Overview: The first calculation may be familiar to you, it's the stoichiometric yield and it is the ideal situation (100% pure MgO and 100% yield). A better assumption would be 94% purity.

The next two calculations are an attempt to bracket the mud output based on 100% mother liquor feed and 0% mother liquor feed (100% water). Reality lies somewhere between the two extremes.

1. Stoichiometric Yield (Ideal Yield) Calculation Based on MgO Feed

Assumes 100% purity and yield (Not good assumptions)

Basic reaction:

$$MgO + H_2SO_4 + 6H_2O \rightarrow MgSO_4 \cdot 7H_2O$$

MgO = 40.3 lb/lb-mol at 100% purity
$MgSO_4 \cdot 7H_2O$ = 246.3 lb/lb-mol

At "7" on Liquid Side, feed = 18 lb/min

$$\text{Crystal Yield} = 18 \text{ lb/min} \times \frac{1 \text{ lb-mol MgO}}{40.3 \text{ lb MgO}} \times \frac{246.3 \text{ lb } MgSO_4 \cdot 7H_2O}{1 \text{ lb-mol } MgSO_4 \cdot 7H_2O} = 110 \text{ lb/min}$$

110 lb/min x 1440 min/day x 1 ton/2000 lbs = **79.2 tons/day**

At 28 pounds per minute MgO feed ("7" on Salt Side):

$$\text{Crystal Yield} = 28 \text{ lb/min} \times \frac{1 \text{ lb-mol MgO}}{40.3 \text{ lb MgO}} \times \frac{246.3 \text{ lb } MgSO_4 \cdot 7H_2O}{1 \text{ lb-mol } MgSO_4 \cdot 7H_2O} = 171.1 \text{ lb/min}$$

171.1 lb/min x 1440 min/day x 1 ton/2000 lbs = 123.2 tons/day

For 94% MgO, Ideal Yield is 0.94 x 123.2 or 115.8 tons/day

2. Yield Based on 100% Mother Liquor Feed to Digester

Assumptions:

1. All water going into MgO mix pot is evaporated out.
2. Mother Liquor flow is 20 gpm, 27% $MgSO_4$, and approximately 1.28 density
3. Mud is 34.5% $MgSO_4$ and approximately 1.38 density
4. Feed is **28** lb/min 94% pure MgO
5. Enough acid is fed to convert 100% of the MgO to $MgSO_4$
6. Operation at steady state (not a bad assumption)
7. For yield, 500 gallons of mud makes 1 ton of crystal (not so great an assumption)

First, a basic mass balance around the 1st Digester for $MgSO_4$:

Input + Generation = Output + Consumption

Since there is no consumption , that term is 0. The input is from the mother liquor:

$$\text{Input} = \frac{20 \text{ gallons}}{\text{minute}} \times \frac{8.33 \text{ lbs}}{1 \text{lb } H_2O} \times 1.28 \text{ density (specific gravity)} \times 27\% \, MgSO_4$$

Input = 57.577 lb $MgSO_4$ / minute

Next,

$$\text{Generation} = \frac{28 \text{ lb MgO}}{\text{minute}} \times 94\% \times \frac{1 \text{ mole MgO}}{40.3 \text{ lb MgO}} \times \frac{120.3 \text{ lb } MgSO_4}{1 \text{ mole } MgSO_4}$$

Generation = 78.568 lb $MgSO_4$ / minute

And then,

Output = 34.5% x F_{mud}

Output = 0.345 x F_{mud}

So now,

Input + Generation = Output + Consumption

$$\mathbf{57.577 + 78.568 = 0.345 \times F_{mud} + 0}$$

0.345 x F_{mud} = 136.145

F_{mud} = 394.623 lb/ min

$$F_{mud} = \frac{394.623 \text{ lb}}{\text{minute}} \times \frac{1 \text{ gal}}{8.33 \text{ lb}} \times \frac{1}{1.38 \text{ density}} = 34.329 \frac{\text{gallons}}{\text{minute}}$$

$$\text{Yield} = 34.329 \frac{\text{gallons mud}}{\text{minute}} \times \frac{1440 \text{ minutes}}{\text{day}} \times \frac{1 \text{ ton Crystal}}{500 \text{ gallons mud}}$$

Yield = 98.88 tons Crystal / day using all mother liquor

3. Yield Based on 100% Water Feed to Digester

Assumptions:

1. Water flow is 0% $MgSO_4$
2. Mud is 34.5% $MgSO_4$ and approximately 1.38 density
3. Feed is **28** lb/min 94% pure MgO
4. Enough acid is fed to convert 100% of the MgO to $MgSO_4$
5. Operation at steady state (not a bad assumption)
6. For yield, 500 gallons of mud makes 1 ton of crystal (not so great an assumption)

Again, a basic mass balance around the 1st Digester for $MgSO_4$:

Input + Generation = Output + Consumption

Since there is no consumption , that term is 0. Since only water is fed, the input term is also 0.

From above calculation:
Generation = 78.568 lb $MgSO_4$ / minute

And also, the assumption of 34.5% output is still the same, so:

Output = 34.5% x F_{mud}
Output = 0.345 x F_{mud}

Input + Generation = Output + Consumption
0 + 78.568 = 0.345 x F_{mud} + 0

0.345 x F_{mud} = 78.568

F_{mud} = 227.733

$$F_{mud} = \frac{227.733 \text{ lb}}{\text{minute}} \times \frac{1 \text{ gal}}{8.33 \text{ lb}} \times \frac{1}{1.38 \text{ density}} = 19.811 \frac{\text{gallons}}{\text{minute}}$$

$$\text{Yield} = 19.811 \frac{\text{gallons mud}}{\text{minute}} \times \frac{1440 \text{ minutes}}{\text{day}} \times \frac{1 \text{ ton Crystal}}{500 \text{ gallons mud}}$$

Yield = 57.06 tons Crystal / day using all water