Technical White Paper

Fact or Fancy... Five myths about recovery and refining precious metals from spent process catalysts

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How much do you know about myths: How they start and where they come from? We're not talking about dragons and unicorns, lost cities, or pirates' treasures. We're talking about a subject that can be brought literally down to Earth. Wikipedia defines a myth as, "Usually regarded as a true account of the remote past in 'the society in which it is told'." It goes on to say that, "Many societies have two categories of traditional narrative: 'true stories' or 'myths', and 'full stories'." Of course, myths, legends, fables, and rumors have no place in the real world of hydrocarbon and petrochem processing and production—right? You'd think so, wouldn't you? Yet there are many pervasive myths surrounding the recovery and refining of valuable precious metals remaining in spent process catalysts. We can point out five myths for you now to consider; if you hear of others, we'd like to know of them.

Precious metals are perhaps among the most recycled commodities on Earth, mainly because their value usually makes it worthwhile to spend time and effort to recover them. The process of recovering and refining precious metals has been around for a long time, but even in today's dynamic information age, it remains somewhat of a "hidden" industry. Therefore, we'd like to take you behind the scenes for a few minutes and hopefully debunk at least five of the most common myths surrounding what is considered both a science and an art for recovering maximum value from spent precious metal-bearing catalysts.

The First Myth: All precious metals refiners are the same

Actually, this is one of the most popular myths to debunk; it's important for you as a precious metal catalyst owner to understand the whys, wherefores, and hows of it. When spent precious metal-bearing materials are reclaimed, there are really only two absolute essentials to consider: Accurate sampling and precise analysis of the entire catalyst lot. That's because there are still organizations (or even individuals) who will offer to pay you for remaining precious metals in your spent process catalysts—based upon some unknown (mythical?) and unproved premise instead of actual precious metal content and an accurate assay during the recovery and refining process. A catalyst owner must be aware of this kind of transaction; do your homework, and check your quotes and contracts carefully.

Another area that feeds this myth concerns the recovery and refining process itself: the methods and procedures that ultimately extract the remaining precious metals from spent catalyst lots.

Two methods for PGM-bearing catalyst recovery

Precious metals refiners typically use one of two discrete methods to recover and refine platinum group metals (PGMs) from spent catalysts. PGMs include platinum (Pt), palladium (Pd), ruthenium (Ru), and rhodium (Rh); rhenium (Re), which is not considered a PGM, is also present in many spent catalysts and is also a valuable precious metal. These refining methods are pyrometallurgical and hydrometallurgical technologies. There is a clear

distinction between these technologies that affects the outcome with regard to capturing the highest possible amount of remaining precious metals in the spent catalyst lot—including rhenium, now worth about $3,000/kilo.

After a batch of spent precious metal-bearing catalysts is homogenized and a representative sample drawn (The Science and Art of Sampling Precious Metal Catalysts, Kevin M. Beirne, Hydrocarbon Engineering, December 2010) a series of sophisticated laboratory instrument analysis procedures is conducted, commonly known as assaying (Rhenium: A Hidden Asset, Robert T. Jacobsen, Hydrocarbon Engineering,, June 2013). To put it simply, sampling is a series of processes used by precious metals refiners to create a homogeneous mass from spent catalyst lots which are randomly "sampled" in order to determine the type—and percentage—of precious metals remaining in the entire lot. However, in cases where the lot size is large (as it usually is in the petroleum and petrochemical industries), sampling is accomplished from a moving stream (auto sampling). (Material Flow: Necessary and Dangerous for Accurate Sampling, Robert T. Jacobsen, Proceedings, Recycling Metals from Industrial Waste, Colorado School of Mines, June 2014.)

Assaying ultimately enables the precious metals refiner and the catalyst owner to agree on the value of the recoverable precious metals contained in the spent catalyst. Once this is done, the actual refining can begin: the processes that extract the precious metals by one of the two previously mentioned techniques.

Pyrometallurgical vs. hydrometallurgical processing

Here's a typical example of myth vs. reality: What happens when your spent catalysts contain a significant quantity of Re? Rhenium is usually present in about a third of PGM-bearing hydrocarbon processing catalysts; for example, in combination with platinum for reforming naphthas into other desirable products. While all precious metals refiners are capable of recovering most of the rhenium content from spent process catalysts on soluble alumina carriers, until recently none has been able to recover virtually all of the rhenium content. There are many reasons for this, but the main reason concerns the inability to separate the remaining rhenium with a practical process for its recovery and subsequent refining. That's because most precious metals refiners recover rhenium by dissolving their carriers (typically gamma aluminum oxide) with strong caustic or acidic chemicals (the hydrometallurgical or "digesting" process). While this process is capable of recovering the soluble PGMs and rhenium content in spent catalysts, an unknown portion of the desirable "pay metals," sometimes as much as 20%, may remain behind due to the insolubility of their substrates or carriers. That insolubility occurs because the substrate may change phase as a result of overheating during years of operation, preventing their dissolution, even with strong solvents.

A refiner that uses pyrometallurgical technology (for example, Sabin's Pyro-Re™ process) can recover virtually all the Re content from spent catalyst lots (semiregenerative and cyclic fixed bed), particularly from catalysts on substrates that cannot be dissolved with caustic chemicals. The Pyro-Re™ process also offers significant advantages with regard to maximizing return value of all precious metals in the catalyst lot—including PGMs and Re.

The second myth: Cheaper is better

No matter what you buy, you'll likely agree that you usually get what you pay for. To that end, in most purchases for goods and services, cheapness usually proves to be false economy. Take, for example, a precious metals refiner's recovery/refining reclamation contract that's five cents lower per kilo than the next lowest quote. The myth here lies in the fact that many so called "refiners" are not refiners at all, but rather "middle men" who simply broker your materials out to third party vendors. In the precious metals refining industry, there are essentially three categories of refining organizations: Full service refiners (those organizations that provide full in-house recovery and refining capabilities—including transport logistics to eliminate transshipping charges and delays for settlement returns; there are "samplers/processors" (those organizations which partially process your materials, perhaps upgrading them somewhat and combining smaller lots into larger lots); and, there are brokers (companies or individuals who simply buy and sell refining services and use off-site, third-party refiners). In these cases a decision on which refiner to work with should be obvious when you consider the bottom line transaction. We've seen some of these organizations promise returns as high as 99.99% of remaining precious metals. We consider this a myth; here's why:

If you want to know how to "debunk" this myth, you must first learn the answer to the question: 99.99% of what? We've seen this happen many times over the years, where responsible people at major refineries award recovery/refining contracts on the basis of a few

pennies per pound difference in processing fees. Think of it: A few pennies per pound when many thousands of dollars are involved; it really doesn't make much sense. In fact, there are organizations that require the lowest bidder to get the business — no matter what the cost. While they are understandably trying to cut costs, this strategy has little to do with the real money involved — the actual returned value of precious metals in the spent catalysts. Quite the contrary, it simply proves again that cheapness is false economy since there may be tens of thousands of dollars in precious metals value that they may never receive. This is another good reason why catalyst owners should consider working with a refiner that provides full in-house processing capabilities, beginning with storage and shipping arrangements and continuing through in-house sampling and assaying — with an open line for the catalyst owner or its representative to be present at any of stage of the process. Remember, middle men in this industry simply add margin but no value. Many times large lots of spent catalysts are sent to two or three different processing facilities — obviously adding costs and delays along the way. When this happens, settlements are delayed, and the catalyst owner may have to finance replacement metals for new catalyst to ensure a smooth, seamless process flow at its refining facility.

While quality never comes cheap, it usually comes best in the final analysis. "Quality" precious metals recovery and refining (if we may use this term) requires skilled people, sophisticated equipment, and many years' experience to complete the full cycle and arrive at accurate (and agreed upon by the catalyst owner) samples that are used to determine actual precious metals content in a spent catalyst lot. The quality of these key factors is directly correlated to the investment made in plant and equipment and, obviously, in experienced and

knowledgeable people at all levels at the refiner's facilities.

The Third myth: Do you know how many ounces — and what kinds—of precious metals are in your spent catalysts?

Obviously you have documentation on the type and quantity of precious metals incorporated into your process catalysts when they were purchased. You may even have had some of this material sampled and tested. However, there are many circumstances that can affect the "bottom line" with regard to acquiring highest possible amounts of remaining precious metals. Here are just of few of them to consider:

First, the variability (contents) of precious metals loading when the catalyst was manufactured; we know that each catalyst bead is slightly different, so it stands to reason that each drum of catalyst is also slightly different. Anyone who manufactures a product composed of at least one extremely valuable ingredient is going to try very had to keep the level of that ingredient at the bare minimum (we are not talking about fraud, but we must look at the law of averages). In other words, it's not impossible that a drum filled with precious metal bearing catalyst contains slightly less precious metals content than contracted for. On the other hand, we've seen it both ways: sometimes half the drums contain less than the average, and half contain more than the average. An average is an average!

The second key issue is the amount of water the catalyst contains prior to a processing campaign which typically lasts for a number of years. The average water content may be

listed on the certificate when the catalyst was purchased, but there's no way for the catalyst owner to accurately determine the average water content after the catalyst's life cycle. The difference here can be significant with regard to total precious metals recovered.

Adding to the myth of actual precious metal-bearing catalyst composition are the other elements that accrue during processing such as coke, carbon, sulfur, and perhaps additives that may have been used to extend their life cycles. All these elements have an affect with regard to final recovery at the precious metals refiner. However, going back to our first myth, when the spent catalyst lot is processed by hydrometallurgical techniques, these factors become more critical since they can interfere with the "digesting" method and its ability to capture all of the lot's remaining precious metals and its rhenium content as well. This should be clearly understood by the catalyst owner with regard to which technique — pyrometallurgical or hydrometallurgical — is used for recovery and refining. One more interesting fact: When conventional pyrometallurgical processes are used, everything in an electric arc furnace melts but the rhenium may be lost by vaporization of its oxide. Sabin Metal's Pyro-Re process eliminates this loss. The bottom line: Higher returns of remaining precious metals to the catalyst owner — fact, not myth.

The Fourth Myth: Are you getting your original precious metals back?

Precious metals refiners of any significant size receive thousands of customers' spent catalyst

lots every year. It is obviously not cost-effective to refine each lot separately; that is, after the sampling stages are completed and remaining values are agreed upon with the catalyst owner. Instead, think of the entire recovery/refining process as you would think about how a bank works: You deposit your money, but when you withdraw it you don't get the same bills back. Obviously, it's irrelevant that you get the same bills back because that's not what matters. What matters is that your money was counted properly when you made the deposit...and that's why proper sampling and analysis is critical to help assure maximum returns of remaining precious metals.

Accurate sampling is critical for maximizing returns

As previously stated, in order to determine a commercial value the materials must first be treated or processed to allow them to be homogenized. Once the materials are rendered homogeneous, samples are drawn that represent actual precious metals content of the entire bulk materials lot. There are a number of ways of doing this: melting, dissolving into solution, and blending are a few examples. Suffice to say that the method chosen to achieve this uniform state must be "fit for purpose". The goal is to eliminate anything that can get in the way of obtaining that representative sample, because without that even the best analytical lab in the world will be of no use.

Once a precious metals refiner and the catalyst owner have agreed on a value, or "settled the lot" as it's known in the industry, the money can change hands. Usually this "money" is in the form of high-purity metals returned to a pool account with a catalyst manufacturer so the

customer can order another parcel of fresh catalyst, but other options are typically available for the final commercial transactions including replacement metals and/or payment.

In other words, the catalyst owner does not receive the same metal back, only its equivalent in new metal or cash. In the end it's all about math: mathematical calculations determine the values, and the cost-effectiveness is achieved by the precious metals refiner by refining large batches of like materials in a single run.

The Fifth Myth: That's all I need to know;
I'm ready to ship

This myth may have been better positioned as our first myth, because there are many other differences between precious metals refiners that only an on-site visit or audit will reveal.

For example, does the refiner have an AML (anti-money laundering) policy as required by Sarbanes-Oxley and the U.S.A. PATRIOT Act? Next, does the refiner have appropriate environmental management policies — for every jurisdiction in the world in which it operates — and are they adhering to them?

These subjects must be discussed openly; keep in mind that none of the above information protects you from anyone whose "morality" might change under unusual circumstances. Again: do your homework because there is a lot at stake. Visit or audit your precious metals refiner; if you can't, have a reputable third party representative do this for you. It's actually

the only way to make direct comparisons of everything you need to know to select the best refiner for your spent precious metal-bearing catalyst.

Chances are you are familiar with the American Petroleum Institute (API). Unfortunately, there is no equivalent organization representing the precious metals refining industry. There are virtually no industry-wide accepted standards for the analysis of precious metals, with the exception of a few international high-purity bullion test methods and/or criteria. That means that all manufacturers, refiners, and independent laboratories run their analyses according to their own internal best practices. If you visit a few of these refiners, you will see major differences between them.

Enhancing corporate profitability

Most hydrocarbon and petrochemical processors operate precious metals asset recovery departments in one form or another. These are typically managed as independent profit centers, which, because of global economic uncertainties, have assumed more important roles in the past few years. Finding and working with the right refiner can make a significant difference in returns, thus enhancing overall corporate profitability.

There are more than a few unfortunate stories about an organizations' selection of, and relationship with, its precious metals refiner (again, think about the above myths and others as well). Your relationship with a refiner may have serious legal implications if the refiner violates environmental regulations when processing your spent catalysts.

With the dynamics of cost, profits, and possible legal issues, it's clearly in your best interest to work with a precious metals refining organization that does the following:

- Provides the highest possible returns
- Provides rapid processing turnaround time
- Complies with applicable environmental standards concerning process effluent disposal or atmospheric discharges at its facilities
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As you see, there are many criteria to consider when selecting a precious metals refiner. Mainly the rules come down to specific areas that can be controlled and that apply to virtually all refiners that process spent catalysts containing PGMs, rhenium, or other precious metals. These include the policies and procedures associated with the refiners' sampling, assaying, processing, and logistics arrangements. Each of these areas is briefly covered as a way of examining how to select and work with the right refiner to meet the catalyst owners' specific requirements.

Conclusion

In summary, the key to selecting, and working with a precious metals refining organization hinges upon due diligence on your part with regard to determining all of its policies and

procedures from start to finish — including point-to-point transport logistics which will also reduce costs and speed processing and thus return your materials' values quickly. Key emphasis must be placed on the refiner's environmental policies and procedures, since you essentially are establishing a "partnership" with the refiner which may ultimately affect you if it violates laws associated with its recovery and refining operations.

How to select and work with a precious metals refiner

Select a refiner that uses state-of-the-art techniques and equipment.

Choose a refiner that has a long and successful history and good reputation in the industry.

Discuss the refiner's performance and policies with its customers.

Request appropriate reference material, including environmental documentation.

Determine whether the refiner has the financial resources to pay you in a timely manner.

Select a refiner that has full in-house capabilities. The use of outside subcontractors might affect your returns, in terms of values and timeliness.

Ask the refiner about laboratory techniques and replications.

Request detailed weight and analysis reports on your shipment.

Ask if you are allowed to be present during sampling of your material and whether you can conduct your own independent analysis if desired.

For more details on sampling and assaying procedures, visit sabinmetal.com.