Effects of new drainage, retention, and formation technology for improving production rates and runnability of recycled fiber cylinder machines

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ABSTRACT

Multivat cylinder paper machines typically manufacture recycled paperboard from a variety of fiber sources. They operate under a high degree of water closure leading to several problems. A new wet-end chemical program provides improved production rates and runnability without changing the incoming fiber mix. The system uses a high molecular weight cationic dispersion or emulsion polymer with a modified natural polymer. The new system does not require any change in operating conditions or involve any mechanical modifications to the paper machine. Long-term use of the new additive program has led to machine speed increases of 6–8% and reductions in operational downtime of 13–25%.

Application:

A combination of water soluble additives increases production rates and runnability in the manufacture of recycled paperboard.

THE PULP AND PAPER INDUSTRY has long excelled in recycling. Additional demands and regulations now dictate the necessity to recycle even more waste streams of lower fiber quality. These outside forces and additional sources of post-consumer fiber cause additional volatility in the recycled fiber market.

Multi-ply cylinder machines have long been the workhorses of the recycle market. They produce a variety of products including gypsum wallboard facing, tube stock, and chipboard. Recycled fiber pricing, availability, and quality are quite volatile in today's market. These factors can strain the ability of a recycled fiber mill to produce consistent product quality and quantity economically.

Specialty chemicals have found wide applicability in these mills. They improve drainage and retention; prevent inorganic scale and deposits; and provide biological control, contaminant passivation, defoaming, etc. *(1)*. High molecular weight charged polymer drainage/retention (D/R) aids the prime chemicals to control wet-end performance. D/R aids have grown to widespread use over the last two decades for improving first-pass retention and free water drainage in the cylinder vat *(2, 3)*. These D/R aids are typically single component, high molecular weight, charged, acrylamide-based polymers. The flocculating action of these synthetic polymers on all solid components of the dilute stock aids in retention. Although the flocculated solids allow water to drain through the cylinder mold at a greater rate, they can reduce the mass uniformity of the individual ply—formation. This reduced formation can manifest itself in appearance in the outer plies. It can also affect the inner ply bonding and subsequent water removal through the multiple plies. One can predict performance of these D/R aids using standard laboratory procedures such as CSF and Britt jar retention testing.

The objective of this work is to introduce a new drainage/retention/formation (D/R/F) program that goes beyond the standard, single polymer D/R aid to provide enhanced production and runnability in cylinder machine operations. The new D/R/F program uses a high molecular weight, cationic emulsion or dispersion polymer—similar to a D/R aid—with a modified lignosulfonate. Both polymers are water soluble. For simplicity, we will refer to the high molecular weight cationic dispersion polymer as a D/R aid and the lignosulfonate as a D/R/F aid. The synergistic combination of the two will be the D/R/F program. We will show that standard laboratory test methods have limited use in predicting the performance of this D/R/F program. We also discuss results of standard laboratory testing of a synthetic recycled furnish's response to a D/R aid and the new D/R/F program. This paper presents the results of an on-machine evaluation of the dosage level and paper machine response for both treatments. In addition, we analyze the impacts of long-term use of this new D/R/F program for three paperboard grades made on the paper machine used in the evaluation.

EXPERIMENTAL

Laboratory studies

Preparation of synthetic recycle pulp furnish. Due to the variability in furnish at most recycle paper mills, we synthesized a reproducible standard recycle furnish. This allowed fiber and water chemistry uniformity between experiments. We determined "typical" water chemistry by averaging six samples of white water from three recycle mills subjected to standard mineral analysis and testing. Table I lists the important aspects of this furnish.

Testing of synthetic recycle pulp furnish. We evaluated the synthetic furnish using standard laboratory methods under various treatment conditions. A Schopper-Riegler drainage tester determined drainage rate, and a vaned Britt dynamic drainage jar fitted with a 30-mesh screen evaluated first-pass retention. Table II describes the sequence for treatment of the furnish. This sequence is a combination of calculated residence times from the actual machine approach piping system—to determine injection times—and actual first-pass retentions averaged across all vats—to determine mixing speed.

Following are the definitions of the treatment levels. Addition of the single D/R aid polymer was in 0.2 lb/active ton increments over a range that has been typical for cylinder paper machines. Addition of the single product program was only post-screen to simulate the most common addition point in these types of systems. The addition of the two products for the D/R/F program occurred in the following manner. We added the D/R aid pre-screen and the second natural polymer product—the D/R/F aid—post-screen. Application of the D/R aid was at the same dosage levels as in the single product testing and for the D/R/F aid was at a 1:1.2 ratio of active D/R aid polymer to active D/R/F aid. This addition sequence and ratio form the optimum using previous on-machine evaluations.

Fiber	25/25/25/25 OCC/Chipboard/ONP/ Xerographic (MOW)
Water	400 ppm Ca, 500 ppm Na, 150 ppm Cl, 1500 ppm SO_4^{-2}
Consistency	0.5%
Conductivity	~ 3500 μΩ
pH	~ 6.5

OCC = old corrugated container
ONP = old newsprint
MOW = mixed office waste

I. Synthetic recycled furnish composition

Mixing time, sec	Unit operation	Mixing speed, rpm	Comments
t_0	-	1200	Begin agitation
t_5	Pre-centri-screen	1200	Add D/R aid
t_{15}	-	600	Reduce mixing speed
t_{20}	Post-centri-screen	600	Add D/R/F aid
t_{30}	-	-	Conduct test

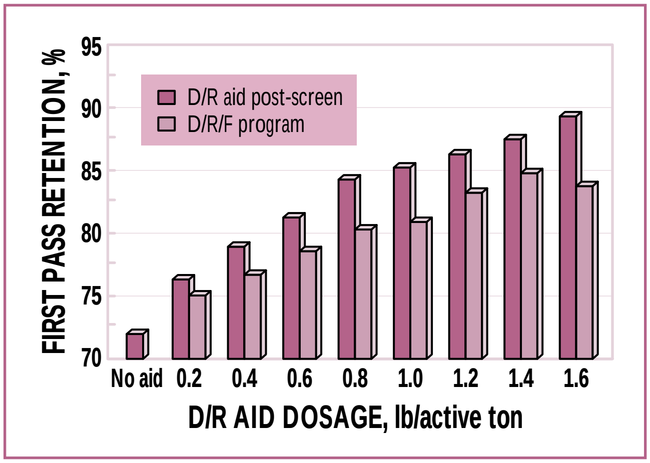
II. Synthetic furnish treatment sequence

	POST-FAN PUMP		POST-CENTRI-SCREEN	
Test	Product	Dose, lb/ active ton	Product	Dose, lb./ active ton
1	-	-	D/R aid	0.12
2	-	-	D/R aid	0.23
3	-	-	D/R aid	0.34
4	-	-	D/R aid	0.45
5	D/R aid	0.21	D/R/F aid	0.27
6	D/R aid	0.32	D/R/F aid	0.39
7	D/R aid	0.42	D/R/F aid	0.54
8	D/R aid	0.53	D/R/F aid	0.68

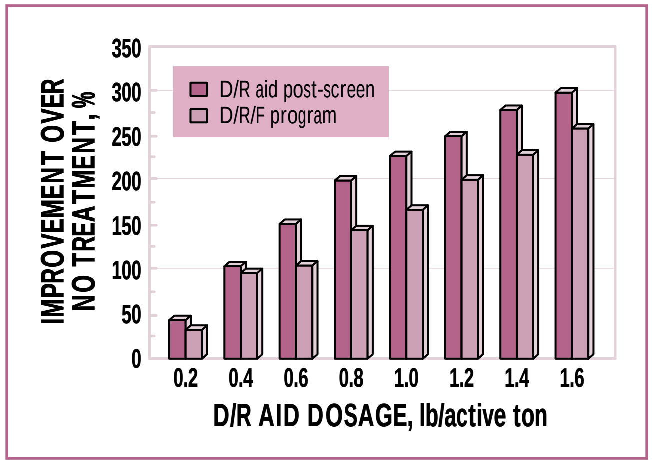
III. D/R/F program feed points and treatment levels evaluated

On-machine studies

The objective of these studies was to determine the dosage related impacts of the single D/R aid standard application and the new, dual product D/R/F program on an actual multivat cylinder paper machine. The paper machine itself had a ten-vat forming section, three conventional presses (two with vacuum), 88 can drying section, and two calender stacks. The machine had a 96-in. width with 87-in. trim and could run at 500 ft/min. Our study used approximately 16 h of machine run time with as many conditions as possible maintained at fixed values. The grade—31 point tube—and basis weight—100 lb/1000 ft^2—remained fixed while evaluating eight feed point and product dosage combinations. Table III shows details for the



1. Synthetic furnish laboratory testing showing percentage of first-pass retention



2. Synthetic furnish laboratory testing showing Schopper-Riegler drainage as percentage improvement over blank

Wet end

Vat drainage rate, vat level, vat level valve position, thick stock flow rate, thick stock flow valve position, entrained air level, first pass retention, refiner amperages, furnish freeness, furnish mix, saveall efficiency

Dry end

Press loadings and vacuum levels, steam flow, steam pressure, dryer section differentials, wet sheet weight, dry sheet weight, on-machine caliper, sheet temperature at reel, machine speed, breaks, downtime

Product quality

Basis weight, caliper, moisture, Mullen, stiffness, immersion test (sizing), ply-bond, ring crush, visual appearance and defects, reflectance formation index (M/K)

IV. Operating parameters monitored during evaluation

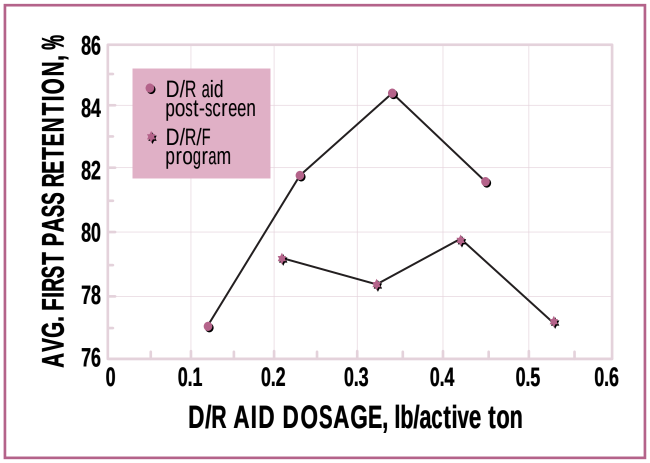
combinations. We maintained each treatment condition for approximately 1.5–2 h until reaching operating system equilibrium. Machine operators maintained normal machine conditions during the period. We measured as many operating parameters as possible and recorded them toward the end of each treatment condition period. Table IV lists all the operating parameters measured or recorded directly in each evaluation period.

We measured retentions by determining solids on vat and white water samples from each cylinder mold. We made entrained air measurements on each cylinder using a sample from the vat and a standard entrained gas tester. Drainage evaluation used a 500-mL drainage tube fitted with a 100-mesh screen at one end and rubber stoppers at both ends. We filled the tube with 500 mL of vat stock from each cylinder, sealed it, inverted it four times, allowed the sample to drain through the screen, and recorded the time required to drain the first 100 mL of sample.

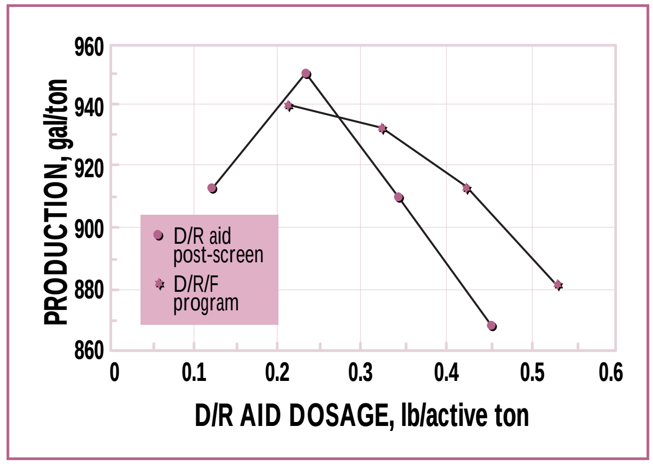
RESULTS AND DISCUSSION

Laboratory studies

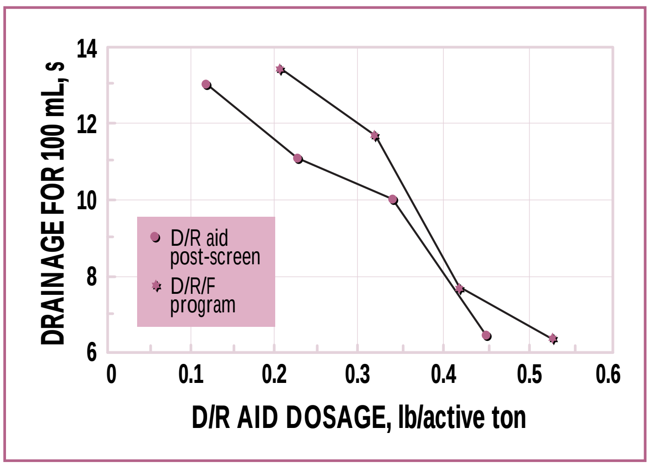
The purpose of these controlled experiments was to compare the impacts of the new D/R/F program to the known impacts of a D/R aid alone. We hoped the operational changes expected on the paper machine would occur in the laboratory. Figure 1 presents the results of first-pass retention evaluations. The control with no aid is an average of three tests. Figure 2 shows the laboratory drainage rate results as percentage improvement over no treatment measured by Schopper-Riegler drainage tester. Note that both drainage rate and first-pass retention are lower for the two component D/R/F program than the single polymer D/R aid at each dosage level. These results are the direct effect of increasing the shear energy applied to the high molecular weight cationic dispersion D/R aid by moving it from post-screen to pre-screen. This change has a greater effect on these laboratory test results than it does on the actual cylinder machine performance results as seen shortly. It is not unusual that the performance of a D/R aid decreases when exposed to greater mechanical shear forces.



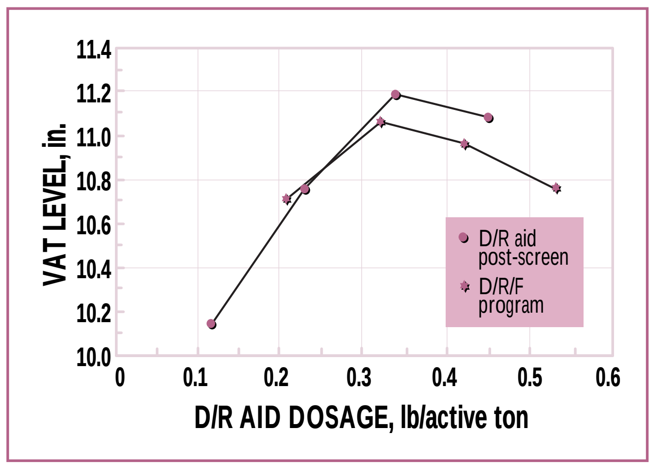
3. Wet-end operations showing average first pass retention as percentage of total vats



4. Wet-end operations showing average thick stock flows per vat in gallons/ton of production



5. Wet-end operations showing average drainage time for 100 mL stock per vat in seconds

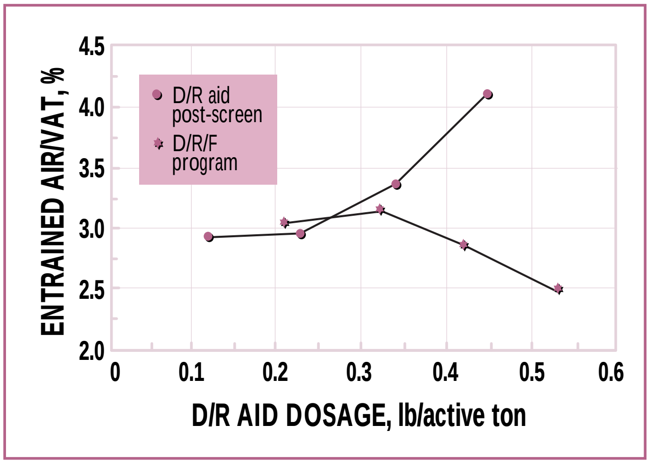


6. Wet-end operations showing average vat levels as inches

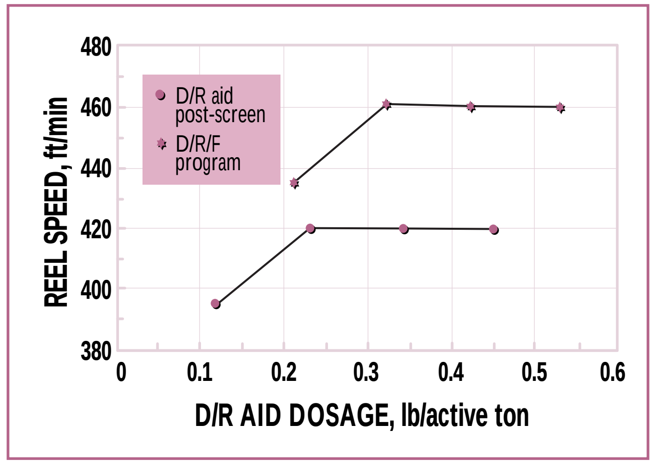
On-machine studies

Our primary goals during the on-machine dosage studies were keeping the incoming furnish and outgoing grade and weight variations to a minimum and allowing the paper machine and operators to respond solely to changes resulting from the variations in the chemical treatment program. We tried to capture as many of those responses as possible as Table IV lists. Discussion will focus on responses that varied significantly and were due to the chemical treatment program. For example, note that refiner amperage varied significantly. This was only to adjust for normal incoming furnish changes so there is no discussion.

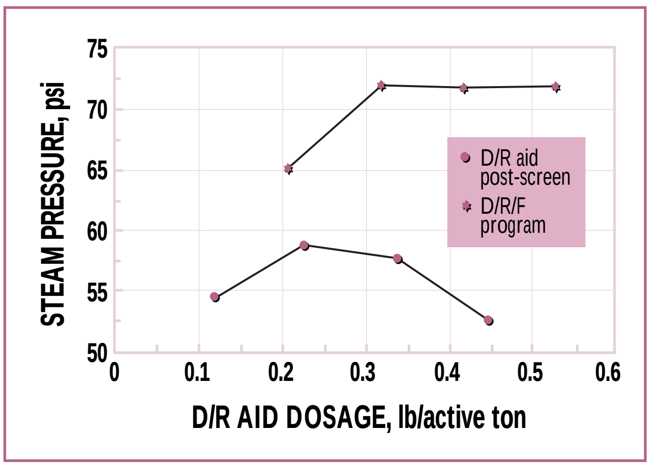
Wet-end performance characterization. The greatest anticipated changes would be in the cylinder vats themselves. Typical single component D/R aids help in both retention—capturing the solids and sending them out with the paper—and drainage. This helps the water move through the forming mat and mold wire. The cylinder forming process is subject to several drainage related problems. These include "roll back" (stock rejection from the couch nip) and "crushing" or "rolling" (stock buildup and rolling in the vat next to the mold). For the particular paper machine under study, the drainage aspects of the D/R aid are most critical in obtaining optimum operating speeds. It is especially necessary to avoid crushing in the vats, since this causes an unacceptable finished sheet defect. It is difficult to quantify these drainage aspects other than by visual observation. These measures of performance in the vats often limit production rates even when steam, speed, and fiber are available.



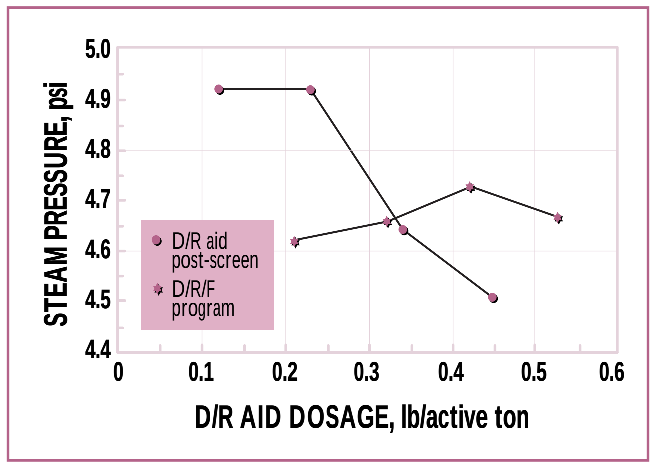
7. Wet-end operations showing average amount of entrained air per vat as percentage



8. Dry-end operations showing reel speed for 30 point tubing grade in ft/min



9. Dry-end operations showing main dryer section steam pressure in psi



10. Dry-end operations showing total steam flow from boilers in 1000 lb/ton production

We will first review the retention data followed by the drainage related data. As Fig. 3 shows, first-pass retention results obtained from on-machine sampling agreed with the laboratory results in Fig. 1. First-pass retentions for the new two component program were consistently lower for equal D/R aid dosage levels. We expect this result due to the shift of the D/R aid feed point from post-screen to pre-screen and the subsequent reduction in floc size due to the additional shear. This data, however, does not provide the entire picture in terms of total retention. The vat to vat first-pass retention variations were greater than the differences between dosages presented in Fig. 3. This shows that these numbers are difficult to measure accurately. A comprehensive indication of total retention results from the averaged thick stock flow per vat per ton presented in Fig. 4. The last three points of each curve were at constant machine speed and dry sheet basis weight. This indicates an increase in first pass retention with increasing dosage for both treatment programs. In judging what really happened with these apparently conflicting results, it is more accurate to look at the total inflow vs. outflow of solids rather than the limited view provided in the first-pass retention measurements. This view shows improved first pass retention using the D/R/F program. It also shows that static laboratory testing cannot always simulate the total dynamics of a paper machine.

The other key aspect of wet-end performance is drainage in the cylinder vats. The results show a conflict similar to that seen for the retention data reviewed above. Figure 5 shows the "limited view" provided by the static drainage testing performed using a 500-mL drainage tube on each vat. This figure shows slower drainage rates for the D/R/F program at equal D/R aid dosage exactly as Fig. 2 would predict. This opposes the "total view" measurements such as the vat pond levels recorded in Fig. 6. These results show equal or lower pond levels indicating equal or better drainage for the D/R/F program at equal D/R aid dosage, although the production rate is higher for the D/R/F program. Another "total view" measurement is entrained air. Increasing entrained air impedes drainage rate *(4, 5)*. Figure 7 indicates that entrained air levels for the D/R/F program were equal to or less than the D/R aid levels at equal D/R aid dosage. Of more importance, the D/R/F program showed a trend in the opposite direction to the single D/R aid. This indicated the synergistic impact of the modified lignosulfonate D/R/F aid. It is again more accurate to look at machine operating data and tests such as entrained air rather than static drainage tests. These results indicate an improvement in total drainage rate for the D/R/F program.

Dry-end quality performance characterization. It is common knowledge that any polymer treatment program can have significant influence beyond the forming section of the paper machine. This influence can be positive or negative. As mentioned in the previous section, either steam pressure or vat performance typically but not exclusively limits the production speed for this paper machine. For the four dosages run with the single D/R aid post-screen, steam was available. Crushing in the vats prevented further increases in speed above 420 ft/min as Fig. 8 shows. The vat crushing problems increased with each D/R aid dosage increase until they were severe enough to cause sheet defects at the highest single polymer D/R aid dosage of 0.45 lb/active ton. We reduced the dosage immediately after gathering the data to prevent a sheet break. For the new D/R/F program, vat performance was excellent. Steam became the limiting factor at 460 ft/min as Fig. 8 shows.

Steam flow from the boilers showed the same trend as steam pressure in the dryer section as Figs. 9 and 10 indicate. A key indicator of total drying efficiency is the sheet temperature before the calender stacks. We measured this with an infrared sensor at the subject mill. Figure 11 gives the values of the sheet temperature at the different treatment levels. The single-component D/R aid program varied erratically while the new D/R/F program produced steadily increasing sheet temperatures until the highest dosage. Mill personnel often indicated confirmation of these two observations previously. The board coming off the reel did not vary significantly in any quality parameters during the trial except a slight loss in Mullen burst strength test during the D/R/F program treatments. We also note this occurrence in the long-term production effects discussed below. Reel samples from each set underwent surface formation analysis using a M/K Formation Tester (model M/K950R). Surface formation was good at the higher production rates as a net average formation index of 20.6 during post-screen D/R aid addition and a 19.8 average formation index during the D/R/F program treatment indicate. There were no net trends in formation index vs. dosage, and the above numbers are statistically equivalent.

Several qualitative observations are worthy of mention after this review of the quantified aspects of our evaluation. The variables mentioned in Table IV but not discussed either did not vary significantly or varied in response to outside influ-

	PAPERBOARD GRADE		
Treatment program	Tubing	Chipboard	Folding carton
Single D/R aid	550	555	525
D/R/F program	314	245	299

V. Running time hours for historical grade analysis

Grade	Reel speed	Moisture	Down time
30 point tubing	+6.6%	-10.1%	-21.7%
31 point chipboard	+6.4%	-8.6%	-13.5%

VI. Historical production values for chipboard and tubing grades

Grade	Mullen	Ring crush	Immersion	Ply-bond
30 point tubing	-5.6%	+3.5%	+2.9%	+0.9%
31 point chipboard	-9.8%	-0.9%	+21.1%	-6.8%

VII. Historical quality values for chipboard and tubing grades

Reel speed	Moisture	Down time
+7.5%	-4.9%	-25.4%

VIII. Historical production values for folding carton grade

BCMD	BCOD	Smoothness	Water drop	U-bond
+2.3%	+3.8%	-1.8%	-6.3%	-6.3%

BCMD = Block compression machine direction
BCOD = Block compression other direction

IX. Historical quality values for folding carton grade

Grade	Amperage	Freeness
30 point tubing filler	+18.5%	+4.1%
30 Point tubing liner	+19.9%	+2.2%

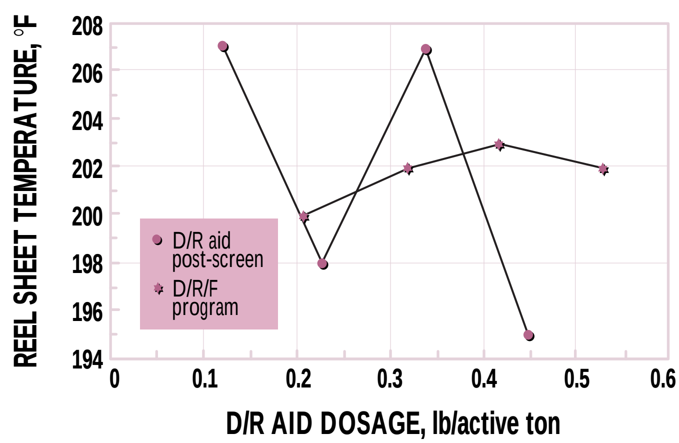
X. Refining amperage and stock freeness for historical tubing grade

ences. The refining amperage mentioned earlier is an example. The apparent "leveling effect" of the new D/R/F program seen in Figs. 10 and 11 was also apparent in other aspects of the paper machine operation. Cross-machine profiles leveled out and required fewer wing adjustments in the vats. Saveall efficiency reached almost 100% without any chemical treatment. Operators reported this effect at this mill and others using the new D/R/F program. The paper machine did not experience a single break during the entire evaluation.

Long-term production effects characterization. The speed increases attributed to the new D/R/F program over the single-polymer D/R aid came during a controlled short-term evaluation. The myriad of variables affecting day to day operations of a recycle mill could easily explain this speed increase. One could therefore ask how this new D/R/F program performs over the long term. To answer this question, we compiled historical data for three major grades for two years at the subject mill. The 24-month period from May 1993 to May 1995 used the single D/R aid applied at both pre-screen and post-screen feed points. Ten months used the new two-component D/R/F program. Note that for the last six months of the single polymer D/R aid treatment program, the D/R aid feed point was moved to the pre-screen feed point and the dosage was increased by 20% to help drainage and retention in the vats. This change did help vat performance but was not significantly distinguishable from the other eight months of single-polymer D/R aid treatment. This again emphasizes the synergistic effects of the D/R/F program. The data was an average of the values during a given grade run with weighting of the averages against the length of time in hours of the run. Table V presents the total hours running on a given grade. We then calculated total weighted averages for the 14-month period of the D/R aid treatment and the ten-month D/R/F program treatment. Tables VI and VII present the percentage change progressing from the single D/R aid to the new D/R/F program for tubing and chipboard grades. Tables VIII and IX show a folding carton grade. The speed increases for each grade are significant. The consistent decrease in moisture indicates that more speed may still be available. Historical dryer section steam pressures were not available. The most startling finding was the reduction in operational downtime due to breaks, blows, or other nonmechanical reasons. Most of the quality variables did not appear to change significantly as one would expect. There were consistent decreases in Mullen and ply bond or U-bond on two grades, however, and consistent increase in water pickup—increase in immersion test or decrease in water drop test—across all grades. While these changes are significant, the paperboard produced is still well within the quality specification requirements. The production changes are far more significant since the mill is always trying to run as fast as possible within its quality and capacity limitations.

As another check, we compiled refiner amperages and stock freeness levels for the tubing grade over the same period. Table X shows these findings as percentage differences between the two treatment regimens. This information shows that even with increased refiner amperages—exaggerated by increased production rates—the stock became more free. There are no complete records available for the daily furnish mix to determine if there were any significant changes. A review of monthly records indicated no significant changes, however. This possible furnish change and the significant moisture level drop may be partly responsible for the Mullen *(6)* and sizing changes noted in Tables VI–IX.

KEYWORDS
Additives, cylinder machines, drainage aids, fibers, formation, lignosulfonates, machinery, paper machines, paper making equipment, productivity, reclaimed fibers, retention aids, runnability, sulfonates, wet end additives.



11. Dry-end operations showing sheet temperature at reel in °F

SUMMARY AND CONCLUSIONS

We have evaluated a new D/R/F chemistry both in the laboratory and on a cylinder paper machine. Following is a summarization of the D/R/F program and its impacts:

- The D/R/F program is a high molecular weight cationic dispersion or emulsion polymer and a modified lignosulfonate (patented).
- Traditional laboratory methods or static tests do not appear to model accurately the actual on-machine performance of this D/R/F program.
- Dynamic tests and total measurements of machine performance prove the synergistic impact of the two components in the new D/R/F program.
- Long-term use of the D/R/F program has provided 6.4–7.5% improvements in paper machine speed and 13.5–25.4% reductions in operational downtime for the cylinder type paper machine studied. TJ

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