IIT(BHU) VARANASI

STUDENTS' NOTES

UNDERGROUND METALLIFEROUS MINING

TOPIC-NET SMELTER RETURN

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Net Smelter Return (NSR)

- It is the net revenue that the owner of a mining property receives from the sale of the mine's metal/non metal products less transportation and refining costs.
- As a royalty it refers to the fraction of net smelter return that a mine operator is obligated to pay the owner of the royalty agreement.
- The royalty is paid in variable or fixed payments based on sales revenue received by a mining operator in return for mining output. It is contingent only on the sales price and quantity of product sold.

- The term is named so due to the fact most of the time, mining output sold requires further processing by smelters; the mining products purchased directly by smelters are sold to them for a discounted (net) price based on how much further processing is needed.
- The mining lease specifies the selling price (prices are different in spot and forward markets) and is used to verify the exact amount of product that's produced and sold between royalty payments.

- One advantage NSR royalties have over other royalties is that usually, payments are higher in the short term because capital costs and exploration costs cannot be used as deductions (some royalties don't have to be paid until after other costs such as loans/amortization are taken care of). Also, mine life and royalty expiration dates need to be taken into consideration.
- The royalty can be called a Net Value Royalty when deductions are based solely on the contract.
- Alternatively the Gross Smelter Return is a percentage of gross revenue paid by mine owner that isn't subject to any deductions.

- The net smelter return (NSR) refers to the revenues expected from the mill feed, taking into consideration mill recoveries, transport costs of the concentrate to the smelter, treatment and refining charges, and other deductions at the smelter.

- While a few other factors are sometimes mentioned in the literature and in practice, the list presented here captures 98% of the net smelter return value. Not all items listed are applicable to each metal concentrate; for this reason, the reader will have to review the references provided at the end of this section to see where each item applies.

Metal Recovery in the Beneficiation Plant

$$\varepsilon = \frac{\text{concentrate grade}}{\text{feed grade}} \times \frac{(\text{feed minus tailings grade})}{(\text{concentrate minus tailings grade})}$$

Assignment. Determine the recovery for the following data from a zinc mine:

- feed grade = 10% Zn
- concentrate grade = 54% Zn
- tailings grade = 0.5% Zn

$$\varepsilon = \frac{54}{10} \times \frac{(10-0.5)}{(54-0.5)} = 0.96 \quad \text{or } 96\%$$

Concentration Factor and Mass Recovery

$$\mathrm{KF} = \frac{\text{concentrate grade}}{\text{recovery} \times \text{ore grade}}$$

Example. A mine contains in situ ore grading 8% Pb. It produces a 65% Pb-concentrate, with a recovery rate of 95%. Hence, the concentration factor is

i.e. A t of in situ ore are needed to produce 1 t Pb concentrate.

$$KF = \frac{65}{8 \times 0.95} = 8.55$$

- *Example: For iron ore we assume a unit price of 0.50 US $/ u. Accordingly, a mine* producing high grade direct shipping ore of 64% Fe has a revenue of
- 64 × 0.50 = 32.00 US $/ t iron ore
- To arrive at the return f.o.b. mine (free on board, see Sect. 9.4.1) freight costs have to be subtracted.

- *Example: For scheelite concentrates the price shall be 40 US $/unit WO3. A deposit* has grades of 0.8% WO3. This ore has to be beneficiated first before yielding a saleable product. Recovery is assumed to be 85%. Hence the return from 1 t of in situ ore with 0.8% WO3 is

- 40 × 0.8 × 0.85 = 27.20 US $/ t

- The unit-price in previous example applies to standard concentrate with a minimum quality of 65% WO3. Here the rule applies that for each percent below 65% WO3 1 US $/ u is deducted, e.g. if the concentrate grade has only 60% WO3.

- The price per unit will be 40 – (65 – 60) × 1 = 35 US $/unit.

Non ferrous metal

- Cu, AL, Pb, Zn or Ni

- *Example. We are to evaluate a porphyry copper deposit with an ore grade of 0.7% Cu.* For the sake of simplicity, we assume that the Mo, Au or Ag grades, common in this type of deposit, are so low that these metals are not paid for in the concentrate. What is the revenue per tonne of ore?

- For the calculation of revenues we have to make certain assumptions:

The main factors required for the calculations are

- Recovery factor of the metal at the mill - to know what proportion of the metal sent to the mill is actually sold. assume 90%, i.e. of the 0.7% Cu, 0.63% Cu are recovered.
- Concentrate grade - to establish how much metal is contained in a tonne of concentrate. Grades of concentrates normally lie between 25 and 30% Cu. One can assume 25% Cu.
- Freight for concentrates from mine to smelter is assumed to be 20 US $/ t.
- Transport cost - from the gate at the mine site to the smelter. Associated costs are charged for loading and representation at port facilities.
- Payable metals - to establish the base quantity of metal that the smelter will use to determine payment. Some deductions are fixed, while others are based on a sliding scale as a function of the grade of the metal in the concentrate.

- Treatment charges - to determine the cost of processing one tonne of concentrate at the smelter. This refers to a tonne of concentrate. A reasonable assumption at present is T/C = 85 US $/ t concentrate.
- Penalties - the extra cost of processing deleterious elements present in the concentrate.
- Price participation - a proportional escalator cost to capture large metal price variations during the contract period.

- Treatment losses: Since losses occur during treatment in the smelter, these losses are subtracted from the metal content of the concentrate. Treatment losses can vary, with copper they normally amount to 1 unit (u).
- Refining charges - to determine the cost of refining the metal recovered at the smelter. This is based on the paid metal (minus treatment losses!) in the concentrate. A reasonable assumption at present is R/C = 8 US ¢ / lb paid Cu.
- Metal price: This is the most important assumption. We assume 0.90 US $/ lb

The calculation is carried out as follows:

- The concentrate grade is 25%; from this we have to subtract the treatment loss of 1 u(= 1%), so that 24% Cu will be paid. 1% corresponds to 22.046 lb per tonne (see Sect. 1.1.4). Thus the gross value of the concentrate is
- (25 – 1) × 22 046 × 0.90 = 476.19 US $/ t
- From this we subtract the treatment charge: T/C = 85 US $/ t

- We also have to subtract the refining charge. If refers to the paid metal content. The R/ C is: (25 – 1) × 22 046 × 0.08 = 42.33 US $/ t concentrate
- As a last step we have to subtract the freight

Summarised, the calculation method looks like this:

Gross value of the concentrate	476.19
–T/C	–85.00
–R/C	–42.33
–freight	–20.00
	= 328.86 US $/t concentrate

- This is the net smelter return of the mine (NSR). However, we are not so much interested in the concentrate but in the net value of the ore: the ore has a grade of 0.7% Cu; we recover 90%, and the concentrate has a grade of 25% Cu. Hence we need to produce 1 t of concentrate.

$$\frac{25}{0.7 \times 0.9} = 39.68 \text{ t of ore}$$

- Thus the concentration factor KF is 39.68. From this we arrive at a net smelter return for the ore:

$$\text{NSR} = \frac{328.86}{39.68} = 8.29 \left(\frac{\text{US\$}}{\text{t}} \right)$$

which is of course rounded to 8.30 US $/t.

Net smelter return factors

- Estimate rapidly the value of every block in the resources and reserves models by multiplying the grades by the factors.
- The blocks can easily be sorted as required. Estimate the value of a mining sector for an economical study.
- Calculate the revenues of mine plans.
- Calculate the value of broken mineralization in the mine to decide whether to send it to the mill or to waste.
- Perform quick metal price sensitivity studies

There are many advantages to this approach

- Polymetallic ores grades are rapidly converted to dollars per tonne.
- The value of reserves can be quickly compared to the applicable costs to determine their viability; cut-off grades become cut-off NSRs.
- At the design stage, spreadsheets can be used to quickly identify economical reserve blocks.
- During the extraction of a sector, its value can be quickly estimated by comparing the reconciled grades to the design.
- The effect of commodity price fluctuations can be evaluated quickly.

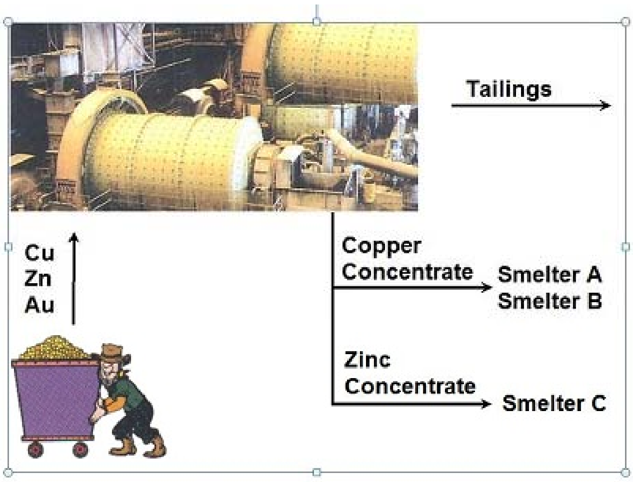
The method does have some limitations

- This approach tends to smooth out the statistical distribution of the block values.
- This will happen if the metal recovery at the mill is proportional to the feed grade.
- This way, lower grade blocks are over-valued and higher grade blocks are undervalued.
- This approach is valid only within the operating parameters of the mill.

Production Life Time

- Rule based on experience
- Empirical formula
- Market based

- Let's assume that chalcopyrite and sphalerite produced in the mine are sent to a mill with copper and zinc flotation circuits, and that the copper concentrate is sold to two smelters and that the zinc concentrate is sold to a zinc smelter.



- The mill feed is 275,000 tonnes grading 2.32% Cu, 2.55 g/t Au, and 5.69% Zn.
- This mill feed can represent three months' or a year's production from the mine, or is the grade of a sector on which an economical study is conducted.
- Either way, the NSR factors calculated for this feed can be applied to every individual reserve blocks or stopes to calculate their value.

- Copper and gold are recovered in the copper concentrate and zinc and minor gold are recovered in the zinc concentrate.
- The copper concentrate grades 21% and the zinc con grades 53%.
- Values marked in yellow are given and others are calculated.

Metallurgical Balance	Tonnes	Cu (%) (tonnes)	Au (g/t) (ounces)	Zn (%) (tonnes)
Mill Feed				
Grades	275,000	2.32%	2.55	5.69%
Metal Contained		6,380	22,546	15,648
Copper Concentrate				
Mill Recovery		85%	73%	
Tonnes of ore per tonne of concentrate	10.65			
Grades	25,824	21%	19.93	
Metal Contained		5,423	16,549	
Zinc Concentrate				
Mill Recovery			15%	90%
Tonnes of ore per tonne of concentrate	17.57			
Grades	15,648		6.72	53%
Metal Contained			3,382	8,293

- details the steps to calculate the value of the copper and gold in the copper concentrate sold to smelter A. In the case of copper:
- A fixed deduction of 1.1 units (22.05 lbs * 1.1) is charged.
- The treatment charge is equal to $75 per tonne of concentrate. Transport, with loading and representation, cost $39 per tonne.
- The refining charges are equal to $0.075 per pound of payable copper.

- As for gold:
- The metal deduction is equal to 2.5 grams. This deduction can be based on a sliding scale set as a function of the concentrate gold grade.
- No treatment or transport costs are applied. This is a judgment call on the part of the user to decide if the costs apply or not and in which proportions they do. In the example, it is assumed that this is the amount of gold present (or absent) in the ore and concentrate will have no influence on the treatment and transport costs of the copper concentrate and that therefore the gold should not have to pay for that portion of costs.
- Refining charges are equal to $6 per payable ounce of gold.

- As a result, the copper and gold net smelter returns for copper concentrate sold to Smelter A are equal to $511 and $515 per tonne of concentrate, or $48.01 and $48.37 per tonne of ore.
- When these numbers are divided by the mill feed grade, the copper and gold NSR factors are equal to $20.69 per % Cu and $18.97 per gram of gold.

	Copper concentrate sold to Smelter A			
	Copper		Gold	
Tonnes of Conc.	25,824	tonnes		
Metal in Conc.	5,423	tonnes	16,549	ounces
Metal per Tonne of Conc.	0.21	tonnes	0.64	ounces
	463	Lbs	19.9	grams
Metal Deduction	24.26	Lbs	2.5	grams
Payable Metals	439	Lbs	17.4	grams
Metal Price	1.50	$ / lb	$925	$ / oz
Value of Metal	658	$ / t. conc.	518	$ / t. conc.
Deduction and Charges				
Treatment Charge (T/C)	75	$ / t. conc.		
Transport	34	$ / t. conc.		
Loading & Representation	5	$ / t. conc.		
Penalties (As, Sb, Bi, Hg)	0	$ / t. conc.		
Price Participation	0	$ / t. conc.		
Subtotal Deductions	114	$ / t. conc.		
Refining Charges (R/C)	0.075	$ / lb	6	$ / oz
	33	$ / t. conc.	3	$ / t. conc.
Value After Deductions and Refining	511	$ / t. conc.	515	$ / t. conc.
tonnes of ore per ton. conc.	10.65		10.65	
Value per tonne of Ore	48.01	$ / t. ore	48.37	$ / t. ore
Grade of Ore	2.32%		2.55	g / t
NSR Factor	20.69	$ / %	18.97	$ / g

The exercise is repeated for copper concentrate sold to smelter B and zinc concentrate sold to smelter C, and the results are combined

Concentrate	Smelter	Relative sales	Copper ($ / % Cu)	Gold ($/gram)	Zinc ($ / % Zn)
Copper	A	35%	20.69	18.97	
Copper	B	65%	19.96	18.97	
Copper		100%	20.22	18.97	
Zinc	C	100%		3.21	7.14
Total NSR factors			20.22	22.17	7.14

These factors can be used to estimate the value of reserve blocks, stopes, daily production, or the average value of the mill feed

	Copper		Gold		Zinc	
Mill feed grade	2.32%		2.55	g / t	5.69%	
NSR Factors	20.22	$ / %	22.17	$ / g	7.14	$ / %
Value per tonne of ore	46.90	$ / t.	56.54	$ / t.	40.61	$ / t.

Net Smelter Return	144.06	$ / tonne