

**FINAL REPORT**  
**GIANT YELLOWKNIFE MINES LIMITED**  
**HI TEMPERATURE GAS**  
**FILTRATION PILOT PROJECT**

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## HIGH TEMP GAS FILTRATION PILOT PROJECT

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## 1.0 Introduction

Following pilot testing at RPC's pilot roasting plant in New Brunswick, it was apparent that high purity arsenic trioxide could be produced by filtering contaminants out of  $\text{As}_2\text{O}_3$  vapour. Product grading +99.5%  $\text{As}_2\text{O}_3$  was routinely produced at RPC by the use of ultra fine sintered metal filters installed in the roaster exhaust gas train. Unfortunately the testwork did not include filter optimization for full scale installation, and there was only cursory examination of the concept of two stage filtration for selectively removing a saleable antimony oxide product.

When the WAROX project design team began to consider the possibility of staged plant construction, using existing plant equipment to combine current production  $\text{As}_2\text{O}_3$  with material reclaimed from underground, it became clear that more testwork using a sintered metal gas filtration system operating in Giant's roaster exhaust would be required before detailed design and cost-estimating could be done.

By coincidence, the need for more testwork corresponded with query from CANMET about research programs at Giant that might qualify for R&D funding under a Mineral Development Agreement between the GNWT and the Federal Government, the Northern Technology Assistance Program (NTAP). Under the terms of this program, the government will fund up to 75% of the cost of R&D programs qualifying for Assistance.

The Hi-temp Filtration project, estimated at the time to cost \$100,000, was submitted for assistance under the program, and approval to proceed in two stages was granted in February of 1990.

## 2.0 Summary

The pilot plant at Giant was built and operated with the assistance of the Northern Technology Assistance Program of the Canada/NWT Mineral Development Agreement, under which the two levels of government agreed to fund up to 75% of the cost of the project. Successful completion of this \$100,000 project was expected to provide the information necessary to build a full scale high temperature gas filtration plant for the purpose of producing a high quality arsenic trioxide byproduct from Giant's fluosolids roasting operation.

Though the objectives of the project were not entirely met, the necessary data for design of phase one of the full scale plant was collected, and it is now possible to prepare a flowsheet, size the equipment, and produce a detailed cost estimate of the plant. The data indicates that filter element selection is not critical, a wide range of filter media being suitable for use in this application. Product purity can be achieved in all filters tested as long as they are operated at pressure drops ranging from 15" to 25" wg, and at face velocities ranging from 8 to 15 acfm per sq ft of filter area.

Due to budgetary constraints, it was not possible to complete two stage filtration testwork, which was intended to test the possibility of producing a saleable grade of antimony oxide on a second, finer filter. It is possible that this test will yet be conducted before detailed plant design is completed.

### 3.0 Project Objectives

As outlined in the MDA application proposal, completion of the testwork would enable the company to detail full scale plant design. Some of the more important design features of a high temperature gas filtration plant relate to pressure drop across the filter, collection efficiency, face velocity ( acfm/sq ft surface area), etc.. All of these items require that a variety of filter media be tested under actual operating conditions.

Product purity specifications may vary for each customer, but objectives of <0.05% Fe and <.5% Sb would satisfy most requirements. To achieve these results, Sb collection efficiency in the filters must, under normal conditions, exceed 65%, while Fe collection efficiency must exceed 99.8%. Iron oxide particles are much coarser than antimony oxide particles and are therefore easier to collect in the filters.

Increasing collection efficiency to achieve a high purity product requires either a large amount of filter area or a large pressure drop as gas passes through the filter media. The former can result in an excessively large plant with a corresponding excessive capital outlay while the latter will require a high power input to drive fans and blowers. A well designed gas filtration system is a balance between the two extremes and detailed testing of various filters is required in order to achieve that balance.

Secondary objectives that were not achieved, primarily because of budget limitations, included two stage filtration for antimony oxide recovery, seeding the condenser gas stream to promote  $\text{As}_2\text{O}_3$  crystal growth, and fuming baghouse dust in the hi-temp filter feed line to examine the full scale potential for this idea.

### 4. Pilot Plant Design

Scale effect in gas handling pilot systems can be quite significant, especially if temperature control must be closely maintained. Small diameter piping has greater surface area for each unit of volume than larger diameter piping and unless external heating is applied, it is difficult to limit heat loss from small diameter gas flues. In the pilot plant, it is likely that heat loss from the hot filter feed line caused precipitation of arsenic in the hot filter and consequent high levels of arsenic in the filter residue. In most other respects it is possible to predict full scale plant operation from results obtained in quite a small pilot plant. Solids lading, pressure drops, face velocity, condenser temperatures, etc.. are all fairly independent of scale and can be directly transferred to full scale design.

The pilot plant at Giant has a number of similarities to the gas handling system used on RPC's 6" fluosolids roaster, though Giant's plant has some enhancements intended to improve data collection and operator convenience. For example there are ports in the cold baghouse exhaust line and the condenser cold air inlet line to permit reading gas velocities and temperatures in the lines. A calculation can then be made to determine gas flowrate through the filter elements. Each operating unit in the pilot plant is equipped with upstream and downstream pressure taps to measure pressure drop across the equipment. In addition, absolute pressure is measured upstream of the filters and downstream of the cold baghouse, alerting the operator of potential feedline plugging.

## 5.0 Gas Filtration Design Considerations

As<sub>2</sub>O<sub>3</sub> purity is Giant's primary consideration in designing a gas filtration system. In this case, iron and antimony oxides are the only contaminants of real significance in the gas stream, and both can be effectively filtered out using a filter of the correct design. The resulting As<sub>2</sub>O<sub>3</sub> product can consistently grade >99.5% purity, with an Fe concentration typically <0.05% and an Sb concentration <0.5%.

The roaster exhaust gas from current operations contains a solids loading of approximately 300 mg/m<sup>3</sup> which corresponds to a capture of about 20 mtpd of solids in the existing electrostatic precipitator. When baghouse dust from underground storage is recovered, twice the dust loading will be experienced in the filters and the filters must be designed to operate under the more rigorous conditions. This will affect blowback interval, blowback pressure, collection hopper design, and conveying equipment.

At the particle size and solids loading ranges experienced at Giant, a gas filter capable of removing particulates down to 0.1 micron dia is required, owing to the presence of extremely fine antimony oxide particles. Antimony oxide accounts for 1 to 4% of the total weight of solids in the gas before filtration, but it accounts for at least 75% of the weight of solids remaining in the gas stream following filtration. As these ultra fine antimony oxide particles are subsequently captured in the cold baghouse along with arsenic trioxide, it is clear that full scale filter design must consider antimony removal efficiency.

The four filters tested at Giant had the following design features as presented in the manufacturer's literature or as stated by the manufacturer's representatives.

Table I

Manufacturer	Mott	Pall	Fluid Dyn#1	Fluid Dyn#2
Model	2AB	S200	XS37	XT69
Filter area (sq ft)	2.2	2.0	2.0	2.0
Pore size (abs micron)	2.0	10.0	1.3	0.4
Delta P @ 20 ACFM	13"wg	8.3"wg	3.5"wg	40"wg
Filter medium	powder	powder	fiber	fiber
Suggested face velocity	8-12	15-50	10-20	<15

Actual pressure drops at maximum flowrate through the system when the filters were installed were as follows:

Mott	Pall	Fluid Dyn#1	Fluid Dyn#2
20-24"wg	11"wg	27-49"wg	26-40"wg

One interesting possibility for full scale plant design is that of using excess heat in the roaster exhaust gas to fume additional crude As<sub>2</sub>O<sub>3</sub> bearing baghouse dust recovered from

underground storage. The gas temperature would be reduced to 370° C from 430° C as  $\text{As}_2\text{O}_3$  in the baghouse dust vaporizes. Under the proposed scheme volumetric flows in the roaster off gas system would be much reduced, as follows:

	Current ACFM	Proposed ACFM
Hot filtration (ESP)	8,700	7,970
Cooling Air (20° C)	26,160	10,514
Baghouse/stack	35,000	18,446

If properly utilized, the gas has sufficient excess heat to treat 8,000 tons per year of crude dust to produce 4,000 tons per year of purified  $\text{As}_2\text{O}_3$  product. The detailed heat balance can be found in appendix D.

One of the unrealized objectives of the pilot test was to examine the effects of feeding crude baghouse dust directly into the hot roaster exhaust gas stream. It is felt that volatilization may occur almost instantaneously provided that the very fine baghouse dust particles are adequately dispersed in the gas stream.

The test was not conducted because of excessive heat loss in the filter feed line, and because of budget constraints.

## 6.0 Plant Operation

Following plant construction, commissioning took place during the period June 25 to July 16, during which time systems were calibrated, additional instrumentation was installed, the cold baghouse was replaced, etc.. Once the plant was finally started under actual test conditions, it was operated around the clock to simulate normal operating conditions and to minimize upsets caused by frequent startups and shutdowns. Overall, four sets of filters were tested for a total of 301 hours under a variety of operating conditions during the period July 16 to August 15, 1990. The plant was not difficult to operate but did require fairly close attention for the following reasons:

1. Temperature control was not automated
2. Operating conditions were recorded every half hour.
3. Manual filter blowback was required during the first few days.
4. Occasional dust hangups occurred in the filter assembly.
5. Samples were collected every two hours.

Temperature control proved to be the single most difficult operating problem and was never entirely satisfactory. The temperature gradient in the filter assembly, even after installation of six heating elements totalling 11,000 watts, was approximately 317° C (approximately 304° C at the bottom and 621° C at the top). Though filter inlet temperature was not recorded, it is assumed that a great deal of heat loss occurred in the 2" inlet line between the roaster flue and the filter assembly, accounting for the low temperature at the bottom of the filter. There is also some speculation that the very high temperatures maintained at the top of the filters in an attempt to prevent arsenic precipitation and consequent high arsenic levels in the filter residue, may have

caused volatilization of the antimony in the filter housing and poor antimony capture in the filter elements. There is some justification for this theory in that filter porosity appears to have had very little effect on antimony collection efficiency.

The 2" line between the filter outlet and the condenser was also equipped with 1500 watts of heat tracing. The temperature in the cold baghouse was difficult to maintain above the acid dew point and it was usually unnecessary to add quench air to the condenser to reduce the gas temperature. The effect of this was a high concentration of  $\text{SO}_2$  in gas at a temperature below to acid dew point. Fairly extensive corrosion of the walls of the cold baghouse were experienced, and on some occasions, large flakes of rust were found in the arsenic product. Scaling in the cold baghouse exhaust line caused some buildup on the lobes of the rotary vacuum pump. Acid treatment using a 25% solution of nitric acid, was effective in cleaning the lobes of the vacuum pump.

## 7.0 Operating Results

The four filters tested were surprisingly similar in antimony collection efficiency, and three of the four had similar pressure drops for a given flow rate. This in spite of substantially different design and operating characteristics indicated in the manufacturers' literature.

There was no major difference in iron capture in the filters and all filters were capable, when operated at pressure drops exceeding 24", of producing an arsenic product meeting an Fe specification of 0.05%. One exception was the Fluid Dynamics .4 micron filter, which achieved good iron collection at a pressure drop of only 15". When operated at similar pressure drops by controlling blowback intervals, there was little difference in antimony collection efficiency, and none of the filters achieved consistent collection efficiencies exceeding 75%. This resulted in an antimony concentration in the arsenic product ranging from 0.5 to 1.0%, not quite the performance hoped for. As mentioned earlier, the possibility of antimony volatilization caused by excessive heating of the filters may be a factor. The theory is supported by the fact that during the first two days of operation, and only during this period, filter temperatures did not exceed 343° C. As shown in fig 1 below, antimony concentration in the CBH product did not exceed 0.2% during this period. This was the only time during the test that the filters were operated at such a low temperature, and the only time that antimony concentrations were anywhere near this low. The theory is further supported by the results obtained from the Fluid Dynamics test run in which the .4 micron filter elements were in use at high filter temperatures. In this case, Fe capture was almost twice as good for a given pressure drop as in other tests, yet antimony capture was similar to that of other tests.

Gold capture in the filters was excellent, reducing gold in baghouse dust from the full scale average of 0.123 oz/t to <0.01 oz/t. Current gold losses to baghouse dust average about 720 oz/yr. Installation of hi-temp filters would reduce this to less than 60 oz/yr.

Fig 1

**Temperature Effect on Antimony Collection**



The following table summarizes some of the more interesting test results. On the evidence of these results, there is little to choose between the very coarse Pall filter operated under conditions as in Run #2, and the very fine Fluid Dynamics filter operated under quite similar conditions.

Table 2

Filter	Mott Run#1	Mott Run#2	Pall Run#1	Pall Run#2	FD 1.3m	FD 0.4m
Blowback int (min)	10	30	10	30	10	30
B'back press (psi)	30	60	50	60	30	60
Avg delta P	25	25	10	20	20	15
Avg face velocity	14	12	10	19	11	14
Avg temp (deg C)	337	399	428	428	379	467
Fe in CBH (%)	.20	.09	.16	.10	.18	.08
Sb in CBH (%)	.24	.49	.65	.37	.91	.59

The concentration of Fe and Sb in the cold baghouse product during the various test runs is illustrated in the graphs shown in Fig 2.

Fig 2

Iron and Antimony Concentration in CBH Product

Blowback interval of the filters is a function of the dust loading of the gas and the pressure drop desired. In pilot scale, the filters were blown back sequentially at timed intervals but in full scale, blowback of a set of filters (out of several sets in operation) would take place only when a specified pressure drop was exceeded. In the pilot plant, the pressure drop changed with the dust loading on the filters and the flow rate through the filters also changed. The feed to the filter was a bleed stream from the main flue, drawn through the filter by induced draft and affected by pressure changes across the filters. This caused some fluctuations in face velocity that would not occur at full scale.

Data from pilot plant operations was compared to full scale plant operation to ensure that standard operating conditions applied during the test program. It was encouraging to note that the important control elements were in very close agreement.  $As_2O_3$  upgrading in the filters was much more effective than in the full scale electrostatic precipitators, and a grade of 99.23%  $As_2O_3$  was achieved in the pilot plant vs an average grade of 93.88%  $As_2O_3$  at full scale. Antimony removal efficiency averaged 62.44% in the pilot plant vs 56.04% in the main plant. Iron removal efficiency in the pilot plant was not calculated because of contamination of the product by rust flakes during periods of low temperature baghouse operation, however iron concentration in pilot plant CBH product averaged 0.14% vs an average of 1.31% in full scale CBH product.

Gold extraction testwork, using composite samples of hot filter dust to correspond with daily hot cottrell dust production, yielded excellent results. The following table shows gold recoveries as compared to full scale plant experience. It should also be noted that the carbon plant recoveries have recently been much better than usual, probably owing to the recent cottrell overhaul.

Table 3

Date	Carbon plant recovery	Pilot plant recovery	
		#1	#2
Jul 16	87.35	94.9	94.8
Jul 19	87.60	87.5	87.8
Jul 20	83.61	87.4	89.6
Jul 22	-	86.9	89.5
Jul 26	87.50	90.1	91.3
Jul 31	88.74	90.4	89.3
Aug 07	88.94	92.1	92.9
Aug 9-11	88.04	91.1	91.2
Average	87.40	90.1	90.8

At an annual feed rate of 11,000 oz in the cottrell dust, the 3.0% difference in recovery amounts to about 330 oz in additional gold. It is likely that the differential in gold extraction from a full scale hi-temp filter installation would be greater than 3% because of reduced arsenic collected in the filter residue.

## 8.0 Conclusions

Given the similarity in antimony removal efficiencies achieved by all filter elements, none of which were more than adequate, with the single exception discussed below, choice of filter should be a matter of iron removal efficiency, selecting the filter media that will do the job under normal operating conditions at the lowest pressure drop. As demonstrated, the Pall filters, with a pore opening of 10 microns and a delta P of only 7" - 9" wg, achieved an antimony collection efficiency almost equal to the Fluid Dynamics filter with a pore size of only 0.4 micron and a pressure drop exceeding 16" wg, though iron collection efficiency in the Pall filter was only about half that of the Fluid Dynamics filter. Collection efficiency can be varied by modifying the blowback frequency and controlling the filter cake thickness. It is possible that good antimony removal efficiency (>90%), may be achieved only under high differential pressure conditions, possibly as high as 60" wg as demonstrated at RPC, though for some reason, the Mott 2 micron filters operated at a high Sb collection efficiency at a pressure drop of only 25" wg.

The evidence suggests that, due to the necessity of applying external heating, volatilization of antimony in the filter assembly introduced an error in the antimony collection efficiency achieved by the filter elements, but this is only speculation at this time.

## 9.0 recommendations

It is recommended that the full scale plant be designed to operate at a normal pressure drop of 15" wg, with the ability to operate at pressures up to 30" wg continuously by installing a booster fan downstream of the filters. This will provide adequate antimony removal under normal conditions and will help in treating underground feedstocks containing antimony concentrations up to four times as high as at present. Additional power requirements are expected to be in the order of 220 kw at maximum pressure, an operating cost of approximately \$150,000/yr.

The filters installed should be relatively fine, having an absolute pore opening of perhaps 0.4 - 0.8 microns. Under conditions of low antimony in the feed, or when product quality is not critical, the filters can be operated at quite a low pressure drop (<10" wg) by frequent blowback. At other times, the pressure drop can be allowed to rise to the point where the necessary collection efficiency is achieved. Design face velocity for these fine filters should not exceed 10 acfm/sq.ft of filter area, and given the low cost of the filter assemblies, even more conservative design would be appropriate, especially if future plant expansion is contemplated.

The capital cost of the installation is an important factor in selection of a filter assembly, but should not override all other considerations. It seems there is little to choose among the various products as far as antimony removal is concerned, but it is apparent that the Fluid Dynamics .4 micron filters demonstrated a superior iron collection efficiency for a given pressure drop than any of the other filters. Too, the Fluid Dynamics people have shown more interest than either Mott or Pall, going so far as to provide a set of filters at their expense, and to send a representative from their plant in Florida to observe the testwork. Fluid Dynamics have also quoted the lowest price for a budget estimate of a full scale system.

Additional pilot testing would be useful to answer the following questions; can antimony be recovered in two stage filtration, and is it likely that antimony was volatilized in the filter during

the pilot testing by applying heat to the filter assembly? Such a test could be conducted in approximately 3 days of operation following approximately 6 manshifts of plant modifications. The total cost of additional testwork would be \$7,000 - \$10,000.

# Engineered Systems for Continuous Service Applications

Pall Porous Metal Filter Systems are quality engineered and built for continuous automated service in small or large flow applications.

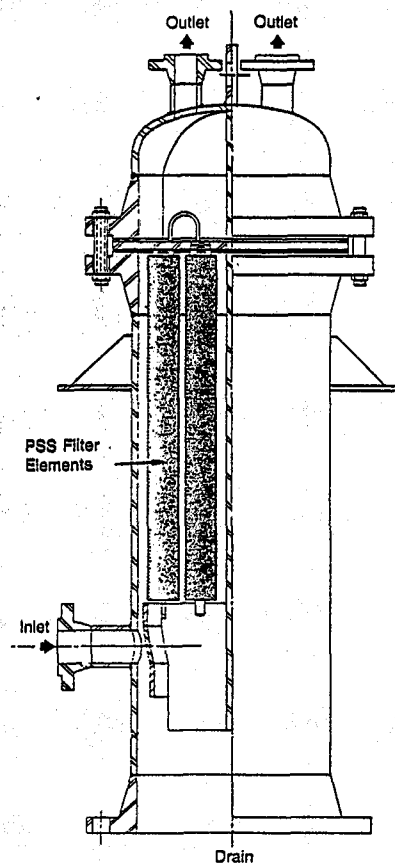
In blowback operations where uninterrupted flow is desired, chambered single vessel and multiple vessel modular designs are available. The chambered single vessel is designed for small flow continuous service applications. Two to four chambers permit 100% forward flow at all times with one of the chambers at a time in the reverse flow cleaning mode.

For large flow continuous gaseous service, modular designs may be used with either the Reverse Flow

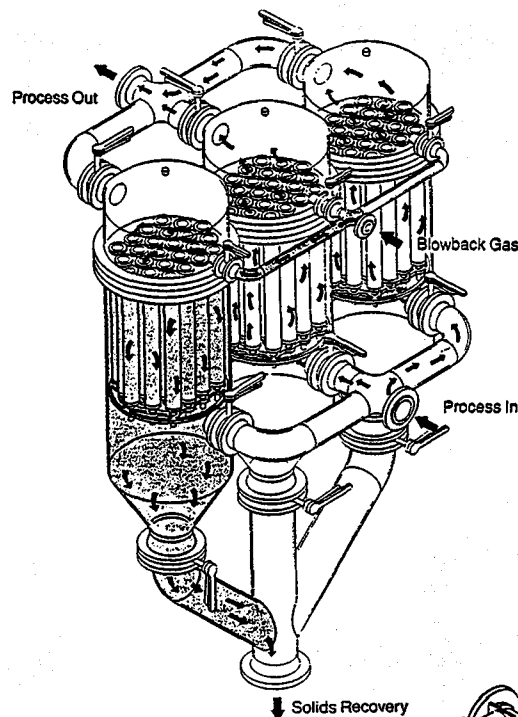
or Jet-Pulse method of blowback, as detailed on page 6. In the case of Reverse Flow, multiple vessels are required with individual vessels being blown back sequentially. The Jet-Pulse method utilizes one or more vessels. 100% forward flow can be maintained at all times while individual groups of filter elements or individual vessels are blown back sequentially.

For continuous automated operation in liquid applications, Pall offers manifolded Backwash Filter Assemblies. Multiple units permit 100% forward flow at all times and allow sequential backwashing of each vessel as required.

**Quadrant design single vessel blowback unit**



**Multi-vessel blowback arrangement**



**Manifolded liquid system**

