FISH—State-of-the-art technology in final diamond recovery

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Synopsis

The name FISH (Fully Integrated Sort House) refers to a class of technology deployed at Jwaneng Mine final diamond recovery. The FISH concept is based on three pillars, namely:

- Improved sorting efficiency
  FISH is based on laser technology, which is more efficient than hand sorting for certain product categories. Laser sorting is based on measuring in-elastically scattered light from molecules and this is referred to as Raman spectroscopy. The Raman scattered light occurs at wavelengths that are shifted from the incident light by the energies of molecular vibrations
- Availability of production information
  Roller gap diamond size distribution information is generated on line for upstream process optimization
- Improved product security
  A 'hands-off' philosophy reduces security risk during operation and maintenance of the plant.

In addition, a number of lessons were learnt about the application of new technologies in the industry:

- The required human competency profile demanded by new technology should match the available competencies of the operational staff
- An integrated information management system should be fully functional for both production management and diamond control purposes
- Operational feedback must be correctly evaluated to identify design, maintenance, training and operational issues so as to accelerate the maturity of the new technology within the time span of the sustainable operations project
- Project execution and technology maturity risks have to be evaluated and married to ensure risk mitigation by means of suitable project resource and contracting model selection.

Introduction

This paper provides an insight into the Fully Integrated Sort House (FISH) concept as deployed at Debswana Jwaneng Mine's 'Aquarium' plant.

The Jwaneng Aquarium plant houses two classes of technology, CARP (Completely Automated Recovery Plant) and FISH (Fully Integrated Sort House). Also housed within the Aquarium building is the Bulk Acid Handling Facility (BAHF) that supplies acid to the FISH process. The Aquarium replaced the old recovery plant, hand sorting and the Central Acidising Centre (CAC) by CARP, FISH, and BAHF respectively.

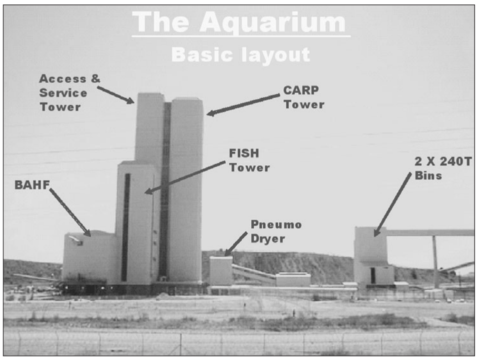

Figure 1—Jwaneng Aquarium

The CARP was designed to treat concentrate from the Jwaneng Main Treatment Plant (MTP), and the Jwaneng Recrush Plant, and tailings from the Jwaneng old recovery tailings dump.

The FISH was designed to treat all Jwaneng sources, as well as diamond concentrate from Orapa CARP, consisting of concentrates from Orapa No. 1 processing plant, Orapa No. 2 processing plant, Letlhakane Mine and Damtshaa Mine. Orapa sources are delivered on a weekly basis, while Jwaneng sources are treated as they become available.

The key features of the Aquarium are: improved diamond recovery efficiency, improved security of the product, improved information turnaround time, and reduced operating costs.

The Aquarium construction was completed during the first half of 2000, with

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commissioning competed early 2001. The commissioning followed the traditional C1–C5 commissioning system approach as defined in the De Beers System Acquisition Lifecycle. After commissioning, a number of problems prevented the FISH from achieving and maintaining required production levels on a sustainable basis. This led to a subsequent project being established combining the skills from DebTech, as major technology supplier, and Jwaneng Mine, as owner/operator, in a partnership to address outstanding issues preventing sustainable operation. At the time of writing this paper, the combined team project was nearing completion, with 100% production maintained for 12 months. The success of this exercise now provides valuable insight into the application and operation of new technologies in the diamond recovery field.

This paper begins by giving a brief description of the Aquarium processes. It then focuses on the deployment of the FISH technologies and concept as a first-off for the industry. It further highlights some lessons learnt during the initial project execution and subsequent optimization phases. Finally, recommendations aimed at the practical contribution of this paper to the diamond industry as a whole are made.

Aquarium process overview

The Aquarium design was justified, based on a number of factors. The main ones are:

- To improve diamond recovery efficiency
- To ensure a quick production information turnaround time
- To improve the security of the diamond product.

The old recovery process was 95% efficient, a sizeable percentage of diamonds therefore reported to the tailings dump. The plant also used grease belts (for recovery of fine diamonds) that were maintenance intensive and operating at 87% recovery efficiency. Improved technologies provided opportunities to replace/upgrade the old systems with more efficient and cost effective systems, thus increasing revenue.

The new Aquarium processes uses proven state-of-the-art technology to recover diamonds using X-ray and laser sorting technology.

Typical design expectations for the new systems were

- *Improve diamond recovery efficiency*
  Old recovery plant recovery efficiency v/s
  CARP recovery efficiency 9–10%
  Old sort house v/s FISH sorting efficiency 2–6%
- *Production information turnaround time*
  Old recovery/sort house
  production information pipeline 4-12 weeks
  FISH/ CARP production information pipeline 24 hours from start of processing
- *Security of the product*
  Labour intensive, 'hands-on' recovery and sorting
  CARP/FISH—'hands-off' operation and maintenance, 'hands-off' sorting and packaging.

The three pillars of the FISH/Aquarium concept can be represented as indicated in Figure 2. The internal boundary defines the original system, while the outer triangle depicts the three core requirements on which the Aquarium system design was based. The shift was to be achieved by means of improved/new technologies employed in the Aquarium.

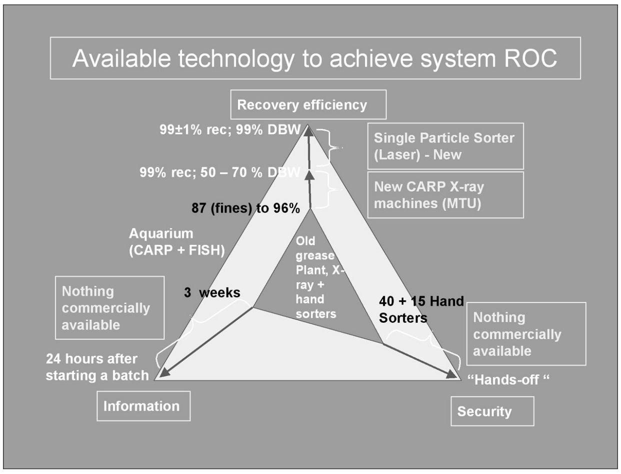

Figure 2—FISH/Aquarium design concepts

CARP description

Refer to Figure 3 for the basic CARP flow sheet. It is important to note that CARP is a continuous flow process.

Dense Medium Separation (DMS) concentrate from both the recrush plant and the main treatment plant is stored in each plant's respective 240-tons head feed bin, from where it is transferred by a belt weigh-feeder into a dewatering screen. The dust fraction from the dewatering screen is removed through the effluent system while the oversize fraction is recycled to the recrush plant through a sicon conveyor. The old recovery tailings go through a similar feed preparation stage. The concentrate from the de-watering screen is transferred into two pneumo dryers in series.

The pneumo dryer conveys the material to a deceleration bin, from where it is presented to a primary sizing screen, which splits the feed into three fractions. These fractions are stored in their respective 10-ton bins. From the 10-ton bins, material goes through the Rare Earth Drum Separators (REDS) where bulk reduction of the magnetic fractions takes place to reduce head-feed to X-ray machines (about 70-percent reduction). The magnetics are fed to the recrush plant tailings dump via the sicon conveyor, while the non-magnetics form head-feed to the X-ray machines. The description below refers to coarse stream; other streams are similar except where noted.

The material is stored in a 1.5 ton X-ray machine feed bin. The material is then gravity fed into a primary batch weigher. The batch weigher feeds a primary dry-chute 3-channel, one-pass X-ray machine. The tailings from the primary machine report to a secondary machine, while the concentrate from both the primary and secondary machines reports to a 1.5-ton re-concentration feed bin. The tailings generated from the secondary machine goes into a 0.5-ton audit bin. Material from the audit bin is fed into an on-line audit X-ray machine whose function is to audit for diamond losses on the tailings of the production machines.

Feed from the re-concentration feed bin is fed into a primary re-concentration X-ray machine via a re-

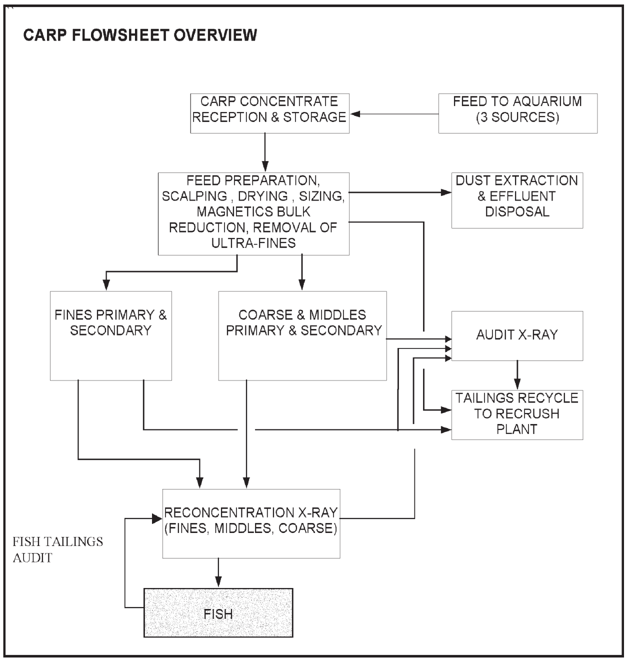

Figure 3—CARP flowsheet overview

concentration batch weigher. The re-concentration X-ray machines remove ceramics and other non-diamond luminescent particles by using the advanced luminescence discrimination principles. The concentrate reports to a 0.5-ton final product bin. Tailings from the primary re-concentration machine reports to another re-concentration X-ray machine for further scavenging before being stored in a 0.5-tonne final product bin. The material from the product bin is subsequently transferred in 20-kg batches by a product batch weigher to the FISH via the Gilgen trolley system. The middlings stream is similar in configuration to the coarse stream.

There are two fines streams, which have a similar configuration to the coarse and middlings streams up to the 1.5-ton re-concentration section feed bins. Material from the re-concentration bins is transferred by a re-concentration batch weigher, into a re-concentration X-ray machine. The tailings of the primary re-concentration machine go through a secondary re-concentration machine, which acts as a scavenger. Concentrate of both the primary and secondary re-concentration machines is stored in the final product bin, while the tailings of the secondary machine are audited through the fines audit machine.

FISH Description

Refer to Figure 4—FISH Flow sheet overview. Note that FISH is based on batch processing philosophy with batches optimized around 20 kg of concentrate for production accounting purposes. Material is conveyed through the plant on a proprietary rail carriage system (Gilgen).

The first stage of processing concentrate from Jwaneng and Orapa CARP is the Metallics Removal Unit Process (MRUP) where copper and aluminium are dissolved using nitric acid and hydrochloric acid respectively. These acids are supplied directly from Bulk Acid Handling Facility (BAHF) on demand.

The dried material from MRUP is sent to sizing using the Gilgen trolley transport system. The sizing unit process classifies the material using roller gap sizers into two fines-, three coarse- and a dust fraction. The dust fraction is recycled to CARP.

The fines fractions from sizing are sent to the Mid Point Shape Splitters (MPSS) machines where the oversize (flats) are removed using square aperture sizing provided by a profiled roller gap-sizer. The flats report to the Single Particle Sorting Coarse (SPSC) machine, while the undersize reports to the Single Particle Sorting Fines (SPSF) machine. The fines MPSS fractions are subsequently sent to the SPS-fines machines. Laser sorting is based on measuring in-elastically scattered light from molecules and this is referred to as Raman spectroscopy. The Raman scattered light occurs at wavelengths that are shifted from the incident light by the energies of molecular vibrations.

The coarse roller-gap-sized material plus oversize from the Mid Point Shape Splitters (MPSS) is sent to the coarse SPS machine. The principle of sorting is similar to the fines machines. The final tailings from the SPS machines is re-cycled to CARP, while the concentrate is transported by the Gilgen trolley system to the Acid Cleaning Unit Process (ACUP). All the spent chemicals are decanted through the effluent system and the material subsequently dried.

The dried material is transferred to the Size Distribution Unit Process (SFD) to classify and count diamonds into different size fractions. The material is sized and weighed into fourteen roller gap size fractions ranging from 8.05mm to 0.5mm. The information is presented in production control graphs comparable to traditional diamond sieve sized analysis used for upstream process optimization. Diamond size frequency distribution information from the SFD is made available within 24-hours of receiving a batch into the FISH.

The product from SFD is transferred to Packaging and Weighing (PAWS) by the trolley system where the diamonds are weighed and packed in canisters. The canisters are automatically sealed after packaging and information for individual canisters is produced.

The diamonds contained in sealed canisters from PAWS are then taken to Washing and Drying (WAD) where they are first cleaned with a rinse aid before being rinsed with water to ensure cleanliness to an acceptable standard for valuation purposes. The diamonds are then dried with a hot air blower, before being weighed and transferred to the WAD unit process output station within the vault. The final product will then be ready for export to Botswana Diamond Valuing Company (BDVC).

FISH concept discussion

As outlined above, FISH is made up of the following high level processes

- ➤ Feed preparation
- ➤ Sorting
- ➤ Cleaning
- ➤ Packing.

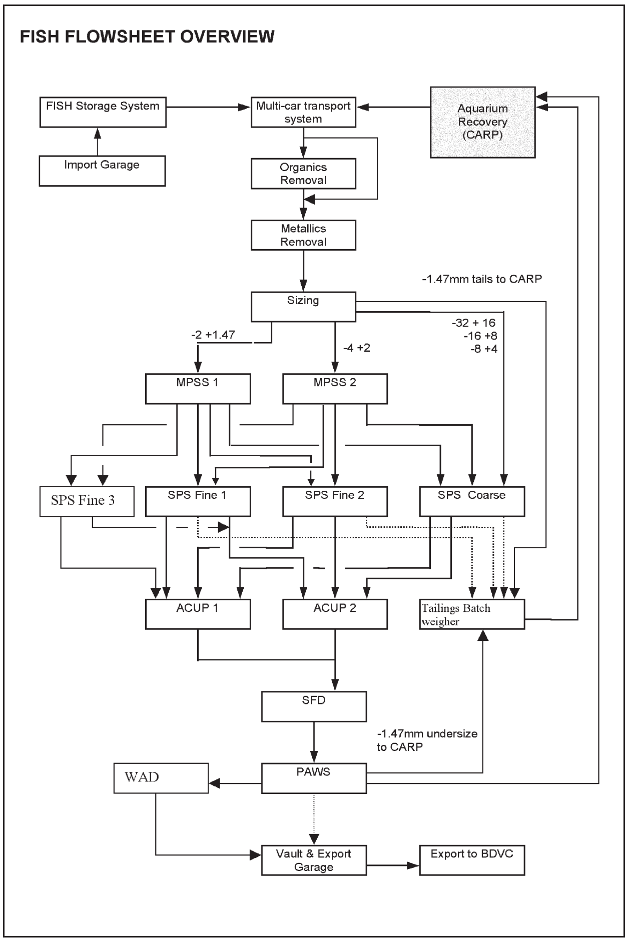

Figure 4—FISH flowsheet overview

While the technologies employed at the micro level in each of these are proven commercially, the integration and packaging of the same is unique to FISH. Not what it does, but how it does it, is of importance.

The concept provides an integrated Diamond Value Management (DVM) system comprising the following main elements

- ➤ Product handling that minimizes potential for physical diamond damage
- ➤ Real time information systems that allow tracking an auditing of production
- ➤ Full integration with security systems to prevent and report any breach in security protocols.

Information management systems and query facilities have been integrated into the mine production information and management systems through direct polling of PLC information. One of the problems experienced in this regard related to the separate development and rollout of such systems due to the sensitive security environment. The daunting amount of process and production information generated through the FISH required specific attention to storage and processing of the same. This area specifically developed substantially since full production was achieved due to on-going operational learning and understanding of the complex relationships between unit processes in the plant.

Deploying state-of-the-art technology in Jwaneng Mine involved application of the systems acquisition approach. This ensured that all requirements of the system being deployed are documented and taken into account during the design phase of the project.

Integrative systems

A relatively complex configuration of independent systems and sub-systems such as found in FISH, relies on interface boundary definition and management that has to be managed as a main risk element. A formal systems engineering approach allowed a structured way to identify and manage all the elements that impact on the various systems levels.

One of the potential weaknesses identified was the level of systems integration that took place during project planning and execution. An integrative system such as FISH has far-reaching impact on the whole diamond pipeline and emphasis was placed on systems engineering levels three and four during the project, which resulted in specific contracting and management models employed. The following illustration depicts the system engineering levels as applied to the FISH concept.

It is important to note that while the importance of systems engineering levels five, six and seven as defined above were recognized during the Aquarium project, the contracting was based largely on levels 3 and 4 design and delivery. This meant that the client was required to take a large role in the integration of the unit processes into an operational entity, as well as the integration of the FISH into group systems.

Technology maturity

Following problems experienced during commissioning and full production ramp-up, a joint venture or partnership was established between DebTech, as main equipment supplier, and Jwaneng Mine, as owner/operator of the integrated system, to deliver FISH in terms of ROC. This partnership proved to be extremely successful and, in hindsight, might have been a more suitable model to adopt from the outset of the project. The main reason was that the technologies employed were largely unproven in a commercial production environment, which resulted in substantial on going

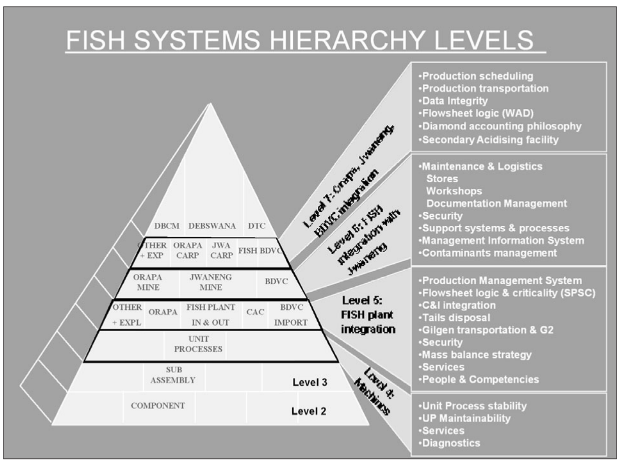

Figure 5—FISH systems hierarchy levels

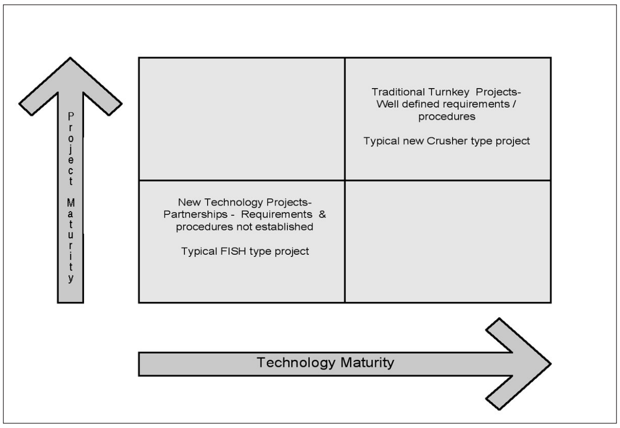

Figure 6—Technology maturity/project model impact

improvements based on operational learning. Figure 6 depicts the relationship between maturity of the core technologies and potential contracting models that best suit the project environment.

Competency/culture maturity

The human resource structures were elevated to the level of the technology being deployed. It is important to note that this required a paradigm shift from the status quo in order to match the technology skills base requirements.

It was also necessary to increase the technical staff complement in order to cope with the new demands. The performance monitoring of the new technology also required that there be an increase in technology managers, at least while still developing automatic performance tracking systems.

The FISH, being the first of its kind, did not allow opportunities for benchmarking with similar operations, specifically on manpower requirements. Also the type of technology employed was unique to De Beers and the diamond industry at large. Traditional operational structures therefore had to be reviewed to sustain the process.

The three basic stages of new technology deployment, planning, installation and evaluation—succeeded in varying proportions as outlined below:

Planning

Given the expense of the new systems and high cost to the organization, both financial and in terms of morale, of failure to adopt, it was crucial to ensure organizational readiness.

During this period, all Aquarium users, operators, technicians, engineers and metallurgists were selected for training at DebTech on the mine test unit. The focus was mainly on CARP technology at that stage, as FISH would only be commissioned once CARP was stable. Although there were practical hands-on exercises for operators and technicians on the CARP, only theoretical aspects were covered on the FISH technology. The other factor was that, while CARP was a semi-continuous operation with minimal integration required, the FISH required a lot of integration for which no one had been trained. The adoption process therefore took more time on the FISH than on the CARP side, leading to some of the units in FISH not being commissioned fully initially.

Deployment and commissioning

At this stage, the focus was on the individual unit process levels. The CARP can be viewed as a single unit process, due to minimal integration required as well as low system complexity in terms of sequencing. Each batch processing stage in the FISH is considered a unit process with its own sequences and interlocks. Therefore FISH has fourteen unit processes while CARP is a single system. Integration of the CARP and FISH unit processes, as well as the transport system and other services, proved to be cutting edge.

System integration was the most challenging, due to various equipment supplied by various companies. The software that was written to integrate the units and schedule batches, could not succeed as a result of unit process breakdown and poor trolley system reliability. The trolleys were supplied by Gilgen, while DebTech supplied the unit processes. There was, however, no one responsible from both these suppliers to ensure that the two systems can be integrated. It is crucial in future technology deployments to ensure that all stakeholders are available until the whole system is integrated. In this instance, the project management team was left alone to do the integration with mine operational personnel.

Commissioning of process plants delivered on a sub-contracted basis (versus turnkey), traditionally depended on sub-contractors commissioning their sub-systems to operational level only. Integration into the operation system relied on another party to integrate various third party delivered 'system components'. In the FISH instance, this role was largely played by the client's operational/commissioning team.

This new diamond recovery technology as an integrated system was the first of its kind; therefore, no industry benchmarks were available for manpower requirements and productivity targets. It was therefore necessary to scope manpower requirements and optimize as experience was gained.

Information management systems also had to be integrated with the system to ensure metallurgical accounting and decision-making.

Evaluation

Once the technology has been deployed and users confident with the system, a formal evaluation process is necessary. The CARP is going through this evaluation process, while the FISH is still going through commissioning and optimization. The full evaluation of FISH can only be undertaken now that full production levels have been achieved and maintained for a period of more than one year.

Lessons learnt

In order to address challenges facing the minerals industry in developing countries, it is important to consider the following when deploying new technology.

- New technology must be given a sufficient industrialization period to ensure maturity for sustainable operation before hand-over to normal operations.

- Partnerships should be considered as a suitable risk-mitigation tool when establishing contracts for unproven technology projects.
- Systems engineering should be adopted from the concept exploration phase of integrative projects to ensure proper evaluation and definition of system boundaries and cross system impact.
- Integrative systems verification should follow sub-system commissioning, especially where third party supply items are being integrated into the new system.
- The required human competency profile demanded by new technology must match the available competencies of the operational staff. A transition team may be required to bring new technology systems to full production on a sustainable basis. This will facilitate a period of knowledge transfer to operational staff as well as identify and address problems that impact on operation—both technical and operational.
- Involvement of operational personnel during the design and implementation phases of any new technology development is desirable in order to enhance technology and knowledge transfer for accelerated acceptance and maturation.
- Integration of various technologies proved to be the cutting edge, rather than the technology itself. It is imperative that this integration is managed properly at a high level.
- The technology deployed must be appropriate to the end user, and sustainability aspects must be addressed during the development phase.
- Cognizance to be taken during project scoping of integrated logistics support models and tools employed by the operation where the technology is deployed.

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