Energy Efficiency Frontier – Lean and Green Refining

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ABSTRACT

Refining is one of the most energy intensive processes in the manufacture of paper and paperboard. While refining combines a blend of science, art, and operating experience, nearly all papermakers acknowledge that we over-refine our paper machine stock fiber. Series and parallel equipment line-ups are commonplace, and different hydraulic paths are necessary to accommodate the plethora blends of virgin, recycle, and broke pulp. Tremendous opportunity exists in the reduction of both no-load and refining load electricity consumption through equipment driven by low-to-medium voltage motors generally over 150 kW (200 hp) each. Most paper mills' connected refining power alone falls between 1,500 to 15,000 kW. In conjunction with reducing refining energy intensity, opportunities exist to:

- Improve sheet first quality and target sheet properties by optimizing stock furnish blends.
- Integrate supply chain fiber cost and quality considerations into controlled refining operations.
- Reduce the time needed to change or start-up on grade.
- Reduce sheet breaks and reduce scrap.
- Realize additional energy savings through improved sheet dewatering upstream of the dryer section.

Best practices as well as new technologies are available to reduce refining energy intensity by an estimated 5% to as much as 40% from the status quo. The following measures should be considered in refining operations:

1. Conversion of double-disc refiner from mono-flo to duo-flo hydraulic paths.
2. Replacement of standard refiner plates with updated design high efficiency or spiral plates.
3. Installing reduced diameter refining plates in existing refiner where higher recycle and broke furnishes are used increasingly in place of virgin fiber.
4. Modification of refiner piping line-up to accommodate bypass of one or more refiners up to the tickler.
5. Optimization of existing stock chests to refine only those streams requiring it.
6. Installation of splined rotor in double disc refiner.
7. Use of quality control measurements to manually adjust refiner plate gaps, and implement repeatable operating practices for different basis weights or grades based on furnishes.
8. Integration of fiber length and width distribution into refiner operating practices.
9. Deployment of fiber morphology analysis to effect closed loop refiner control to achieve predictable sheet spec properties (targeting tensile strength, porosity, tear, etc.) and reduce refining energy intensity as a result of optimized refiner bypass and controlled plate gap.
10. Other new technologies with documented results indicating energy intensity reduction in refining.

This paper will explore and support these measures with case history information including measured or estimated energy savings where applicable. One approach resulted in a 25.0% reduction in refiner energy intensity by combining multiple improvements; another yielded an 18.5% reduction in refining energy. A new technology deployment's early results show a 13.3% reduction in refining electricity versus total connected motor load, and a greater reduction when comparing actual power consumption before and after. Economic payback will be discussed for various approaches. Two examples of energy efficiency resources will be briefly highlighted:

- Assistance from a statewide energy program resource such as Focus on Energy, Wisconsin's statewide program for energy efficiency and renewable energy. This statewide program provides technical assistance, support of test/trial for energy savings verification, financial incentives if eligible, and project financing for the deployment of emerging technologies (repaid based upon measured energy savings).

- The U.S. Department of Energy's *Save Energy Now* LEADER initiative intends to offer technical assistance toward energy efficiency through deployment of process optimization using new technology, under a signed pledge to reduce overall site energy intensity by 25% in ten years (the SEN Leader pledge).

INTRODUCTION

TAPPI Paper Machine Energy Conservation[1], provides excellent guidance and details. From a high level it outlines five basic principles for paper machine energy efficiency and energy intensity reduction. One of these five principles is, "minimize electrical consumption for key users." Refiners are among such key energy users.

Refining operations are very energy intensive (high energy per unit quantity of throughput). Widely accepted practices are available to reduce the amount of refining or the amount of energy required for refining, or both. In addition, new technologies are commercially available and currently in trial to further reduce the energy intensity of refining.

The intent here is to highlight the widely accepted or "best" practices in refining with respect to energy conservation and to discuss some recent project experiences, as well as describe a new technology currently in beta site deployment that is expected to reduce refining energy intensity by up to 25%, while providing additional benefits. Given portable power monitoring instrument devices, it is relatively straightforward to measure the electrical energy use before, during and after various trials and modifications to equipment and/or process changes. Working with available state energy conservation programs and/or electric utility account executives may provide assistance with measurement and monitoring activities.

BEST PRACTICES IN REFINING[2]

- Run low intensity plate designs, especially on hardwood
- Check refiner mechanical condition regularly
- Refine each pulp type separately
- Shut down tickler refiners when possible
- Operate in design hydraulic flow ranges (using recirculation and standpipe if necessary)
- Upgrade double disk refiners with splined rotors
- Consider modern energy-efficient designs when replacing refiners
- Minimize stock flow through deflakers

Energy efficient plate designs are available from refiner vendors, including spiral patterns that offer optimized angular relationship between the rotating and stationary plates. Idling of unnecessary equipment, such as shutdown of the tickler refiner or bypass and shutdown of refiners not needed for a given grade or furnish (for example, high recycle content) is a best practice, but a mill must study through controlled trials when and how best to do this.

Over-refining may occur when refining recycled pulps, when unable to bypass one or more refiners, or simply over-working the fiber due to avoidance of under-refining or following long standing practices. The resulting excessive impacts can lead to increased fines and weakening of the refined fibers. As much as 70% of the total fibers may not be treated at all, while others may be over-treated. There is opportunity to optimize, and many mills have dedicated significant time and effort to improve.

CASE HISTORIES

<u>Case History No. 1 – Mono- to duo-flo conversion (flow mode diagrams located in Appendix)</u>

At the Little Rapids Corporation Shawano Specialty Papers mill (Shawano, WI) two 508-mm (20-inch) refiners operate side by side, each driven by its own 250-hp motor, one in mono-flo arrangement, the other converted to duo-flo. The Measurement and Verification (M&V) activity, performed by Focus on Energy with support from Shawano mill personnel and Wisconsin Public Service Corporation (utility), involved measuring the energy used by each of the two refiners while holding all other variables constant, and taking pulp samples for lab analysis throughout. The kW reduction and projected kWh savings comparison was determined from the data collected onsite, measuring the energy use of each of the units sequentially operating under the same conditions. The duo-flo refiner equipment provider (vendor) projected that this upgrade would result in annual energy savings of up to 20%. Based on the data recorded during the study an average demand reduction of 18.5% was observed by the M&V team. A summary of the verified demand reduction and projected energy savings follows:

Mono-flo vs. Duo-flo Refiners – annual energy savings, based on side-by-side comparison					
Location	**Demand Reduction Observed**	**Hours of Operation**	**Calculated Energy Use Reduction**	**Blended Utility Rate**	**Total Cost Savings**
Little Rapids Corp. Shawano Specialty	**18.5%**	**8,350**	**> 250 MWh/yr**	**Confidential**	**Confidential**

Table 1. Summarized results of mono-to-duo-flo energy comparison.

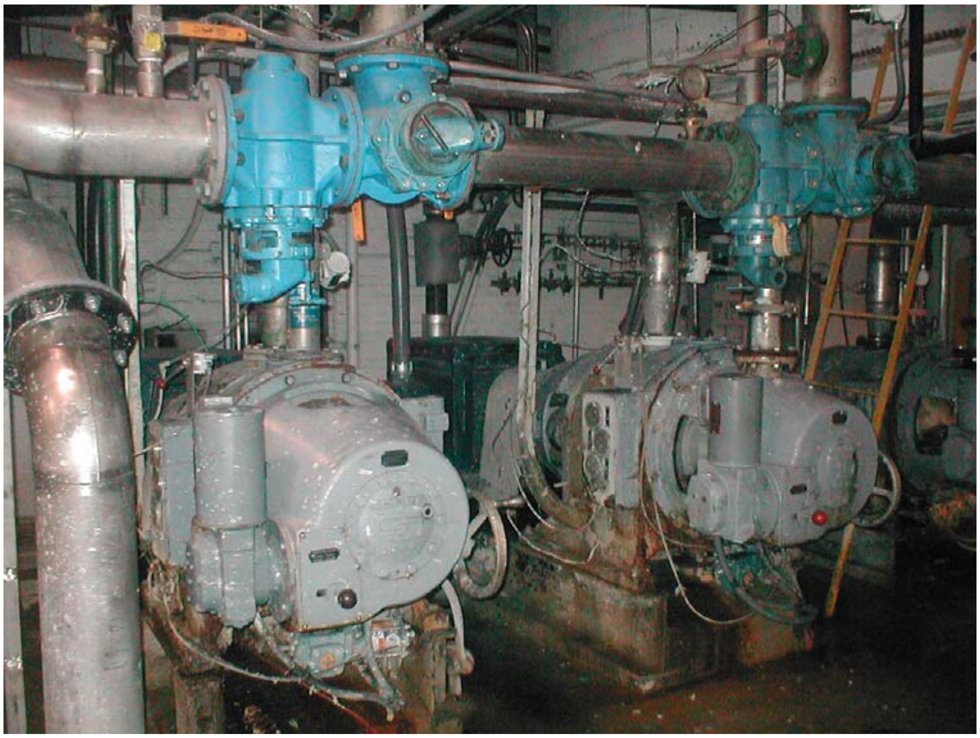

Photo 1. Refiners compared in Case History No. 1 (courtesy of Focus and Shawano Specialty Papers)

Modifying an existing mono-flo refiner is estimated to cost about $35,000 to $75,000 depending on refiner size and other factors, with a simple payback period less than three years (generally, the larger the refiner, the shorter the payback period). After the M&V, Shawano converted two refiners to duo-flo before the end of 2010. Demand reduction for the project was 62 kW, with the associated annualized energy savings more than 500,000 kWh. Based on the projected energy savings, the mill received a financial incentive from Focus on Energy to reduce the payback period and improve the project's ROI.

Case History No. 2 – Splined Rotor Refiner Upgrade (photographs in Appendix)

At a Wausau Paper mill in Wisconsin one of the paper machine's refiners flow was below the manufacturer's minimum hydraulic flow recommendation. A recirculation line was added to maintain adequate flow. Stable supply pressure required addition of a pressure relief line. The additional process control requirements of these two loops dictated a control upgrade which incorporated improved refiner loading control in addition to the process control.

Two 700-hp refiners on the PM were converted from mono-flo to duo-flo, and the splined rotor conversion was implemented, which added to the capital cost. Power metering before and after the project was accomplished by data loggers and the machine tender. The measurements prior to conversion indicated the refiners were drawing 580 kW each. After conversion, the measured power was 400 kW, or an approximate 31% decrease in electrical demand. Based on operating hours, predicted annualized energy savings for the couple were 3,063,750 kWh (~ 25% reduction).

Project cost = $160,872. Energy savings = $183,825/year. Simple payback < 11 months. Focus on Energy provided technical assistance for this project, while the ROI was so good it was not eligible for financial incentive.

Case History No. 3 – Physical refiner changes (best practices), and closed loop refiner control (emerging tech)

The cross-functional mill energy team at BPM, Inc. (Peshtigo, Wisconsin), with participation and support from Focus on Energy and Wisconsin Public Service, studied and identified many opportunities to improve the mill's energy efficiency and bottom line. The mill restarted in 2006 with the sulfite pulp mill remaining shutdown, decommissioned and eventually dismantled. With the resulting change in the fiber supply to the paper mill operations, often using recipes containing high recycle content, the five refiners in series, without bypass capability, consumed more electricity than needed for many of the grades produced.

BPM Inc. became one of the original 32 companies nationwide to sign the U.S. Department of Energy's *Save Energy Now* LEADER pledge, a commitment to reduce manufacturing energy intensity (energy consumed per unit of product produced) by 25% in 10 years, relative to a baseline year's energy and production data. Joining this elite group of companies provided BPM with an additional resource, a DOE-funded technical account manager (TAM), to help in offering technical assistance to the mill and company. Refining optimization was one of many energy efficiency projects and initiatives that the mill undertook.

The mill energy team identified refining operations as having significant energy intensity reduction potential, which the team developed and implemented largely using internal resources and some outside help as well. The energy team began by undertaking central and recurring questions of "How much extra work is being done to the fibers?" and "How much excess energy is utilized in refining?" A review indicated that BPM's refiners were already in duo-flo mode. The physical line-up of the five refiners in series without bypass capability, along with their position relative to both the dump chest and the machine chest, presented efficiency opportunities (see Figure 1). This starting point of hydraulic arrangement required all paper machine stock to flow through all #1 paper machine refiners, even if running a 100% recycle furnish grade.

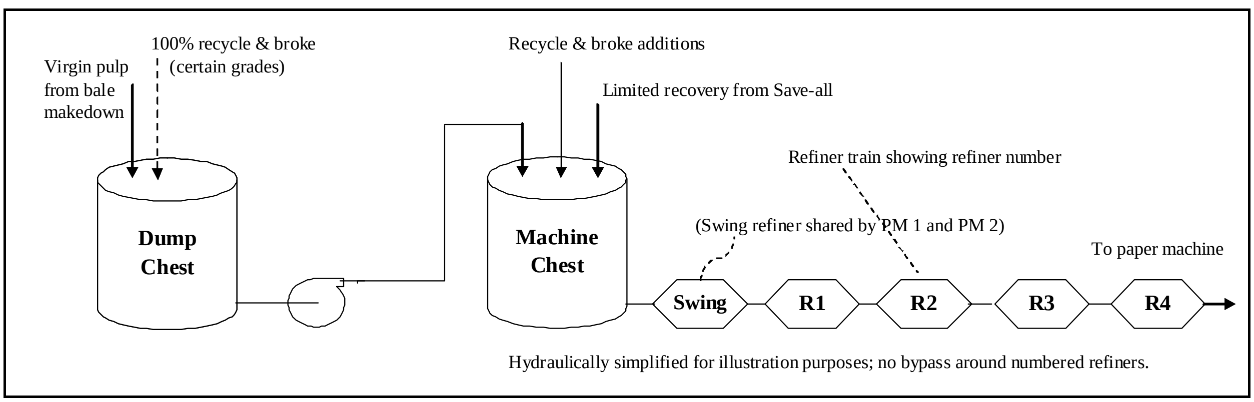

Figure 1. Arrangement of BPM #1 PM refining equipment prior to optimization.

With spatial ingenuity and hard work, the BPM paper mill personnel reconfigured the process flow path of #1 PM refiners with respect to the stock dump chest and the machine chest (see Figure 2), and added bypass piping and valving around each. Prior to this change, even an unnecessary refiner(s) for a particular grade of paper needed to operate at least at no-load condition as a "wide spot in the pipe." Process modifications to improve recovery of stock and sweetener supply from the Save-all to the paper machine were first trialed, and were later made permanent. A standpipe with recirculation loop including machine chest level control was added around the #1 refiner. This was essential, because the stock throughput flow rate for most paper grades was lower than refiner design flow rate. The mill worked closely with a refiner vendor in preparing for and executing these changes.

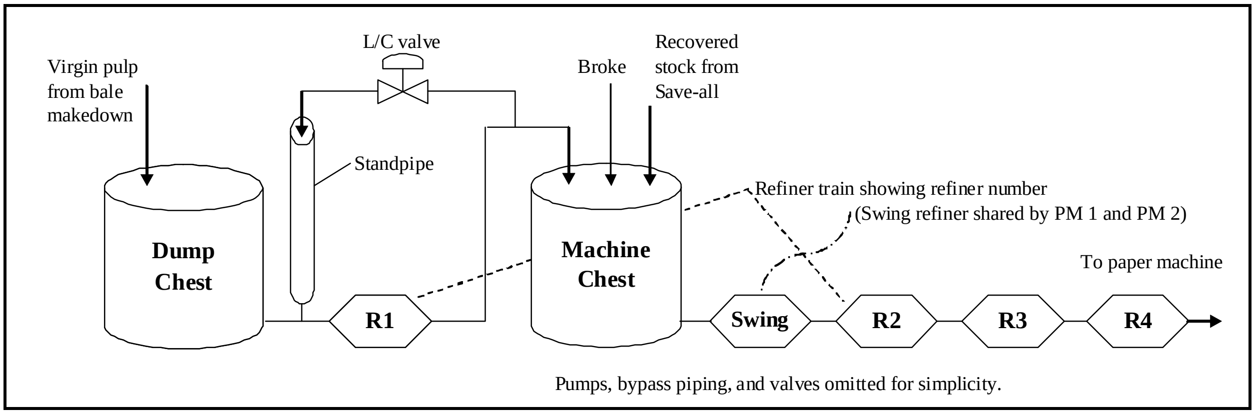

Figure 2. Modified arrangement of BPM #1 PM refining equipment with respect to stock chests.

Other physical changes included plates in the #4 refiner for #1 paper machine, was retrofitted with 584-mm (23-inch) plates installed in the 660-mm (26-inch) double disk refiner (see Figure 3), thus improving the hydraulic flow of the stock for the refiner's actual vs. design flow, and the evaluation of higher efficiency plates available from the supplying vendor. Subsequent monitoring and process measurements indicated that these changes were effective, and looking forward to the implementation of closed loop refiner control, would be very helpful in achieving the desired end of reducing energy intensity in the refining process.

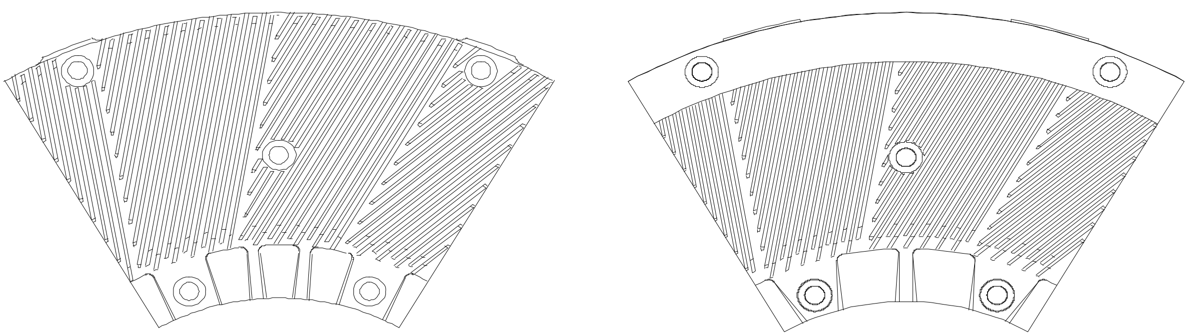

Figure 3. Illustration of downsizing refiner plates for hydraulic flow and refining optimization[3].

During the period 2007-2008, Focus on Energy began evaluating and vetting an optical fiber analyzing technology that had been developed for large pulp mill refiners. The technology in this early application proved to reduce TMP refiner electrical energy as well as reducing scrap at beta sites in European mills. Later this was replicated in a Canadian TMP refiner. Early results were monitored in a Wisconsin TMP refiner application, however a project financing activity was not pursued for several reasons (only two TMP operations in Wisconsin limiting replication opportunity being one reason).. Yet, a common vision was shared with the technology inventor that the technology could be adapted for energy reduction, refiner optimization, and other benefits, in paper machine refining as well.

With the above-described physical and operational process changes planned and beginning implementation at BPM, Focus proposed to BPM the emerging technology of a closed loop refiner control using the output and feedback of a commercially available optical fiber morphology analyzer to reduce refining energy intensity, and to accomplish additional benefits with positive impacts on indirect energy and other parameters. The project team, consisting of members of BPM, Focus on Energy and WPS, had evaluated instruments available from several suppliers, at first looking primarily to control freeness based on refiner energy input. However, BPM's technical needs were more to control porosity, which could be predicted via a model based on fully-developed fiber morphology. The technology had matured and was featured in the "New Technology Showcase" at the TAPPI Papermakers Conference in May 2010, and was discussed with a representing vendor during the PaperCon 2010 associated Trade Fair. The optical analyzer produces approximately 200 images per hour, and predicts the virtual sheet properties before the paper is made. BPM accepted the recommendation, and an introductory meeting between the project team, supplying vendor, and the analyzer's inventor was conducted, and the mill project team produced a defined path forward, including designing and conducting several test/trials and how energy savings would be measured and verified.

BPM installed stock piping access saddles in two locations, where one fiber analyzer could be installed on a temporary basis, or ultimately one or two instruments permanently. BPM provided additional labor and materials needed for instrument/computer power, and dilution and purge service function for the sampler. Specific trials on commonly produced grades of paper were run, and were well supported by the supplying vendor as well as the technology inventor, including the borrowed use of equipment and trial participation technical services. Focus on Energy and WPS provided equipment for power monitoring and recording, and trial participation. BPM facilitated the trials, provided paper lab testing, and results were recorded under controlled conditions of hardwood and softwood furnish, specific pulp supplies, varying degrees of broke pulp in the furnish for certain trials, monitoring of refiner energy consumption and recorded observations of trial data. These trials began during summer of 2010, and have continued through winter of 2010-2011. The manually controlled results have been documented such that demand/energy savings of approximately 150 kW and more than 1.0 million kWh/year would be realized based on #1 paper machine annual operating hours (note: total connected refining power for #1 PM is 1120 kW).

Phase 1 of the project involves use of the fiber analyzer real time results to activate manually actuated changes in number of operating refiners and refiner plate gap for those operating, developing confidence in the promising results obtained thus far, and continuing trials on various grades, while documenting refining energy intensity compared to historical values for like grades. Phase 2 of the project involves implementation of control algorithms and software to activate refiner plate gap, and therefore direct input refining energy, using feedback control. In addition, secondary benefits of getting on grade faster, reduced scrap, and fiber supply cost optimization are anticipated, and these latter benefits might even eclipse the direct energy intensity improvement.

As a U.S. DOE *Save Energy Now* LEADER, BPM is assigned a Technical Account Manager (TAM) by the DOE, who works together with the mill's assigned energy point and Focus on Energy (as a program ally) to establish baseline energy intensity, track energy intensity reduction annually, network available technical resources, and consider other help. BPM as a *SEN* Leader company is eligible to request technical assistance funding (amount not disclosed) for a related portion of this refining project, due to the potential energy savings at BPM site as well as providing "multiple observers" from other interested paper mills to visit the site and review how the technology saves energy, along with the development and publication of a high level case study based on the success of the implementation at BPM, the beta site. The project team is confident that this technology and associated refiner optimization project implementation will help BPM to achieve, maintain, and even exceed their 25% energy intensity reduction (energy consumed per ton of production) under the *SEN* Leader commitment. It is already helping BPM's bottom line.

CONCLUSIONS

Clearly, there are opportunities to improve energy efficiency in refining operations, and these have a direct impact on electrical energy consumption in the paper mill. Through the deployment of applicable best practices and emerging technologies, significant energy intensity reductions are possible in refining, and the associated cost savings make the related projects cost-justifiable. One factor must be emphasized here involves the allocation of qualified technical human resources to pursue energy efficiency in a holistic approach with process optimization. The mills featured in these case histories began evaluating and doggedly pursuing these changes first and foremost because they have an energy team that meets regularly, engages outside support from a statewide program and from their utility companies, and mill energy/team personnel have authority to influence project implementation priority – this resulting because the mill ownership and mill management team sees first-hand and understands the on-going bottom-line benefits of energy efficiency. BPM assigns the seasoned mechanical plant engineer nearly full-time to energy efficiency projects, which cross into all aspects of operations. These companies and their mills also have cultivated an energy efficient culture throughout their respective plant populations and organizations.

Assistance, both technical and usually financial, is available from state energy offices, statewide energy efficiency programs, the U.S. Department of Energy, and other sources. One is encouraged to seek available resources, even for assisting in "selling the merits of energy efficiency" up the chain of command in the mill and company.

ACKNOWLEDGMENTS

The author is grateful to many people for their assistance in the background work and project results associated with the subject matter herein. Among these are Little Rapids Corporation/Shawano Specialty Papers; Wausau Paper; BPM project, energy, production and maintenance teams; Wisconsin Public Service Corporation's Senior Account Executives, and Focus on Energy Industrial Sector personnel, including Focus field energy advisors for BPM, Shawano Specialty, and Wausau Paper.

References

1. TAPPI TIP 0404-63, Paper Machine Energy Conservation, ©2006.
2. Cited with permission from Dick Reese, Dick Reese & Associates, Inc., "Improving Paper Machine Energy Performance," ReadyTalk conference Webinar, sponsored by TAPPI Papermakers Committee, 25 January 2011.
3. Reproduced with permission from Dick Reese, Dick Reese & Associates, "Improving Paper Machine Energy Performance," PowerPoint presentation slides.

APPENDIX

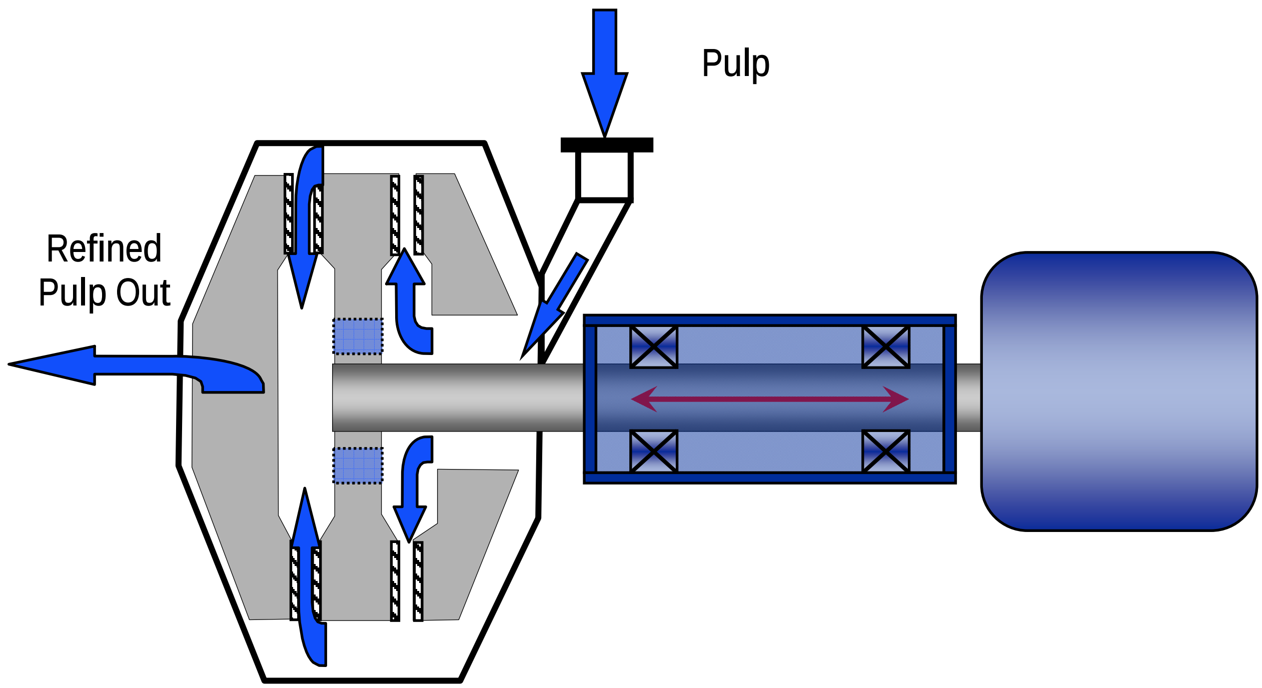

Figure 4. Double disc cantilevered refiner, floating shaft, in mono-flo mode (diagram courtesy of GL&V).

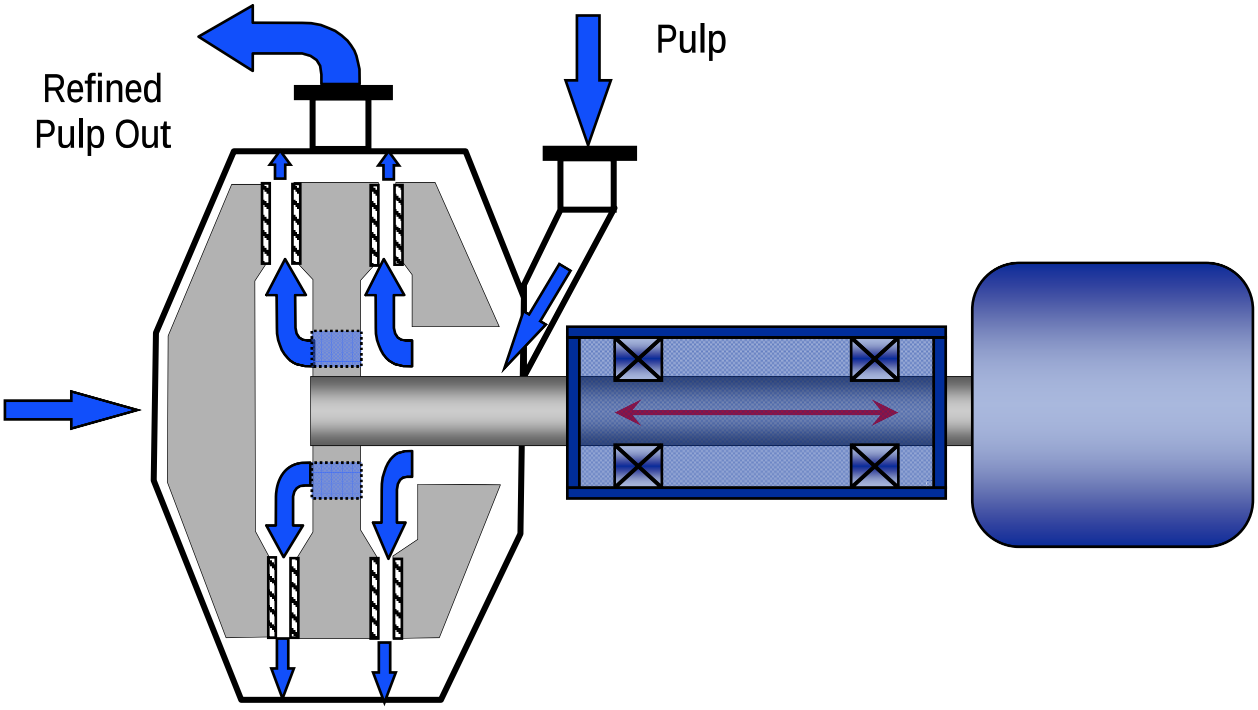

Figure 5. Double disc cantilevered refiner, floating shaft, in duo-flo mode (diagram courtesy of GL&V).

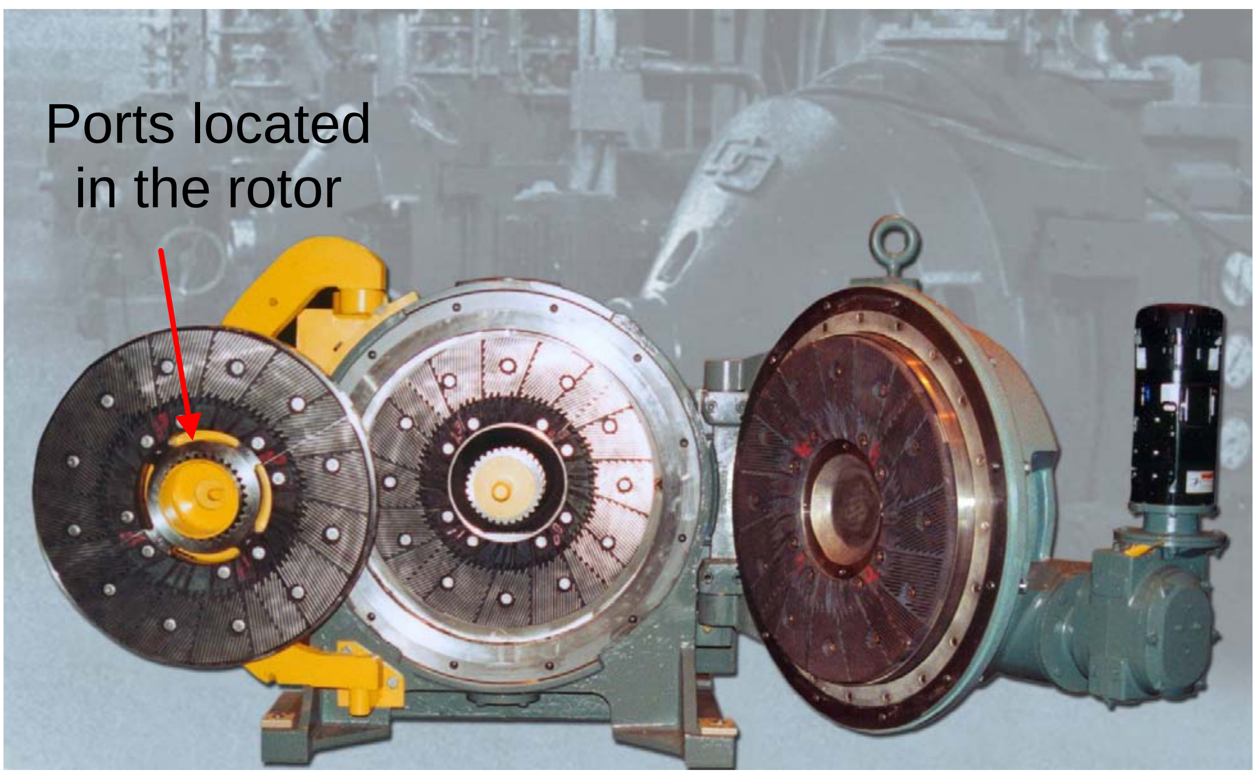

Photo 2. Double disc splined technology (courtesy of GL&V).

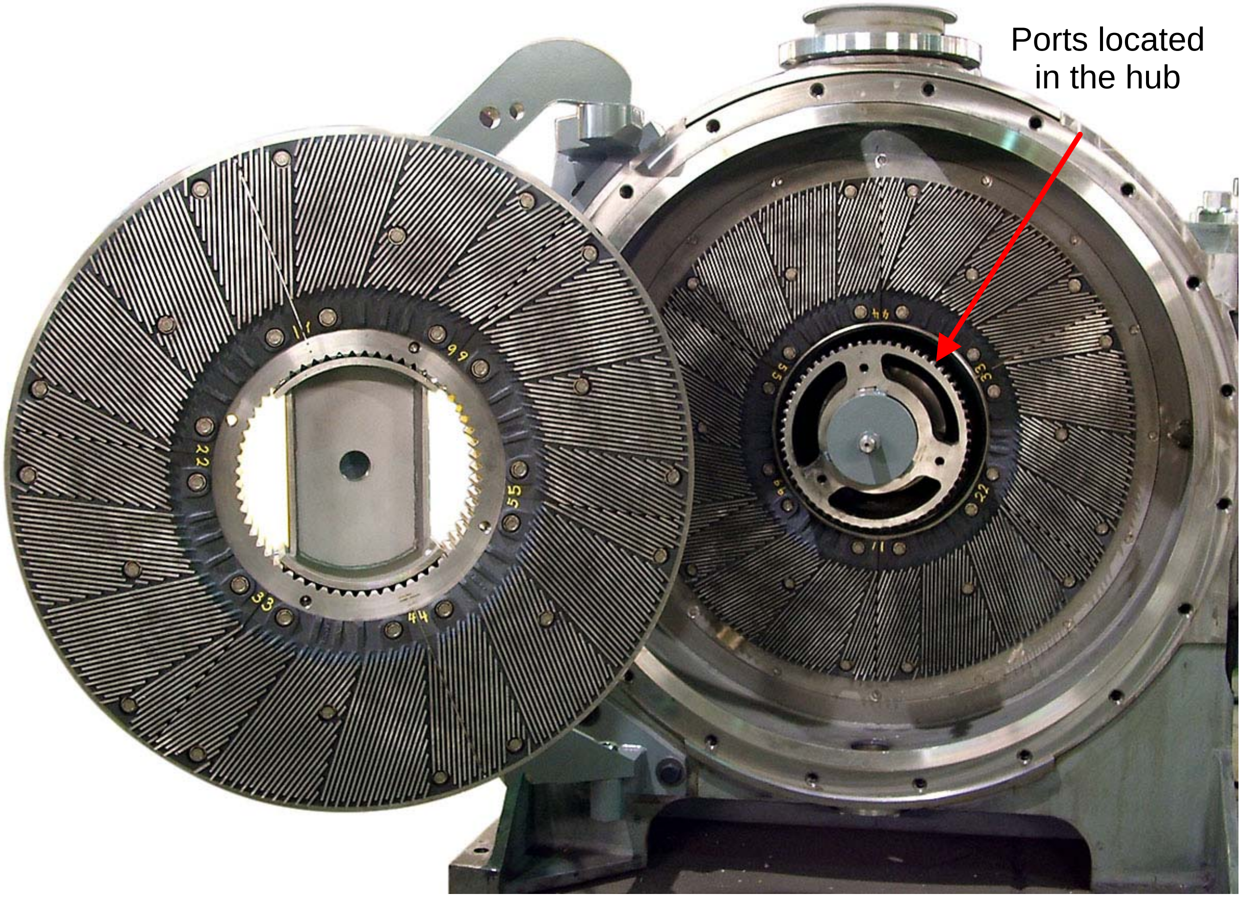

Photo 3. Double disc splined technology (courtesy of GL&V).