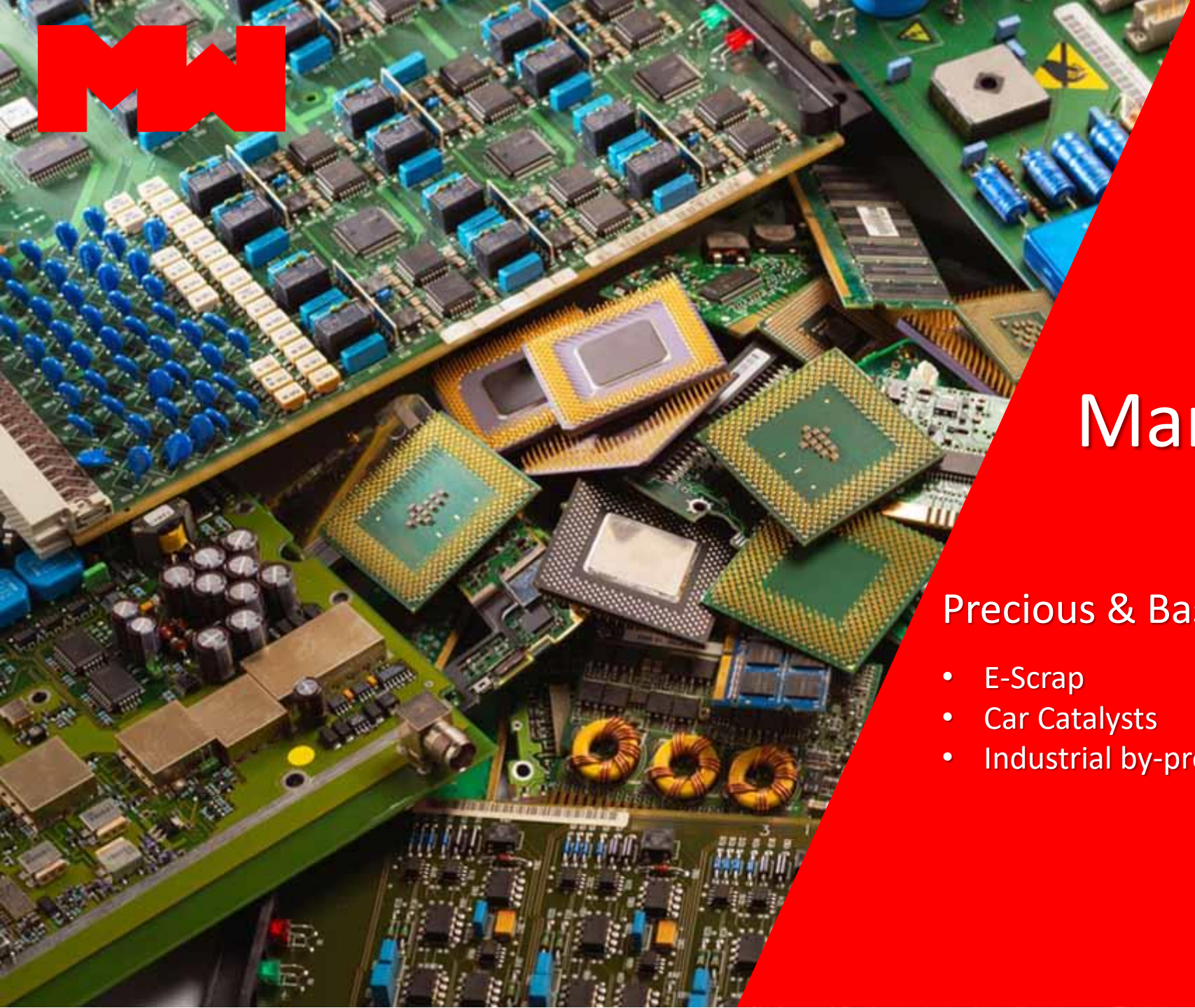


Mark & Wedell A/S

Precious & Base Metals recycling sector

- E-Scrap
- Car Catalysts
- Industrial by-products

Precious & base metals recycling sector – market size and development

Recycled material / Input	Market Value	CAGR
E-Scrap (WEEE)  Print Boards Laptops (without scn & battery) Cell Phones Small IT devices	Recycled WEEE $39.8 bn (2022) $75.3 bn (2027)	CAGR: 13.6% (2022-2030)
Car Catalysts  Car Catalyst	Recycled Car Catalysts $4.7 bn (2022) $6.4 bn (2027)	CAGR: 6.5% (2020-2028)
Industrial by-products & others  Slags Bottom-ash Mattes Sludges	Recycled by-products $21.3 bn (2022) $25.0 bn (2027)	CAGR: 3.2% (2020-2027)

- **Total value** of recycled precious & base metals: **$65.8 bn (2022) expected to grow to $106.6 bn (2027)**
- **Annual average growth in value of $6,826 milllion** = Compounded Annual Growth Rate (CAGR) of 8.4%

Source(s)
E-Scrap: Statista & ResearchAndMarkets
Car Catalysts: Grand View Research
Industrial by-products & others: Estimated based on Allied Market Research and Zion Market Research
Pictures: Mairec.com

Problems when estimating the true value of recycled precious & base metals

- The value of the market is growing significantly each year by an average of $ 6,826 million

- **Correct (representative) sampling in the recycling sector is critical:**
  - Overstating or underestimating metals content – even in very small fractions - **can lead to large losses for buyer/seller**

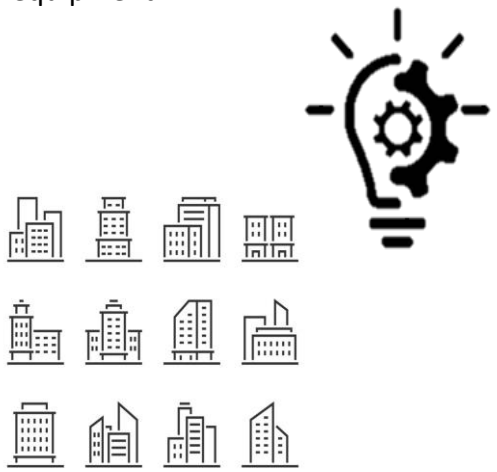
Problems

Heterogeneous materials

- Distribution of metal content can vary significantly within a sample

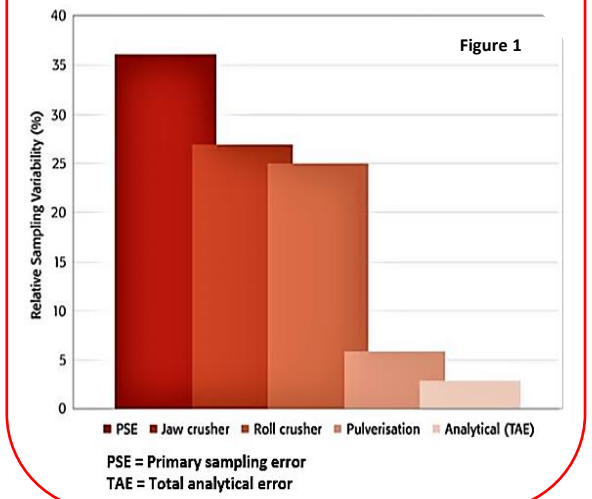
Fragmented market

- Market for collecting and selling recycled materials is fragmented.
- A lot of smaller companies without necessary sampling expertise and equipment



Huge bias risks in primary and secondary sample taking

- Theory of Sampling: *"At primary sampling, biases can be up to 1,000%, up to 50% at secondary sampling, while they almost never exceed 0.1 to 1% at analysis (in the laboratory)".* (Pierre Gy founder of TOS)



Garbage In = Garbage Out

- Easy to buy and use laboratory equipment for analysis of final sample but:
- Risk of: Garbage in – garbage out
- Sampling must be both *accurate* (unbiased) and *precise*

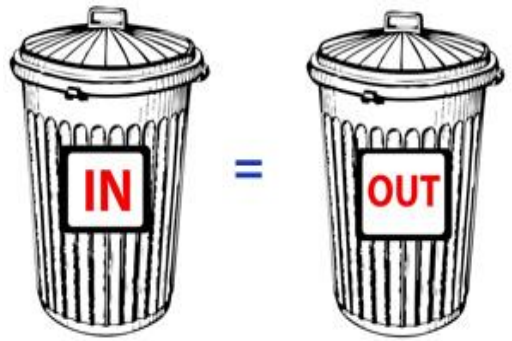


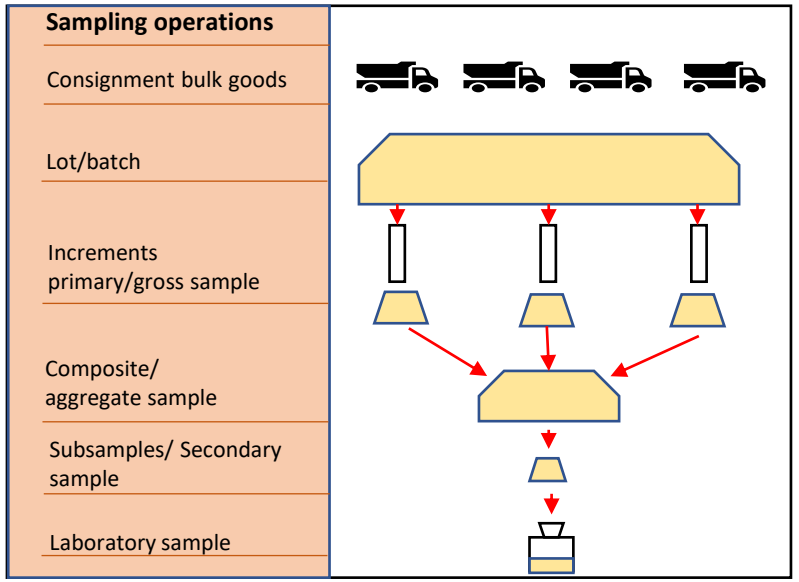
Figure 1 shows the key results from Replication Experiments made by Elkem Metal, Canada, which show that 35% of the total sampling variance (where mistakes can occur throughout the full sampling process) occurred during the phase of primary sampling and 50% during the crushing phases i.e., 85% of the total sampling variance occurred before pulverization and laboratory analysis

Source(s): Pictures: Mairec.com

Solutions for estimating the true value of precious/ base metals in recycled materials

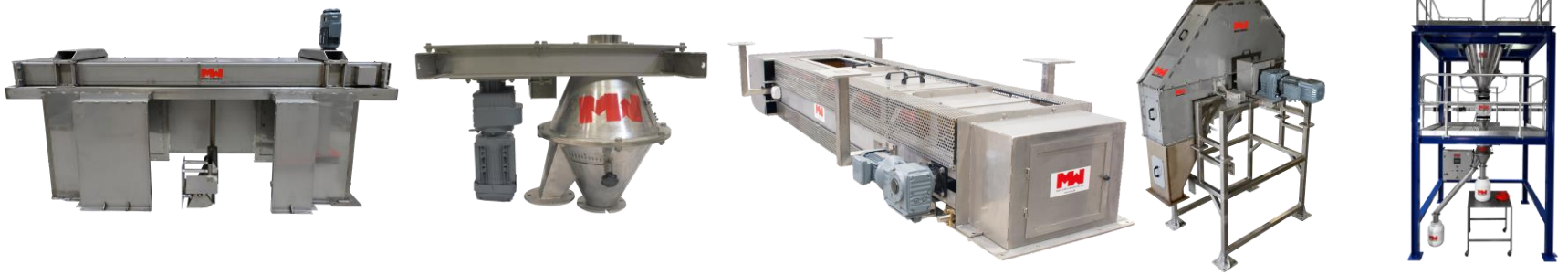
1. **Develop and implement a (correct) sampling plan**
   a. Key focus on primary and secondary sampling (where a lot of companies typically go wrong, and the biggest mistakes occur)

   b. Know the variability of material (range, mean deviation and standard deviation etc.)
   - The more variable the material = the greater the number of samples will be required
   - Minimum number of samples (increments) for a consigned lot must be identified



2. Use correctly engineered automated samplers for primary and secondary sampling
   - Human grab sampling will <u>not</u> do the job

3. M&W JAWO Sampling: Full range of primary and secondary samplers and dividers, sampling material transportation units and inter-stage crushers for recycled materials:



Source(s): TOS presentation by Kim Esbensen

Primary samplers for recycled metals

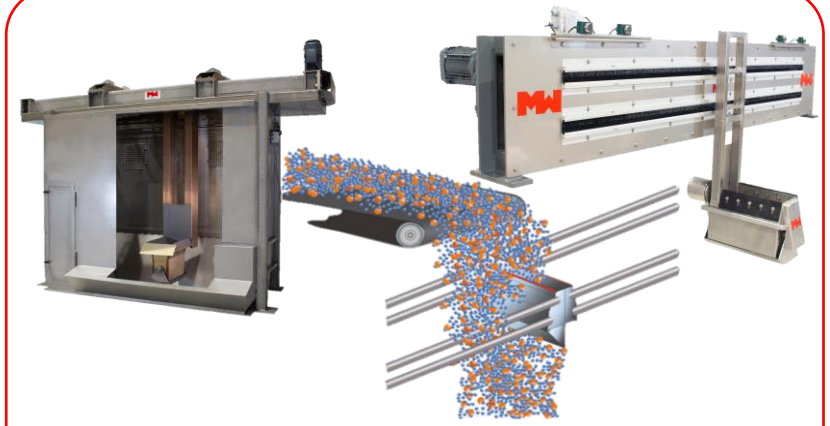
- Important for determining quality and quantity of precious metals in the incoming materials
  - Crucial information for determining the value of the materials + for making decisions on how to process and extract metals efficiently

- In the precious and base metals etc. recycling industry primary samplers are used for:
  - Crushed scrap materials (e.g., e-waste)
  - Precious metal-bearing residues (e.g., slags, spent catalysts and filter cakes)
  - Secondary precious metal products (materials having undergone some level of processing e.g., reclaimed precious metal wires)

*3 categories of primary samplers: **Falling stream samplers**, on-the-belt samplers and stationary samplers.*

Falling Stream Samplers (examples)

Cross Stream Sampler (CSS)



Takes a sample cut of falling material at the end of a conveyor belt – good for all material sizes and up to large quantities

- Theory of Sampling (TOS)-compliant giving every particle in the material an equal probability to be included in the extracted increment
- Enclosed in a cover housing to avoid cross-contamination
- Designed to be scaleable, which makes it well suited for sampling from high-capacity bulk material handling

Bucket Sampler (BS)

Extracts increments/cuts from a f-falling flow of materials in a vertical duct or below an inlet hopper – good for finer and medium-sized particles and in small-medium quantities

- The Bucket Sampler collects a full cross section of the material flow
- Fine particles are kept enclosed in the Bucket Sampler by a cover housing
- If space is a constraint the Bucket Sampler is beneficial due to its compact design

Vezin Sampler (VS)

Extracts increments from falling material in a duct – good for finer particles like concentrates or powders in small-medium quantities

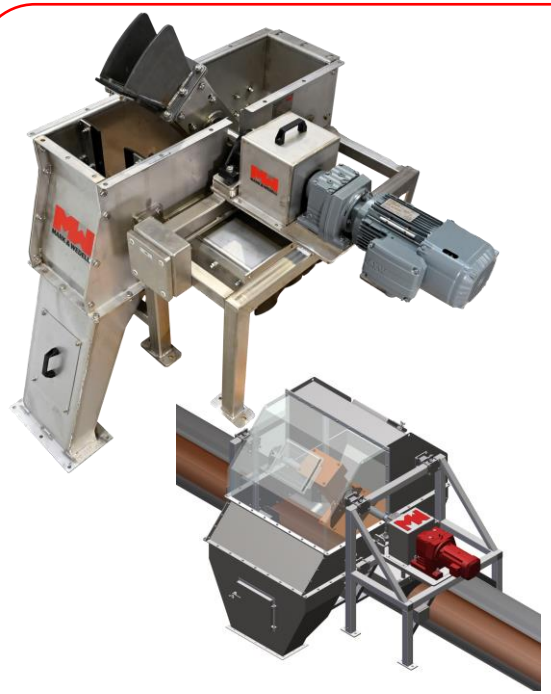
- Well suited for relatively small volumes of bulk material in particular powdered material with lumps up to 45 mm
- Easy to install and operate in a duct
- Equipped with an easily accessible hatch for optimal inspection and maintenance process

Primary samplers for recycled metals (continued)

*3 categories of primary samplers: Falling stream samplers, **on-the-belt samplers and stationary samplers**.*

On the belt samplers and stationary samplers

Cross-Belt Sampler (CBS)



Takes a sample cut from material transported on a conveyor belt – used for all material sizes and up to large quantities

- Is easy to install almost anywhere along a conveyor belt
- Eliminates the need for hazardous and manual grab sampling
- Saves time and money allowing for sampling without belt stoppage
- Can be modified to, in addition, remove identified unwanted magnetic/metallic material from the conveyor belt

Automated Truck & Train Sampler (ATTS)

Extracts increments from a stationary lot in the X, Y and Z axis – can be used for all material sizes and up to large quantities

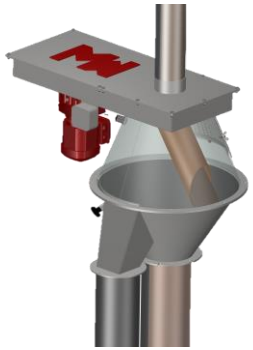
- Fully representative an unbiased samples taken in the X, Y and Z axis of load at a completely random point
- Fully automated: No plant staff needed
- Camera monitoring and detection system removes risk of damaging truck, sampling unit and humans during sampling

Secondary samplers and dividers for recycled metals

- Dividers, also known as sample splitters, divide large quantities of material into smaller representative samples for further analysis of their metals content
- The M&W JAWO Sampling dividers are engineered to ensure that each smaller sample is representative of the larger quantity of material and that the metal/ content is evenly distributed across each sample
- Can also be used as primary samplers in case of smaller amounts of material being sampled
- The following M&W JAWO Sapling solutions are ideal for mass-reduction of primary samples:

Secondary samplers & dividers

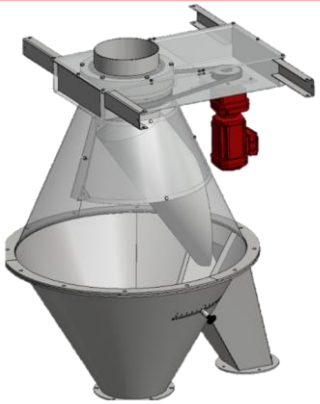
Rotary Tube Divider (RTD)


Is ideal for representative mass reduction and division of small-medium sized material – or as primary sampler for smaller material flows

- Comes with one or more sample outlets
- Provides reliable accurate mass reduction with no risk of cross-contamination between sub-samples
- Variably adjustable dividing ratio
- Can be used for mass reduction of virtually any type of material
- Is used in many multistage sampling systems but can also be used as a stand-alone divider

Virtual Adjustable Divider (VAD)



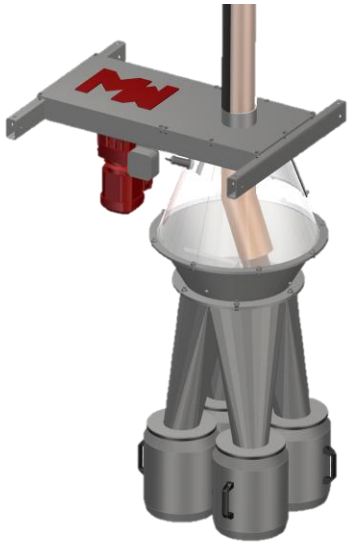

Is ideal for representative mass reduction and division of small-medium sized material – or as primary sampler for smaller material flows

- Is similar to the Rotary Tube Divider but does not require manual adjustment
- The division ratio is set from the control panel and can be adjusted stepless in the range 10-90%
- Comes with one or more sample outlets
- Provides reliable, accurate mass reduction with no risk of cross-contamination between sub samples

Secondary samplers and dividers for recycled metals (continued)

Secondary samplers & dividers

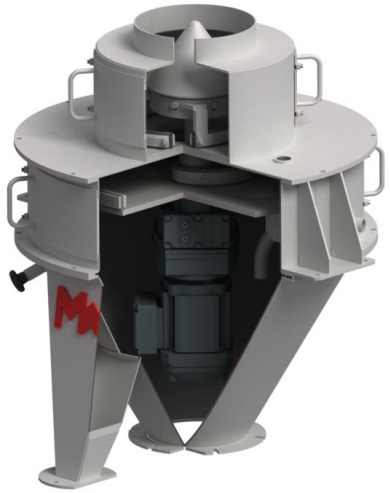
Rotary Tube Splitter (RTS)



Is designed for representative splitting of small-medium sized material

- Comes with two or more sample outlets
- Similar to the Rotary Tube Divider but can be used for duplicate samples extraction (A, B, C and D samples)

Rotary Disc Divider (RDD)



Combines dosing and representative division of small-medium sized material – can be used for sudden large and uneven material inflow from e.g., a big-bag

- Has a built-in dosing function in cases where the sampled material does not come in a continuous flow
- Enables a more even distribution of material before division
- Designed with steep angles to ensure smooth and reliable flow of sample material

Inter-stage crushers for recycled metals and

- Inter-stage crushing is of particular importance in the metals and recycling industry given heterogeneity and large quantities of incoming material.

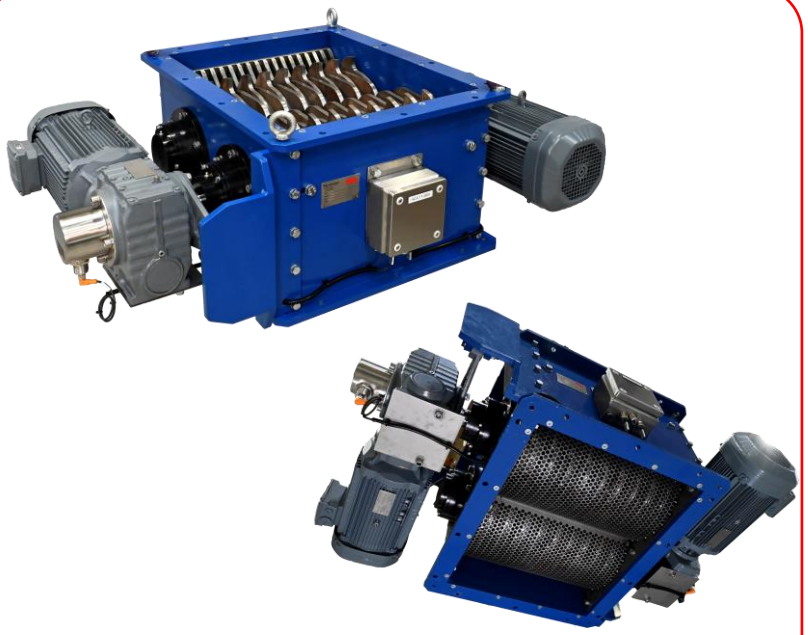
Inter-stage crushers

Jaw Crusher (JC)

Quickly crushes the hardest (3-9 on Mohs scale) and most abrasive materials - (optionally with tilted vibrating sieve for sudden large portions of incoming material)

- Works well with dry or slightly wet materials like iron pellets, quartz, stones, minerals of any kind, silicon fines and nickel and copper concentrate containing lumps
- Is easily adjustable and precise
- Up to 1:45 crushing ratio

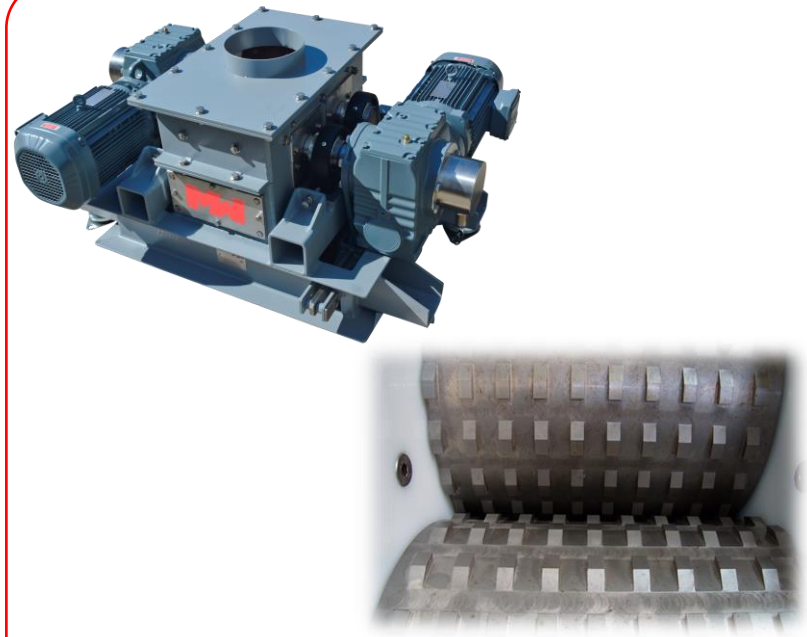
Twin Roll Shredder (TRS)



Is made for soft and medium-hard materials which are dry or slightly wet and semi-sticky

- Works well with materials like electro-scrap and some metal waste like milling waste
- Has a jaw-like knife design with serrated edges, which ensures power efficient shredding
- Easily fitted into the process line with its low height

Twin Roll Crusher TRC)



Is able to crush almost every type of material

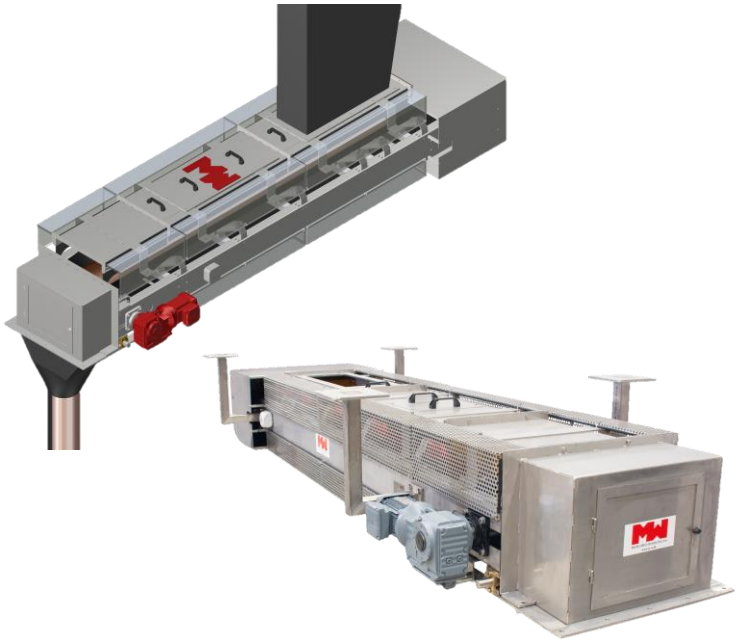
- Is able to crush almost every type of material
- Works well with dry or slightly wet materials like ores, cement clinker, gypsum, coal etc.
- Torque switches to prevent damage if a hard object (e.g., a tool) is accidentally dropped into it

Sample transfer equipment for recycled metals and

- Transporting samples between sampling stages and in even flows at avoiding cross contamination is crucial

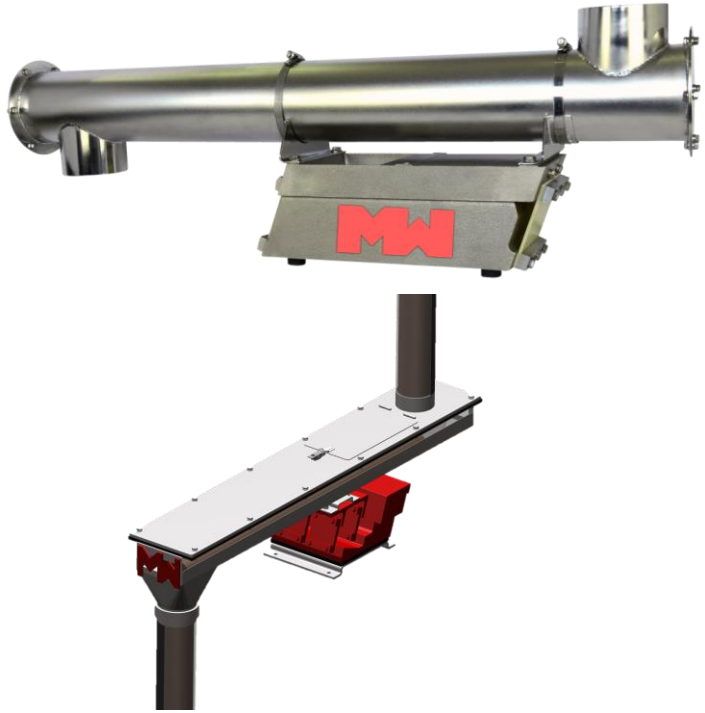
Sample Transfer Equipment

Dosing Conveyors (DoC)



- Specially designed to transport high volumes of sample material
- Can be engaged in any of the steps of the sampling process
- The special design of the dosing conveyor reduces spillage, contamination and issues with dust

Vibration Feeder (VF)



- Provides accurate dosing of sample material
- Has a compact design and is well suited when there is space constraints

Screw Conveyor (SC)

- Our screw conveyors are guaranteed to have no spillage of material or production of dust due to closed transportation
- Can operate from vertical to horizontal angle
- Can transport material in a dust-f manner and is weatherproof

Combined samplers for recycled metals and

Combined samplers

Hopper Discharge Sampling System (HDSS)

Is a stand-alone modular sampling system which for example can include a sample feed hopper, a vibration feeder or a dosing conveyor, a crusher (not shown), a rotary tube divider and a sampling bucket

- Assembled in sections and can be split up
- Fully automatic with graphical user interface
- Pre-programmed sampling sequences

Dividing Plant (DP)

Is designed for multiple representative division of bulk materials with various particle sizes. Consists of a feed hopper, a vibration feeder, a rotary tube splitter, a supporting steel structure and several dust-proof sample buckets

- Automatically divides bulk material into several representative samples or equal size and with minimum interference from the operator
- Is a flexible sampler that can be easily moved around in the laboratory or production facility
- Can be used in different parts of the production line

Key drivers behind high growth in demand for recycled precious & base metals

Population increase = Higher demand

- 8.0 bn people (2022) – 8.5 bn people (2030) – 9.7 bn people (2050)

Precious and base metals increasingly used for industrial purpose

- Increased demand for electronics and renewable energy technologies

Electronics	Renewable Energy
Market Value	Market Value
$1.7 tn (2020)	$928.0 bn (2020)
CAGR: 6.5%	CAGR: 7.4%
$2.5 tn (2026)	$1,512.3 tn (2026)

- High growth potential for recycled E-scrap (only 20% recycled at present)

Precious and base metals commodity prices have increased 2-4 times since 2000

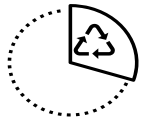
Recyclers increasingly efficient in extracting metals

Growing legislation for recycling e-scrap, industrial by-products etc.

- 78 countries in 2019 compared to 61 in 2014

Amount of the total supply of precious metals that comes from recycling:

- Gold (30%) – (1,200 tonnes recycled – 3,300 tonnes from traditional mining)
- Silver (30%)
- Platinum (30%)
- Palladium (40%)



Source(s): United Nation, ResearchAndMarkets, Grand View Research, Allied Market Research, Statista, McKinsey & Company, World Gold Council, IMF

For further inquiries please contact us

Oldenvej 5, 3490 Kvistgaard, Denmark

(+45) 4913 9822

m-w@mark-wedell.com

www.mark-wedell.com

Mark & Wedell A/S