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Fogbank: Lost Knowledge Regained

During Japan's Muromachi period (1392–1573), swordsmiths developed the katana, often called the samurai sword, which was fabricated from special steel. Secret techniques in quenching, tempering, and polishing made the sword one of the deadliest on any battlefield.

In the 16th century, firearms were introduced to Japan. Expert swordsmiths, whose skills had been acquired from previous generations, were no longer needed. Thus, the skills associated with making such deadly blades were lost.

Today, the science of metallurgy is advanced enough so that researchers understand the processing variables that gave the katana its distinct properties. Moreover, scientists can replicate the processes to a great extent by using modern methods.

Like the katana, a material known as Fogbank has undergone a similar sequence. Produced by skilled hands during the 1980s, Fogbank is an essential material in the W76 warhead. During the mid-1990s, Fogbank production ceased and the manufacturing facility was dismantled. As time passed, the precise techniques used to manufacture Fogbank were forgotten.

When it came time to refurbish the W76, Fogbank had to be remanufactured or replaced. In 2000, NNSA decided to reestablish the manufacture of Fogbank. Officials chose to manufacture Fogbank instead of replacing it with an alternate material because Fogbank had been successfully manufactured and historical records of the production process were available. Moreover, Los Alamos computer simulations at that time were not sophisticated enough to determine conclusively that an alternate material would function as effectively as Fogbank.

Although Fogbank is a difficult material to manufacture, scientists soon discovered that restoring the manufacturing capability would prove an even greater challenge. Scientists faced two major challenges:

- most personnel involved with the original production process were no longer available, and
- a new facility had to be constructed, one that met modern health and safety requirements.

Despite efforts to ensure the new facility was equivalent to the original one, the resultant equipment and processing methods failed to produce equivalent Fogbank. The final product simply did not meet quality requirements.

Personnel took a more careful look at the design of the new facility, comparing it closely with the old one. They discovered that some of the historical design records were vague and that some of the new equipment was equivalent, but not identical, to the old equipment. Differences that seemed small during the design phase became more significant once the new facility began to produce material. The situation was exacerbated by construction delays, which put the project a year behind schedule.

As the original deadline quickly approached in March 2007, many additional resources were engaged when an emergency condition was established for Fogbank production. Personnel made multiple changes to multiple processes simultaneously. The result was production of equivalent Fogbank and recertification of the production process in 2008.

Despite this success, personnel still did not know the root cause of the manufacturing problems. In fact, they did not know which process changes were responsible for fixing the problem. After production was reestablished, personnel implemented process studies in an attempt to determine the root cause. These studies proved daunting because

- the processes are complex and depend on each other, and
- the material characteristics that control quality of the final product were not understood.

Personnel formed a hypothesis for the root cause of the manufacturing problems by combining results from recent studies with information gathered from historical records. Historical information indicated that occasionally there were production problems with Fogbank for which the root cause could not be satisfactorily resolved. The historical production problems were similar to those observed when reestablishing production.

When investigating historical records with respect to impurity levels during the Fogbank purification process, personnel discovered that in some cases the current impurity levels were much lower than historical values. Typically, lower impurity levels lead to better product quality. For Fogbank, however, the presence of a specific impurity is essential.

Laboratory data show that the presence of one particular impurity in the Fogbank purification process plays an important role in the quality of the final material. The impurity's presence in sufficient quantity results in a different morphology (form and structure) of the material. Although the change in morphology is relatively small, it appears to play an important role in the downstream processes. A review of the development records for the original production process revealed that downstream processes had been implicitly based on that morphology.

However, historical records lacked any process controls designed to

- ensure that the purification process produced the impurity morphology or
- evaluate the success of some of the important processes.

Currently, personnel are proposing additional process controls designed to check both morphology of the material and the effectiveness of the down-stream processes.

Further analyses of the restart activities revealed that there was a small variation in the feed material used in the purification process. This variation led to the change in impurity content and thus the resultant change in morphology. Scientists found that modern cleaning processes, used in the manufacture of the feed material, clean it better than the historical processes; the improved cleaning removes an essential chemical.

Historically, it was this chemical that reacted during purification of the feed material to produce the impurity necessary for proper morphology. The historical Fogbank production process was unknowingly based on this essential chemical being present in the feed material. As a result, only a maximum concentration was established for the chemical and the resulting impurity. Now the chemical is added separately, and the impurity concentration and Fogbank morphology are managed.

Just as modern scientists unraveled the secrets behind the production of the Japanese katana, materials scientists managed to remanufacture Fogbank so that modern methods can be used to control its required characteristics. As a result, Fogbank will continue to play its critical role in the refurbished W76 warhead.

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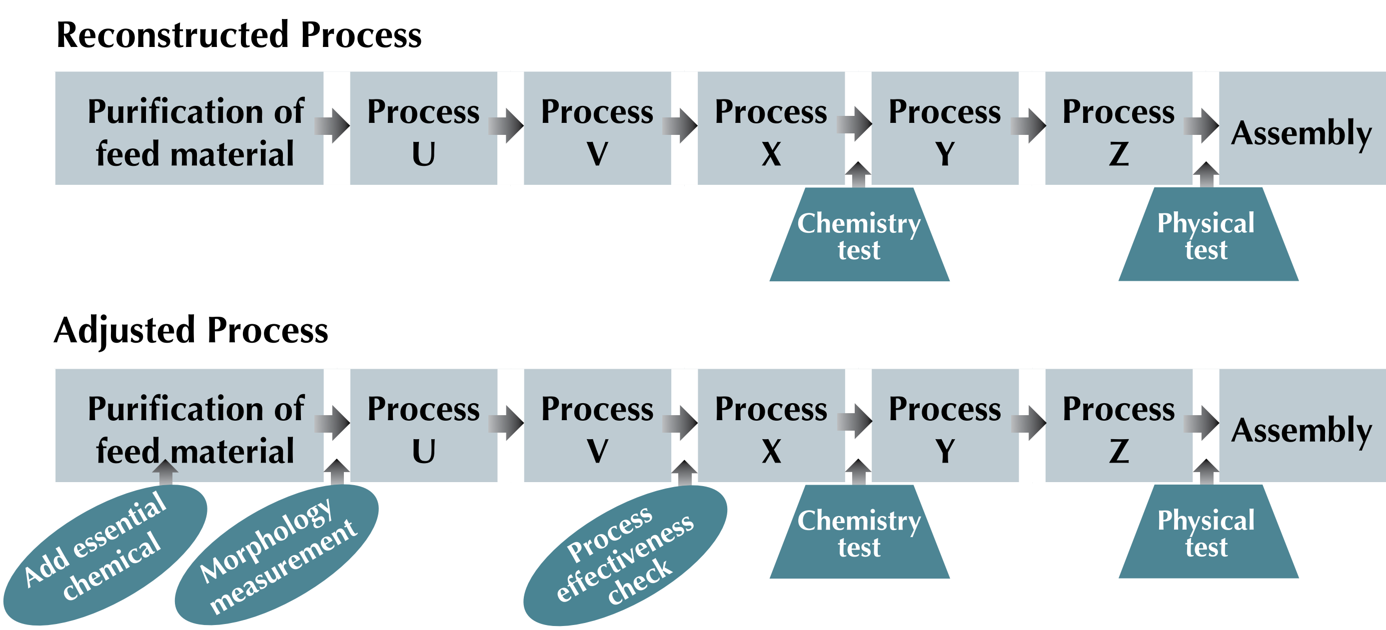

To fabricate new Fogbank, modern scientists reconstructed the historical manufacturing process *(top)*. However, when the resultant Fogbank assembly did not meet quality requirements, scientists analyzed the historical manufacturing process and discovered one minor difference that, when adjusted properly *(bottom)*, yielded quality Fogbank.