SIT Paper # 1273: Increasing Net Yield through Screening Optimization

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Abstract

C&H Sugar in Crockett, CA is known for producing one of the industry's largest grain pure cane sugar products, but has faced challenges in recent years with its large grain yield due to variations in strike particle size distribution. Inefficient screening led to the rejection of in-spec material, including entire strikes, resulting in increased operational costs and reduced line capacity. This study explores the optimization of Rotex screening parameters to enhance the large grain production yield. The research employed a systematic approach, considering screening mesh parameters, mean aperture requirements, historic screening data, and experimental investigations to identify key factors influencing screening performance. By addressing specific inefficiencies for each grade through control of screen mesh size and feed rate, the study successfully optimized Rotex configuration variables, eliminating strike rejection and increasing net yield. The findings contribute to enhanced line efficiency, reduced operational costs, and increased capacity to meet growing market demands, overcoming infrastructure limitations.

Introduction

C&H Sugar takes pride in the ability to boil sugar strikes on the confectioner line with a high level of accuracy and precision, resulting in a consistent and predictable final product crystal distribution. This is significant as it is the only line at C&H boiled manually. The process has been honed and refined so that the centrifuged sugar is within quality specification, and technically doesn't need to be screened. This has meant that the screening needs have been minimal, removing only dust and crystal lumps from the product stream, but recent years have seen increased variability in crystal size distribution. There are many factors that can contribute to this, including equipment condition, seed quality, and manpower or experience related deficiencies. Over the last year C&H has lost more than 100 years of experience on the pan floor, which has aligned with the increasing variability. Because of the screening methods used, up to 15% of strikes do not meet quality specifications after the screening stage and need a process intervention, or to be recycled if that intervention does not work. By optimizing the screen selection of the screening stage to ensure rejection of out material that is out of quality specification, while maximizing material retained within specification, net yield can be increased to reduce or eliminate excess material recycling.

Materials and Methods

Sugar: All material (sugar) used in these trials was boiled by the Head Sugar Controller using standard C&H production equipment, practices, procedures and sugar liquor as used during the normal coarse of operation. Any material processed through a test screen was collected and recycled to prevent contaminating production material in the event that it was out of quality specifications for that grade.

Figure 1: Rotex Industrial Separator [2]

Screening: All screening was performed with one of two 54A AASL Rotex® Screeners, similar to Figure 1, using standard tensile bolt cloth screens. Modifications to the outlets were made to allow for the collection of material during the trial, but the all equipment, settings, and inlet configurations were maintained as they would in a production environment.

Figure 2: RO-TAP Test Sieve Shaker [3]

Sample collection & processing: For each screen trial, three 1 lbs samples were collected from each outlet directly after the Rotex, before the sugar came in contact with any other equipment. The samples were split using a riffle type sample splitter and 100 grams of each sample was screened with a RO-TAP® test sieve shaker. The weights from each sieve was taken and calculated as a percentage of the total sample. The screened and weighed sample material was then recycled.

Rotex Stream Definitions:

Overs: Material rejected over the top screen that consists of material too large to pass through the top screen, such as large crystals and crystal lumps. If the screen is too fine then material that meets specification may be rejected, leading to high recycle rates and poor yield. Alternately, if the screen is too coarse then oversized material may be passed to the product stream, increasing proportion of coarse material in the product stream high enough to bring the product stream out of specification. This can lead to recycling the entire product stream, quality impounds, and/or customer complaints and returned product.

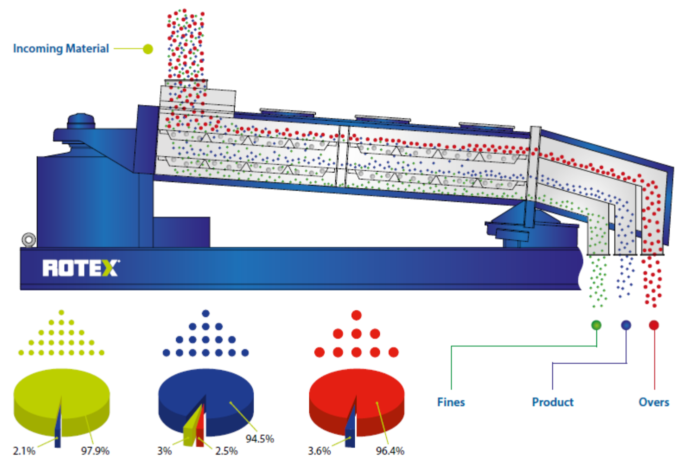

Figure 3: Illustration of Rotex screener with one product stream [4]

Product: Material that passes through the top screen but over the middle screen, or bottom screen if there is no secondary product/seed stream. This is the primary product stream and is sent to packaging. If the middle/bottom screen is too fine then material that should have been rejected to the next stream would retained in the product stream. This can result in shifting the product a high fines ratio, bringing the product stream out of specification. This can lead to recycling the entire product stream, quality impounds, and/or customer complaints and returned product. If the middle screen is too coarse, then material that should be retained as product is passed to the next stream.

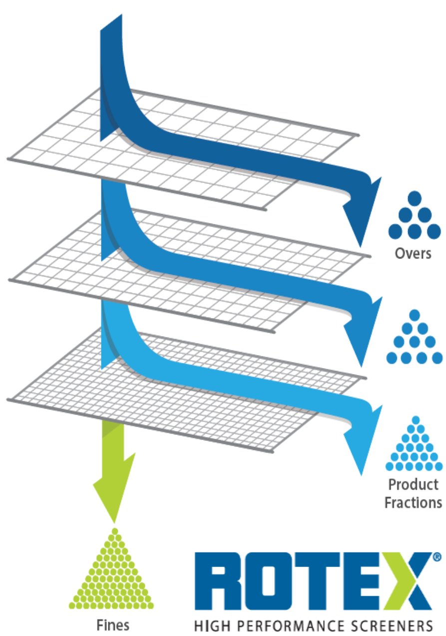

Figure 4: Illustration of separation with multiple product streams [5]

Seed: Material that passes through the middle screen, but is retained over the bottom screen. This is the secondary product stream and is material that is either sent to packaging or used internally to seed future strikes. Where seed or secondary product is not produced/retained, then the bottom screens would be an open frame, passing material directly to the pan. If the bottom screen is too fine, then material that should have been rejected to the pan would be retained in the seed stream. This can result in high fines ratio in the seed, bringing the entire stream out of specification. This can lead to recycling the entire seed stream, quality impounds, and/or customer complaints and returned product. Even worse, high fines can shift the seed MA (mean aperture) to a smaller size. If the MA is too low and seed is measured by weight, then the seeded strike will have a smaller MA which leads to higher recycle rates or product out of specification.

If the middle screen is too coarse, then material that should be retained as product is passed to the seed stream. If the bottom screen is too coarse, then material that should be retained as seed is passed to the pan. This leads to higher recycle rates and a larger seed MA. If the seed is measured by weight, the MA is high, and a correction is not made to adjust the amount used, then too little seed will be used which can cause issues such as false grain formation. *Note: For the purpose of this paper, the seed stream will not be considered. Any grade with a seed stream will combine seed material with the PAN stream material.*

PAN: Material that is rejected through the bottom screen as fines and is recycled. If the bottom screen is too coarse then seed will be passed to the pan, leading to higher recycle rates.

Screen Selection: Screen selection can be difficult as the screening efficacy depends on multiple factors, such as mesh size, feed rate, screener motion, etc. Production screening has been observed to have noticeably different characteristics from lab screening, so screen efficacy must be obtained empirically using the actual equipment, settings, and methods to be used during normal production. Production screen opening sizes compared to the opening sizes of the quality screening sieves are used to select the production screens most likely to be effective, then tested to determine efficacy. Once data is selected and efficacy determined, the standard screen configuration can be updated to incorporate the test screen, another screen can be selected for further testing, or the standard screen configuration can remain unchanged. By using the conversion table (see Apendix A), to convert the US Sieve mesh size openings to bolt cloth mesh size openings and the decision tree in Figure 5, a screen is selected that will meet the quality specification for the grade in question by increasing or decreasing the screening of coarse or fine material from the selected stream.

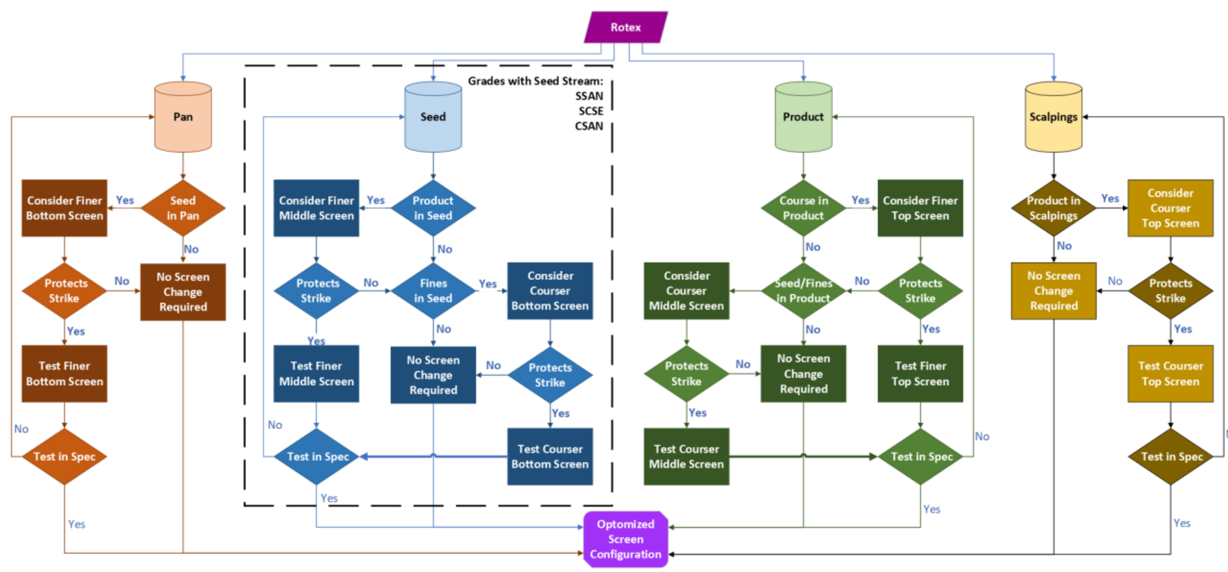

Figure 5: Screen selection decision tree.

Material Analysis: There are many ways to apply screening methods to crystal separation. One such method is to boil a strike with a wide crystal distribution and screen it into multiple products that meet specific specifications. In this case the screens would need to be carefully tuned to ensure only the correct material is retained between screens regardless of the crystal distribution of the strike. Another method, which has been used on the C&H confectioner line, is to boil a strike with such high precision and accuracy that it results in a strike with a crystal distribution already within specification, which only needs large crystals, lumps and dust removed. A major downside to this method is that the entire strike will have to be recycled if the distribution is outside of the screening stage to maintain quality specification.

Figure 6 illustrates the screening analysis of three different feed profiles and the quality specifications for the screened material for a specified grade. In a normal feed scenario the feed technically does not need to be screened to meet the product quality specifications. If feed material is always close to this profile, then only large crystals, lumps, and fine dust need to be removed before packaging. This results in minimal screening requirements and maximum yield per strike through the screening stage.

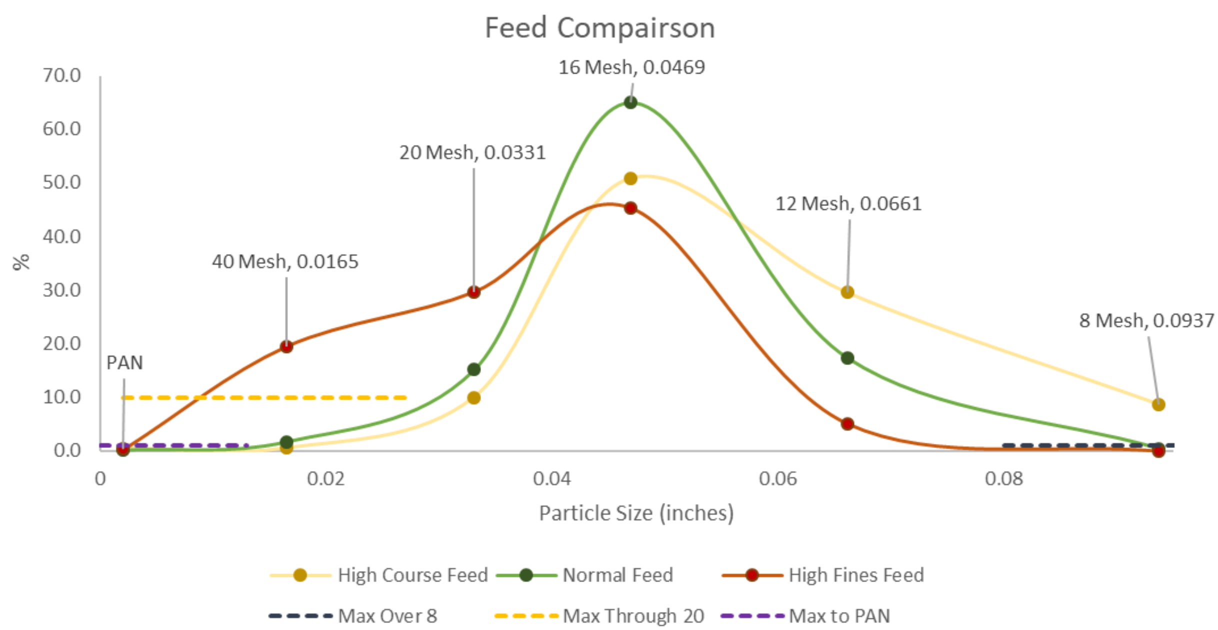

Figure 6: Comparison of three feed material profiles before Rotex screening. Normal feed profile, feed profile with high percentage of fines, and feed material with high percentage of coarse material. Screened product requirements indicated by dotted lines.

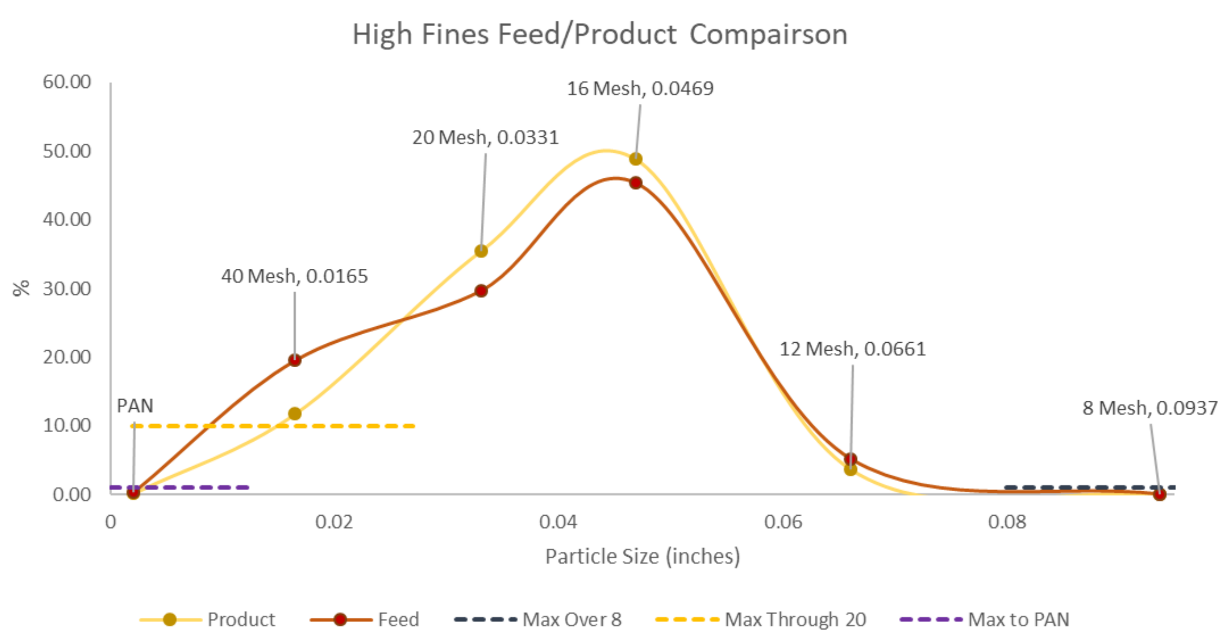

Figure 7: Comparison of the feed and screened product of a feed material with high fines percentage compared to a normal feed profile.

In an undesired feed profile with screening configuration optimized for a normal feed profile, such as if the feed contains a high percentage of coarse material, then the screened material will most likely be out of specification as illustrated in Figure 7, and the entire strike will need to be recycled if another outlet is not available. The same is true for feed with high fine material with a screening configuration optimized for a normal feed profile as illustrated in Figure 8. In the case where there is a high fines ratio, some steps are possible at the centrifugal stage to reduce fines content, but there are drawbacks. For example, if you increase the wash to melt the fines you actually melt some of the large crystals as well, shifting the distribution towards a smaller mean aperture, which could result in the screened product being out of specification. If the screened material is still within specification after the increased wash, then the yield is reduced by significantly more than the fines that were melted.

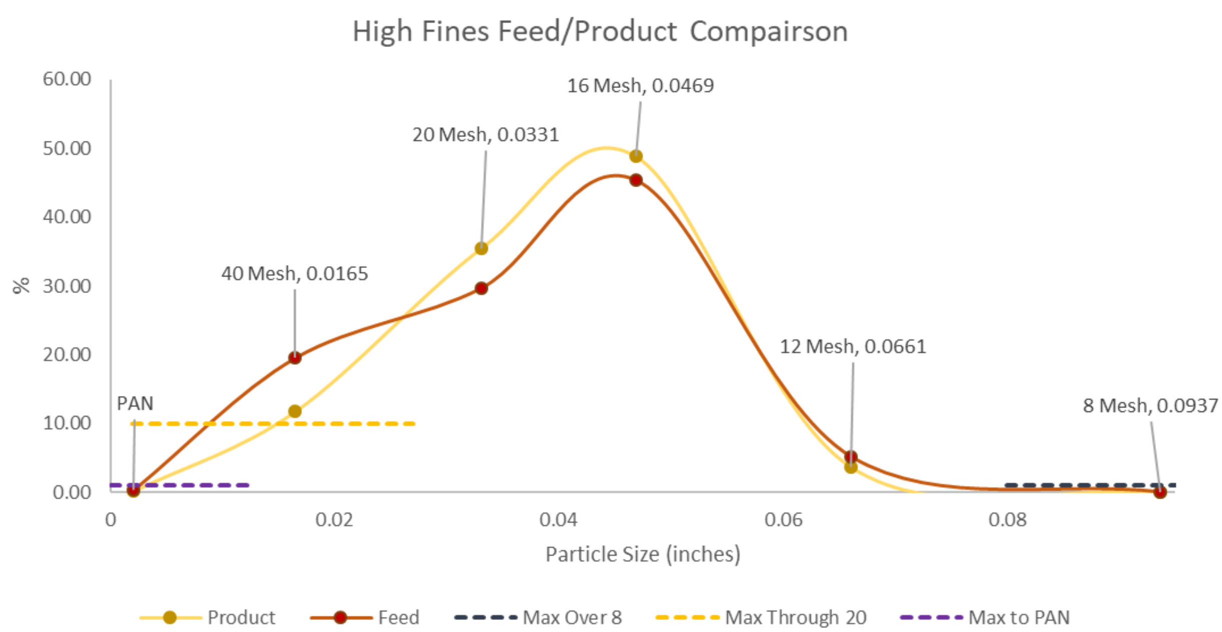

Figure 8: Comparison of the feed and screened product of a feed material with high coarse percentage compared to a normal feed profile.

Grey Area: If your quality specification allows for a significant percentage of coarse or fine material in your product stream, such as 25% over the top or bottom screens, then it makes it difficult to optimize unless your strikes are both precise and accurate. If you lose too much of the coarse or fine material then you will reduce your yield, recycling material that could be packaged. If the screening allows too much coarse/fine material, then strikes a higher coarse/fines distribution will exceed the screening capacity to maintain quality specifications. In this case, an extensive analysis of the strike history will need to be performed to ensure a balance between yield reduction from screening out coarse/fine material and strike recycling due to screened material falling below quality requirement.

Results & Discussion

Optimizing for Insufficient Screening: Coarse Material Passed to Product Screen

Using a similar feed and quality requirements to the example in Figure 7, Rotex feed with a high fines ratio resulting in the product being out of specification, the screen selection needs to ensure <10% thru 20 US Standard Sieve and <1% to the PAN. The screen selection that resulted in the strike being out of specification is a 30 mesh tensile bolt cloth bottom screen. This has openings of 0.0268", compared to the 0.0335" opening of the 20 mesh sieve. A 24 mesh tensile bolt cloth test screen with 0.0342" openings for the bottom screen was selected, which has slightly larger openings than the sieve. This allows for some slight inefficiency in screening of fines, which would retain some percentage of crystals smaller than the screen openings, in the product stream. This selection potentially ensures that the product will remain within specification even when the strike contains a higher than normal ratio of fines.

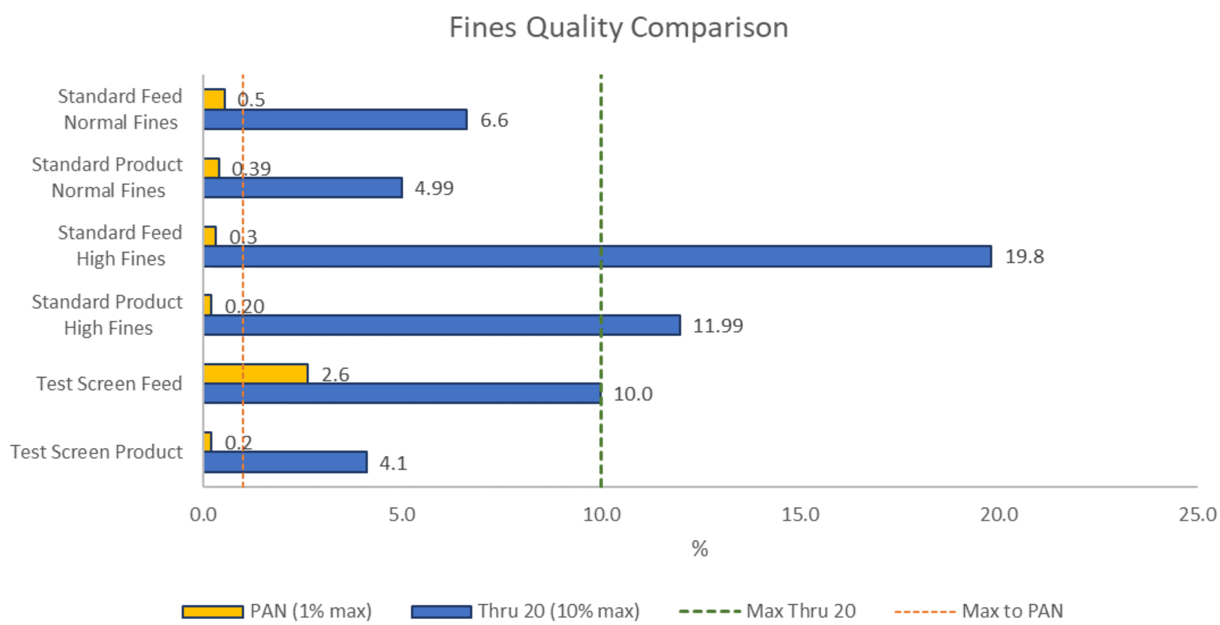

Figure 9: Comparison of standard screen configuration feed/product fines, both in specification and out of specification (OOS), and the test screen feed/product.

Figure 9 shows a comparison of the fines content for both the feed and product streams out of the Rotex for the test screen trial, and standard screen configuration with normal and high fines feed content. This illustrates a significant increase in the amount of fines screened out of the product stream, and a potential elimination of product streams out of quality specifications.

Optimizing for Inefficient Screening: Rejecting Material within Product Specification

As seen in Figure 10, a significant amount of the material that was rejected to the PAN was within product specifications, while almost all fines were rejected. In this case, 72% of the material rejected to the PAN stream, which amounts to as much as 20% of the total feed into the Rotex, was within product specification.

If reduced, the overall yield could be increased by up to 14%. This is not the desired target however, as the rejected fines are passed to another screening stage for a secondary product stream. In order to increase the product yield without eliminating the secondary product stream a more conservative target was determined, with a reduction in the fines reject stream composition of over 40 US Sieve material by 4 to 7%.

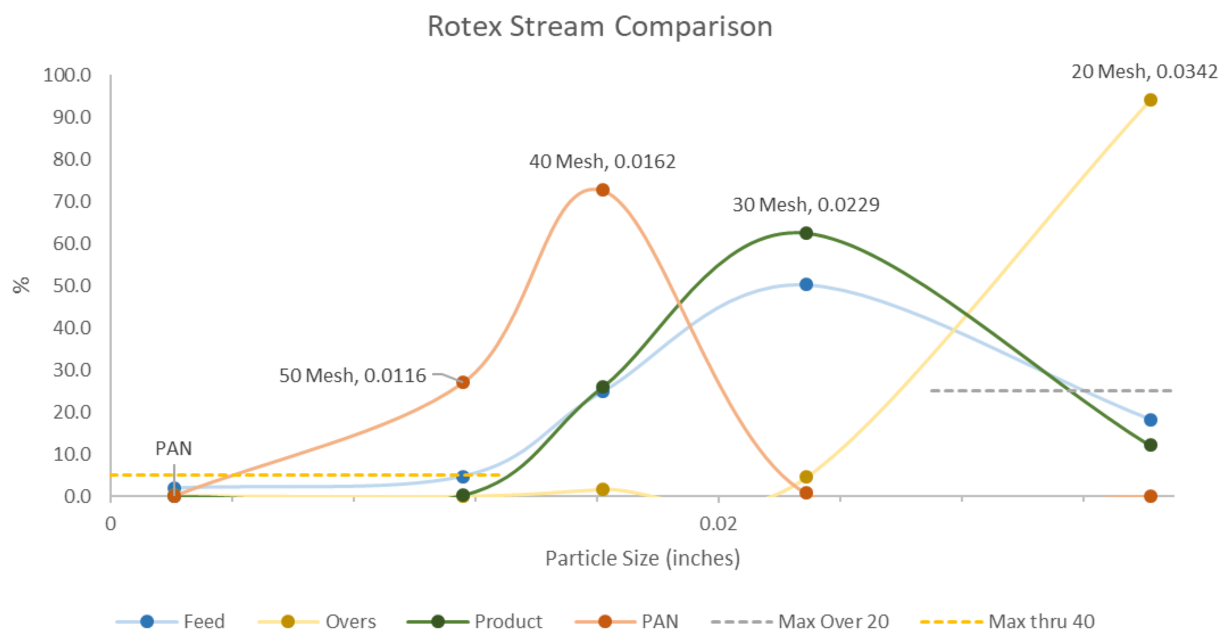

Figure 10: Rotex stream comparison of a strike with a product within quality specification. Feed, overs, product, and PAN streams with screened product specification indicated by dotted lines.

The screen selection that resulted in the excess material rejection was a 34 mesh tensile bolt cloth bottom screen. This has openings of 0.0229", compared to the 0.0167" openings of the 40 mesh US Sieve. A 38 mesh tensile bolt cloth bottom screen with openings of 0.0198" was selected for testing, which has larger openings than the sieve. This would allow for some rejection of material within product specification for the secondary product stream while meeting the yield increase target and accounting for screening inefficiency.

Figure 11 shows the material over and through 40 US Sieve content for the feed, product, and PAN streams out of the Rotex for the test and standard screen configurations, with normal and high fines feed content for the normal configuration. This illustrates a reduction in the over 40 material composition of the PAN stream by 5.2%, despite a higher over 40 content in the feed stream during the test screen trial, which equates to a net product yield increase of >1%. The yield could be increased further at the expense of the secondary stream, but this has met the target for this trial.

These trials were performed for all confectioner grades, but final implementation, production data, and efficacy determination has been effectively collected and analyzed for two of these grades, designated CONA and Special Coarse. As seen in the data, yield increased for CON A and SCSE grades by 10% and 11% respectively.

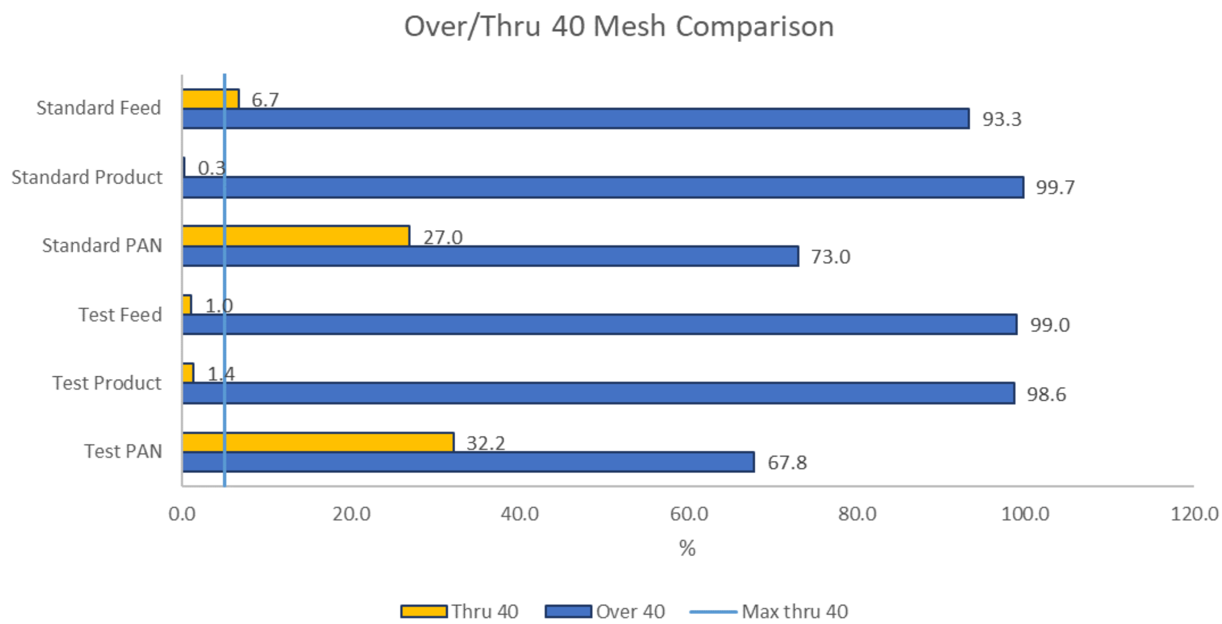

Figure 11: Comparison of material over and through 40 Mesh US Sieve for the feed, product, and pan streams for both standard and test Rotex screen configurations.

Grade	Standard Configuration			Updated Configuration		
	Srike Yield	Strikes OOS	Net Yield	Strike Yield	Strikes OOS	Net Yield
CON A	95%	13%	**83%**	93%	0%	**93%**
SCSE	77%	15%	**65%**	79%	3%	**76%**

Table 1: Yield comparison for two confectioner grades between the standard configuration and the updated configuration tested in the optimization trials.

Conclusion

Screening optimization can be an extensive and time consuming process. It involves close interdepartmental cooperation along with the administrative impetus and resource commitments to carry out. Depending on the screens selected for testing and the variability of strike crystal size distribution, it can take multiple trials and ongoing monitoring. For these trials screening optimization was performed on all five confectioner grades processed at C&H, but only two grades have enough data to fully establish efficacy and warrant full implementation. Even with the partial progress for pending trials, the net change for all grades has been positive, increasing the yield and throughput of the confectioner line. Given the significant increase in yield for the CONA and Special Coarse grades, testing has already seen success and will continue until inefficiency and recycling have been minimized for all grades.

Appendix A

U.S. Std. Sieve		Particle Size		Tensile Bolt Cloth			Market Grade		
Std Sieve	Opening Inches	Inches	Microns	Mesh TBC	Opening Inches	Opening Microns	Mesh MG	Opening Inches	Opening Microns
5	0.1575	0.1570	4000				5	0.1590	4039
6	0.1319	0.1320	3350				6	0.1318	3348
7	0.1102	0.1110	2820				7	0.1080	2743
8	**0.0929**	**0.0937**	**2380**				**8**	**0.0964**	**2449**
10	0.0787	0.0787	2000				10	0.0742	1885
		0.0730	1854				11	0.0730	1854
12	**0.0669**	**0.0661**	**1680**	**14**	**0.0620**	**1575**	**12**	**0.0603**	**1532**
14	0.0551	0.0555	1410	16	0.0535	1359	14	0.0510	1295
16	0.0465	0.0469	1190	18	0.0466	1184	16	0.0445	1130
		0.0410	1041	20	0.0410	1041			
18	0.0394	0.0394	1000	22	0.0380	965	18	0.0386	980
20	0.0335	0.0331	841	24	0.0342	869	20	0.0340	864
		0.0310	784	26	0.0310	787			
25	0.0280	0.0278	707	28	0.0282	716	24	0.0277	704
		0.0268	681	30	0.0268	681			
		0.0248	630	32	0.0248	630			
30	0.0236	0.0234	595	34	0.0229	582			
		0.0213	541	36	0.0213	541	30	0.0203	516
35	0.0197	0.0197	500	38	0.0198	503			
		0.0185	470	40	0.0185	470			
		0.0183	465	42	0.0183	465			
		0.0172	437	44	0.0172	437	35	0.0176	447
40	0.0167	0.0165	420	46	0.0162	411			
		0.0153	388	48	0.0153	389	40	0.0150	381
		0.0145	368	50	0.0145	368			
45	0.0140	0.0139	354	52	0.0137	348			
		0.0130	330	54	0.0130	330			
		0.0127	323	58	0.0127	323			
		0.0122	310	60	0.0122	310			
50	0.0118	0.0117	297	62	0.0116	295			
		0.0111	282	64	0.0111	282	50	0.0110	279
		0.0106	270	70	0.0106	269			
		0.0102	260	72	0.0102	259			
60	0.0098	0.0098	250	74	0.0098	249			
		0.0095	241	76	0.0095	241			
		0.0091	231	78	0.0091	231	60	0.0092	234
		0.0088	224	80	0.0088	224			

Table 2: US Sieve, Particle Size, Bolt Cloth Conversion Table [1]

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[1] "Particle Size / Mesh Conversion Chart." *Powder Technology*, Powder Technology Inc., 3 Dec. 2023, www.powdertechnologyinc.com/particle-size-mesh-conversion-chart/.

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