that greater than 80 percent of the mercury in the crude ore reports to the tailing basin. Recent work by the DNR<sup>3,4</sup> has focused on the mercury in the induration off-gases, and their interaction with the plant scrubbers. Recently published<sup>4</sup> data indicate a relatively large variability in the mercury concentration in the green balls feeding the indurating furnaces within a single operation. For example, data for Hibtac showed a greenball mercury concentration of 10.9 ng/g on 1/27/2004, compared to 26.4 ng/g on 5/19/2005. Similarly, greenballs from Minntac ranged from a low of 12.4 to a high of 24.3 ng/g mercury. The large variation in input mercury translates to large variation in the total mercury content of the scrubbers within a plant. For example, corresponding total mercury values (water

plus particles) in the scrubbers at Hibtac ranged from 502 to 1410 ng/l. However, there does not appear to be a direct correlation between mercury in the greenballs and total mercury in the scrubber discharge.

Previous work by CMRL<sup>5</sup> has indicated that the solids contained in the scrubber water in some of the plants amounts to greater than 5000 tons of iron units annually. Some plants recycle these solids back to the process, which recovers the iron units, but also recycles mercury, a portion of which is probably lost to the atmosphere. Some of the plants send the scrubber solids to the tailings basin, which removes mercury from the system but at a cost of iron units. The objective of this proposal is to determine if standard mineral processing techniques can be used to separate high mercury solids from iron units that can be recycled to the process.

The original test plan called for the collection of bulk composite samples from all of the taconite plants except Northshore, which has very little mercury in the ore. However, after discussions with the DNR and plant personnel, it was decided to take individual samples from each plant, analyze the samples separately, and then composite the solids for bench scale testing.

### **Sampling Procedure:**

With the exception of the 2A and 2B multiclone samples from Keetac, all the samples were collected in acid washed new plastic buckets. The 2A and 2B samples were hot and were collected in metal pails. With the exception of Minntac, all sampling was conducted by CMRL personnel. Minntac sampling was conducted by plant personnel with CMRL supplying the buckets and assisting with the sampling. For the scrubber discharge samples, the slurry pH and temperature were measured and recorded. All samples were brought back to CMRL where the wet weight was measured, the samples were filtered and dried, and the dry weight was used to determine percent solids. Scrubber discharge samples were filtered through #5 paper, which was weighed prior to filtering. Generally, 10 buckets of scrubber discharge were taken for each sample. It was observed that each bucket contained suspended fine solids; therefore, the water column from each bucket was filtered, and then the remaining solids were filtered. For most samples, the same filter paper was used for all buckets; however, for some samples a second paper had to be used due to extremely slow filtering. After drying and weighing the filter paper with solids, the filter cake was removed and the filter paper was weighed to determine the amount of solids remaining in the paper. A portion of the solids was analyzed for total iron, Satmagan iron and mercury. Satmagan iron is a measure of the magnetic iron content of the sample. The filter papers were analyzed for mercury, as was a filter paper blank. Mercury analyses were conducted by dissolution of the samples in a mixture of concentrated hydrochloric and concentrated nitric acid followed by oxidation with bromine mono-chloride. The resultant solutions were analyzed by modified Method 1631 using cold vapor atomic fluorescence spectrometry (CVAFS). Included in each run was a taconite mercury "standard"<sup>6</sup> for quality control. It is thought to be important to use a standard that has the same matrix as the samples being tested.

One drawback of the sampling procedure is the affinity of the solids to absorb mercury from the scrubber water<sup>3,4</sup>. The cited work indicated that scrubber discharge samples that were filtered at the plant had consistently lower mercury content in the particles and higher mercury content in the water than samples that were filtered later. Therefore, the mercury values for the scrubber discharge solids reported in this report are probably overstated. Considering the

residence time in the various scrubber thickeners, it is unknown if the thickener samples have the same bias.

### **Minntac Sampling:**

Samples of scrubber discharge were taken from Lines 4 and 7 at Minntac. Both lines were making fluxed pellets. Both lines use a grate-kiln system, with Line 7 having a ported kiln and Line 4 a standard kiln. Line 7 scrubber also had the addition of surfactant ChemTreat 9080 to reduce PM emissions. The scrubber discharges were sampled on six different days. On two days samples were taken around the Step III scrubber thickener (50 foot thickener) as shown in Figure 1. Samples were taken of the streams flowing into the thickener, (Line 6 and 7 scrubber discharges and chip classifier overflow) and flowing out of the thickener, (thickener overflow and underflow). The extra sampling was done to get a better estimate of how much material is being recycled back to the indurating machines. As shown on Figure 1, about 60 percent of the 50' thickener overflow goes to the concentrate thickener. The purpose of that thickener is to densify the concentrate from 45 percent solids to greater than 60 percent solids, with the concentrate thickener overflow going to the concentrator. In essence, the 50' thickener overflow is sent to the concentrator thickener just as a convenient way to get the water back to the concentrator. The remainder of the 50' thickener overflow goes to the plant reservoir. Therefore, it is unlikely that much of material in the 50' thickener overflow is recycled to the indurating machine. The 50' thickener underflow goes to the reclaim thickener, whose overflow goes to process water and whose underflow goes to the concentrate thickener. Therefore, only those solids that settle in the reclaim and concentrate thickener are directly recycled.

Results from the Minntac sampling are given in Table 1. From the mercury analyses of the filter paper, it is obvious that the solids suspended in the water column are very high in mercury compared to the bulk of the solids. The mercury analyses suggest a possible relationship between feed rate to the grate and the mercury content of the scrubber solids for Line 4. On March 14<sup>th</sup> and 16<sup>th</sup>, Line 4 was running on low tons due to a balling drum being down. Those are the only two days where Line 4 scrubber solids were lower in mercury than Line 7; however, when the amount of solids in the scrubber discharge is added to the equation (total Hg ng/lb of slurry on Table 1), there is no apparent effect of feed rate. The scrubber solids are highly magnetic, as indicated by the Satmagan iron values (Sat Fe). It is interesting to note that Line 7 scrubber solids always have the highest magnetic iron content, and Line 6 solids are the lowest.

Data from the March 7<sup>th</sup> and March 14<sup>th</sup> tests were mass balanced using USIMPAC. A comparison of the computer generated versus actual values is given in Table 2. In general, the agreement is very good, especially for the mercury analyses. Using the balanced data, the annual flow of material can be calculated as shown in Table 3. From this data, it appears that the Step III scrubbers are removing between 7 and 9 lbs of mercury per year, of which about 4.6 to 5.7 lb could be recycling (thickener underflow). Chemistry by size fractions for the thickener underflows from March 7<sup>th</sup> and 14<sup>th</sup>, Table 4, indicates that the majority of the mercury is in the minus 500 mesh fraction. Cyclosizer tests, Table 5, on the minus 500 mesh fractions indicate that the majority of the mercury is contained in the minus 8 micron fraction of the thickener underflow. Looking at the total underflow, about 62 percent of the mercury is in the -8 micron fraction for the March 7<sup>th</sup> sample and about 77 percent for the March 14<sup>th</sup> sample. Since the 50-foot thickener underflow passes through two additional thickeners (reclaim and concentrate), it is probable that the majority of the minus 8 micron fraction reports to one of the overflows and,

hence, is not recycled. Assuming that each additional thickener removes 1/3 of the minus 8 micron material, then, for the March 7<sup>th</sup> sample, the total mercury being recycled would be 3.35 lb/yr or about 39 percent of the mercury entering the 50-foot thickener. For the March 14<sup>th</sup> sample, the mercury recycle would be 2.37 lb/yr, or about 26 percent of the mercury entering the 50-foot thickener. Additional sampling of the other two thickeners would be necessary to determine the actual amount of mercury that is being recycled.

Composites were made of the Line 7 and Line 4 scrubber discharges, so that laboratory concentrating tests could be performed. To simulate the upgrading that could occur in a thickener, elutriation tests were run on the composite discharge samples. The elutriation tests were conducted using a 33 inch long glass tube with diameters ranging from 5/8 inches at the bottom to 1.5 inches at the top with two intermediate diameters between. About 24 inches of the tube has a diameter of 1.5 inches. There is an overflow collection launder at the top. A hose is connected to the bottom and that hose is in turn connected to a glass tee. One leg of the tee is connected to a metered water supply and the other leg, which serves as the drain is clamped off. The test procedure is as follows: The water is set to the desired flow rate, tube is filled about half way with water, the solids are added to the top and the flow is continued until the overflow is clear. The overflow is collected and filtered. The flow rate is increased and the procedure is repeated. When the final flow rate is completed, the drain is opened and the solids are washed out and collected. The Minntac composite discharge samples were run with up flow velocities of 0.0067, 0.0101 and 0.0135 feet per second (as measured in the 1.5 inch diameter portion of the tube). The results shown on Table 6 indicate that greater than 50 percent of the mercury and less than 6 percent of the iron in the scrubber discharge could be removed at the lowest velocity. For comparison purposes, a 50-foot diameter thickener with an overflow of 7000 gpm has an up flow velocity of 0.0079 feet per second.

To determine the effect of magnetic separation, extra 5-gallon pails of Line 4 and Line 7 scrubber discharges were taken with the March 16<sup>th</sup> sampling. Rather than filtering the two extra pails, they were run as received through the laboratory drum magnetic separator. The results are shown in Table 7. Results from Line 7 are promising, with 49 percent of the mercury and about 8 percent of the iron being rejected. The results for Line 4 scrubber discharge were poor, with only about 18 percent of the mercury being rejected as tailing. It should be noted that the laboratory magnetic separator has a limited feed rate for slurry, which would be impractical in commercial operation. In general, magnetic separation is not run on slurries with such low percent solids. The limiting factor will be the gallons per minute flow to the separators. The closest commercial operation is the pre-classification of flotation feed as currently practiced at Minntac. That operation treats a 17 percent solids stream with an average flow of about 70 gpm per foot of magnet width. Assuming that same flow rate, then each scrubber discharge at 3000 gpm would require at least four single drum machines with 4-ft diameter by 10-ft long drums. Continuous magnetic separator tests on a pilot scale separator would have to be run to determine the effect of volumetric loading and iron recovery and mercury rejection.

### **Keewatin Taconite Sampling:**

The four sets of multiclone discharges were sampled at Keewatin Taconite (KeeTac). KeeTac's scrubber discharge permit precludes recovering any material from the scrubber discharge; therefore, the scrubber discharge was not sampled. The multiclones remove dust from the gas in the grate portion of the grate-kiln machine. The multiclone discharges are double dump valves, which open for a set time. The upper valve opens for a period of time, dumping

the collected dust into a lower chamber. When the upper valve closes, the lower valve closes, dropping the dust into a water swept launder. By measuring the time between consecutive openings of the upper valve, and by collecting all the dust dumped by the lower valve, the rate of dust production can be calculated. There are 4 to 6 discharge valves at each location, and all the valves at a single location open and close at the same time. Therefore, the discharges from all the valves at a single location were composited, and a single time was used to calculate the discharge rate.

Results of the sampling are given on Table 9. There is a significant amount of solids being generated, with the average hourly combined dust being about 11,425 lb/hr or about 5 LTPH with an average mercury of 42.2 mg/hr. The dust from 2 A&B had significantly higher mercury concentrations, (lower weight of solids). The dust at all of the sampling points was high in iron, generally greater than 64 percent, and relatively low in magnetic iron (less than 35 percent). A representative sample from each sampling location for each day was split out and combined to produce a six-day composite for each sampling location. Each composite was screened through 10 microns, and the various fractions were analyzed for total iron, Satmagan iron, and mercury. The results are given on Table 9. The mercury is concentrated in the minus 635 mesh (20 micron) fractions. Generally, the minus 635 mesh fractions are the only ones with mercury concentrations greater than 20 ng/g. There is a trend of increasing magnetic iron with decreasing size fractions for all sampling points. Since the slurried dust goes to a dewatering classifier prior to going back to the process, it is reasonable to assume that the majority of the minus 635 mesh material goes with the water and is not directly recycled to the process. With the relatively low mercury content in the dust, and the probable rejection of close to 40 percent of the mercury in the current process, no further concentrating tests were run on the KeeTac dust.

### **Minorca:**

The Minorca gas cleaning system consists of multiclones to remove the bulk of the dust, followed by 4 wet scrubbers in parallel. The scrubber discharges are collected in a common sump, and the water is recirculated to the scrubbers, with a bleed stream being sent to tailings. Both the bleed stream water and the multiclone dust were sampled. The multiclone dust was not available on the first sampling day due to a plugged hopper. The multiclones operate in the same manner as described for KeeTac, except the cycle period is longer. The results of the sampling are presented in Table 10. The mercury concentration in the multiclone dust sample is low. The mercury in the scrubber water solids is variable, ranging from a low of 111.39 ng/g to a high of 1,246.48 ng/g. The iron in both the dust and scrubber solids is highly oxidized, with a magnetic iron content of between 13.57 and 18.54 percent. Although the current practice at Minorca is to discard the scrubber bleed stream, it may be possible to recover some iron units from that stream. To that end, laboratory magnetic separator tests were run on a sample of scrubber water. The results, Table 11, indicate that although the laboratory drum magnetic separator rejected over 88 percent of the mercury, the mercury concentration of 471 ng/g in the magnetic concentrate is too high to be recycled to the process.

Representative samples of each day's multiclone discharges were composited; a sample of the composite was screened, and the fraction was analyzed, Table 12. The mercury is fairly uniformly distributed across all size fractions, which indicates very little opportunity to reject a high mercury fraction. To confirm this hypothesis, an elutriation test was run on the multiclone composite. The results given in Table 13 indicate little opportunity for mercury rejection.

**Hibbing Taconite:**

Line 3 was sampled at Hibbing Taconite (Hibtac). The gas treatment scheme is similar to Minorca, employing multiclones to remove dust and then 4 wet scrubbers in parallel. The scrubber discharge is pumped to the concentrator, where it is utilized as process water, with the vast majority of the water ultimately going to the tailings basin. The multiclone dust is pumped to the pellet plant thickener, where whatever does not overflow with the water is added back to the process. The sampling results, Table 14, indicate little variation in the mercury concentration in either the scrubber water or dust. The multiclone dust mercury concentrations are about an order of magnitude higher than the dust from either KeeTac or Minorca. Of the mercury removed from the gas stream, about 13 percent is associated with the multiclone dust.

A multiclone dust composite was made by taking a representative sample from each day's dust. A portion of the multiclone composite was screened, and the fractions were analyzed, Table 15. The mercury content of the fractions between 200 and 635 mesh is fairly uniform and increases significantly in the finer (-635 mesh) fractions. A cyclosizer test was run on the minus 325 mesh fraction of the dust composite, Table 16, which showed little variation except for the minus 8 micron portion, which had a mercury concentration about 3 times higher than the other fractions. These results suggest that only a small amount of mercury is being rejected in the pellet plant thickener overflow.

A laboratory magnet separation test was run on the composite dust, Table 17. Somewhat surprisingly, the mercury was concentrated in the magnetic concentrate. To confirm the magnetic separator results, the test was repeated, with the same results, Table 18. These results clearly eliminate magnetic separation as a means of removing mercury from the multiclone dust while still recovering the iron units.

Although the scrubber solids are being sent to the concentrator and are probably being lost to the process, it may be possible to recover some of the iron units without recovering too much mercury along with the iron. A cyclosizer test was run on a scrubber solids composite, Table 19. The results show a reverse correlation between size and mercury concentration, with the minus 8 micron fraction containing about 69 percent of the mercury. Elutriation tests were also run on the scrubber solids composite, Table 20, which indicated that only a very small up flow velocity will remove a significant amount of mercury. To determine the potential for using magnetic separation for removing mercury and still recovering some of the iron units currently being lost, both Davis tube and laboratory drum magnetic separation tests were run on the scrubber solids composite, Table 21. These results are more typical of what has previously been seen with magnetic separation, namely the concentration of mercury in the non-magnetic portion. Assuming an average scrubber water discharge rate of 2500 gpm at 0.035 percent solids and solids specific gravity of 4.8, then the solids rate in the scrubber water is 423 lb/hour. Based on the magnetic separator tests, about 137 lb per hour or about 600 st/yr could be recovered using magnetic separation. However, along with the iron would come about 48.5 grams per year of mercury. These results assume a sufficient number of magnetic separators to handle the volume of water that needs to be treated with the very low percent solids in the feed.

**United Taconite:**

United Taconite's (Utac) gas cleaning system is slightly different from the other systems. Utac draws gas from both sides of the indurating line and then treats each side in its own scrubber. Each scrubber discharges under the water level in separate scrubber thickeners. The scrubber thickener overflow is returned to the scrubber, and the underflow goes to the pellet



plant thickener. The Line 2 scrubber system was sampled. Thickener underflows and overflows were taken from both thickeners. The plant designations are thickener 9 and thickener 10. Results of the sampling are given on Table 22. Unfortunately, plant data for the sampling period was not available. Normal operating conditions have a combined (#9 and #10) overflow rate of 1500 gpm and a combined underflow rate of 980 gpm. As would be expected, the thickener overflow solids had a higher mercury concentration than the underflow solids. For thickener #9, the overflow solids averaged 343.3 ng/g mercury, compared to 160.4 ng/g for the underflow solids. Likewise, #10 thickener overflow solids averaged 463.0 ng/g, and the underflow solids averaged 175.1 ng/g. Assuming the average plant values for the flows, then the combined thickener underflows contain, on an annual basis, about 5,170 long tons of solids at 54.7 percent iron (2,968 lt/yr iron) and 8.8 pounds of mercury.

The individual samples from each sampling point were combined to make four overall composites. The composite samples were screened, and the fractions were analyzed for mercury, Table 23. Surprisingly, the mercury concentration on the solids showed a trend of decreasing with decreasing size down to 10 microns. Below 10 microns the mercury concentration increased. Because of the weight distribution of the sizes, the majority of the mercury is contained in the minus 10 micron fractions. This suggests that when the #9 and #10 thickener underflows are sent to the pellet plant thickener, a significant amount of mercury will be removed in the pellet plant thickener overflow.

To determine the potential for magnetic separation, samples of the composite #9 and #10 underflows were diluted to plant percent solids and run through the laboratory drum magnetic separator. The results, Table 24, indicate that about 80 percent of the mercury could be rejected in the non-magnetic portion, while recovering close to 65 percent of the iron in the magnetic portion. On an annual basis, magnetic separation has the potential to recover about 1,900 long tons of iron and reject about 7.1 pounds of mercury. As with the other plants, continuous magnetic separator tests would need to be run to determine the effect of volumetric loading on recovery and mercury rejection.

To estimate the effect of magnetic separation on the thickener overflow, samples of #9 and #10 composites were run in the Davis tube. The results, Table 25, indicate that it would be possible to recover a magnetic product that contained about 11 percent of the mercury and about 60 percent of the iron. The effect of removing the iron from the circulating load of the scrubber is unknown. It may be that removing the iron on a continuous basis would reduce the mercury content of the magnetic concentrate, since it would not be recirculated back to the scrubber. However, it may also mean that the mercury content of the non-magnetic portion would build up even higher before it finally left the scrubber circulating load.

### **Conclusions:**

The sampling and analyses of the solids indicates that, in general, the mercury is concentrated in the minus 10 mesh fractions, which suggests that thickening and or cycloning will remove a significant amount of mercury from the recycle. The sampling has also shown that some scrubber water contains, on an annual basis, greater than 5,000 long tons of solids. However, not all of those solids are recycled.

On a plant by plant basis, Keetac recycles about 44,700 long tons of dust per year, which contains about 369 grams of mercury, some of which is probably removed along with the water in the classifier. There appears to be little need for beneficiation of the dust. Minorca, like Keetac, disposes of their scrubber water bleed stream and only recycles the multiclone dust. On

average, the mercury content of the dust is less than 10 ng/g and, therefore, additional beneficiation is not needed. Hibtac sends their scrubber water to the concentrator process water sump, which essentially removes the mercury in the solids from the recycled material. Some small fraction may be recovered in magnetic separation, but it is impossible to estimate how much. Based on the laboratory tests, it appears that the vast majority of the mercury will remain with the water and exit the plant. Hibtac does recycle their multiclone dust at the rate of about 990 lt/yr per line, containing about 174 grams of mercury. Neither magnetic separation nor hydraulic classification appears to offer much rejection. To put the mercury in the recycled dust in perspective, a line running at 480 ltph with a mercury content of 15 ng/g contains, on an annual basis, about 64,000 grams of mercury.

Minntac scrubbers contain a significant amount of solids, up to 4,000 long tons per year, containing 7 to 9 pounds of mercury per year. However, not all the material in the scrubber water is recycled. As much as 49 percent of the mercury in the scrubbers appears to report to the scrubber thickener overflow, which is sent to the pellet plant concentrate thickener. The concentrate thickener overflow goes to the concentrator as process water and eventually ends up in the tailing basin. Of the mercury remaining in the thickener underflow, greater than 83 percent of that mercury is contained in the minus 8 micron fractions. Since the thickener underflow reports to the reclaim thickener, followed by the concentrate thickener, it is probable that a majority of the minus 8 micron mercury is removed in the overflows. To confirm the mercury rejection, additional sampling should be taken around the various thickeners at Minntac. One way to enhance the mercury rejection would be to cyclone the scrubber thickener underflow prior to the reclaim thickener. The cyclone overflow would report to the thickener overflow, and the underflow to the thickener feed well.

For Utac, the combined #9 and #10 scrubber thickener underflows send about 3,000 long tons of iron and 8.8 pounds of mercury to the pellet plant thickener. Since over 50 percent of the mercury is present in the minus 10 micron fractions, it is probable that a good portion of that mercury overflows to the pellet plant thickener and is effectively removed from the recycle. Additional sampling will be needed to confirm the mercury rejection. The lab testing has shown that magnetic separation of the combined scrubber thickener underflows can reject at least 80 percent of the mercury while recovering about 63 percent of the iron. Continuous magnetic separator tests on the combined scrubber thickener underflows will be necessary to determine the effect of volumetric loading on iron recovery and mercury rejection.

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**Table 1 - Results from Minntac Sampling**

	ng/g Hg				total Hg ng/lb slurry	pH	Temp, C	Fe, %	Sat Fe, %	gpm	Feed LTPH
	% solids	cake	paper **	tot solids							
3/5/2007											
Line 7	0.038	430.56	2158.32	446.78	77.18	6.70	31.2	62.32	57.49	2995	525
Line 4	0.016	1721.32	2263.47	1775.54	131.41	6.61	35.1	60.70	52.99	3040	560
3/7/2007											
Line 7 scrub discharge	0.077	200.38	1122.29	223.76	78.47	6.43	36.4	63.08	57.81	3010	525
Line 4 scrub discharge	0.019	617.78	2773.00	683.09	59.52	6.61	36.1	61.14	52.30	2985	550
Line 6 scrub discharge	0.042	850.82	3697.00	890.91	168.17	6.56	36.7	60.67	46.28	2998	535
50' thick oflow	0.032	280.23	2170.67	314.39	45.03	7.05	34.1	60.13	48.89	6948*	
50' thick unflow	4.143	69.60		69.60	1309.21	7.08	33.7	61.92	50.97	510*	
Line 7 class Oflow	1.320	12.66		12.66	75.89	8.91	24.8	61.28	49.96	1454*	
3/9/2007											
Line 7 scrub discharge	0.054	338.80	3504.00	386.52	94.38	6.42	35.6	62.30	56.44	3000	500
Line 4 scrub discharge	0.013	981.10	894.00	978.20	57.00	6.48	35.3	60.99	51.10	3041	560
3/12/2007											
Line 7 scrub discharge	0.052	413.00	971.60	422.80	99.05	6.24	36.5	63.07	59.02	3000	535
Line 4 scrub discharge	0.038	405.40	1381.30	426.87	74.12	6.41	38.9	61.69	53.80	2975	565
3/14/2007											
Line 7 scrub discharge	0.063	611.25	4306.67	644.49	184.73	6.39	37.0	64.29	59.95	3002	530
Line 4 scrub discharge	0.096	189.61	4337.00	220.27	96.37	6.71	40.0	63.49	58.17	2975	455
Line 4 scrub discharge			2754.67								
Line 6 scrub discharge	0.027	1073.46	2334.67	1132.58	136.68	6.72	37.0	61.72	41.45	3012	525
50' thick oflow	0.047	258.06	812.86	290.16	61.59	6.94	34.6	59.31	44.44	7131*	
50' thick unflow	3.029	76.18		76.18	1047.67	7.19	33.9	62.95	52.36	432*	
Line 7 class Oflow	0.907	1.25		1.25	5.15	9.23	26.6	61.24	52.60	1544*	
3/16/2007											
Line 7 scrub discharge	0.060	600.30	3151.11	635.19	174.29	6.51	37.1	64.72	60.69	3001	540
Line 4 scrub discharge	0.077	430.28	2035.11	445.02	154.57	6.58	38.7	63.27	53.70	3025	450

\* Calculated from mass balancing program

\*\* Mercury from digestion of filter paper after removal of filter cake

**Table 2 - Mass Balancing around 50-foot Thickener in Step III**

	gpm		% solids		Hg, ng/g		Fe, %		Sat Fe, %	
	measured	computer	measured	computer	measured	computer	measured	computer	measured	computer
3/7/2007										
Line 7 scrub dis	3013	3010	0.0772	0.0773	223.76	233.60	63.08	63.10	57.81	57.83
Line 6 scrub dis	2998	2995	0.0416	0.0416	890.91	891.70	60.67	60.68	46.28	46.29
Class oflo		1454	1.3204	1.3321	12.66	13.30	61.28	61.45	49.96	50.08
Thickener Oflow		6948	0.0315	0.0312	314.39	296.30	60.13	60.11	48.89	48.88
Thickener Unflow		510	4.1433	4.0711	69.60	61.10	61.92	61.73	50.97	50.84
	gpm		% solids		Hg, ng/g		Fe, %		Sat Fe, %	
	measured	computer	measured	computer	measured	computer	measured	computer	measured	computer
3/14/2007										
Line 7 scrub dis	3002	3005	0.0631	0.0631	644.49	632.10	64.29	64.34	59.95	59.72
Line 6 scrub dis	3012	3015	0.0266	0.0266	1132.58	1116.40	61.72	61.74	41.45	41.40
Class oflo		1544	0.9074	0.9009	1.25	1.22	61.24	61.60	52.60	51.30
Thickener Oflow		7131	0.0468	0.0472	290.16	308.00	59.31	59.22	44.44	44.67
Thickener Unflow		432	3.0292	3.0670	76.18	81.00	62.95	62.61	52.36	53.59

**Table 3 - Calculated Annual Material Flow**

3/7/2007	Solids LTPH	lb Hg per yr	LTPY Fe
Line 7 scrub dis	0.53	2.37	3200.2
Line 6 scrub dis	0.28	4.85	1649.4
Class oflo	4.43	1.13	26133.1
Thickener Oflo	0.49	2.80	2841.1
Thickener Unflow	4.85	5.70	28897.4
3/14/2007			
Line 7 scrub dis	0.43	5.22	2656.6
Line 6 scrub dis	0.18	3.90	1077.0
Class oflo	3.19	0.08	18828.2
Thickener Oflo	0.75	4.45	4288.4
Thickener Unflow	2.95	4.62	17947.3

**Table 4 - Chemistry by Size for the 50-foot Thickener Underflow Samples**

3/7/2007					Distribution, %		
Mesh	wt %	ng/g Hg	% Fe	% Sat Fe	Hg	Fe	Sat Fe
100	4	22.92	59.39	27	1.61	4.09	2.16
150	3.2	46.66	50.55	24.06	2.62	2.79	1.54
200	4.6	31.13	49.29	24.45	2.51	3.91	2.25
270	11.3	42.51	57.76	39.33	8.43	11.25	8.89
325	6.3	22.89	63.45	48.85	2.53	6.89	6.16
400	10.3	18.68	65.51	53.24	3.38	11.63	10.97
500	15.4	15.67	66.26	56.37	4.24	17.58	17.37
-500	44.9	94.76	54.12	56.39	74.68	41.87	50.66

3/14/2007					Distribution, %		
Mesh	wt %	ng/g Hg	% Fe	% Sat Fe	Hg	Fe	Sat Fe
100	3.2	29.43	58.61	26.40	1.54	2.95	1.61
150	2.8	32.14	51.09	22.97	1.47	2.25	1.22
200	3.8	27.55	47.38	24.39	1.71	2.83	1.76
270	10.2	20.68	60.37	42.42	3.44	9.69	8.23
325	5.5	21.61	63.46	59.27	1.94	5.49	6.20
400	10.2	18.32	65.54	56.49	3.05	10.52	10.96
500	15.9	22.51	66.27	58.59	5.84	16.58	17.72
-500	48.4	102.64	65.20	56.81	81.02	49.67	52.30

**Table 5 - Cyclosizer Tests on -500 mesh Fraction  
from 50-foot Thickener Underflow**

3/7/2007						Distribution, %		
	wt	wt%	ng/g Hg	% Fe	% Sat Fe	Hg	Fe	Sat Fe
32 u	0.2	0.53	40.63			0.34	0.00	0.00
24 u	3.7	9.89	7.76	71.42	66.19	1.22	11.09	11.72
17 u	9.4	25.13	7.80	69.39	61.95	3.10	27.38	27.87
11 u	9.9	26.47	15.79	64.74	58.10	6.62	26.90	27.53
8 u	3.4	9.09	26.47	64.03	56.26	3.81	9.14	9.15
-8 u	10.3	27.54	191.64	58.98	48.14	83.55	25.50	23.73
Oflow paper	0.5	1.34	64.24			1.36	0.00	0.00
3/14/2007						Distribution, %		
	wt	wt%	ng/g Hg	% Fe	% Sat Fe	Hg	Fe	Sat Fe
32 u	0.2	0.53	185.01			1.56	0.00	0.00
24 u	4.3	11.47	13.40	71.80	66.01	2.43	12.92	13.55
17 u	9.4	25.07	17.44	69.80	62.73	6.92	27.46	28.14
11 u	9.9	26.40	35.42	65.66	59.90	14.80	27.21	28.30
8 u	3.5	9.33	47.99	65.30	56.68	7.09	9.57	9.47
-8 u	9.2	24.53	246.01	60.40	48.64	95.55	23.26	21.36
Oflow paper	1	2.67	17.24			0.73	0.00	0.00

**Table 6 - Elutriation Test on Scrubber Discharge Composites**

Line 7						Distribution, %		
feet per sec	wt%	ng/g Hg	% Fe	% Sat Fe	Hg	Fe	Sat Fe	
0.0067	6.84	2446.78	34.16	22.21	52.95	3.63	2.59	
0.0101	10.53	273.76	56.42	42.84	9.11	9.23	7.69	
0.0135	41.58	161.59	68.31	63.97	21.25	44.13	45.38	
Unflo	41.05	128.52	67.42	63.3	16.69	43.01	44.34	
Line 4						Distribution, %		
feet per sec	wt%	ng/g Hg	% Fe	% Sat Fe	Hg	Fe	Sat Fe	
0.0067	7.89	3145.97	43.46	27.18	65.18	5.59	3.96	
0.0101	20.79	313.48	64.91	57.61	17.10	22.00	22.08	
0.0135	23.95	133.63	67.44	64.74	8.40	26.32	28.58	
Unflo	44.47	79.81	63.58	55.35	9.32	46.09	45.38	

**Table 7 - Magnetic Separator Tests  
on Scrubber Discharges from 3/16/07**

	Wt %	Fe	ng/g, Hg	Fe Dist, %	Hg Dist, %
Line 4 concentrate	82.26	68.23	199.46	96.80	82.37
Line 4 tailing	17.74	10.45	197.89	3.20	17.63
Line 7 concentrate	73.04	70.61	185.84	92.28	50.98
Line 7 tailing	26.96	16.01	484.20	7.72	49.02

**Table 8 - KeeTac Multiclone Sampling**

Date	Sample	Time, sec	wt	% Fe	% Sat Fe	ng/g Hg	Solids		
							lb/hr	mg Hg/hr	g Hg/yr
2/12/2007 Green ball rate 930 LTPH	1 A	72	16059.8	64.86	21.83	3.70	2558.60	4.30	37.65
	1 B	70	27898.3	64.90	23.48	2.82	4301.50	5.51	48.24
	2 A	36	13910.4	64.90	23.33	39.59	1088.93	19.57	171.45
	2 B	56	6590.5	66.05	33.59	37.74	816.99	14.00	122.62
2/15/2007 Green ball rate 920 LTPH	1 A	72	19926.3	64.90	23.33	3.76	3174.60	5.42	47.47
	1 B	70	32681.7	64.40	22.92	2.01	5039.03	4.60	40.28
	2 A	36	9167.8	64.83	33.37	37.70	717.67	12.28	107.60
	2 B	56	12140.6	64.71	29.48	26.75	1505.01	18.28	160.11
2/16/2007 Green ball rate 920 LTPH	1 A	72	28420.4	65.67	22.76	7.87	4527.86	16.17	141.65
	1 B	70	46217.2	65.73	23.62	2.54	7126.00	8.23	72.09
	2 A	36	9193.5	65.74	33.24	17.16	719.69	5.61	49.11
	2 B	56	9034.6	65.66	29.17	12.31	1119.97	6.26	54.83
2/21/2007 Green ball rate 840 LTPH	1 A	72	16934.2	64.79	23.13	3.67	2697.91	4.50	39.38
	1 B	70	36365.4	64.97	22.74	4.05	5607.00	10.31	90.31
	2 A	36	11304.6	65.16	32.52	28.64	884.95	11.51	100.80
	2 B	56	8580.6	64.59	28.01	27.48	1063.69	13.27	116.25
2/22/2007 Green ball rate 880 LTPH	1 A	72	14437.2	64.67	20.92	4.23	2300.09	4.42	38.69
	1 B	70	38998.6	64.79	22.15	3.12	6013.00	8.52	74.61
	2 A	36	9443.2	64.94	31.40	30.46	739.23	10.22	89.55
	2 B	56	5675	64.50	26.26	20.72	703.50	6.62	57.97
3/6/2007 Green ball rate 930 LTPH	1 A	72	26604.4	64.70	23.05	4.66	4238.54	8.96	78.47
	1 B	70	59746.4	65.21	26.63	4.18	9212.00	17.47	153.02
	2 A	36	10669	63.17	32.93	44.79	835.19	16.99	148.79
	2 B	56	12575.8	64.78	29.15	28.13	1558.96	19.91	174.43



**Table 9 - Chemistry by Size for Keetac Multiclone Composite Dust Samples**

1A					Distribution, %		
mesh	wt %	% Fe	% Sat Fe	ng/g, Hg	Fe	Sat Fe	Hg
100	8.77	65.81	12.05	2.91	8.97	4.79	4.11
150	7.79	62.34	15.87	2.11	7.55	5.61	2.65
200	15.05	62.95	21.30	2.27	14.72	14.54	5.51
270	24.15	65.56	23.51	1.89	24.61	25.76	7.36
325	10.10	66.49	23.68	2.15	10.43	10.85	3.50
400	6.12	66.88	23.22	2.49	6.36	6.45	2.46
500	13.74	67.02	24.83	2.83	14.30	15.47	6.27
635	6.61	65.90	27.70	3.26	6.77	8.31	3.48
10 u	6.07	66.72	29.84	43.52	6.29	8.22	42.60
-10 u	1.60			85.27	0.00	0.00	22.06
2A					Distribution, %		
mesh	wt %	% Fe	% Sat Fe	ng/g, Hg	Fe	Sat Fe	Hg
100	1.70	63.86	10.71	13.09	1.71	0.58	1.10
150	3.84	61.44	18.08	17.74	3.72	2.23	3.35
200	10.47	62.44	26.92	11.93	10.30	9.04	6.15
270	21.65	65.70	32.34	7.79	22.41	22.45	8.30
325	10.28	66.52	33.21	10.31	10.78	10.95	5.22
400	5.99	66.92	34.45	11.69	6.31	6.61	3.44
500	18.42	67.09	35.12	15.06	19.47	20.74	13.65
635	10.82	66.95	36.03	17.35	11.41	12.50	9.24
10 u	13.31	66.21	34.90	58.88	13.89	14.90	38.57
-10 u	3.52			63.42	0.00	0.00	10.98

**Table 9 – Continued**

1B					Distribution, %		
mesh	wt %	% Fe	% Sat Fe	ng/g, Hg	Fe	Sat Fe	Hg
100	4.75	65.64	12.18	2.77	4.77	2.46	3.97
150	5.87	61.91	19.12	4.28	5.56	4.77	7.58
200	14.02	62.85	24.30	2.59	13.48	14.47	10.95
270	25.87	65.79	26.36	1.68	26.04	28.96	13.11
325	11.62	66.86	25.67	1.28	11.89	12.67	4.49
400	7.67	67.13	24.01	1.30	7.88	7.82	3.01
500	16.57	67.95	24.00	1.88	17.23	16.89	9.39
635	10.00	66.87	21.89	2.22	10.23	9.30	6.70
10 u	2.87	66.15	21.92	31.97	2.90	2.67	27.66
-10 u	0.76			57.54	0.00	0.00	13.15
2B					Distribution, %		
mesh	wt %	% Fe	% Sat Fe	ng/g, Hg	Fe	Sat Fe	Hg
100	3.09	64.02	11.44	4.45	3.10	1.25	0.79
150	6.88	61.36	20.95	4.68	6.61	5.10	1.85
200	16.03	62.44	27.19	5.74	15.68	15.43	5.28
270	24.13	64.99	28.62	6.73	24.57	24.45	9.33
325	9.84	65.84	29.21	8.03	10.15	10.18	4.54
400	3.28	66.62	27.15	13.20	3.43	3.16	2.49
500	16.73	67.63	32.42	15.98	17.73	19.21	15.36
635	10.80	66.18	32.72	20.30	11.20	12.51	12.59
10 u	7.30	65.72	33.68	86.92	7.52	8.70	36.43
-10 u	1.93			102.34	0.00	0.00	11.33

**Table 10 - Results from Sampling at Mittal's Minorca Plant**

Sample	% solids	ng/g Hg			total Hg ng/lb slurry	time seconds	Dust lb/hr	Dust Hg mg/hr	pH	Temp, C	% Fe	% Sat Fe
		cake	paper *	tot solids								
3/19/07 scrubber	0.07	645.47	6826.86	681.17	243.92				6.13	40.85	64.16	14.87
			12624.60									
3/20/07scrubber	1.14	111.41	83.11	111.39	578.58				8.08	44.10	60.07	13.82
multiclones		6.68				173.00	1690.75	5.13			62.49	13.57
3/21/07scrubber	0.28	376.10	1323.71	379.56	490.07				7.39	43.75	60.76	17.82
multiclones		9.12				173.00	445.32	1.84			62.27	14.13
3/22/07scrubber	0.10	1227.83	3251.69	1246.48	554.64				6.57	41.33	59.73	14.68
multiclones		11.42				173.00	192.11	1.00			59.88	18.54
3/27/07scrubber	0.12	551.61	9993.71	588.85	333.45				6.65	43.26	60.17	11.23
multiclones		9.98				173.00	280.02	1.27			61.67	14.26
3/28/07scrubber	0.12	607.02	8915.60	639.84	348.70				6.98	42.34	61.73	13.81
multiclones		9.86				173.00	267.42	1.20			60.16	17.15

\* Mercury from digestion of filter paper after removal of filtercake.

**Table 11 - Magnetic Separator Test on Minorca Scrubber Water**

Sample	wt%	% Fe	Hg, ng/g	Distribution, %	
				Fe	Hg
Concentrate	23.08	67.56	471.27	24.95	11.58
Tails	76.92	60.97	1079.39	75.05	88.42

**Table 12 - Chemistry by Size for Minorca Multiclone Composite**

Mesh	wt %	% Fe	% Sat Fe	Hg, ng/g	Distribution, %		
					Hg	Fe	Sat Fe
100	5.99	60.63	3.57	10.88	6.63	6.08	1.41
150	3.64	55.22	3.82	7.99	2.96	3.37	0.92
200	6.39	50.36	7.36	9.63	6.26	5.38	3.11
270	14.55	55.65	14.02	7.76	11.49	13.55	13.48
325	11.08	61.68	17.99	5.92	6.68	11.44	13.17
400	15.99	63.41	18.94	6.38	10.39	16.97	20.02
500	20.96	65.37	19.01	8.09	17.27	22.93	26.33
635	10.48	65.29	18.25	17.64	18.82	11.45	12.64
10u	8.11	65.10	16.68	16.35	13.50	8.84	8.94
-10u	2.82	-	-	20.85	5.98	-	-

**Table 13 - Elutriation Tests on Minorca Multiclone Composite**

feet per second	wt %	% Fe	% Sat Fe	Hg, ng/g	Distribution, %		
					Fe	Sat Fe	Hg
0.0135	53.44	60.40	7.58	7.00	52.67	24.08	30.92
0.0169	14.25	61.56	21.28	17.60	14.31	18.03	20.73
Underflow	32.32	62.61	30.14	18.10	33.02	57.90	48.35

**Table 14 - Results from Hibtac Sampling**

Sample	% solids	ng/g Hg			total Hg	time	Dust	Dust Hg	g Hg/yr	pH	Temp, C	% Fe	% Sat Fe	Scrubber gpm
		cake	paper *	tot solids	ng/lb slurry	seconds	lb/hr	mg/hr						
4/12/2007 scrubber	0.0330	556.83	3325.12	672.71	83.31			892.88	6.88	30.90	67.61	16.43	2442	
multiclones		229.69		229.69		204	225.00	23.46	205.53		66.43	35.56		
4/16/07scrubber	0.0357	587.28	4705.85	690.24	111.83			1219.67	6.91	33.13	65.66	16.05	2485	
multiclones		134.58		134.58		204	257.65	15.74	137.90		66.76	33.57		
4/20/2007 scrubber	0.0344	643.54	5836.31	728.16	113.76			1231.71	7.05	33.97	64.30	12.33	2467	
multiclones		153.32		153.32		204	220.59	15.35	134.51		67.04	29.32		
4/23/07scrubber	0.0332	619.62	3180.00	696.39	105.08			1159.81	6.82	34.32	64.13	16.18	2515	
multiclones		234.32		234.32		204	224.12	23.84	208.86		66.74	36.33		
4/24/07scrubber	0.0306	528.08	3472.00	630.12	87.64			961.59	6.84	33.93	64.68	15.29	2500	
multiclones		222.09		222.09		204	196.76	19.84	173.79		65.93	40.90		
4/25/07scrubber	0.0396	608.58	2461.05	654.41	117.76			1325.09	6.93	34.52	65.34	14.43	2564	
multiclones		116.15		116.15		204	390.00	20.57	180.15		66.41	25.35		

\*Mercury from digestion of filter paper after filtercake was removed.

**Table 15 - Chemistry by Size for Hibtac Multiclone Composite**

mesh	wt %	% Fe	% Sat Fe	Hg, ng/g	Distribution, %		
					Fe	Sat Fe	Hg
65	6.10	65.49	2.13	6.46	6.27	0.40	0.23
100	1.00	62.24	3.88	49.05	0.98	0.12	0.29
150	1.50	52.69	7.15	74.64	1.24	0.33	0.66
200	3.30	50.33	18.69	143.80	2.61	1.90	2.79
270	10.00	62.38	37.29	154.47	9.79	11.47	9.07
325	10.10	66.6	42.92	154.42	10.56	13.33	9.16
400	16.00	67.43	42.62	178.71	16.94	20.97	16.79
500	21.00	68.05	39.12	176.46	22.43	25.26	21.76
635	13.80	67.72	33.20	113.28	14.67	14.09	9.18
10	13.60	67.97	29.01	304.44	14.51	12.13	24.31
-10	3.60	-	-	272.60	-	-	5.76

**Table 16 - Cyclosizer Test on Composite Hibtac Multiclone Composite**

Sample	wt	wt %	% Fe	% Sat Fe	Hg, ng/g	Distribution, %		
						Fe	Sat Fe	Hg
32 u	6.90	17.88	68.87	27.18	116.92	17.76	22.43	13.80
24 u	18.80	48.70	67.91	21.17	157.66	47.71	47.59	50.71
17 u	9.00	23.32	66.88	18.88	136.08	22.49	20.32	20.95
11 u	3.90	10.10	65.70	15.60	134.07	9.57	7.28	8.94
8 u	Trace							
-8 u	1.00	2.53	66.10	19.98	327.12	2.47	2.39	5.60

**Table 17 - Magnetic Separator Test on Composite Hibtac Multiclone Composite**

Sample	wt%	% Fe	Hg, ng/g	Distribution, %	
				Fe	Hg
Concentrate	64.27	67.44	199.87	65.32	89.67
Tails	35.73	64.39	41.4	34.68	10.33

**Table 18 - Repeat Magnetic Separator Test on Composite Hibtac Multiclone Composite**

Sample	wt%	% Fe	Hg, ng/g	Distribution, %	
				Fe	Hg
Concentrate	63.88	67.58	195.23	65.07	87.07
Tails	36.12	63.94	37.6	34.81	9.48

**Table 19 - Cyclosizer Test on Composite Hibtac Scrubber Solids**

Sample	wt	wt %	% Fe	% Sat Fe	Hg, ng/g	Distribution, %		
						Fe	Sat Fe	Hg
32 u	7.70	20.98	67.50	27.18	54.38	22.04	31.23	5.01
24 u	5.60	15.26	66.82	21.17	77.27	15.87	17.69	5.17
17 u	6.00	16.35	66.36	18.88	81.40	16.88	16.91	5.84
11 u	7.00	19.07	65.08	15.60	102.29	19.32	16.30	8.56
8 u	2.40	6.54	64.74	14.59	132.70	6.59	5.23	3.81
-8 u	7.60	20.71	59.88	11.15	756.79	19.30	12.65	68.77

**Table 20 - Elutriation Tests on Composite Hibtac Scrubber Solids**

feet per sec	wt%	ng/g Hg	Hg, Dist, %
0.0067	80.99	335.06	93.95
0.0101	5.21	138.52	2.50
Unflo	13.80	74.37	3.55

**Table 21 - Magnetic Separator Tests on Composite Hibtac Scrubber Solids**

Davis Tube	wt%	% Fe	Hg, ng/g	Distribution, %	
				Fe	Hg
Concentrate	30.34	69.64	126.82	32.48	10.85
Tails	69.66	63.05	453.56	67.52	89.15
Lab Mag Sep					
Concentrate	32.50	67.41	88.73	33.68	8.36
Tails	67.50	63.91	468.39	66.32	91.64

**Table 22 - Results from Utac sampling**

Sample	% solids	ng/g Hg			total ng/lb slurry	gpm	Solids		pH	Temp, C	% Fe	% Sat Fe
		cake	paper *	tot solids			LTPY	g Hg/yr				
5-7-07 #9 O'flo	0.2132	94.3	192.82	94.93	91.90	750	690.15	302.49			43.79	15.20
5-7-07 #9 Un'flo	0.4448	70.93		70.93	143.24	490	940.65	308.05			48.24	19.81
5-7-07 #10 O'flo	0.1320	782.32	10083.93	968.00	579.94	750	427.12	1908.90			54.52	26.61
5-7-07 #10 Un'flo	1.1396	159.99		159.99	827.76	490	2409.86	1780.10			57.54	31.27
5-8-07 #9 O'flo	0.1310	173.6	501	175.02	104.12	750	424.11	342.72	3.85	43.25	54.59	31.27
5-8-07 #9 Un'flo	1.8870	90.59		90.59	776.08	490	3990.29	1668.96	4.83	42.10	58.35	40.34
5-8-07 #10 O'flo	0.0973	382.445	1940.165	391.85	173.12	750	314.98	569.85	4.04	43.50	57.74	31.05
5-8-07 #10 Un'flo	1.1893	144.42		144.42	779.77	490	2514.87	1676.89	5.03	40.70	57.30	32.04
5-10-07 #9 O'flo	0.1641	341.83	588.38	343.00	255.46	750	530.99	840.88	3.86	43.58	57.99	32.68
5-10-07 #9 Un'flo	2.0015	151.54		151.54	1377.01	490	4232.43	2961.26	4.74	42.80	58.03	33.41
5-10-07 #10 O'flo	0.1034	251.99	353.33	252.62	118.59	750	334.67	390.33			61.15	33.34
5-10-07 #10 Un'flo	1.6701	175.9		175.90	1333.75	490	3531.72	2868.22	4.17	42.70	60.06	31.70
5-11-07 #9 O'flo	0.1459	344.26	396.25	344.47	228.17	750	472.23	751.03	3.80	42.80	52.27	26.28
5-11-07 #9 Un'flo	1.0752	308.48		308.48	1505.75	490	2273.54	3238.10	4.09	40.90	59.42	40.34
5-11-07 #10 O'flo	0.0741	288.88	797.5	290.31	97.64	750	239.78	321.39	3.81	44.00	58.46	32.55
5-11-07 #10 Un'flo	1.1647	270.11		270.11	1428.32	490	2462.99	3071.59	4.37	41.10	56.87	32.56
5-15-07 #9 O'flo	0.1003	590.41	1503.95	600.51	273.40	750	324.59	899.93			51.82	27.26
5-15-07 #9 Un'flo	0.9883	159.34		159.34	714.94	490	2089.89	1537.48			53.91	32.64
5-15-07 #10 O'flo	0.1146	590.59	3542.35	628.76	327.06	750	370.84	1076.54			58.53	33.12
5-15-07 #10 Un'flo	1.0941	140.67		140.67	698.73	490	2313.60	1502.62			60.33	36.36
5-16-07 #9 O'flo	0.1284	515.2	271.54	513.42	299.30	750	415.61	985.17	4.03	40.85	54.51	29.90
5-16-07 #9 Un'flo	1.0884	181.75		181.75	898.10	490	2301.59	1931.36	4.62	38.80	58.54	33.11
5-16-07 #10 O'flo	0.0892	481.8	511.71	482.22	195.30	750	288.74	642.85	3.85	42.90	59.71	34.88
5-16-07 #10 Un'flo	0.9270	159.71		159.71	672.12	490	1960.16	1445.38	4.58	40.80	60.24	35.93

\* Mercury from digestion of filter paper after filtercake was removed.



**Table 23 - Mercury by Size for Utac Composite Samples**

		#9 Thickener Underflow			#10 Thickener Underflow		
mesh	wt %	ng/g Hg	Hg Dist	wt %	ng/g Hg	Hg Dist	
100	0.20	2018.33	3.74	1.10	639.55	6.33	
150	0.20	1121.00	2.08	1.00	287.15	2.58	
200	0.80	415.87	3.08	2.30	125.41	2.60	
270	2.80	146.28	3.80	7.10	66.02	4.22	
325	3.10	105.05	3.02	6.00	65.47	3.54	
400	6.00	97.87	5.44	9.40	56.75	4.80	
500	15.00	79.55	11.06	13.30	58.79	7.04	
635	13.30	56.52	6.97	13.70	58.30	7.19	
10	14.90	59.78	8.26	11.00	56.86	5.63	
-10	43.70	129.72	52.55	35.10	177.53	56.08	
		#9 Thickener Overflow			#10 Thickener Overflow		
mesh	wt %	ng/g Hg	Hg Dist	wt %	ng/g Hg	Hg Dist	
100							
150	0.20	350.28	0.25				
200	0.30	316.85	0.34	0.20	371.18	0.22	
270	0.90	151.25	0.49	0.90	128.50	0.34	
325	1.00	114.07	0.41	1.20	107.12	0.38	
400	2.60	94.39	0.89	2.90	85.52	0.73	
500	10.50	94.08	3.58	10.20	89.66	2.68	
635	12.80	68.29	3.17	11.20	76.97	2.53	
10	14.00	73.50	3.73	8.40	90.68	2.24	
-10	57.70	416.40	87.12	65.00	476.50	90.89	

**Table 24 - Laboratory Magnetic Separator Tests on Utac Thickener Underflow Composites**

	wt%	% Fe	Hg, ng/g	Distribution, %	
				Fe	Hg
#9 Underflow					
Concentrate	54.22	67.86	61.43	65.61	20.76
Tails	45.78	42.13	277.71	34.39	79.24
#10 Underflow					
Concentrate	54.22	66.56	58.79	62.97	18.65
Tails	45.78	50.63	331.78	37.03	81.35

**Table 25 - Davis Tube Tests on Utac Thickener Overflow Composites**

	wt%	% Fe	Hg, ng/g	Distribution, %	
				Fe	Hg
#9 Underflow					
Concentrate	42.32	68.26	68.44	54.80	11.05
Tails	57.68	41.31	404.42	45.20	88.95
#10 Underflow					
Concentrate	55.56	66.56	58.79	66.26	10.97
Tails	41.02	45.90	646.52	33.74	89.03

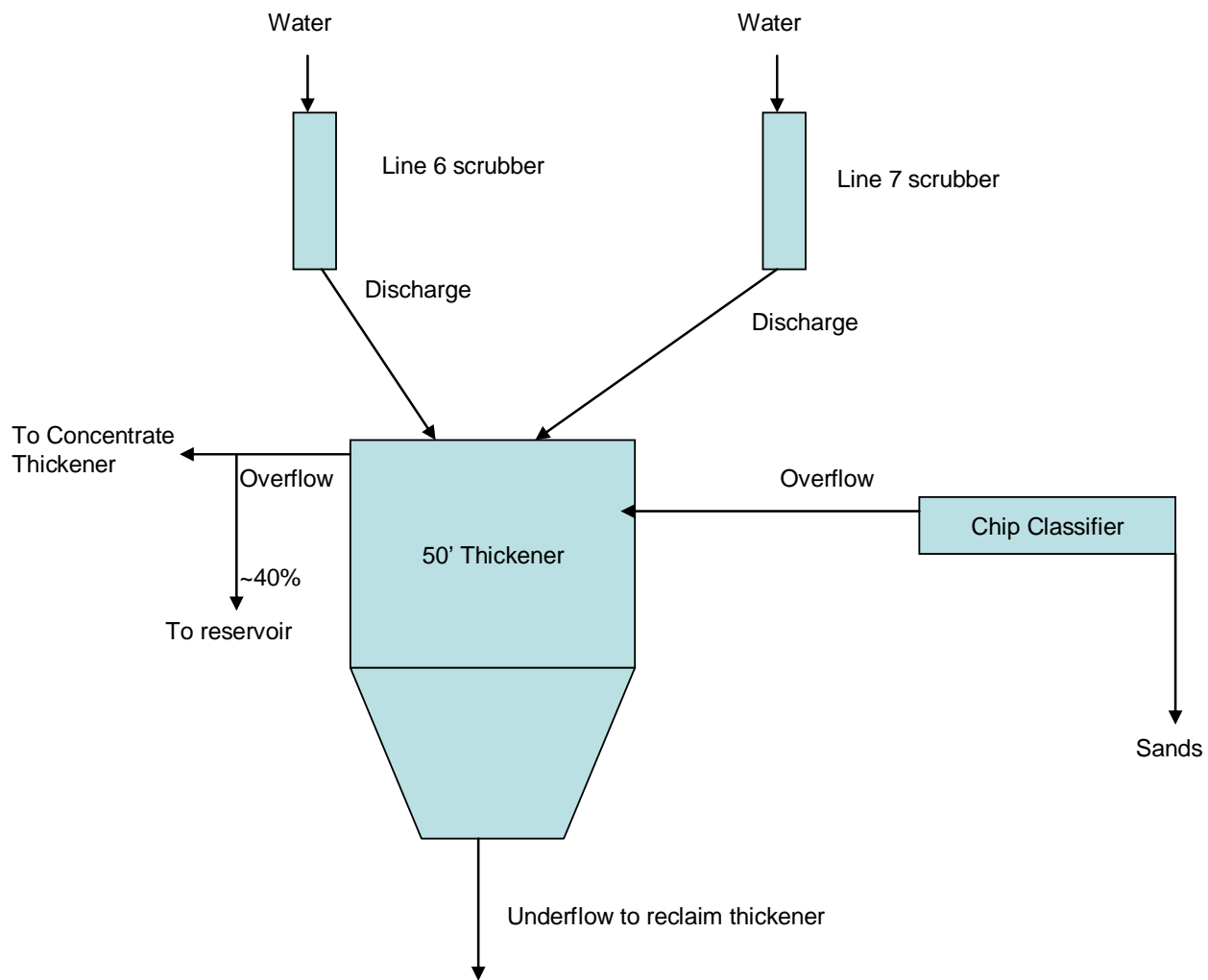


Figure 1 – Schematic of Minntac Step III Sampling