Institute for Briquetting and Agglomeration Newsletter Q2 2022

Monday, April 14th, 2022

Good Day to all of our Membership:

The bi-annual IBA Conference will be held in Denver, CO, September 18th - 21st, 2022. The host hotel is the Oxford; Backup hotel is the Crawford. Make your reservations as soon as you can. See phone numbers and links below.

The Oxford Hotel: (800) 228-5838 or
https://gc.synxis.com/rez.aspx?Hotel=239&Chain=6052&arrive=9/18/2022&depart=9/21/2022&adult=1&child=0&group=252220917IBA

The Crawford Hotel: (844) 432-9374 or
https://be.synxis.com/?Hotel=61147&Chain=6052&arrive=9/18/2022&depart=9/21/2022&adult=1&child=0&group=331220915IBA

Membership:
Membership dues are due now for the 2021/2022 time period at $300.00 for individuals and $400.00 for consultants. Please pay by check, wire or Paypal. See the website for details. If I can be of any help please reach out!

WELCOME NEW MEMBERS as of this printing: Thanks for being part of the IBA!

Paul Lake	Bio Agri Mix, LP	Mitchell, Ontario	Canada
Jacob Sulzie	Bepex	Minneapolis, MN	USA
Methilesh Sinha	Manish Metals Processing & Engg. co. p. Ltd.	Jharkhand, India	India

---

WHAT IS THE NEAL RICE AWARD?

The Neal Rice Award was established in 1979 honoring Neal Rice, a founder of the IBA and its Secretary / Treasurer from 1949 to 1977, this award is given to the author of the paper judged to have the most excellent technical content and presentation at each biennial conference.

Highlighted Neal Rice Award Winner - Technical Paper from the 2019 IBA Conference in Charleston, S.C.:

The best technical paper of the IBA – Institute for Briquetting and Agglomeration Conference in Charleston, SC in 2019 was presented by the Clorox Co., Nathan Davis and Don Swatling, pictured below. The Board Of Directors wishes to congratulate the 2019 Neal Rice Award winners for the membership and their contributions to the IBA.

Nathan Davis

Don Swatling

Computational Modeling of a Litter Agglomeration Process Using Discrete Event Approach

Abstract

Agglomeration processes can be difficult to model due to the complex flow behavior of solids, the propensity of solid material to segregate and the mechanisms of solid processing. Poor control over particle size in agglomerators creates recycle loops of oversized and undersized particles. These recycle loops introduce variability in product attributes. In this work, a Discrete Rate model is developed using experimental data and is used to create a black box model of an agglomerator, with assumed particle size distributions. This simple model of agglomeration allows for industrially relevant information on product composition to be determined and predicted throughout the process. The results of the model, using various process conditions, inform the theory of operation and determine when pack line demand can no longer be met. The model can then be used to identify potential manufacturing issues and develop more robust processes.

1. INTRODUCTION

Clorox Cat Litter brands use activated carbon to absorb odors and improve the consumer odor control experience. Activated carbon is incorporated into some litter particles using an agglomeration process. The finished product formula is produced by blending particles both with and without activated carbon. The same agglomeration process produces both particles and alternates between them to supply base product for the final blending step. Switching between formulas with and without carbon creates material, referred to as transition material, which has a carbon level between the two particles carbon specifications. This transition material needs to be added to finished product in small amounts. Minimizing the amount of this transition material generated allows for improved operating efficiency in manufacturing.

The complexity of the agglomeration process requires a computational model to produce a deep understanding of the process. A simple excel mass balance cannot account for different particle properties based on size and the time dependent behavior of the process. In particulate processes like this one, residence times, composition, and other properties of particles may vary as a function of their size. As a result, population balance modeling has been leveraged by Clorox to improve the understanding of the litter agglomeration process.

The model tracks the level of activated carbon throughout the process to predict product quality and process yield. Using this information, new formulas and operating scenarios can be tested without conducting expensive factory trials. Process interventions and failure conditions can be tested to understand the response time design required to mitigate the failures.

2. PROCESS AND METHODS

2.1 PROCESS DESCRIPTION

A flow sheet of the agglomeration process is depicted in figure 1. The agglomeration process consists of an agglomerator that takes in raw materials, recycle material, and water to create particles. The wet, newly formed particles are then dried in a dryer. The residence time of particles in the dryer is a function of particle size. Smaller particles have a shorter residence time and larger particles have a longer residence time. Material exiting the dryer is then screened. Oversized particles are sent to a mill and then sent back to the screener. Undersized particles are recycled in the agglomeration process. Particles that are within the correct size are sent to product storage silos. There are storage silos for high carbon, low carbon, and transition product. Material in the storage silos is then blended together with minor ingredients downstream in a batch mixer to create the finished litter product.

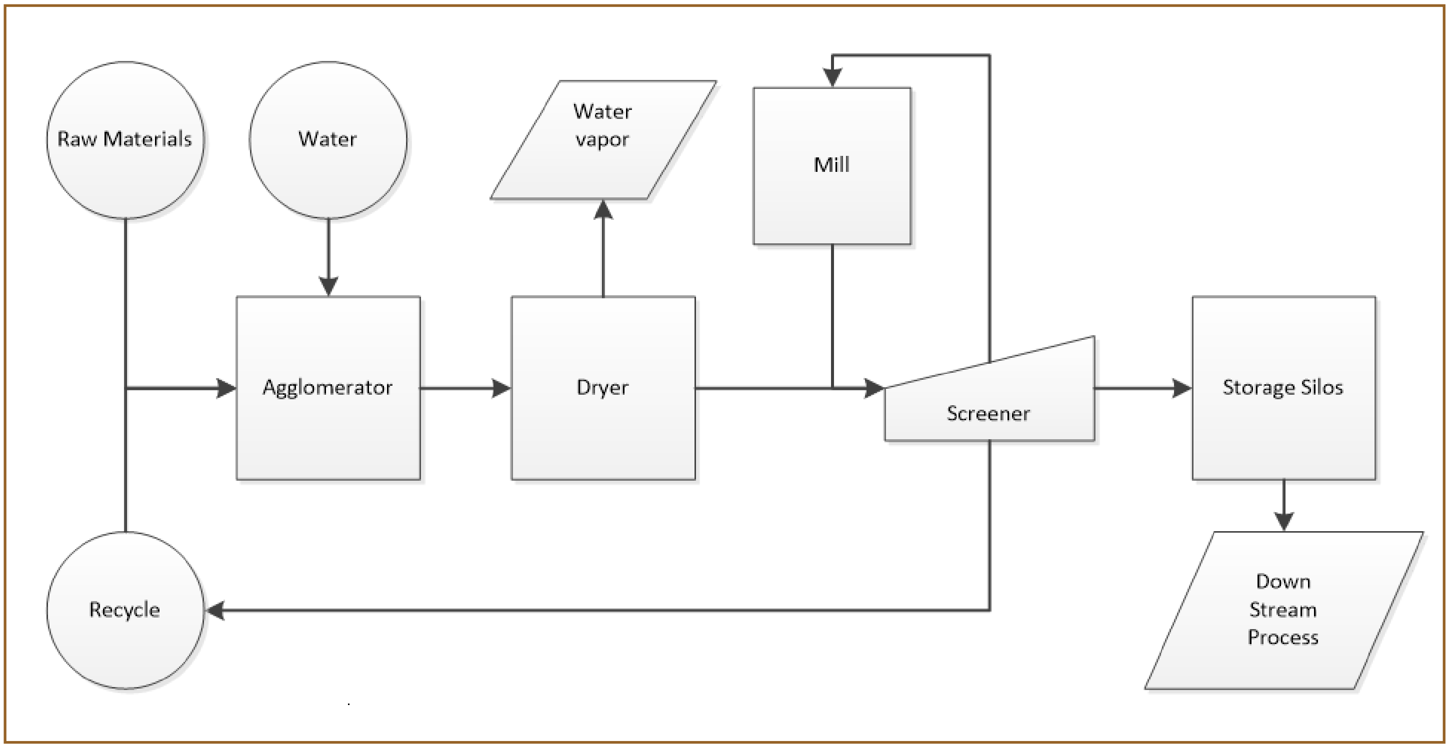

Figure 1. Agglomeration Process for Cat Litter

The complex behavior of the agglomeration process is modeled using a population balance modeling approach. The population balance model divides the agglomerator product material stream into 7 size “numerical bins” (Overs 1, Overs 2, Inspec 1, Inspec 2, Inspec 3, Fines 1, and Fines 2). Dividing the stream into bins allows particles of a specific size to be assigned different compositions and residence times throughout the process. The model also keeps track of whether the material has passed through the mill or not and keeps the mill product stream numerically separate from the product that did not pass through the mill. This is required to appropriately model the residence time difference between particle sizes.

The simulation does not model specific mechanisms of the agglomeration, drying, or milling process. Instead, experimental data is used to create correlations to predict the output of specific unit operations. The particle size distribution of the agglomerator product is based off of experimental data and assumed to be constant throughout the course of the simulation. Experimental data was also collected for activated carbon level in each size by screening the dried product and testing each sieve cut for activated carbon using thermal gravimetric analysis (TGA). The agglomerator model partitions the total input mass of activated carbon across the size bins based on the experimental correlation. The particle size distribution of the milled product is also based on experimental results by measuring the input and output particle size distributions. Experimental data for the residence time distribution of the dryer and other unit operations is used to set residence times for the various particle sizes passing through the dryer. Table 1 summarizes the residence time for each particle size bin.

Table 1. Residence Time Distribution of particles in the dryer

Particle Size	Dryer Residence Time [min]
Overs 1	20
Overs 2	17
Inspec 1	14
Inspec 2	11
Inspec 3	8
Fines 1	5
Fines 2	2

The remaining process residence times are estimated based on equipment capability. The process is simplified by dividing it into sections, each with a residence time. Figure 2, describes the residence time of the whole process.

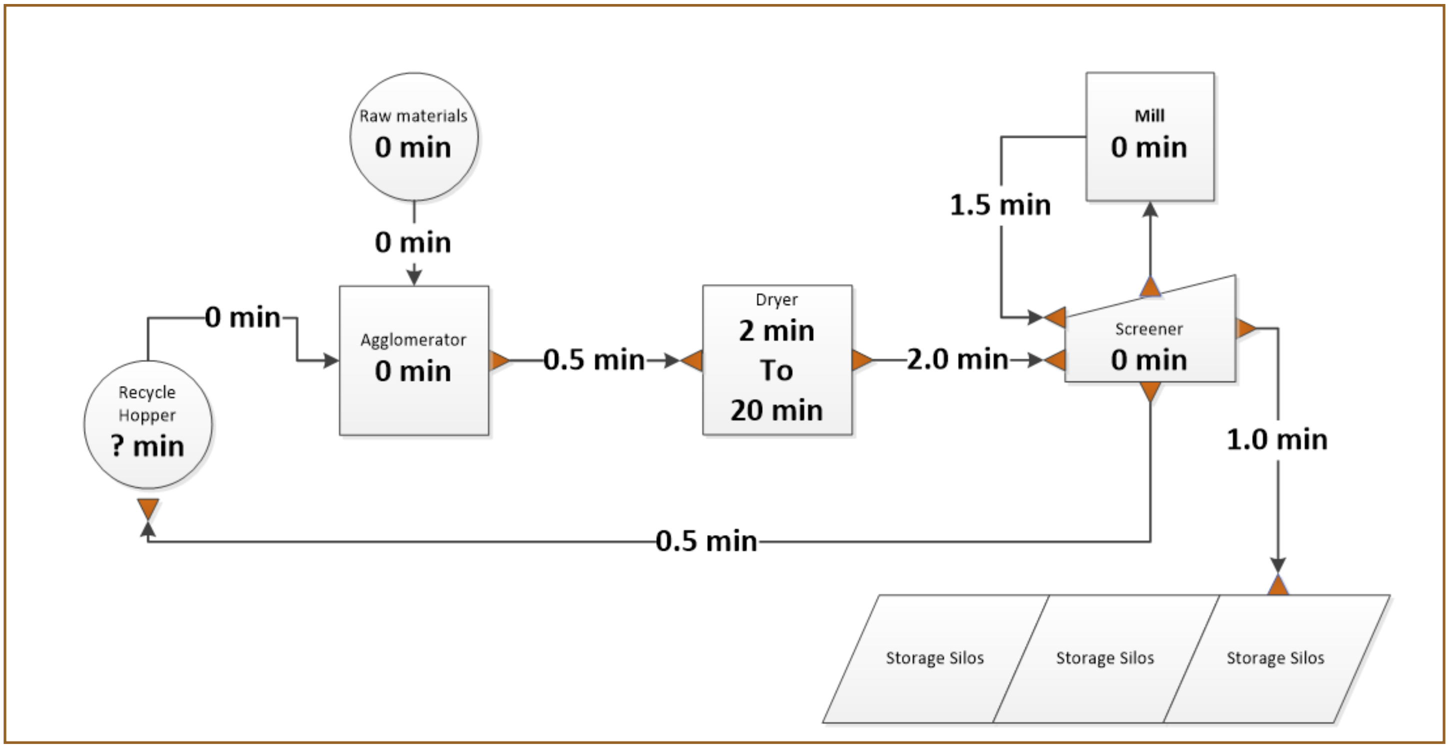

Figure 2. Residence Times of all unit operations

2.2 MODEL DESCRIPTION

ExtendSim version 9 was used to develop a discrete event rate model of the agglomeration process. ExtendSim is a discrete rate and event software tool developed by Imagine That Inc. useful for process modeling and optimization. A discrete event model is a type of continuous model that completes calculations based on events. In the discrete rate model, calculations are preformed when an input value to an equation changes. If there is no change in equations parameters, the simulation skips the calculation. The benefit of this approach is that the simulation saves time by not performing unnecessary calculations at every time step. However, for simulations investigating variability, the values may change continuously which removes the discrete event benefit and slows down the model.

The ExtendSim simulation outputs the attributes of the entire material stream at key points throughout the process. The screener product data output in the typical format is shown in the table below. Collecting the data in this way allows the model to track the distribution of carbon across different particles rather than just reporting the average value for the entire stream.

Time [min]	Particle Size	Mill [y/n]	lb/min	clay %	carbon %	water %
5	Total		120	x.x %	x.x %	x.x %
5	Overs 1	no	10	x.x %	x.x %	x.x %
5	Overs 2	no	10	x.x %	x.x %	x.x %
5	Inspec 1	no	15	x.x %	x.x %	x.x %
5	Inspec 2	no	15	x.x %	x.x %	x.x %
5	Inspec 3	no	20	x.x %	x.x %	x.x %
5	Fines 1	no	15	x.x %	x.x %	x.x %
5	Fines 2	no	15	x.x %	x.x %	x.x %
5	Overs 1	yes	0	x.x %	x.x %	x.x %
5	Overs 2	yes	0	x.x %	x.x %	x.x %
5	Inspec 1	yes	4	x.x %	x.x %	x.x %
5	Inspec 2	yes	6	x.x %	x.x %	x.x %
5	Inspec 3	yes	4	x.x %	x.x %	x.x %
5	Fines 1	yes	3	x.x %	x.x %	x.x %
5	Fines 2	yes	3	x.x %	x.x %	x.x %

2.2 MODEL DESCRIPTION

Operationally, the agglomeration process must alternate between high and low carbon formulas in order to supply the downstream packaging process. The blending and packaging process creates batches of finished product using material from the three product silos. The process is assumed to run at a constant rate and depletes silo inventory over time if not replaced with new agglomerated product. The formula carbon level produced in the agglomerator is changed based on the inventory level in the silos. The process changes over if one of the materials will run out or if the current silo risks over filling. During a transition, the carbon level in the product converges to the steady state formula value as carbon is either purged or added to the recycle loop. The time required and amount of transition material generated depends on many factors including residence times, agglomerator particle size distribution, amount of recycle in the process, and formula targets.

The simulation was validated by comparing the stream output with the experimental data and the expected value from the converged process, based on the mass balance and assumptions. The material stream composition tables are compared to the deterministic calculations of an ideal process. The residence times are validated by confirming the material appears in each data table at the correct simulation time. Based on correct composition, mass balance, and residence time, it is assumed that the time dependent portion of the process is adequately modeled.

3. RESULTS AND DSICUSSION

3.1 DRYER RESIDENCE TIME DISTRIBUTION

The dryer residence time distribution has a significant impact on the process. Figure 3 shows the cumulative distribution of the dryer product based on the inlet feed. The dryer distribution is step wise based on the assumptions described in Table 1. The total cumulative distribution does not sum to 1 due to the moisture being driven off in the dryer.

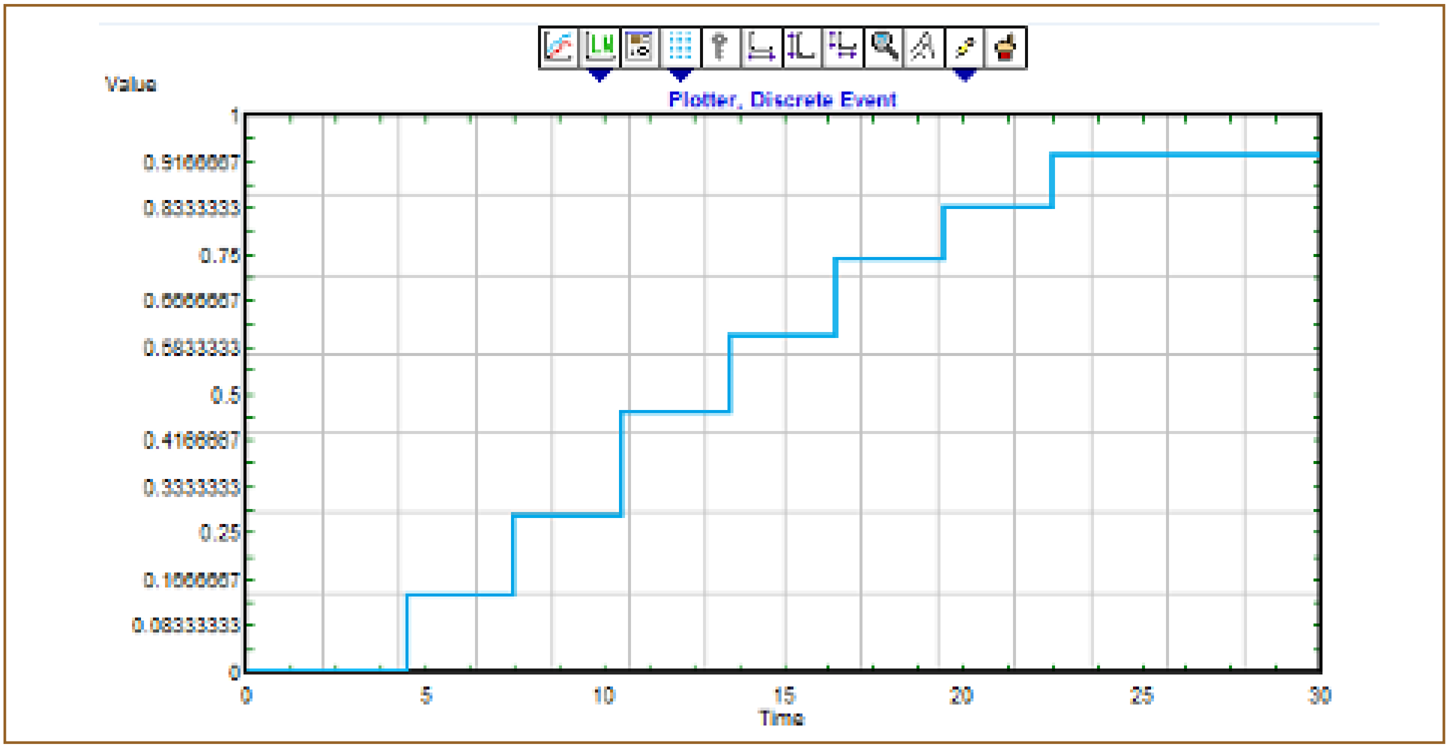

Figure 3. Dryer residence time cumulative distribution

The dryer residence time distribution is one the main reasons that transition material is generated in the product. During a formula transition the small, new carbon level particles begin exiting the dryer while the previous formula particles are still drying. This creates an undesired blended product until the largest particles streams have transitioned to the new formula.

3.2 AGGLOMERATOR FORMULA TRANSITION

The transition from the high to low carbon formula introduces a step change into the agglomerator that propagates through the process. During the transition, the product will be in-between specifications targets for the two formulas. Figure 4 shows the carbon level in the product during a transition from a high carbon set point to a zero carbon set point.

The process runs at the high carbon level for the first 300 minutes. The agglomerator formula changes to zero carbon at 300 minutes and begins to exit the screener several minutes later. Initially, the carbon level rapidly decreases and then slowly converges to the final value as carbon in the recycle loop is purged from the process. The stepwise decrease in the carbon level is due to the previously described dryer residence tie assumption. Each size bin exits the dryer one at a time as seen in the previous figure reducing the carbon level in the product.

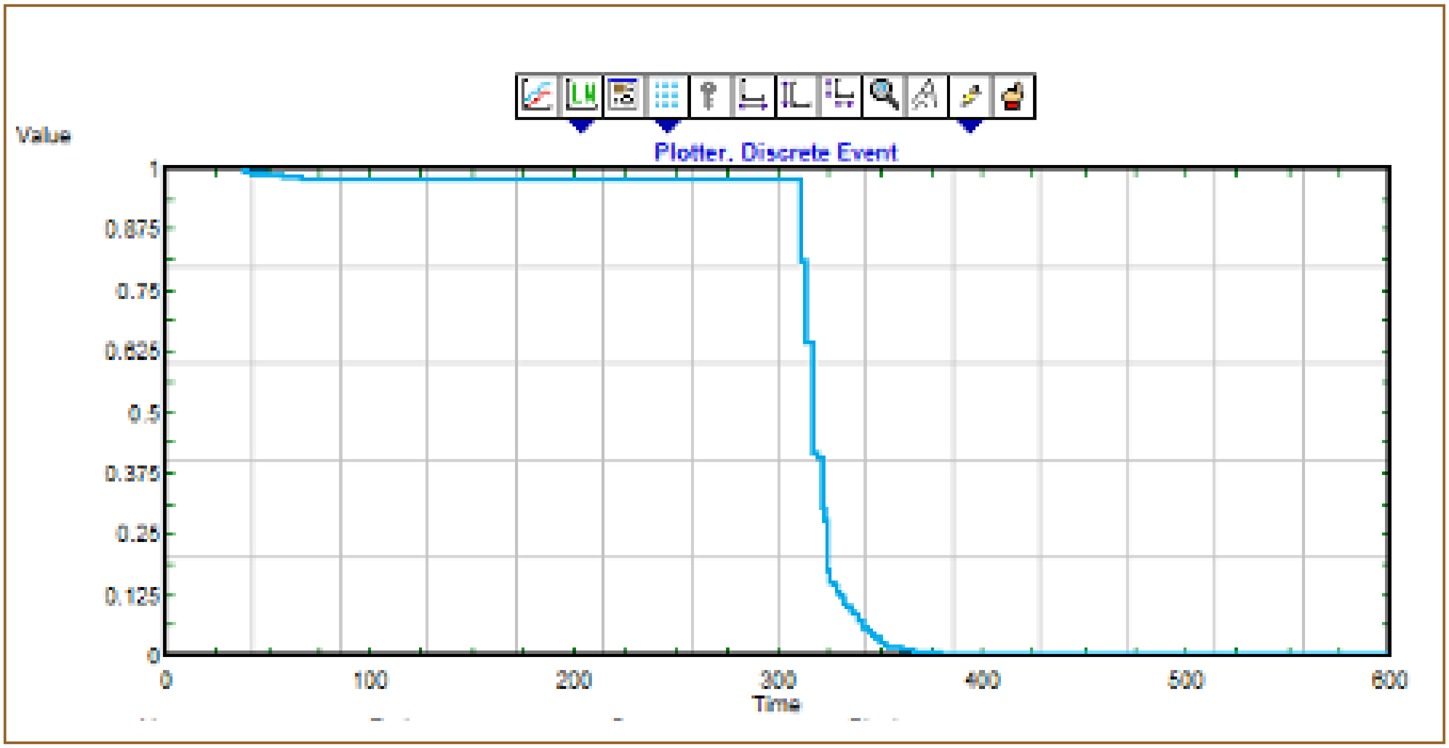

Figure 4. Dimensionless activated carbon level after recipe transition at 300 minutes.

The product material between the set points in considered transition material that must be stored separately to incorporate into the finished product. Minimizing the amount of transition material is key to improving the operating efficiency of the process and reducing product variability.

Transition time is significantly impacted by the amount of recycle in the process and recycle storage bin. During a high carbon to low carbon transition, the carbon in the recycle must be purged from the system. Figure 5 shows the increase in transition time based on the amount of recycle in the system. The minutes of recycle refers to the steady state residence time of material in the recycle tank at the current flow rate.

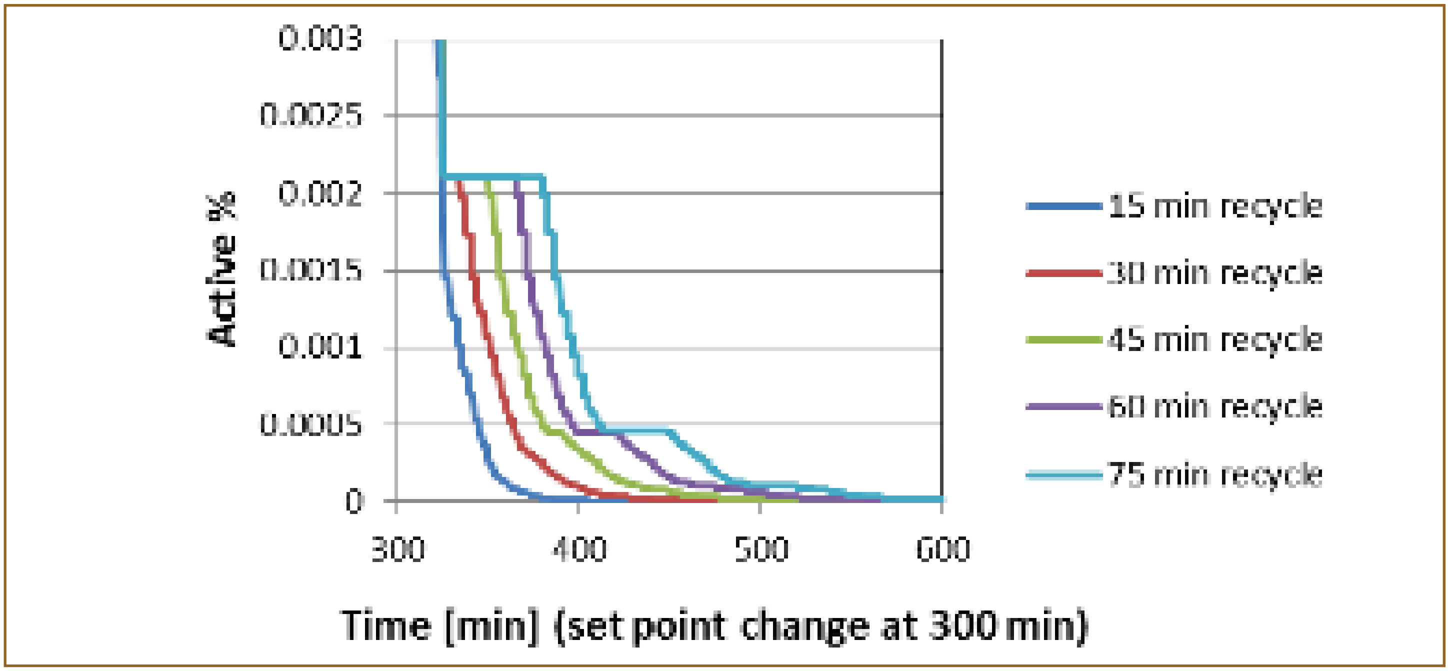

Figure 5. Transition time differences as a function of recycle level in recycle tank

After the initial amount of recycle is purged the carbon level reduces to 0.21% carbon, after the second round of recycle is purged the carbon level reduces to 0.046%. Each stage of the carbon reductions are a 22% reduction compared to the previous level. This is summarized in following table. After 2 passes of recycle the carbon is less than 5% of the initial set point and after 3 passes of recycle the carbon level is at 1% relative to the initial level. The relative effect will be seen for any carbon initial carbon level and is affected by the yield of the process and the carbon partition assumptions.

Table 3. Example for drop in carbon level during high carbon to low carbon transition

Step	carbon level	step change	total change
initial	0.98%		100.%
first drop	0.21%	22%	22%
second drop	0.046%	22%	4.7%
third drop	0.010%	22%	1.0%

3.3 SILO FILL LEVEL

Figure 6 depicts the agglomerated intermediate product silo levels over time. In this example, initially the high carbon silo starts full and the low carbon silo starts half full. Silo inventory is consumed by blending together the two materials, along with transition material, to produce the finished product. The agglomeration process begins on the low carbon formula and fills the silo. During the simulation, the low carbon silo gets close to hitting the maximum capacity. At that point, the process transitions to the high carbon formula. Transition material is generated and diverted to the transition silo until the material reaches the high carbon specification and begins filling the high carbon silo. The agglomeration switches back and forth between formulas to maintain inventory of both materials, ensuring sufficient inventory exists to produce finished product.

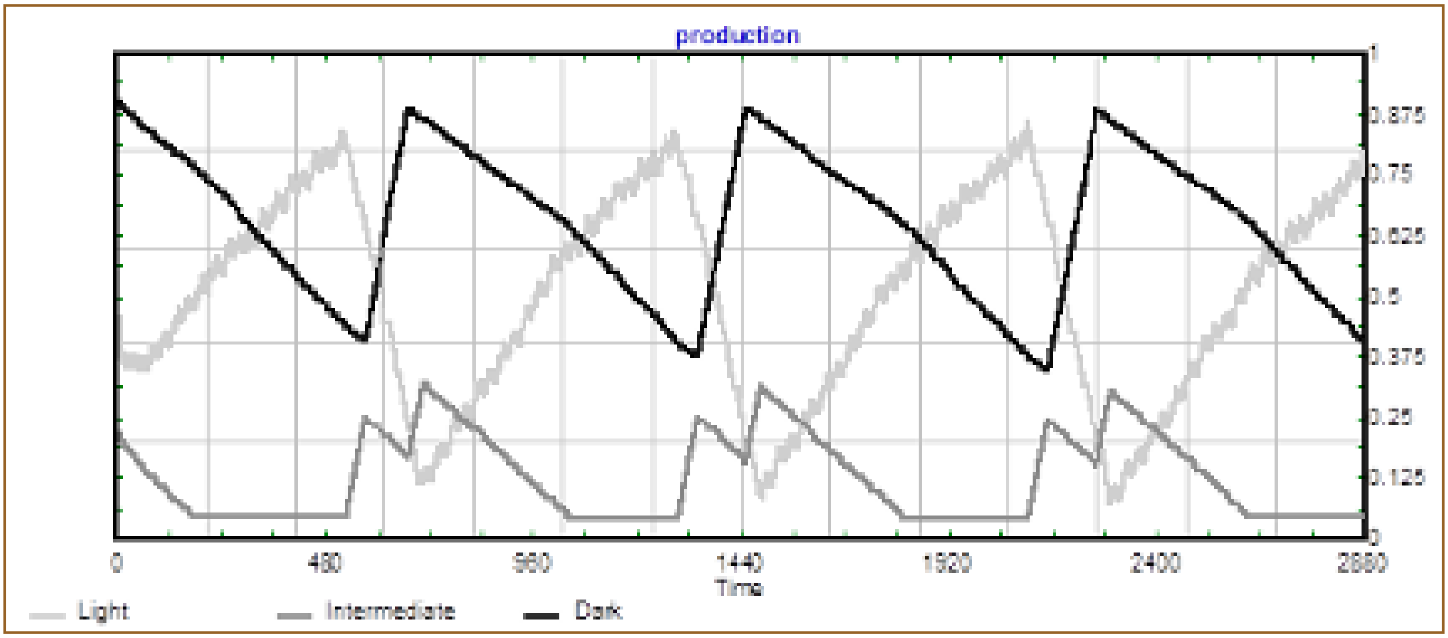

Figure 6. Silo Levels of agglomerated particles

Figure 7 is the carbon level of the agglomerated product entering the silos in figure 6. Transition material is created as the agglomeration product moves from one set point to the other.

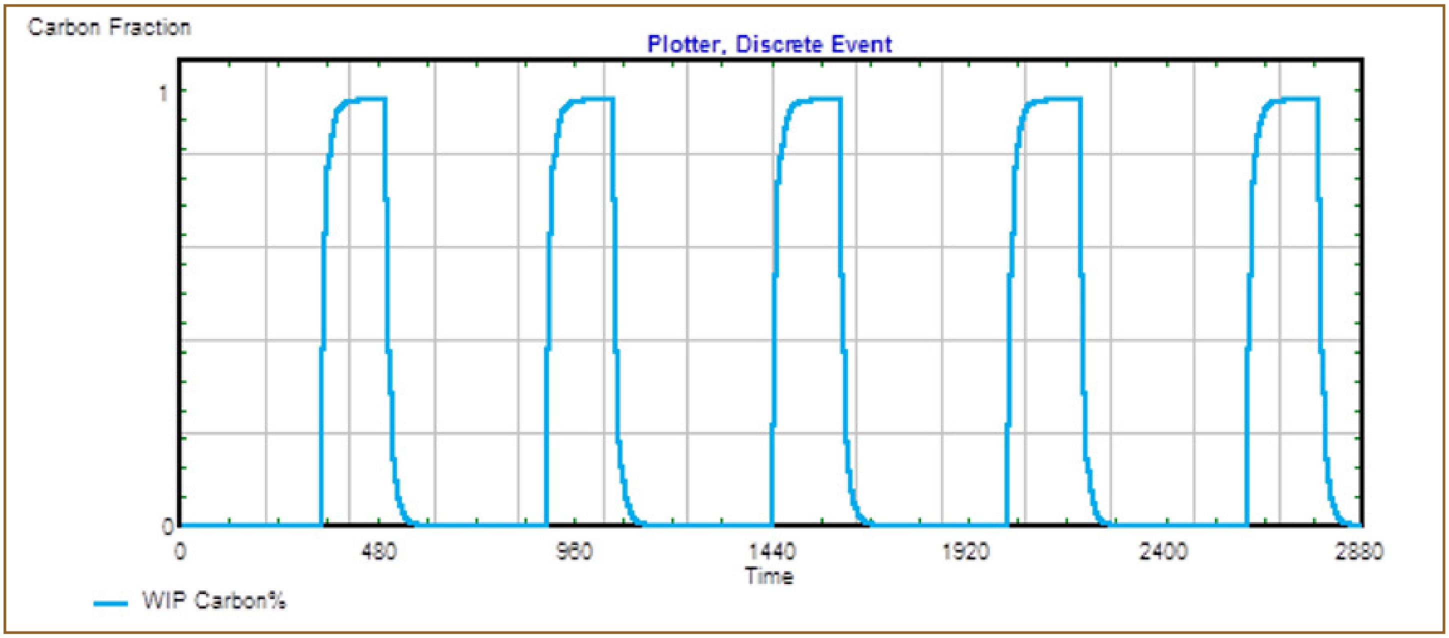

Figure 7. Carbon level of agglomerated particles leaving the screener.

3.4 TRANSITION AMOUNT IN FINISHED PRODUCT

As previously described, the downstream process blends transition material into the finished products at a fixed amount, chosen by the user. The carbon level of the transition material varies in carbon between the high and low carbon spec. Adding transition material without knowing the carbon level of the added material creates variability in the carbon level of the finished product. Higher levels of transition materials increase the variability of the finished product. However, the total consumption rate of transition material must be greater than the generation rate from the agglomeration process for continuous operation.

Figure 8 shows carbon level in the finished product. The carbon varies around the set point due to transition material. The carbon level increases when transition material with higher carbon is added to the finished product. Conversely, the carbon level decreases when the transition material with low carbon is added to the finished product. The cycle repeats for each of the transitions observed in the process. The minimum and maximum observed carbon level is a function of the amount of transition material added to the process and the carbon level of the high carbon agglomeration formula.

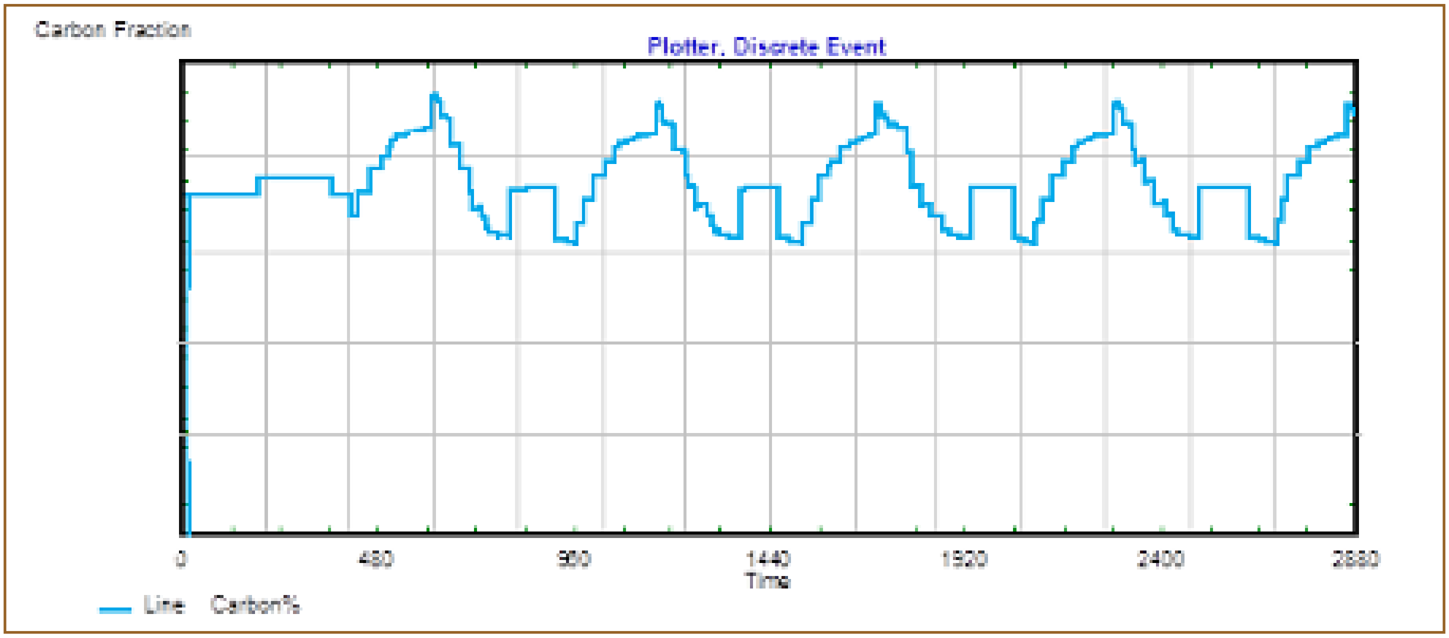

Figure 8. Carbon variability of finished product

Figure 9 shows the variability of carbon level in the finished product due to increasing the amount of transition material in the finished product formula. The carbon level in the finished product falls out of the specification range when between 15% and 20% transition material is added to the finished product. This result requires that process operating conditions cannot generate more than 15% transition material during normal operation cycles.

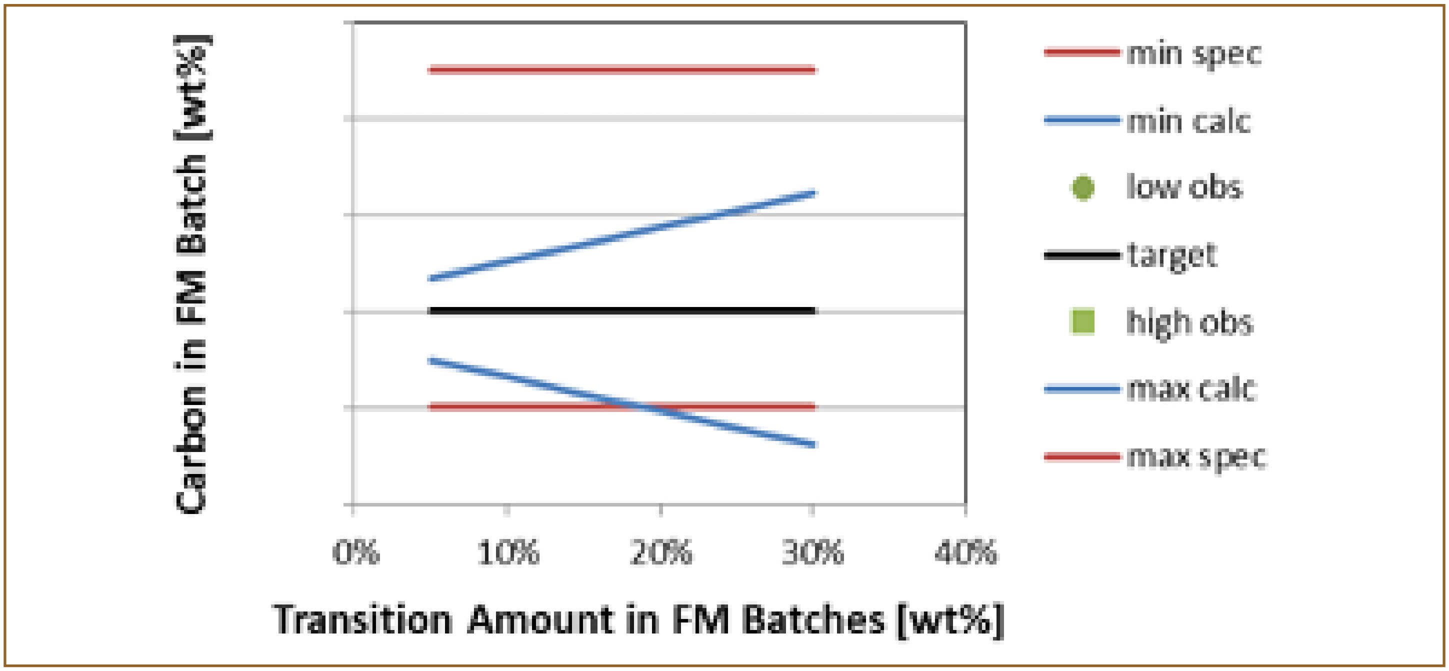

Figure 9. Carbon variability in finished product as a function of transition material added

Minimizing the amount of transition material generated during changes will allow for more consistent finished product. Additionally, inline measurements of carbon could be used to determine the carbon level of transition material added to final product. The amount of high and low carbon product can then be adjusted to more accurately target the final product. This change would remove operating constraints on manufacturing and improve factory flexibility and OEE, but is not built into the model.

3.5 AGGLOMERATION PARTICLE SIZE DISTRIUBTION AND YIELD

The agglomeration particle size distribution and; therefore, process yield can vary over time due to a variety of reasons including normal variability, changes in raw materials, and formula changes. Variations in particle size distribution will change the residence time in the dryer and the amount of material going to the overs mill, recycle stream, and the product stream. These differences will change the net production rate of the agglomeration process filling the silos. Variations in agglomeration particle size distribution also impact the recycle rate of the process necessary for continuous operation. Table 4 summarizes three typical particle size distribution cases with different yields. The medium PSD case is set to rate match the downstream process.

Agglomerator Yield	Overs wt%	Inspec wt%	Fines wt%	Net Production Rate (yield)	Recycle Rate
Small PSD	10%	**50%**	**40%**	**89**	**43%**
Medium PSD	20%	**50%**	**30%**	**100**	**36%**
High PSD	30%	**50%**	**20%**	**111**	**29%**

Table 4. Yield scenarios for the agglomeration process

Decreases in yield will cause silo inventory to decrease as the downstream process consumes more material than is generated. Increases in yield will cause total silo inventory to increase. Figures 10 - 12 show the silo inventory levels over time for the three yield scenarios. For these cases, the simulation will pause if any silo reaches the high-high level or if the agglomeration process receives requests to produce both high and low level carbon agglomerates simultaneously. The low yield scenario pauses after 21 hours due to low agglomerated product level while the high yield scenario pauses at 27 hours. The results demonstrate that there is plenty of time for an operator to intervene in the process provided the process yield and silo inventory information is known to the operators.

During the high yield scenario, the process rapidly switches agglomerator formulas due to a high level signal from the silos. The more frequent transitions generate additional transition material that eventually maxes out the silo capacity. Reducing the agglomerator production rate in high yield conditions can mitigate this issue.

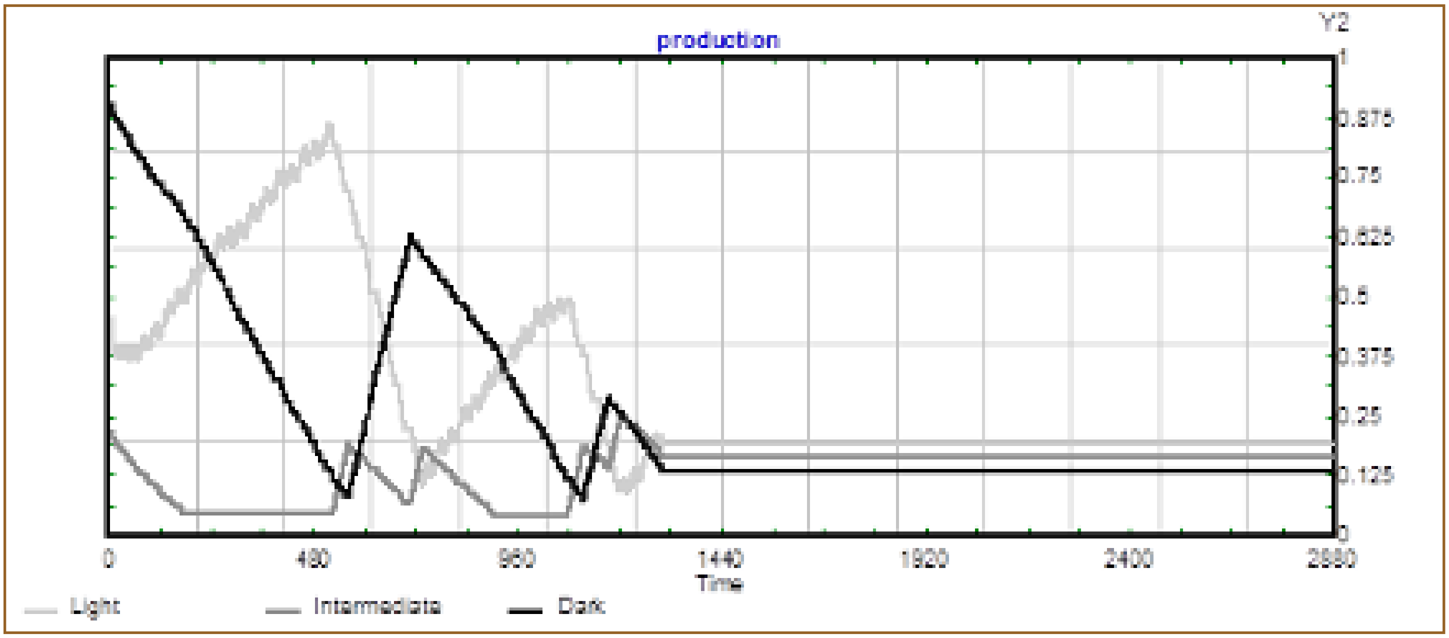

Figure 10. Low Yield Silo Inventory Agglomeration cannot fulfil downstream demand and Process shuts down due to low silo inventory.

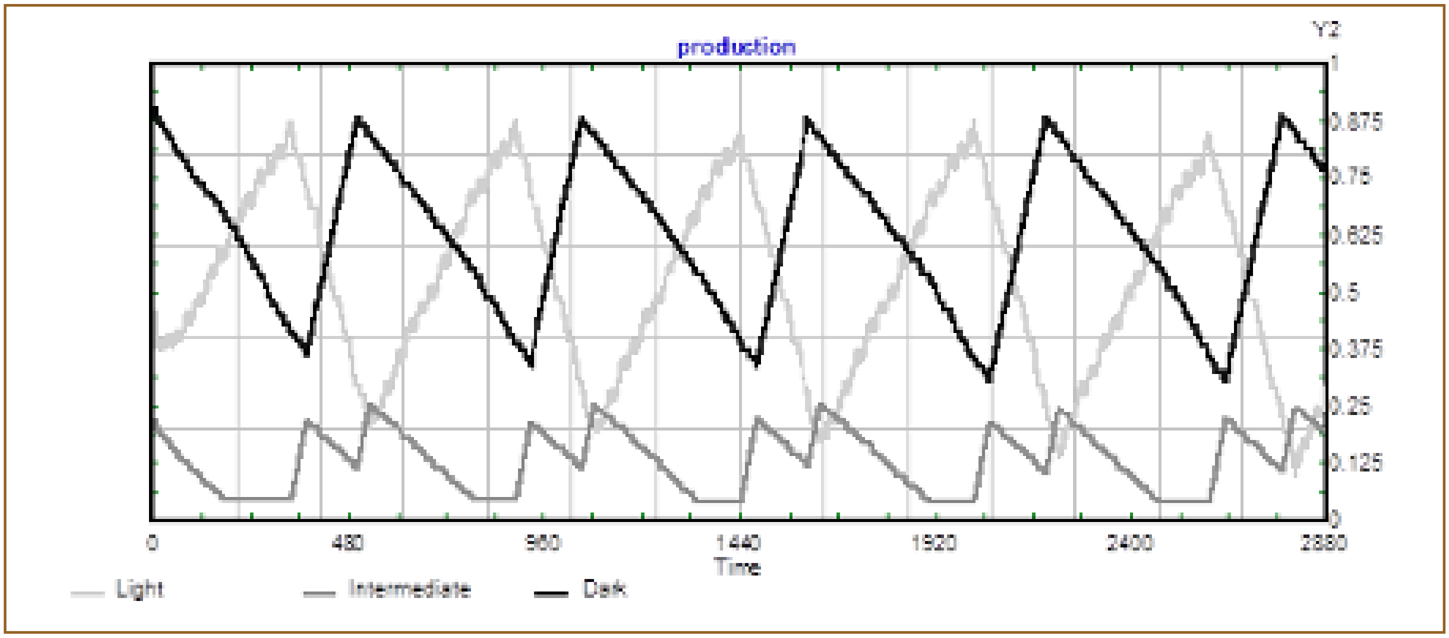

Figure 11. Medium Yield Silo Inventory: Agglomeration is rate matched to the downstream demand.

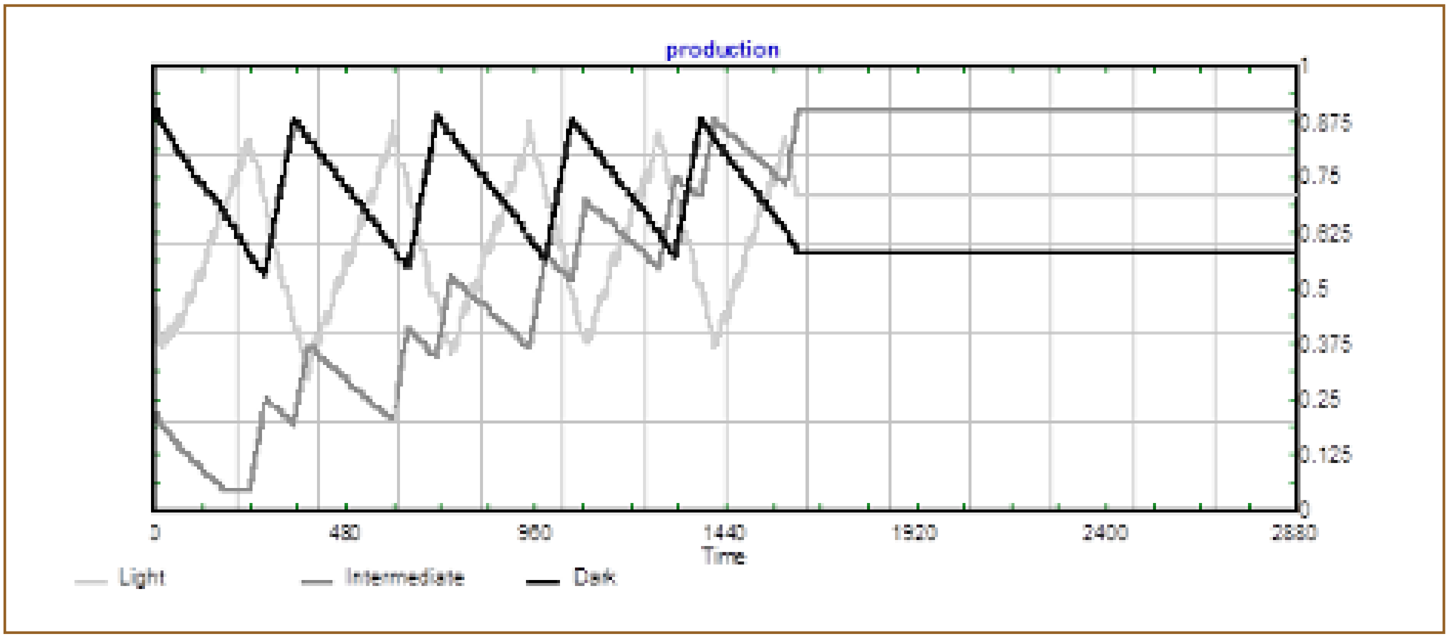

Figure 12. High Yield Silo Inventory: Agglomeration process exceeds downstream demand and over-fills silo. Transition material is not managed.

The agglomerator particle size distribution also impacts the amount of transition material generated during each transition. Smaller particle size distributions generate less transition material than larger particle size scenarios. This is due to the dryer residence time distribution. Larger particle size distributions increase the average time material spends in the dryer. The oversized particles are milled, with the fines being sent back as recycle. This increases the amount of time required for the recycle loop to converge due to an increased recycle cycle time.

Agglomerator Yield	Mass Average Recycle Residence Time [min]
Small PSD	7.7
Medium PSD	9.3
Large PSD	12

Table 5. Transition Time as a function of process yield

3.6 IMPROVED FORMULA TRANSITION

The transition from a low carbon formula to a high carbon formula creates extra transition material due to the low carbon recycle still in the process. The amount of transition material generated can be reduced by adding extra carbon, at some fixed amount, until the recycle material reaches the steady state carbon level. With this modification, transition material is only generated due to the dryer residence time distribution and the milling loop. Figure 13 and 14, compares the process with and without extra carbon feeding and shows the improved transition with additional carbon. The modification allows the product carbon level to rapidly reach the formula value without the asymptote behavior observed in the initial scenario.

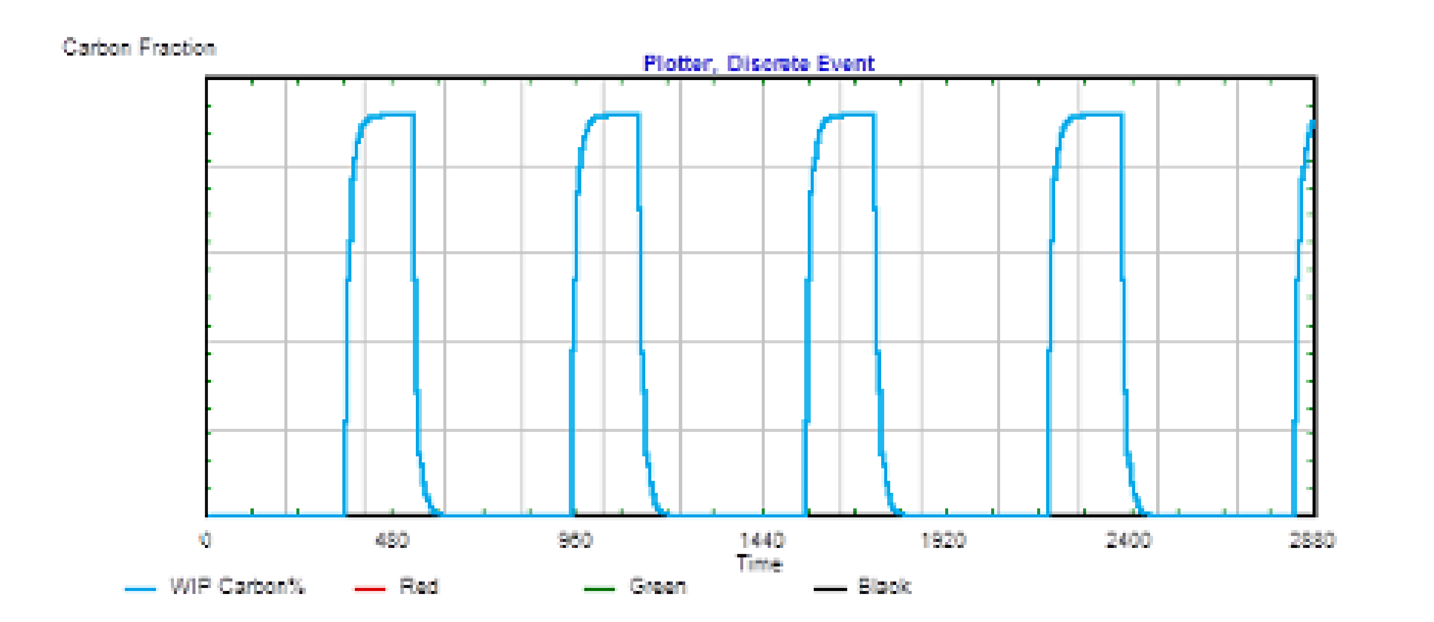

Figure 13. Original Carbon Feeding Profile

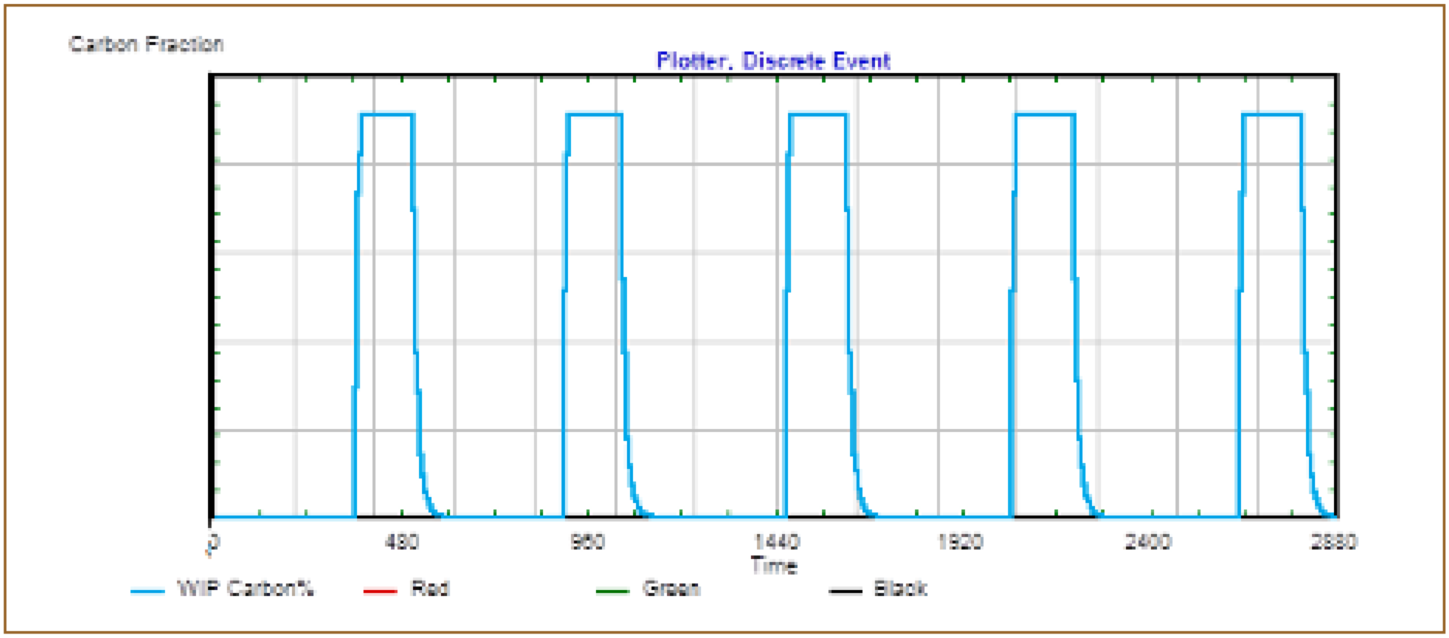

Figure 14. Improve carbon feeding to minimize transition material

The new operating condition reduces the low carbon to high carbon transition time from 31 minutes to 14 minutes. The high carbon to low carbon transition however, is unaffected by this improvement. Implementing this level of control in manufacturing will reduce the total amount of transition material by 25%, reducing the amount of transition material that needs to be added to finished product. This, in turn, reduces product variability and improves operating efficiency.

4. CONCLUSIONS

The population balance model provides a robust description of the agglomeration process operation. Although the specific mechanisms of agglomeration are not modeled, experimental data is sufficient to describe factory level behavior, including residence times and recycle loop behavior. Dividing the agglomerator product stream into multiple size bins allows for differing residence times and product attributes in each size. This produces a more realistic description of process behavior and allows for the distribution of particle attributes to be tracked rather than only the average value of the entire stream.

Agglomeration particle size distribution and yield has a significant impact on process operation. The time to failure is over 20 hours. This is sufficient time to intervene and correct or adjust the process. Minimization of transition material is key to reducing product variability. The minimum amount of transition material required is set by the size and number of transitions. Other process controls, such as over feeding carbon to the finished product can reduce the amount of transition material by up to 25%.

Models for solids processes are difficult to create and required a significant amount of experimental data, assumptions, and development. However, once a model has been developed they can be utilized to test different operating conditions, formulas, equipment specifications, upset conditions, and process optimization. With the model of the agglomeration process, Clorox can rapidly and cheaply identify ways of improving the operating efficiency of the manufacturing facility.

Upcoming Conferences

- **European Biomass Conference:** May 9th -12th, 2022, Online www.eubce.com
- **AISTech Conference:** May 16th - 19th 2022. Pittsburgh, PA.
- **Scrap Expo:** September 13th - 14th, 2022. Kentucky Exposition Center, Louisville, KY
- **CONEXPO-CON/AGG:** March 14th - 18th, 2023. Las Vegas, Nevada

---

Important Source Links:

There are 5 member links on our website, by equipment manufacturers, processors, additive suppliers, and research groups. We thank our advertisers. Please visit our website for details. Please add your company name to the list with a $200.00 fee for 2 years 2021/2022. You can do this on the website through PayPal.

www.agglomeration.org
https://www.linkedin.com/groups/8494240/
https://www.powderandbulkshow.com/en/home.html
www.aist.org/conference-expositions/aistech

It's not too early to submit an abstract for the 37th Bi-Annual IBA Conference for the Fall of 2022 in Denver, CO. The sooner the better: That way we can advertise and drive our membership and attendance at the next conference! Please commit to a paper and also get your colleagues to submit a paper!

Companies / Technical Consultants that have committed to giving papers in 2022 are:

- Greg Mehos, Ph.D., P.E., AIChE Fellow
- Nick Slater, Freund-Vector
- Colorado School of Mines – Corby Anderson
- J.C. Steel, Mac Steele
- Direxa – Clement Cardier
- BASF – Willy Cilengi
- Jenike & Johanson – Kurt Naugler
- NU-Rock – Mahroun Rahme

It is now time to register for the conference. You can do this on the website, www.agglomeration.org.

The cost per person is as follows:
CONFERENCE FEES & TECHNICAL SESSIONS:

	PRIOR TO AUG. 19	AFTER Aug. 19
MEMBERS:	$950.00	$1,050.00
NON-MEMBERS:	$1,250.00	$1,350.00
GUEST:	$375.00	$375.00 (No Technical Papers / Significant other)

VENDOR TABLE: $950.00*
** Advise if 120V-1PH-60HZ is required.*

STUDENT DISCOUNT – ½ PRICE FOR TECHNICAL SESSIONS. Proof of attending an Accredited University required. Pre-approval by the Executive Committee is required before registration. Send info to iba@agglomeration.org.

TOTAL: (ALL FEES ARE IN U.S. DOLLARS)

PRELIMINARY SCHEDULE:

Sunday, Sept. 18:	9:00 a.m. - Noon	Registration
	2:00 p.m. - 5:00 p.m.	Registration
	5:00 p.m. - 8:00 p.m.	Vendors Night
Monday, Sept. 19:	7:30 a.m. - 8:30 a.m.	Authors Breakfast
	7:30 a.m. - 9:00 a.m.	Registration
	9:00 a.m. - 5:00 p.m.	Sessions 1 and 2
Tuesday, Sept. 20:	9:00 a.m. - 5:00 p.m.	Sessions 3 and 4
	6:30 p.m. - 9:00 p.m.	Presidents Banquet
Wednesday, Sept. 21:	9:00 a.m. - Noon	Session 5
		Roundtable Discussion
		Membership Meeting

See you in Denver!

Jim Torok
Executive Director-Institute for Briquetting and Agglomeration
219-765-2378
Jiluc@comcast.net
1301 Service Rd.
West Barnstable, MA 02668
iba@agglomeration.org

Please, if you have not paid your dues and or you want to become a member, please go to the site, www.agglomeration.org to do so! We look forward to your membership!

Be safe, stay healthy!

Jim Torok
Executive Director