Winding and Reeling Quality and Productivity Optimization

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ABSTRACT
A real-time parent reel or wound roll caliper and density measurement system has proved to be a valuable tool for monitoring, diagnosing and solving problems associated with the compression of paper during the reeling and winding process. Extremely precise roll diameter measurement, based on roll and drum rotation sensing, is accurate and responsive enough to detect small changes in wound-in compression as the parent reel or roll builds.

Paper quality diagnostics include wound-in caliper and density profiles, which show the tightness of reeling or winding as a function of diameter. A new technique has been developed to obtain wound-in caliper profiles during the critical period when the reel is in the primary arms.

These on-line measurements, either portable or permanently installed, have been used to diagnose and solve crepe wrinkling, paper bursting and other roll structure or web break problems. Solving these problems has resulted in reduced paper waste in a number of mills.

This technology also serves as the measurement foundation for a diameter-based reel size optimization system. These systems reduce chronic reel overbuild and left-on-spool losses by providing precise, real-time diameter, caliper and density measurement. A reel turn-up alarm allows the backtenders to precisely make the correct amount of paper required for downstream winding process, with no excess wastage. The wastage monitoring systems have also been used in complex finishing lines to determine the degree and location of slab-off losses from parent reels, during the supercalendering process and in winding. Precise diameter measurements, RFID spool tracking and winder cycle state inference allows automated allocation of time and slab loss amounts and types. Case studies, in single-line and multi-line mills, demonstrate loss reductions of 2 to 4 % of gross production.

KEYWORDS
Reel density and diameter measurement, dry end losses, tear-off, winder loss management

INTRODUCTION
In paper mills, the winding and reeling process is typically the source of both intermittent and chronic quality and productivity issues. It is not uncommon for several percent of gross production to be wasted as left-on-spool losses and other "unaccounted" losses. The unaccounted shrinkage problem is even more severe in multi-line mills where paper machine parent reels are processed in multiple off-line coaters, supercalenders and rewinders.

Some of the chronic losses are related to quality issues like crepe wrinkling and other built-in roll structure defects. Often, parent reels are overbuilt to compensate for these defects. This practice, which is not effectively measured or regulated, often leads to excessive left-on-spool losses. Parent reel or wound roll diameters may not be controlled precisely. Hence, parent reels are built to higher than needed diameters and the waste problem is aggravated, or inappropriately based on length for orders which are based on roll diameter.

The diagnosis of winding and reeling problems and unaccounted shrinkage losses is difficult due to the lack of visibility of roll and reel quality and how much paper is actually wound in. The immediate, real-time measurement of the reel or roll density machine-direction uniformity and precise diameter is lacking. Usually, it is not known precisely how much paper is wound in a parent reel and whether it is just enough to satisfy the downstream finishing processes in the mill, with a minimum of waste.

There are huge savings to be realized in almost all paper mills by making the transition from the typical error prone length or tape measure and look-up table based reel turn-up approach to a more controlled approach based on precise measurements. Reduction of unaccounted losses can produce a large return on investment for most paper mills with a typical payback time of three to nine months.

The starting points for an unaccounted waste reduction program are the measurements of the

roll or reel structure and the reel or roll diameters at all stages of the process. Once these measurements are in place the losses can be quantified and real progress can be made.

BACKGROUND

LSZ PaperTech Inc. of Toronto and Vancouver, Canada, has focused on supplying process automation systems and consulting for reeling and winding quality and productivity optimization since it was formed in 1992 by three papermaking physicists.

LSZ combines advanced, commonly available computer technology with the best available product and process physics expertise to provide paper wastage monitoring and control systems and process expertise for its customers. These products and services have led to improved roll and reel quality, improved production from existing equipment and reduced waste on its customers' paper making lines.

ON-LINE MEAUREMENT OF LENGTH, DIAMETER, CALIPER AND DENSITY

The heart of a loss tracking system is the ability to accurately determine the precise diameter of rolls and reels in the production line. With a basis weight input, the calculation of paper losses in the line is possible. At every process unwind or windup station and for every stop, start, eject, turn-up and break event, the measurements record the precise diameter and caliper of the reel or roll being built or unwound. This technique is generally applicable to any reeling or winding operation, including the paper machine reel, re-reelers, supercalenders, off -machine coaters and winders.

Reel or roll diameters are determined through a calculation which uses rotation counts of the building or unwinding roll or reel and pulses counted from a tachometer on a reference roll having a known diameter. The reference rolls are typically a paper machine reel drum, a supercalender drive roll or a winder back drum. The accuracy and resolution relies on the use of a very precise measurement of length during a fixed number of revolutions of the winding or unwinding roll or reel. This is typically achieved by counting pulses for the reel or winder drum using a tachometer having 60 to several thousand pulses per revolution. The principle of measurement is shown in Figure 1.

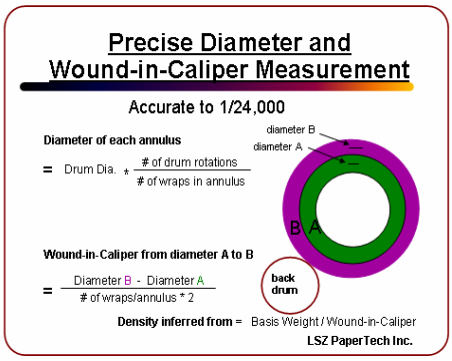

Figure 1: Principle of on-line diameter and wound-in caliper measurement

A high resolution pulse count provides an extremely precise measurement of the length of paper wound into a defined number of reel or roll rotations. Dividing this length by π and the number of rotations yields the diameter. Diameter resolution of 1 part in 24,000 is typical. This corresponds to precision of about two sheet wraps in the building reel or roll. Caliper is calculated from the diameter and length measurements. Density is calculated from the caliper measurement using a basis weight input. In a papermaking line, the speed, length and diameter measurements, together with basis weight, are used to calculate mass losses from the parent reel to the finished, wound product.

NEW MEASUREMENT REFINEMENTS

The basic method of determining diameter and wound in caliper from these signals has been well known since the 1980s[1] when it was developed for assessing wound roll structure. Since then, this algorithm has been developed progressively to achieve the accuracy and robustness required for loss tracking in instances where some slippage on the reference roll can occur.

With increasing power, speed and decreasing cost of computer processing it has be possible to achieve the accuracy and resolution of a tachometer having several thousand pulses per revolution using a one pulse per revolution signal. This is done by sampling the tachometer voltage pulse train at 25KHZ or higher and interpolating between pulses to obtain the length of a partially completed pulse at the moment a calculation is triggered.

The use of a 1 pulse-per-revolution drum signal is a significant simplification since the sensors are inexpensive and can be installed in just a few minutes. An optical or magnetic sensor detects the rotation of a reflective or

magnetically coupled target on the drum or motor shaft. This permits a temporary installation for problem solving purposes with little or no requirement for downtime or integration with mill tachometers used for drive controls or other controls. A similar optical or magnetic sensor measures the rotation speed of the building reel or roll.

The high resolution that this new measurement and signal processing development achieves has made it possible to obtain wound in caliper profiles in the building paper machine reel during the period when the reel is in the primary arms.

DENSITY MEASUREMENTS SOLVE REELING AND WINDING PROBLEMS

These measurements were initially used for roll structure evaluation of wound sets on winders. Portable RDM units have been used on paper machine reels, supercalenders and many other winding or unwinding processes. The purpose has been to investigate and solve problems of reel or roll structure such as crepe wrinkles, telescoping, and out-of-roundness. Crepe wrinkling problems on paper machine are often associated with primary and secondary arm loading, nip relief, timing of the transfer from primary to secondary arms and lack of standard operating procedures.[2]

In a Canadian newsprint mill a portable density monitoring system was used to tune the bumpless transfer from primary to secondary arms and thereby avoid a drop in density at the point of transfer[3]. This retuning avoided chronic crepe wrinkling and left-on-spool losses at this point of transfer. Figure 2 shows how the machine direction density profiles were improved at the point of transfer. Much higher resolution density curves have been obtained after this early work shown here.

Figure 3 shows the reel building structure during the entire period when the reel bar is in the primary arms. This was made possible by the new measurement technique. Although the controls appeared to function properly, a deeper investigation found significant problems with the nip relief hydraulics, which were corrected.

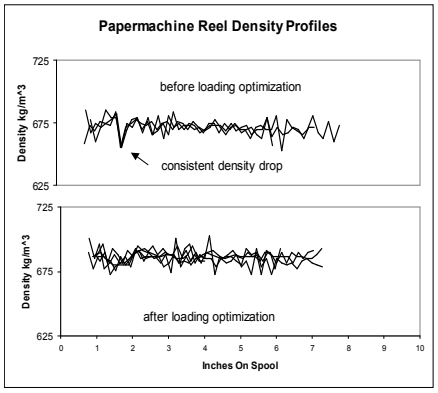

Figure 2: Tuning of the bumpless transfer between primary and secondary arms prevented a reduction in density at the point of transfer. Crepe wrinkling problems were alleviated.

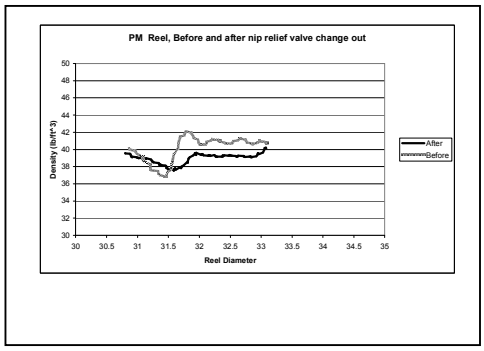

Figure 3: RDM demonstrated how density profiles were corrected by adjusting nip relief hydraulics. The density profiles are based on averages of five reels.

ON-LINE DRY END PRODUCTIVITY SYSTEMS

Permanent measurements of reel or roll diameter and density have been installed on paper machines and finishing lines and have been incorporated in comprehensive dry end productivity management systems provided by LSZ. These loss tracking systems calculate and report the flow of paper product from paper machine to the winders. These systems provide the operators with an indication of slab-off losses at various points in the process and prompt them to minimize losses by taking appropriate actions. The information from these systems has been used by paper mills to develop strategies and to implement actions to

reduce dry end waste and to improve productivity.

These systems track losses by type and reason. For instance, operator and supervisors are presented with left on-spool loss trends and are prompted when abnormal losses are detected. Mill management is presented with longer term statistics, trends and Pareto analysis for strategic decision making.

The components of a complete dry end loss tracking system include:

- Diameter and caliper (or density) measurement of every reel or roll
- Spool tracking (RFID or bar coding)
- Process state tracking, which is needed to save diameter and caliper data and perform loss calculations
- Operator displays that make it easy to use the tools, add comments, and pick reasons that make the recorded data more useful
- Integration with other mill systems for establishing standard reel identification and reporting of trim and cull losses for complete dry end loss reporting

These productivity systems also include automatic and semi-automatic functions such as stop-on-diameter roll winding and reel turn-up triggering, which ensures optimum parent reel sizing.

CASE: NEWSPRINT MILL REDUCES LEFT-ON-SPOOL LOSSES

A Canadian newsprint mill solved crepe wrinkling problems using a RDM system to diagnose and correct crepe wrinkling problems. See Figure 2. This allowed them to use potentially all the available paper on a parent reel for producing saleable wound rolls. To further reduce unaccounted dry end losses the mill installed a LSZ Roll Wastage Monitoring system (RWM) on the single winder and a Reel Turn-up Triggering system (RTT) on the paper machine reel. Both systems included permanently installed diameter and caliper measurements.

The RWM system was initially installed to precisely monitor and define the tear-off and other unaccounted losses. Using the information supplied by these systems, the baseline level for tear-off was verified to be 2.8% of production.

To build sets with a consistent amount of paper, the Stop-On-Diameter feature was incorporated in the RWM. The system calculates when the stop should be initiated using precise diameter, caliper, speed and drive deceleration characteristics. Figure 4 shows how the stop-on-diameter feature improved the accuracy of final roll diameter. Now, 80% of rolls are within 0.1 inches of target and less than 1% are more than 0.2 inches from target.

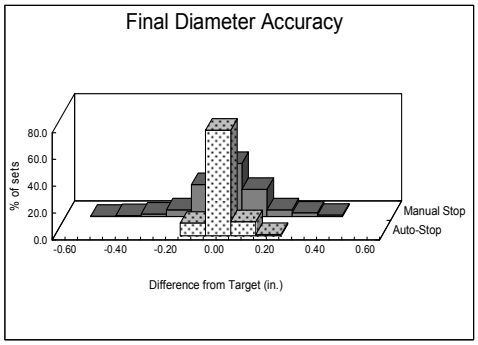

Figure 4: The Stop-on-Diameter control significantly improved the accuracy of final wound roll diameter

With consistent roll diameter, the amount of paper consumed to build a set is now very predictable. Left-on-spool losses which were due to undersized sets were therefore reduced. The operators could further reduce jacket losses since they no longer had to build in a safety margin to allow for wound rolls which were occasionally larger than the target diameter.

The RWM also gives the winder operators the ability to define sets with a minimum of splices. With a complete inventory of available jumbo reels on the computer screen, the operator can use the "cookie cutter" function to test and try combinations of jumbo reels which will produce the required sets with a minimum number of splices. "Orphaned" reels, which were taken off the paper machine because of a break, can now be more efficiently used with less waste cut down into the broke pit pulper.

Once loss tracking and consistent winder operation were achieved, the mill attacked the problem of how to build a reel with just the right amount of paper required for the winder orders. The Reel Turn-up Trigger (RTT) precisely monitors the amount of paper in the building reel, and alarms the backtender to turn

up at the precise moment needed to match the amount of paper needed for the winder orders.

While the target reel diameter is being approached, the "countdown clock", a large character video display, shows the operator the minutes and seconds left before turn-up. Two minutes and thirty seconds before turn-up, a warning light is activated, providing the operator with sufficient time to prepare to turn-up the moment the countdown reaches zero. With the RTT as an aid, the turn-ups are now precise and repeatable. This allows for consistent operation even when less experienced workers are on the job.

The backtender builds the reel to targets defined by the mill order system.
The backtender enters additional data into the RTT to accommodate for a defined amount of tear-off for testing, a minimum left-on-spool amount and a safety factor for bad starts. The backtender can also decide to precisely add extra paper on the jumbo, if the winder operator requests it to complete a partial set.

The reel turn-up and winder systems are data linked for information transfer. The linking of the systems has improved the communication between the winder operators and the machine backtenders so their activities are coordinated. This allows for more comprehensive time and paper wastage reporting.

With the wastage monitoring and control functions of the LSZ systems, tear off losses have been dramatically reduced from the baseline levels - from 2.8% to less than 1%. Figure 5 shows the downward trend of tear-off losses during the period when the monitoring system was being developed and the operator tools were being implemented sequentially.

The ongoing production savings of 10 tonnes per day have translated into a sustainable return on investment of over C$1Million per year.[3]

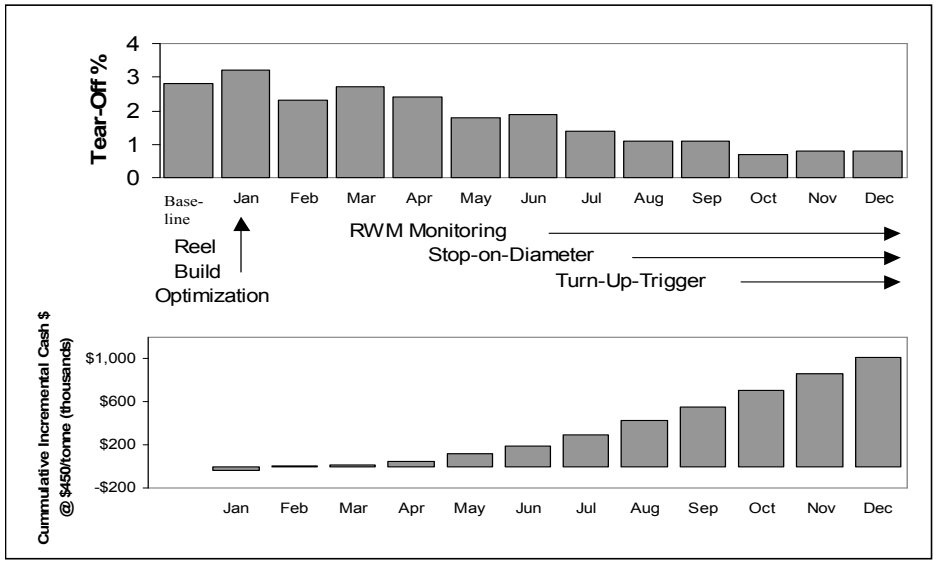

Figure 5: Tear-off losses showed a downward trend after the optimization of reel building using RDM, followed by RWM and RTT implementation. The bottom chart shows the cumulative benefits in dollars.

In addition to the wastage monitoring and operator tools, the winder system also includes a Roll Density Control function. The system controls wound in density based on target rider roll load, drum torque differential and grade-dependent tension curves.

The mill reports the system has been useful in providing an insight into roll structure, diagnosing winding problems and achieving stability in their roll quality, especially in the larger roll sizes.

CASE: WASTAGE MONITORING AND REDUCTION IN AN SC MILL

A Canadian SC paper mill has three paper machines, five supercalenders and three winders. Production from each paper machine is streamed to the same supercalenders and winder. The paper machine widths are similar, giving the operators the flexibility to optimize use of equipment and efficiency by occasionally crossing production paths. The paper machines, the supercalenders and the winders were equipped with reel diameter and caliper measurements as described previously.

The tracking system which used the roll diameter measurements had to be flexible, modular and sophisticated enough to track the spool, reel and waste through all possible production pathways. Also, the mill produces a range of grades having quite different properties, clay content and degree of calendering.

For this system, a database was developed that tracks diameters for every roll and reel and links the rolls and reels to each other by tracking them through the process line using RFID (radio frequency identification) or bar code technology. Diameter differences within and between process stations are automatically measured and logged and the lost paper weight is calculated.

In addition to tracking losses, LSZ provided operator tools to actively reduce these losses. These tools include:

- Reel size target determination on the paper machine, based on the planned grades and diameters or lengths
- A count-down display clock and RTT alarm at reel turn-up
- Run list management and tracking of wound sets to prevent over and under runs.
- Determination of makeup required to complete a partial reel or roll
- Reel usage optimization tools at the winder to optimize consumption of partial and orphaned reels
- Automatic wound roll stopping to a target size or length to minimize consumption variability

Automatic stopping allows the supercalender to run at full operating speed, ensuring constant quality to the last moment. This reduces waste by stopping precisely at the target size and reduces maintenance by eliminating cases when the tail runs through the stack due to operator inattention.

Because the loss tracking closely monitors process states in order to build the paper loss database it also records process stops and down time. The loss time data has become one of the more heavily used parts of the system.

Most of the data is automatically collected without operator involvement. However, operator input can be used to add detail to the loss data to allow more thorough analysis to be done. All the data is stored in an MS SQL database. (Oracle also sup[ported).

Short term loss trend data is provided to the operators where it helps motivate and aid them to make better operating decisions. Higher level and longer term loss data is summarized in a variety of reports for management to monitor performance and make resource allocation decisions.

Figure 6 shows the left-on-spool loss trend for one paper machine for a day. This trend gives the operator feedback for adjustment of reel target size at the paper machine.

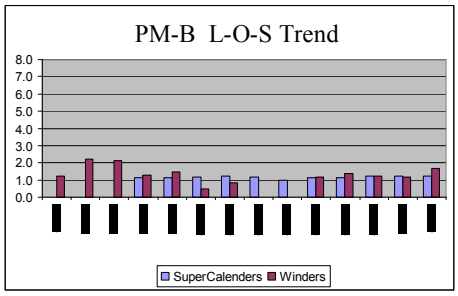

Figure 6: Trends of left-on-spool losses for a paper machine at the supercalenders and the winders.

Whenever a loss is greater than a threshold defined by the mill, the operator is prompted for a reason code from a pre-defined list. The loss type (e.g. slab, heel, splice, small set or tear-off) is automatically determined. The addition of a reason code provides additional insight. Data showing how much tonnage was lost due to paper machine breaks or turn-up problems, off spec paper or simply overbuilding the reel is valuable. This allows management to focus efforts and investments to the areas with the largest payback.

The loss information can be presented in many ways with different degree of detail. Figure 7

shows a Pareto analysis of loss by mill specific reason codes.

Previously "unaccounted" losses have been significantly reduced simply by making them visible, accountable and actionable. Operator software tools supporting optimal reel sizing at the paper machine, and optimal consumption of partial and orphaned reels at the winder actively minimize slab losses. The result is a sustained 2% improvement to the productivity for this paper mill.

Figure 8 shows the reduction in waste paper losses from 2000 to 2006. Unaccounted losses were calculated as the difference between paper machine gross production and wrap line weight as a percentage of gross production. PM A & B achieved sustained 1.5 to 2 % reductions in unaccounted losses. Initially PM C had a similar reduction but the reduction was not sustained. This is partially explained by an increase in PM C break frequency related to other process developments. Relative PM break frequencies are shown in Figure 8 along with the loss reduction data. PM C unaccounted losses decreased again as this situation improved.

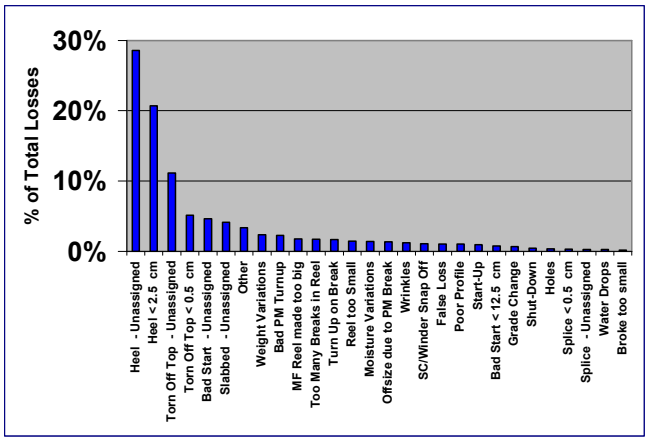

Figure 7: Pareto analysis shows the loss contribution in decreasing order of mill specific "reason" codes.

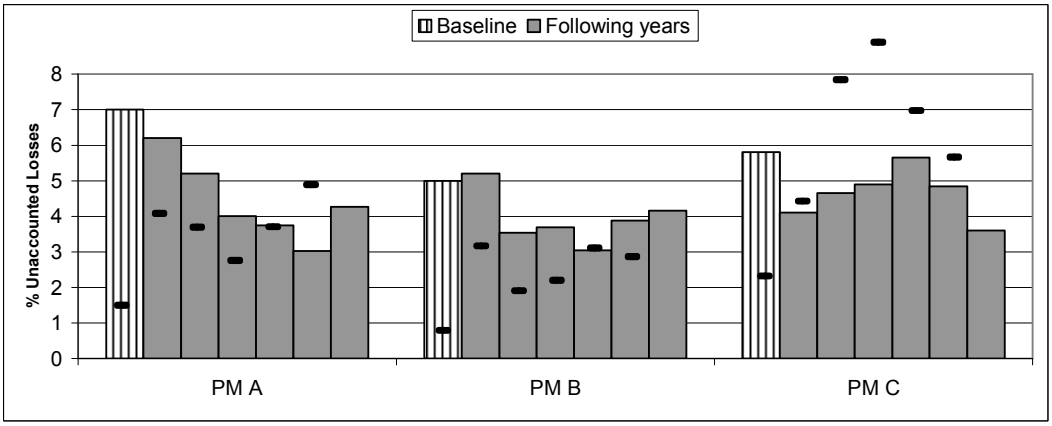

Figure 8: Unaccounted losses on three paper machines in an SC mill were reduced significantly. The dashes indicate the un-scaled, relative PM break frequency.

CONCLUSIONS

On-line measurements of paper reel or roll diameter and caliper have been used to diagnose and solve crepe wrinkling, paper bursting and other roll structure or web break problems. Solving these problems has resulted in significant reductions in reduced paper waste.

Moreover, the same density or caliper monitoring technology serves as the measurement foundation for a diameter-based reel and roll size optimization system. These

systems reduce chronic reel overbuild and left-on-spool losses by providing precise, real-time diameter, caliper and density measurement. The origins of unaccounted losses can be precisely defined and action plans to reduce them can be focused.

With automated diameter controls, winder sets are built to precise diameters. Reel turn-up alarm allows the backtenders to make the correct amount of paper required for downstream winding process, with no excess wastage.

The wastage monitoring systems have also been used in complex finishing lines to determine the degree and location of slab-off losses from parent reels, during the supercalendering process and in winding. Case studies, in, single-line and multi-line mills, demonstrate loss reductions of 2 to 4 % of gross production. This reduction of previous unaccounted losses can produce a large return on investment for most paper mills.

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