Journal of Engineering Research and Reports

22(4): 32-43, 2022; Article no.JERR.85320
ISSN: 2582-2926

Beverage Coaster Paper - A Protective Paper Grade Development

Klaus Dölle [a*]

[a] Department of Chemical Engineering (CHE), College of Environmental Science and Forestry (ESF), State University of New York (SUNY), One Forestry Drive, Syracuse, NY 13210, USA.

Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

Article Information

DOI: 10.9734/JERR/2022/v22i417533

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/85320

Original Research Article

Received 24 January 2022
Accepted 01 April 2022
Published 05 April 2022

ABSTRACT

Beverage coaster paper represents a specialty paper grade, which has its origin in the late 1880s. Its primary function is to serve as a barrier between the beverage and the table surface by soaking up the condensing water of the cold beverage and protect the wooden table surface as well as the customer from droplets of the condensing water.
A beverage coaster grade was developed utilizing thermos mechanical pulp, bleached softwood and bleached hardwood Kraft pulp. Manufactured on a 48-inch (1219 mm) wide small commercial Fourdrinier paper machine with an oven dry basis weight basis weight of 473.6, and thickness of 886 µm.
The water absorbance achieved a value 784 g/m² for the top side and 693 g/m² for the wire side of the paper. The smoothness value was 2734 ml/min for the top and 2784 ml/min for the wire side
The burst index was measured at 0.56 kPa*m²/g, a tear index of 14.68 mNm²/g for the machine direction and 10.78 mNm²/g for the cross machine direction.
The manufactured beverage coaster paper had no visible signs of dirt and a yellowish white color, an opacity a value of 100%, a brightness of 79.14% and a whiteness of 54.76%. The yellowish white colour had an 95.24% value for the L*, -1.62 for the a*, and 7.23 for the b*.

Keywords: Beverage coaster paper; beermat; handsheet making; papermaking; paper machine; paper testing.

**Corresponding author: Email: kdoelle@esf.edu;*

1. INTRODUCTION

Paper products are available in many forms, and countless paper grades have been developed all over the world. Each of the products are unique and manufactured to the specific requirements of the end user. According to Gullichsen & Paulapuro paper is classified in four major categories, which are: (i) printing and writing papers, (ii) Paperboard, (iii) Tissue, and (iv) specialty papers [1].

Todays manufactured paper grades can be characterized as an orthotropic thin plate with specific mechanical, optical and physical properties. Different basis weight distinguish between paper which has basis weight of up to 150 g/m², board which has a basis weight over 150 g/m² to 600 g/m² or higher, and tissue between 10 g/m² to 60 g/m². However, the basis weight boundaries are not fixed and allow some flexibility for the manufacturers and individual product specifications [2]. Specialty paper for instance can be found in all basis weight ranges and represent paper grades that are not considered commodity grades. They can include handmade and machine made paper grades produced in quantities from a few sheets to large lot sizes. [3-4]. Specialty paper grades, such as beverage coasters, are produced on more specialized paper machines that have a fraction of the 4.500 metric-tons per day product capacity, length of up to 600 m and width of up to11.5 m of today's large paper machines that are used to produce commodity grades [2,5-6].

Beverage coaster, shown in Fig. 1, are also called beermat, coaster, drink coaster, beverage coater or pulpboard coater, etc., and are produced in many sizes forms and shapes. They can be considered a specialty paper grade, because only a few companies produce this paper material. For instance the Katz Group, today a member of Koehler Paper [7] is according to the Packaging Gateway, the world market leader in producing beverage coasters [8] and produces beverage coasters since 1903.

The costars primary function is to serve as a barrier between the beverage and the table surface by soaking up the condensing water of the cold beverage and protect the wooden table surface as well as the customer from droplets of the condensing water. Its secondary function, is to protect the table surface from impact, denting or scratching when a bottle, glass or other liquid containing container is placed onto the table surface. Tertiary functions include advertising surface, leveling chairs and tables, toys and many more. In addition, beverage coasters can serve as a legal document and receipt showing how many beverages and food have been consumed and the monetary funds owed to the serving entity [10].

Fig. 1. Beverage Coaster [9]

Beverage coasters as a specialty paper product can be also considered as a special type blotter paper which origins can be traced back to the 15th Century [11]. Both paper grades have in common to absorb liquids substances, and therefore can be produced from the same or similar raw materials [2].

In descriptions of the beverage coaster history it is often referred to Fridrich Horn a resident Bruckau in the state of Saxony-Anhalt. Friedrich Horn was an industrial manufacturer who cut out beverage coasters in 1880 from 5 mm to 8 mm thick board paper. The board paper was produced on a cylinder paper machine made from a pulp suspension containing fir ground wood and gypsum for reinforcement stability purpose [10].

According to the American Breweriana Journal [12], the history of beverage coasters starts 1892 in Germany. Robert Sputh of Dresden, Saxonia is credited with the invention of the coaster. He was granted a U.S. Patenet 571,580 on November 17,1896, with prior art to an granted patent in Austria-Hungary with number 1,666 on July 4, 1892, and a patent granted October 25, 1892 by the German Empire with patent number 68,499 [13]. With this method the beverage coaster was manufactured by an pressing operation which is dewatering a pulp suspension filled into a form. Beverage coasters produced with this method had a diameter of 107 mm and a thickness of approximately 5 mm [14].

The following manuscript describes the development and manufacturing of a coaster paper product that is used as advertising material for the SUNY-ESF Chemical Engineering Departmets Paper Engineering Program. The development included laboratory bench scale development and testing, upscaling to a 12-inch (304 mm) wide laboratory paper machine, followed by a scale up semi commercial production run on the Chemical Engineering Departments 48-inch (1219 mm) wide pilot paper machine.

2. MATERIALS AND METHODS

The following materials and methods were used for the beverage coaster paper development from laboratory bench scale investigation, trial runs on a 12-inch (304 mm) wide Laboratory Fourdrinier Paper Machine (LFPM), and manufacturing the beverage coaster paper using a 48-inch wide Small Commercial Fourdrinier Paper Machine (SCFPM).

2.1 Materials Used

For the beverage coaster paper production, a mixture of different pulp products were used: (i) tissue grade Northern Bleached Softwood Kraft (NBSK) pulp which utilizes a mixture of the long fibers of northern coniferous tree species applicable to tissue products, (ii) regular Northern Bleached Softwood Kraft (NBSK) pulp which utilizes the long fibers of northern coniferous tree species, (iii) mixed Northern Bleached Hardwood Kraft (NBHK) which utilizes a mixture of short fibers from northern deciduous tree species, (iv) Softwood Bleached Sulfite Pulp (SBS), and (v) hardwood Thermo Mechanical Pulp (TMP).

The additives used for the beverage coaster grade are cationic starch (Cato 232) from National Starch, Alkyl Ketene Dimer (AKD) Hericon^{TM} 195 as a 19% solution from Ashland Hercules Water Technologies, and Potamine^{TM} yellow dye from Kemira.

2.2 Testing Methods

For the beverage coaster paper development and manufacturing research project the following testing methods of the Technical Association of the Pulp and Paper Industry (TAPPI) and International Organization for Standardization (ISO) were used:

TAPPI T 205 sp-12, “Forming handsheets for physical tests of pulp” [15] was used as a guideline for the production of blotter paper. Physical testing of handsheets was performed in accordance with T 220 sp-06, “Physical testing of pulp handsheets” [16]. Freeness of pulp was measured as Canadian Standard Freeness (CSF) according to T 227 om-09 “Freeness of pulp (Canadian standard method)” [17]. Consistency of the pulp suspensions was measured with TAPPI T 240 om-07 “Consistency (concentration) of pulp suspensions” [18].

Conditioning of the paper samples was done according to T402 sp-08, “Standard conditioning and testing atmospheres for paper, board, pulp handsheets, and related products” [19]. Burst Strength was measured in accordance with T 403 om-02 :Bursting strength of paper” [20]. Basis weight was measured with T 410 om-08. “Grammage of Paper and Paperboard (weight per unit area)” [21]. Thickness of the paper was

measured with TAPPI T 411 om-10. “Thickness (caliper) of paper, paperboard, and combined board” [22].

Moisture content of pulp was determined by T 412 om-06 “Moisture in pulp, paper and paperboard” [23].

Water absorbency was measured using TAPPI method T 441 om-04 “Water absorptiveness of sized (non-bibulous) paper, paperboard, and corrugated fiberboard (Cobb test)” [24]. Surface roughness of the paper product was measured with TAPPI method T 538 om-08. “Roughness of Paper and Paperboard (Sheffield method)” [25]. The air permeance of the paper product was measured with TAPPI T547 om-07 “Air permeance of paper and paperboard (Sheffield method)” [26]. Brightness was measured according to ISO 2470 “Paper, board and pulps - Measurement of diffuse blue reflectance factor – Part 1: Indoor daylight conditions (ISO Brightness)” [27]. Opacity was determined according to ISO 2471:2008 “Paper and Board: Determination of Opacity (Paper Backing) – Diffuse Reflectance Method” [28]. Whiteness/Color was measured according to ISO 11476:2016 “Paper and Board – determination of CIE Whiteness, C/2° (Indoor Illumination Conditions)” [29].

2.3 Beverage Coaster Laboratory Development

The beverage coaster paper laboratory development focused on finding the best pulp mixture from TMP, tissue grade and regular grade NBSK, NBHK, SBS, and TMP pulp.

Density is an important property and directly linked to the basis weight and caliper (thickness) of the coaster. By evaluating different commercial beverage coaster products it was decided that the two developing beverage coaster grade needs an OD basis weight of 480 ± g/m² and a caliper of 925 µ ± 45 µm. The density comparison shown in Fig. 2. reveals, that the commercial evaluated beverage coasters are below the density level of 480,000 g/m³. The different pulp mixtures were refined to a CSF level of 420 ml, which is required to ensure good operation of a paper machines Fourdrinier section. The first fiber mixture comprised of 50% NBSK which contained 25% tissue grade NBSK and 25% regular NBSK pulp, plus 50% NBHK pulp did not meet the required density.

The pulp composition of 20% TMP, 20% regular NSBK, and 60% NBHK pulp met the needed requirements for the refined and unrefined tests allowing good flexibility during the pressing operation. The pulp composition of 20% TMP, 20% SBS and 60% NBHK pulp showed similar results, but was not selected due to the SBS pulp availability.

The minimum total absorbency of the beverage coaster blotting paper was based on the TAPPI standard T205 sp-06 [16] and set at 500 ml ± 50 g/m² as a minimum at an exposure time of 120 seconds. The beverage coaster paper appearance should be uniform, flat, and free of wrinkles and dirt, because any imperfection in the appearance of the blotter paper, or possible dirt embedded in the beverage coaster paper will impact the appearance.

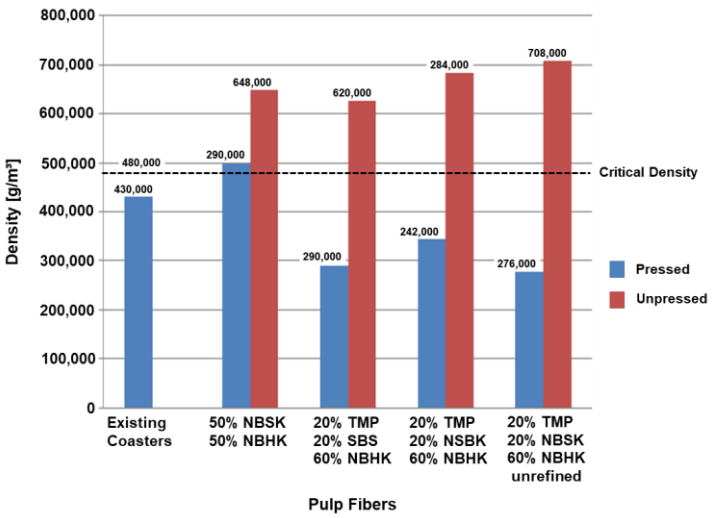

Fig. 2. Density Evaluation

The use of TMP has the possibility of color conversion due to residual lignin contained in the TMP pulp. To compensate for eventual color conversion a dye manufacturer representative was consulted regarding the dye concentration. It was suggested to use a yellow dye addition of 0.06% of yellow dye to achieve the white-yellowish side The color target for the yellowish colour was set by TAPPI handsheet testing at a ISO brightness level according to the ISO 2470 at 76.57% and a color value according to the ISO 11476 method for L*, a*, b*. at 94.32, -0.63, and 5.81, respectively. The final moisture content of the produced beverage coaster paper should be 7% ± 2.5%.

2.4 48-inch Small Commercial Fourdrinier Paper Machine System Operation

To production of approximately 1000 lbs. of beverage coaster paper a large scale, a 48-inch Small Commercial Fourdrinier Paper Machine (SCFPM) located at the pilot plant of the Chemical Engineering Department at SUNY-ESF was used to produce a 48-inch (1219.2 mm) wide continuous paper sheet that can be cut into all paper sizes needed to convert the coaster paper into beverage coasters. The setup of the blotter production run using the SCFPM run can be described as follows:

2.4.1 Stock preparation for the 48-inch small commercial fourdrinier paper machine

The stock preparation of the SCFPM, shown in Fig. 3., consists of a 50 hp (37.28 kW), 1800 gal (6800 l) low consistency pulper, a 15 hp (11.12 kW) transfer pump, a 150 hp (111.86 kW) low consistency conical Jones-Bertram beater, and a storage chests with a usable volume of 15000 gal. (56780 l). The storage chest is agitated with a 20 hp (14.91 kW) propeller agitator. Additives for papermaking can be added either in the pulper, the Jones-Bertram beater or the storage chests.

The beverage coaster paper production on the 48-inch SCFPM was designed for a maximum of approximately 2.0 hours, using 1000 lbs (453.5 kg). The following virgin market pulp were used: (i) 600 lbs (272.1 kg) of NBHK pulp, (ii) 200 lbs. (90.7 kg) NBSK, and (iii) 200 lbs. (90.7 kg) TMP pulp. Two hours of production will leave enough time to start-up the SCFPM, make needed adjustments to meet paper properties, and produce about 500 lbs (226.8 kg) beverage coaster paper at the targeted basis weight of 480 ± 20 g/m².

To prepare the needed fiber for the 48-inch SCFPM run, one batches of 800 lbs (362.8 kg) was pulped using the 1800 gal (6800 l) low consistency pulper followed by refining in the 1800 gal (6800 l) Jones Bertram beater of the of the SCFPM stock preparation system.

The pulping batch contained, 600 lbs (272.1 kg) OD of NBHK and 200 lbs. (90.7 kg) NBSK, and was pulped at a consistency of 5.7% based on Oven Dry (OD) fiber content by adding 1587 gallons (6002 l). The pulp batch consisted then of approximately 1439 gal (6364 l) of fiber slurry. After pulping the fiber slurry from the pulping batch was transferred into the 1800 gal (6800 l) Jones Bertram beater of the of the SCFPM stock preparation system. 200 lbs. (90.7 kg) TMP pulp were added directly into the beater due to the low freeness level of 280 ml, plus additional 19.7.4 gal (74.0 l) of water to arrive at a consistency of 6.67% based on OD fiber content. The final volume of the pulp slurry in the Joans Bertram beater was then 1727 gal (6,529 l).

The initial CSF value of the NBHK pulp was 590 ml and 680 ml for the NBSK pulp. The combined freeness of the pulp suspension containing the NBHK, NBSK, and TMP pulp was 590 ml.

The three pulp fibers were beaten with a load of 1000 lbs (435.5 kg) added to the Jones Bertram beater wheel using a beating time of 10 minutes.

For the first fiber slurry an Ampere (A) beating load of 35 A was used for the pulped fiber slurry, resulting in a 20.13 kW beating net power. The applied energy into the fiber slurries was 41.86 kWh/US ton (46.15 kWh/metric ton) of OD fiber, which lead to a reduction of the CSF of the fiber slurries from 590 ml to 420 ml.

The CSF value was measured with TAPPI test method T 227 om-09.

After refining the pulp fiber slurry was transferred into the 15,000-gal (56.78 m³) machine chest of the SCFPM and diluted to a consistency of 3.0% by adding 5,040 gal (14,517 l) of water. The total pulp fiber suspension volume for the beverage coaster production was 3,999 gal (15,117 l). The resulting pulp fiber mixture was mixed thoroughly before and during the SCFPM operation to avoid settling of the pulp fibers.

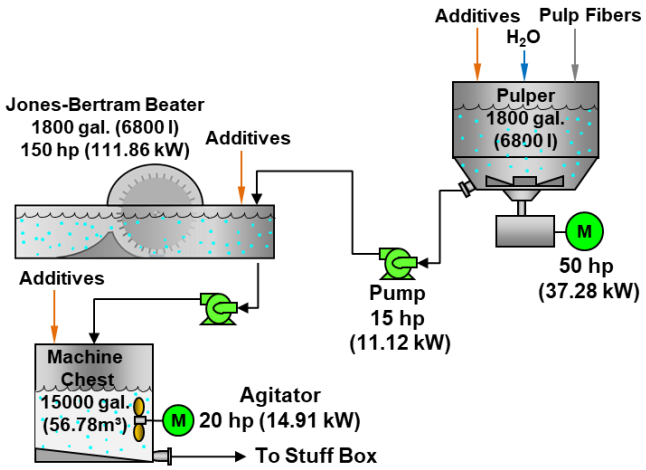

Fig. 3. 48-inch small commercial Fourdrinier paper machine stock preparation [30]

Based on the laboratory development additives were added to the 1000 lbs (453.5 kg) OD pulp mixture in the machine chest by constantly agitating the machine chest. First, 2% cooked cationic starch was added at 1.5% consistency on an OD pulp fiber bases. The Starch was cooked at a 3% solids content for 30 minutes between 190.4°F and 199.4°F (88.0°C to 93.0°C), and diluted to 1.5% prior to adding. Second, 0.05% AKD sizing solution at a 19% solids content was added. Third, 0.06% of yellow dye solution based on OD pulp suspension was added to achieve the yellowish white color.

2.4.2 48-inch small commercial fourdrinier pilot paper machine wet end system

The wet end of the SCFPM, as shown in Fig. 4., consists of a 6500 gal. (56.78 ³) machine chest with a 20hp (14.91 kW agitation propeller. As described in Section 2.5.1. the chest contained approximately 5,040 gal (19,050 l) of refined pulp fiber slurry. The machine chest holds A 15 hp (11.12 kW) impeller pump transfers the stock from the machine chest to a stuff box. A basis weight mixing valve regulates the pulp fiber flow to a 184 gal (743.3) mixing chest, where the pulp fibers are mixed and diluted with the white water from the paper machine, head box overflow, additives and pressure screen reject flow to a head box consistency of approximately 1%. The white water used for dilution consists of removed water from the table rolls, low vacuum and high vacuum which is pumped from the seal pit to with a 3 hp (2.25k kW) impeller pump to the white-water trough. From the mixing chest, the pulp fiber suspension is pumped with an impeller head box pump having 15 hp (11.12 kW) to a pressure screen driven by a 30 hp (22.37 kW) electro motor. The head box screen supplies the paper machine headbox with the prepared pulp fiber suspension. The volumetric flow to the head box is controlled by a flow control valve. The pressure screen reject is sent back to the mixing chest.

The SCFPM vacuum system consists of 2 vacuum pumps with 40 hp (29.82 kW) and 20 hp (14.91 kW), having a common header. The vacuum systems provide vacuum for the FCFPM high vacuum boxes, the couch roll and the press section vacuum boxes.

2.4.3 48-inch small commercial fourdrinier paper machine run

The SCFPM shown in Fig. 5. has a 280” (7112.0 mm) long Fourdrinier Forming Section (FFS) with a 48” (1219 mm) headbox slice opening and forming board. The Breast roll of the FFS is attached to a shake having 3 hp (2.23 kW) and a stroke of 0 to 7/8-inch (0 to 22.23 mm) adjustable to a frequency between 0 to 10 Hz for improving sheet formation and fiber orientation on the forming wire. In addition, the FFS contains 13 table rolls with a diameter of 3.5” (88.9 mm), 3 foil boxes, 4 high vacuum sections, a 12” (304.8 mm) dandy roll, and a 14” (355.6 mm) diameter vacuum couch roll, including a couch pulper with a 1 hp (0.75kW) electro motor. The couch roll is driven by a 20 hp (14.91 kW) electro motor.

The blotter paper production run was estimated to run for approximately 2 hours including set up of the paper machine, adjusting the basis weights for the 480 ± 20 g/m² OD basis weights.

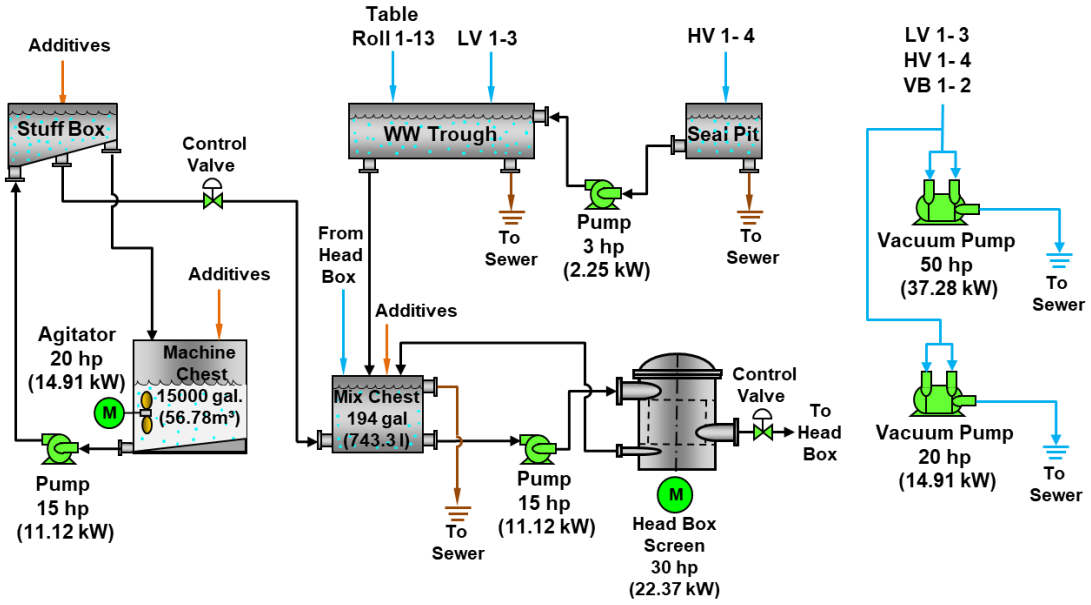

Fig. 4. 48-inch small commercial Fourdrinier paper machine wet end system [30]

The speed of the SCFPM blotter paper run was set to be 27.8 ft/min (8.45 m/min) with a headbox slice opening of 1.75 inch (44.45 mm), and a shake frequency of 35 strokes per minute and an amplitude of 0.656 inch (16.66 mm). The fiber suspension flow to the headbox was adjusted to approximately 0.82% in the mixing chest by recirculating the white water from the white-water through with an fiber suspension flow of about 132.9 gal/min (502.5 l/min) (see Fig. 2), in order to achieve the targeted basis weight of 480 ± 20 g/m² OD of the beverage coaster paper.

The vacuum levels for the fourdrinier table were set for the three low vacuum boxes 1 to 3 at 497 Pa, 1493 Pa, and 1990 Pa respectively. The four high vacuum boxes 1 to 4, the vacuum was set at 746 Pa, 746 Pa, 1244 Pa, and 995 Pa respectively. The couch roll vacuum was set at 1368 Pa.

The beverage coaster paper is trimmed on the machine operating and drive side with water jets by 2 inches (50.8 mm) before it is transferred into the Press section.

The paper is transferred from the FSS to the press section which contains a 1st and a 2nd press with a maximum loading of 500 pli (87.6 kN per m) press loading. The 1st press has a press roll with 13" (330.2 mm) diameter and a 14" (355.6 mm) grooved roll. The 2nd press has a press roll with 14" (355.6 mm) diameter and a 14" (355.6 mm) smooth roll Each press section is driven by a 10hp (7.46 kW) electro motor.

For the beverage coaster paper production the 1st and 2nd press was operated at 10 psi and 15 psi pressure respectively, which correlates to a line pressure of 7.23 kN/m for the1st and 14.1 kN/m for the 2nd press.

The pressed beverage coaster paper is fed into the dryer section featuring dryer cans that have a non-chrome smooth metal surface.

In general, based on experience, the solids content of the paper product leaving the Fourdrinier section and entering the press section is approximately 34%. After the press section the solids content is increased to approximately 40%.

Doctor blades are used to keep the drying cylinders clean. The 1st dryer section contains 13 dryer cylinders. The first dryer cylinder has a diameter of 24" (609.6 mm). The remining dryer cylinders have a diameter of 48" (1219.2 mm). The dryer section is driven by interlocking gear drive powered by a 30 hp (22.37 kW) electromotor. The 2nd dryer section contains five 48" (1219.2 mm) diameter drying cylinders driven by an interlocking gear drive powered by a 20 hp (14.91 kW) electromotor. All dryers in the drying section are supplied with steam at a pressure of up to 15 psi (103.42 kPa).

The two dryer sections of the SCFPM, as shown in Fig. 5, contain eighteen dryer cans D1 to D18. The seam supply for the first dryer section was at 5 psi (34473.8 Pa) and for the second dryer section at 15 psi (103421 Pa). For the beverage coaster paper production run dryer cans in the first dryer section were heated as follows: Dryer can D1 was not heated. Dryer can D2, D3, and D4 were operated at a temperature of up to 199°F (92.7°C), 184°F (84.4°C), and to 234°F (112.2°C) respectively. Dryer can D5 and D6 was not heated. Dryer can D7, D8, D9 and D10 were operated at a temperature of up to 182°F (83.3°C), 195°F (90.5°C), 214°F (101.1°C), and to 212°F (100.0°C) respectively. Dryer can D11, D12, and D 13 were not heated. In the second dryer section Dryer can D 14 was heated at 219°F (103.8°C), all other dryer cans were not heated. The beverage coaster paper produced had at the end of the dryer section a dry content of 93% with a variation of ± 2.5%.

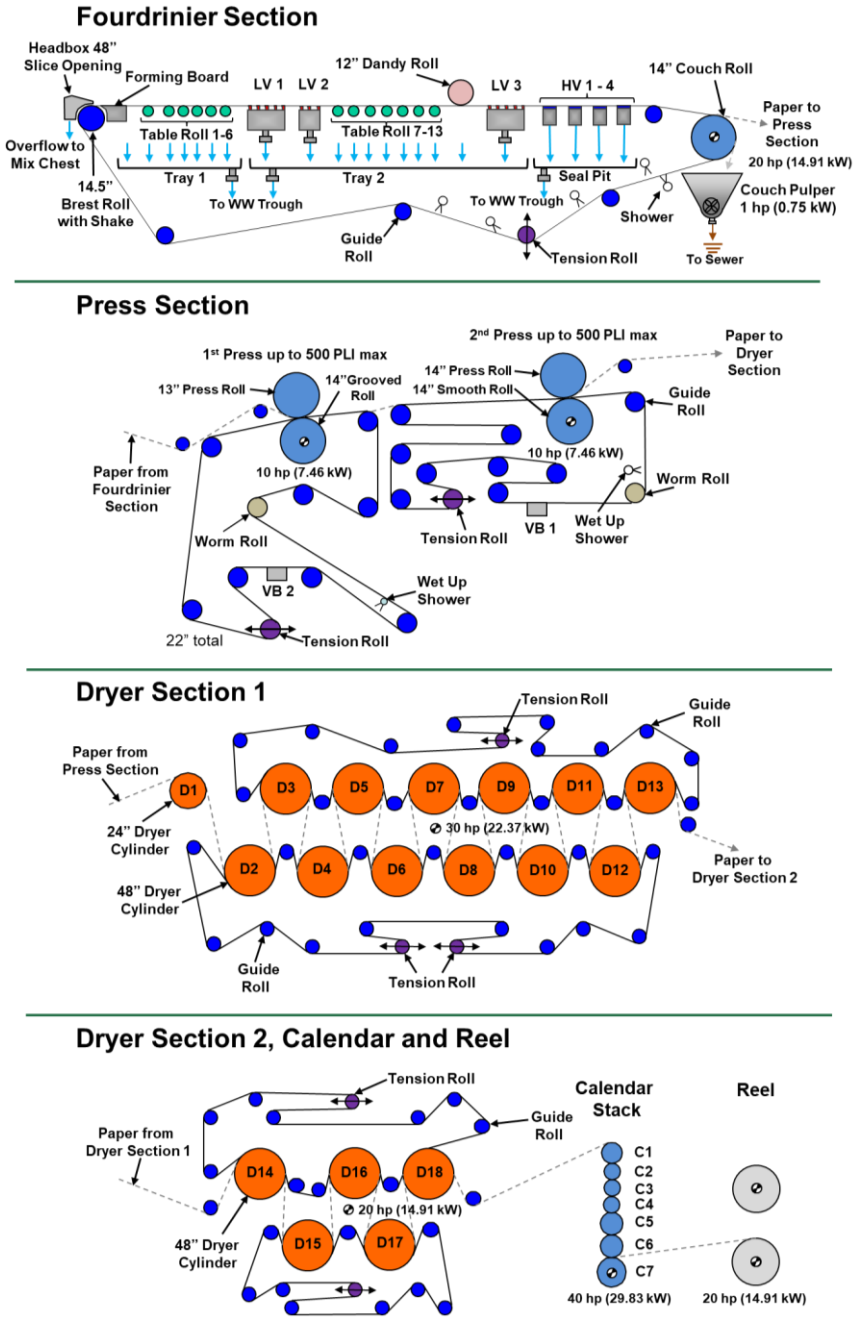

Fig. 5. 48-inch small commercial Fourdrinier paper machine [30]

Afterwards, the drying section the paper is transferred thorough a 7-roll vertical calendar stack. The first roll (top roll) has a diameter of 14" (355.6 mm) and a weight of 4000 lbs (kg). The 3rd, 4th, and 5th roll have a diameter of 10" (254 mm) and a weight of 2500 lbs (kg). The 5th and 6th roll have a diameter of 13" (330.2 mm) and a weight of 4000 lbs (kg). The 7th roll is the supporting and drive roll with a diameter of 20" (508 mm) and is driven by a 40 hp (29.83 kW) electro motor.

For the beverage coaster paper manufacturing operation, the calendar stack was not used and the paper fed through the calendar stack without applying a load. This allowed the sheet to retain bulk and thereby created a more absorbent beverage coaster paper.

The finished beverage coaster paper is rolled up at a two-roll reel section into paper rolls of up to approximately 750 lbs. (340 kg) each. The reel is powered by a 20 hp (14.91 kW) electro motor. The SCFPM can produce a finished paper product with a basis weight between 20 g/m² and 750 g/m² at a width of up to 44" (1118 mm) at a maximum speed of up to 350 ft/min (106.7 m/min).

The total installed electrical power of the wet end system, the SCFMP, and SCFPM vacuum system is 83 hp (61.89 kW), 151 hp (112.60 kW), 100 hp (74.57 kW) respectively, with a total installed electrical power of 234 hp (174.49 kW) for the complete paper production system.

A winding station is used to wind the paper on a smaller core for later converting/cutting the paper from the roll into approximately 44-inch x 36-inch (1118 mm x 914 mm) sheets, which can then later be converted into any paper sheet size needed. For the beverage coaster paper run the large paper sheets are cut into smaller size sheets based on the beverage coaster manufacturer requirements.

3. RESULTS AND DISCUSSION

All tests for this research and development project were performed in accordance with the in Section 2.2. referenced TAPPI and ISO methods. All results stayed in the precision statements for the referenced TAPPI and ISO methods.

3.1 Beverage Coaster Paper Properties Achieved

Table 1. shows the paper properties required that need to be tested according to the TAPPI standards.

The produced beverage coaster paper on the 48-inch SCFPM with targeted OD basis weight of 480 ± 20 g/m² was achieved, having 473.2 g/m² OD basis weight. The moisture content of the off real paper was 5%. However, paper tests were performed as required by TAPPI test method T402 at a temperature of 23°C ± 1°C and a humidity of 50% ± 2%. This increased the basis weight of the 473.2 g/m² to 509 g/m².

The caliper of the manufactured blotter paper was measured at 886 µm, slightly above the minimum specified caliper of 880 µm of the caliper band width of 925 µ ± 45 µm.

The water absorbance of the beverage coaster paper measured as Cobb value was 784 g/m² for the top side and 693 g/m² for the bottom side (wire side). Due to the more compact structure of the wire side the absorbency is lower. Both Cobb values met the minimum total absorbency requirements of 500 ± 50 g/m² as specified.

The manufactured beverage coaster paper had no visible signs of dirt and a yellowish white color. For the opacity a value of 100% resulted. Brightness was at 79.14% and the achieved CIE (Commission Internationale de l'Eclairage; engl. International Commission on Illumination) whiteness and colour was 54.76% for the whiteness, and 95.24% for the L* value, -1.62 for the a* value, and 7.23 for the b* value.

Additional test performed on the beverage coaster paper included burst, porosity, smoothness and tear. The burst index was measured at 0.56 kPa*m²/g. The porosity was at 0 ml/min, because the beverage coaster paper thickness prevented a measurable air flow through the paper from both the top side and the wire side. The smoothness values reached 2734 ml/min for the top and 2784 ml/min for the wire side. The top side showed a lower air flow (higher smoothness) because the paper is pressed against the smooth dry can surface during drying resulting in a more even paper surface. The tear index achieved was 14.68 mNm²/g for the machine direction (MD) and 10.78 mNm²/g for the CD of the paper machine respectively. The manufactured paper was later the used to produce beverage coaster paper.

Table 1. Beverage coaster paper properties

Measurement	Value
Basis weight OD [g/m²]	473.2
Basis weight Cond [g/m²]	509
Thickness [µm]	886
Cobb Top Side [g/m²]	784
Cobb Wire Side [g/m²]	693
Opacity [%]	100
Brightness [%]	79.14
CIE Whiteness [%]	54.76
L*	95.23
a*	-1.62
b*	7.23
Additional Testing	
Burst Index [kPa*m²/g]	0.56
Porosity Top Side [ml/min]	0
Porosity Wire Side [ml/min]	0
Smoothness Top Side [ml/min]	2734
Smoothness Wire Side [ml/min]	2784
Tear Index MD [mNm²/g]	14.68
Tear Index CD [mNm²/g]	10.78

4. CONCLUSION

The presented project describes the development and manufacturing of a beverage coaster paper product utilizing a 48-inch (1219 mm) wide small scale Fourdrinier paper machine.

The costars primary function is to soak up the condensing water of the cold beverage and protection from droplets of the condensing water. Other function include dent and scratch protection, advertising, leveling device, toys and legal document and receipt showing how many beverages and food have been consumed.

Beverage coasters are a specialty paper product which origins can be traced back to the late 1800s.

The manufactured coaster product had an OD basis weight target of 480 ± 20 g/m², a moisture content of 7% ± 2.5%, a caliper of 925 µ ± 45 µm, and an ability to absorb 500 ± 50 g/m² of water.

The developed and manufactured product had a 473.2 g/m² OD basis weight. The moisture content of the off real paper was 5%.

The caliper of the manufactured blotter paper was measured at 886 µm, slightly above the minimum specified caliper.

The water absorbance of the beverage coaster paper 784 g/m² for the top side and 693 g/m² for the bottom side.

The manufactured beverage coaster paper had no visible signs of dirt and a yellowish white color with an opacity value of 100%, brightness value of 79.14%, whiteness of 54.76%, and a color value of 95.24% for L*, -1.62 for a*, and 7.23 b*.

Burst measured at 0.56 kPa*m²/g, porosity of 0 ml/min due to the high caliper. Smoothness values reached 2734 ml/min for the top and 2784 ml/min for the wire side. The tear index was measured at 14.68 mNm²/g for the machine direction and 10.78 mNm²/g for the cross machine direction. The manufactured paper was later the used to produce beverage coaster paper.

DISCLAIMER

The products used for this project are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing entity rather it was funded by personal efforts of the authors.

ACKNOWLEDGEMENTS

Author is thankful to the support by the Department of Chemical Engineering at the State University of New York, College of Environmental Science and Forestry.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1 Gullichsen J. Paulapuro H. Paper and Board Grades. Fapet Oy, Helsinki, Finland; 2000.

2 Dölle K. Blotting paper for bench type testing – A 48-inch pilot paper machine production run. Journal of Engineering Research and Reports (JERR). 21(11):59-69.

3 Share Studios. Retrieved: 1-18-2022.
Available:https://www.sharestudios.me/custom-paper

4 Neenah Paper. Retrieved 12/08/2021.
Available:https://www.neenahpaper.com/brands/neenah-blotter-papers

5 Voith Paper. Hainan PM2 – The largest paper machine in the world. Twogether Paper Technology Journal 31; 2010.

6 Paper Age. Papierfabrik palm successfully commissions new containerboard machine, PM5, in Aalen, Germany.
Retrieved 12/08/2021.
Available:https://www.paperage.com/2021news/07_09_2021palm_startsup_pm5.html

7 Katz.
Accessed 18 January, 2022.
Available:https://www.thekatzgroup.com/en/

8 Packaging gateway.
Accessed 18 January, 2022.
Available:https://www.packaging-gateway.com/contractors/materials/koehler/

9 Dölle K. Beverage coaster images. pdf-file; 2022

10 Internetportal Historisches Unterfranken. Bierdeckeldatnebank.
Accessed 18 January, 2022.
Available:https://www.historisches-unterfranken.uni-wuerzburg.de/db/bierdeckel/bierdeckel/index.php (German)

11 Hunter D. Papermaking the history and technique of an ancient art. Dover Publications Inc., New York; 1978.

12 Nelson Max. The history of the wood-pulp beer coaster. American Breweriana Journal, Museum Commemorative Edition. 2008;82-83.

13 Sputh S. Apparatus for making wood felt. United States Patent and Trademark Office (USPTO). United States Patent US 571,580; 1996.

14 Kellerbergverein Höchstadt e.V.
Accessed 20 January, 2022.
Available:https://www.kellerberg-hoechstadt.de/wussten-sie-schon/der-bierdeckel/der-bierdeckel.html

15 TAPPI T205 sp-06. Forming handsheets for physical tests of pulp.

16 TAPPI T 220 sp10. Physical testing of pulp handsheets.

17 TAPPI T 227 om-09. Freeness of pulp (Canadian standard method.)

18 TAPPI T 240 om-07. Consistency (concentration) of pulp suspensions.

19 TAPPI T 402 sp-13. Standard conditioning and testing atmospheres for paper, board, pulp handsheets.

20 TAPPI T 403 om-02. Bursting strength of paper.

21 TAPPI T 410 om-08. Grammage of Paper and Paperboard (weight per unit area).

22 TAPPI T 411 om-10. Thickness (caliper) of paper, paperboard, and combined board.

23 TAPPI T 412 om-06. Moisture in pulp, paper and paperboard.

24 TAPPI T 441 om-04. Water absorptiveness of sized (non-bibulous) paper, paperboard, and corrugated fiberboard (Cobb test).

25 TAPPI T 538 om-08. Roughness of Paper and Paperboard (Sheffield method).

26 TAPPI T547 om-07. Air permeance of paper and paperboard (Sheffield method).

27 ISO 2470. Paper, board and pulps - Measurement of diffuse blue reflectance factor – Part 1: Indoor daylight conditions (ISO Brightness).

28 ISO 2471:2008. Paper and Board: Determination of Opacity (Paper Backing) – Diffuse Reflectance Method.
29 ISO 11476:2016. Paper and Board – determination of CIE Whiteness, C/2° (Indoor Illumination Conditions).
30 Dölle K., Rainville H. Art paper for large wood relief block printing – A paper development study. Journal of engineering Research and Reports (JERR). 2021; 21(7):1-18.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/85320