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Enhancing Large Diamond Recovery: An Overview of X-ray Transmission (XRT) Technology

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Introduction

The diamond mining industry has witnessed a revolutionary transformation with the integration of TOMRA's cutting-edge X-ray Transmission (XRT) technology in diamond recovery processes. TOMRA is today the world's leading supplier of XRT diamond recovery technology, having recovered some of the largest and rarest gemstones in history. Drawing decades of specialized experience in sensor-based sorting, this presentation encapsulates the basic principles, applications and successes of XRT technology in the realm of diamond mining, particularly focusing on large diamond recovery (>10.8 carats).

X-Ray Transmission (XRT) Principles

XRT technology, renowned for its precision and efficiency, has redefined the sorting paradigm by capitalizing on the differential absorption of X-rays by materials with varying atomic densities. Its integration into diamond mining operations has proven pivotal, especially in recovering larger diamonds, which hold significant value in the market.

Figure 1 illustrates the basic operating principle of the XRT sorter. Unsorted material is introduced evenly via a feeder over a transition chute onto a common conveyor belt. Towards the end of the conveyor belt, the XRT technology system detects the material based on its atomic density to eject the diamonds pneumatically into the concentrate chamber.

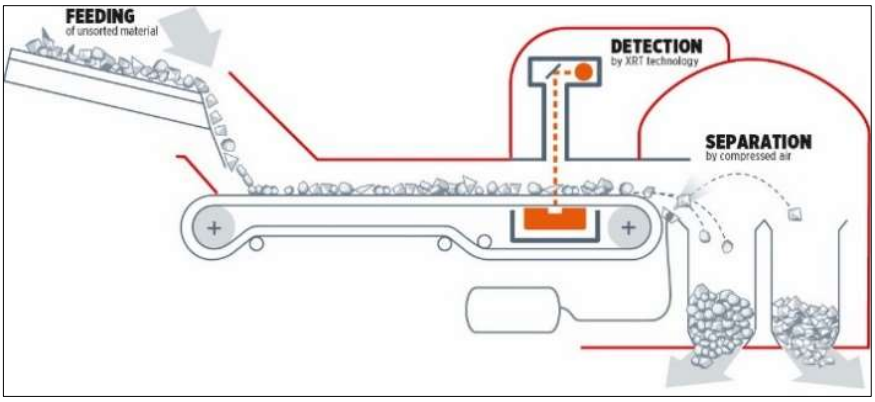

Figure 1: Basic Operating Principle of the XRT Sorter

Figure 2 shows the X-ray Transmission, Detection and Image Processing steps in sorting. An electric powered x-ray tube emits broad-band radiation across the conveyor belt's width, penetrating the stabilized particle monolayer. Directly under the conveyor belt is an x-ray camera (sensor bar) to measure the attenuated x-rays. The extent to which particles absorb x-rays depends on the element, its atomic density, the particle thickness and the intensity of the x-ray. Each mineral absorbs low and high energy x-rays in different ratios. Kimberlite (or alluvial) with a higher atomic density absorb more x-rays than a low atomic density diamond, however the challenge is a flatter kimberlite may have the same x-ray attenuation as a

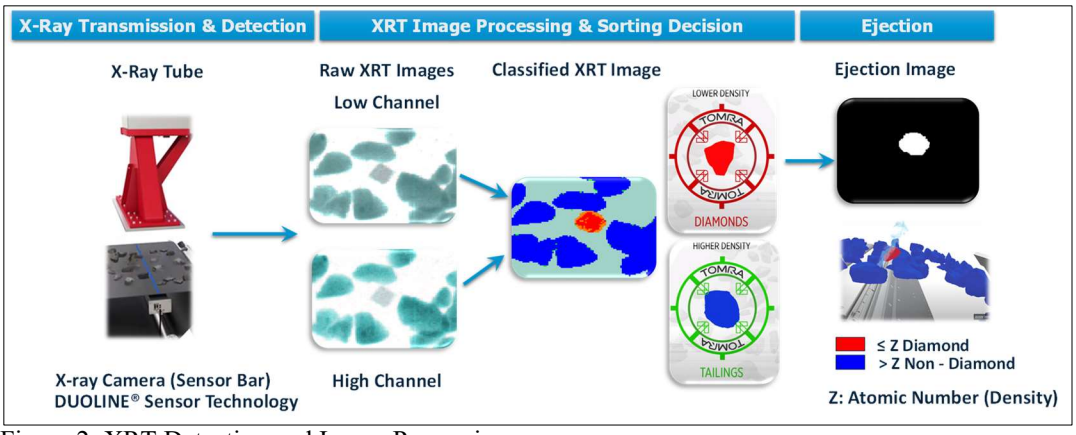

Figure 2: XRT Detection and Image Processing

specific diamond thickness. The solution is a sensor bar with "DUOLINE" proprietary technology, that uses two independent sensor lines with different spectral sensitivities, to measure low and high x-ray energies. This enables the detection of atomic density irrespective of the volume or thickness of the material. Each sensor line, the low- and high energy channel, produces an independent raw image data set, that are then classified by a high-speed proprietary processing unit. A sorting decision commands the compressed air ejection module to eject the low atomic density diamond (indicated in red) into the concentrate chamber, while the high atomic density rocks (blue) drop into the tailings chute. This whole XRT system emphasizes its unparalleled ability to detect and recover diamonds based on its unique physical property of atomic density, consistent for all diamonds regardless of the coating, luminescence / color and type. This unique ability allows a reliable, consistent and stable sorting program.

XRT Diamond Sorting Applications

Primary and secondary comminution (or washing in case of alluvial deposits), screening, Dense Medium Separation (DMS) and final recovery sorting stages are standard in traditional diamond processing. While DMS is reliable and well proven, large diamonds, especially brittle Type II gems and exceptionally large diamonds beyond the DMS top limit of 32mm, are prone to damage or breakage within this conventional flowsheet. In XRT-based processing (downloadable flowsheet: https://www.tomra.com/en/mining), like at Lucara's Karowe Mine, exceptionally large diamonds can be XRT-recovered before secondary comminution, extracting revenue faster and safeguarding diamond value. XRT's ability to produce ultra-low yields reduces the need for multiple concentration stages compared to traditional methods. For instance, +8mm material requires only one bulk concentration stage, while -8mm material needs a second stage. XRT can be applied to a range of diamond recovery applications as indicated in Table 1: Mega Diamond Recovery, Bulk Concentration, Final Recovery, Sort House or Exploration.

Table 1: XRT Diamond Sorting Applications and Capacities

Application	**Mega Diamond Recovery / Bulk Concentration**	**Bulk Concentration**		**Final Recovery/ or Exploration**	**Sort House/**
Sorter	**COM XRT 1200 / D 2.0**	**COM TERTIARY XRT 1200 / D**	**Typical Yield**	**COM XRT 300/FR**	
Size [mm]	**Throughput [metric t/h]**		**%**	**Throughput [metric t/h]**	
-100+50	190	-	<0,0001	-	-
-50+32	190	120	<0,001	-	-
-32+16	130	100	<0,005	5	3,2
-16+8	75	50-55	<0,01	4	1,6
-8+4	-	20-25	<0,05	2,1*	0,8*
-4	-	-	-	1*	0,4*

*Note: Indicative capacities are given per application and size range and are subject to investigations of individual ore types. *Dried feed.*

Examples of XRT Installations and Successful Economic Gains in Large Diamond Recovery

More than 38 bulk concentration XRT sorters are applied to large diamond recovery across various African countries and operations. Table 2 summarises the 21 largest diamonds (>400 carats) recovered over the last decade, since TOMRA XRT bulk concentration installations commenced fully in the diamond industry. Thirteen (13) of these 21 exceptionally large diamonds were recovered by TOMRA XRT and covers a variety of diamond types. Eleven (11) of these diamonds were recovered at Lucara's Karowe Mine (operating 14 bulk concentration XRT sorters). Karowe Mine achieved a return on investment (ROI) of less than 3 months on a major upgrade project, which included the installation of 6 TOMRA XRT sorters as well as crushing and sizing equipment. XRT is responsible for 93-95% of Karowe's total revenue, whereas 60-70% of its revenue comes from 10.8 carat specials recovered by XRT. Karowe holds record breaking recoveries in various categories: 6 of the top 10 historically largest diamonds ever recovered are from Karowe by XRT. An example of a low operating cost for bulk concentration is from 11 Euro cents per ton for parts consumption. [Lucara Diamond Corp.]

Table 2: Exceptionally Large Diamonds of both Gem and Industrial Quality (> 400 carats) recovered since 2014.

Size Rank	Diamond Name	Carat Weight	Year	Country	Type	Colour/ Type
1	Karowe Sewelô	1 758,00	2019	Botswana	Poss IIa	Black Clivage
2	Unnamed Karowe Clivage	1 174,76	2021	Botswana	Poss IIa	Grey Clivage
3	Karowe Lesedi La Rona	1 109,45	2015	Botswana	Zoned IIa	Colourless - D
4	Unnamed De Beers	1 098,00	2021	Botswana	IIa	Colourless - D
5	Unnamed Karowe Gem	1 080,00	2023	Botswana	IIa	Colourless - D
6	Unnamed Karowe Clivage	998,00	2020	Botswana	Poss IIa	White Clivage
7	Lesotho Legend	910,00	2018	Lesotho	IIa	Colourless - D
8	Karowe Constellation	812,77	2015	Botswana	Poss Iab	Colourless - D
9	The Peace Diamond	709,00	2017	Sierra Leone	I	Yellow
10	Unnamed Karowe Gem	692,30	2023	Botswana	IIa	Colourless - D
11	Unnamed Diavik Yellow	552,74	2018	Canada	I	Yellow
12	Karowe Sethunya	549,00	2020	Botswana	IIa	Colourless - D
13	Unnamed Karowe Clivage	544,00	2018	Botswana	I	Grey Clivage
14	Meya Prosperity	476,70	2017	Sierra Leone	IIa	Colourless - D/E
15	Karowe Serowa	472,37	2018	Botswana	IIa	Top Light Brown
16	Light Brown Unnamed Karowe	470,00	2021	Botswana	IIa	Light Brown
17	Letseng Icon	439,00	2020	Lesotho	IIa	Colourless - D
18	Unnamed De Beers	425,00	2018	Botswana	IIa	Colourless - D
19	The Legacy (Cullinan)	424,89	2019	South Africa	IIa	Colourless - D
20	Lulo 4 de Fevereiro	404,20	2016	Angola	IIa	Colourless - D
21	Unnamed Russian Maccle	401,97	2016	Russia	I	Off White Maccle
	TOMRA XRT RECOVERED					

[Ferraris, Ray, QTS Kristal Dinamika; Gem Diamonds; Lucara Diamond Corp; Meya Mining]

Summary of XRT Benefits

XRT offers 100% detection of all diamond types in the specified size range, irrespective of surface coatings & luminescence profile. The technology offers very high recovery rates (>98%) at extremely low yields, independent of heavy mineral content in the feed unsuitable for DMS. Its low-yield enables replacement of multiple concentration stages compared to conventional flowsheets (double stage solutions for -8+4mm; single stage for +8mm material), which contributes to improved and focused downstream security and reduced hand sorting. The technology offers exceptionally low operational costs with massive power savings (installed sorter power ~50kW). Finally diamond producers can economically install large diamond recovery with low capital investment, at low OPEX costs (compared to traditional processing costs) and efficient recovery of ultra-low frequency exceptional diamonds, including +32mm diamonds.

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