HP Indigo Division Technical Note

Subject: Pack Ready feasibility test report

Nobelus BOPP Matte (1.08mil), PET Gloss (1.2mil) and PET (0.8mil) compatible

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1. **Background:**

   Compatible Pack Ready Films are commercially available films with a thermal adhesive polymer (EVA) that can be used as laminates over the LEP print in flexible packaging production.

   Lamination is performed using the Karlville Pack Ready laminator.

2. **Objective:**

   The purpose of this trial is to test the functionality of films from Nobelus laminated to digitally printed films – surface printed Met-PET/PE and surface printed BOPP.

3. **Procedure:**

   3.1 The feasibility of three laminate films type was tested according to a matrix at different lamination conditions in order to find the possible working window per composition.
   Films received were not sealable thus sealing bond strength was not measured.

   The resulting laminates were examined for:

   - Curling
   - Wrinkles
   - Lamination performance between the laminate and the ink – lamination bond strength
   - Seal area appearance. BOPP films are not sealable thus sealing bond strength was no recorded

   In following table, the printed and laminate films are listed as well as lamination conditions:

Printed film (Unwinder 1)	Laminate film (Unwinder 2)	Nip Temperature [°C]	Speed [m/min]	Wrapping angel [deg.]
Ink/BOPP	EVA/BOPP	100	30-40	0
Ink/BOPP	EVA/BOPP	120	30-40	0
Ink/BOPP	EVA/BOPP	140	30-40	0
Ink/MET-PET/PE	EVA/PET (1.2mil)	100	40	90
Ink/MET-PET/PE	EVA/PET (1.2mil)	120	40	90
Ink/MET-PET/PE	EVA/PET (1.2mil)	140	40	30
Ink/MET-PET/PE	EVA/PET ultra-thin (0.8mil)	100	40	90
Ink/MET-PET/PE	EVA/PET ultra-thin (0.8mil)	120	40	60
Ink/MET-PET/PE	EVA/PET ultra-thin (0.8mil)	140	40	30

3.2 The laminated films were sealed according to conditions detailed in table below. Since laminate film BOPP is plain film, not sealable, seal was performed on printed film. Thus, only the appearance of seal area was recorded.

Seal area was tested for:

- Color change
- Seal area appearance

Sealant layer	Upper jaw type	Lower jaw type	Upper jaw temp [C]	Lower jaw temp [°C]	Force [N]	Dwell time [sec]
PE	Flat 1" + Teflon	1" Silicon + Teflon	170-240	RT	450	1, 2
	Grooved 1"	Grooved 1"	170-240	RT	450	1, 2
BOPP	Flat 1" + Teflon	1" Silicon + Teflon	120-180	RT	450	1, 2
	Grooved 1"	Grooved 1"	120-180	RT	450	1, 2

4. Results:

4.1 Laminated film overall appearance

Film on Unwinder 1	Film on Unwinder 2	Nip Temperature [°C]	Speed [m/min]	Wrapping angel [deg.]	Overall appearance
Ink/BOPP	EVA/BOPP	100	30	0	
Ink/BOPP	EVA/BOPP	120	30	0	
Ink/BOPP	EVA/BOPP	140	30-40	0	Film shrinkage. strips
Ink/MET-PET/PE	EVA/PET (1.2mil)	100	40	90	
Ink/MET-PET/PE	EVA/PET (1.2mil)	120	40	60	
Ink/MET-PET/PE	EVA/PET (1.2mil)	140	40	30	
Ink/MET-PET/PE	EVA/PET ultra-thin (0.8mil)	100	40	90	Curling
Ink/MET-PET/PE	EVA/PET ultra-thin (0.8mil)	120	40	60	
Ink/MET-PET/PE	EVA/PET ultra-thin (0.8mil)	140	40	30	

4.2 Lamination bond strength of resulting films with good overall appearance was recorded immediately after lamination process and done again within 24hr post lamination.

Film on Unwinder 1	Film on Unwinder 2	Temperature [°C]	Wrapping angle [deg.]	Speed [m/min]	LBS at t=0hrs [N/in]			LBS at t=24hrs [N/in]		
					Patch #22	Patch #16	Patch #11	Patch #22	Patch #16	Patch #11
Ink/BOPP	EVA/BOPP	100	0	30	NA	6.5	NA	5.9	6.5	20
Ink/BOPP	EVA/BOPP	120	0	30	NA	8	NA	8	8.6	20
Ink/MET-PET/PE	EVA/PET (1.2mil)	100	90	40	NA	6-8	NA	6.8	9.0	9.2

Ink/MET-PET/PE	EVA/PET (1.2mil)	120	90	40	NA	6-8	NA	7.2	8.2, 3.7*	9.8
Ink/MET-PET/PE	EVA/PET (1.2mil)	140	30	40	NA	10	NA	10.2	9.3	12.2
Ink/MET-PET/PE	EVA/PET ultra-thin (0.8mil)	100	90	40	NA	6	NA	5.5	1.7*	4.1
Ink/MET-PET/PE	EVA/PET ultra-thin (0.8mil)	120	60	40	NA	6.5	NA	6.1	2*	8.3
Ink/MET-PET/PE	EVA/PET ultra-thin (0.8mil)	140	30	40	NA	8	NA	7.5	8.8	10, 2.7*

The lamination bond strength (LBS) was tested using the standard T-peel testing procedure, according to ASTM D1876.

* Failure occurred between MET-PET layer, the printed substrate (no at TAP layer) i.e. in this cases LBS values not representing TAP performance.

4.3 Sealed area appearance

Top ply	Second ply	Jaws type	Sealing temperature [°C]	Dwell time [s]	Sealed area visual appearance results
EVA/BOPP	Ink/BOPP	Flat	120-240	1	Good appearance up to 160°C
				2	Good appearance up to 150°C
		Grooved	120-200	1	Good appearance up to 160°C
				2	Good appearance up to 150°C
EVA/PET (1.2mil)	Ink/MET-PET/PE	Flat	170-240	1	Good appearance up to 200°C
				2	Good appearance above 210°C up to 240°C
		Grooved	170-200	1	Good appearance up to 200°C
				2	Good appearance up to 220°C
EVA/PET ultra-thin (0.8mil)	Ink/MET-PET/PE	Flat	170-240	1	Good appearance at 240°C
				2	Good appearance above 220°C up to 240°C
		Grooved	170-200	1	Moderate appearance up to 190°C
				2	Moderate appearance up to 190°C

5. Conclusions:

BOPP//EVA/BOPP

- BOPP laminate found to be non-sealable, hence BOPP//EVA/BOPP sealing bond strength was not tested.
- LBS results show good lamination performance between the thermal film and the digital print under specific working point. Laminating films with NIP temperature 100-120°C at 30m/min and minimum wrapping angle resulted to be the appropriate working window for good lamination appearance and Lamination Bond Strength.
- For higher NIP temperature and wrapping angle, the BOPP substrate starts to deform, causing shrinkage in TD right before the NIP, resulting in aggressive wrinkles defect
- When rising the speed (to 40m/min) with 100-120°C NIP temperature wrinkles are observed on the laminated film. Wrinkles can be avoided by increase the rewinder tension but the high tension spoils the film collection badly thus higher lamination speed is not recommended.

- With Flat jaws, sealing shows good appearance up to 160°C (for 1sec dwell time), and up to 150°C (for 2sec dwell time). With grooved jaws appearance is good only up to 180°C. Using higher temperatures BOPP starts to distort.

PE /PET-MET/Ink // EVA/PET (1.2mil)

- Since PET laminate is a non-sealable layer, sealing bond strength was not tested.
- Laminated film has good appearance at the tested working point.
- LBS results show good lamination performance between the thermal film and the digital print at the tested working point. Laminating films with NIP temperature 100-140°C at 40m/min decreasing wrapping angle at temperature increases, resulted to be the appropriate working window for good lamination appearance and Lamination Bond Strength.
- With Flat jaws, sealing shows good appearance up to 200°C, for 1sec dwell time, and between 210°C and 240°C for 2sec dwell time. With grooved jaws appearance is good up to 200-220°C at 1 and 2 sec dwell time, respectively.

PE /PET-MET/Ink // EVA/PET ultra-thin (0.8 mil)

- Since PET laminate is a non-sealable layer, sealing bond strength was not tested.
- Laminated film has good appearance at the tested working point.
- LBS results show good lamination performance between the thermal film and the digital print at the tested working point. Laminating films with NIP temperature 120-140°C at 40m/min decreasing wrapping angle at temperature increases, resulted to be the appropriate working window for good lamination appearance and Lamination Bond Strength.
- With Flat jaws, sealing shows good appearance at 240°C, for 1sec dwell time, and between 220°C and 240°C for 2sec dwell time. With grooved jaws appearance is good up to 190°C at 1 and 2 sec dwell time. At higher sealing temperatures there is ink creeping on the seal area.

6. Summary:

All Nubelus thermal laminating films tested, BOPP Matte 1.08mil and PET Gloss 1.2 and 0.8mil yield high LBS values with good visual lamination appearance.

In the case of BOPP film, high LBS and with good visual lamination appearance, are identified at a quit narrow working window. BOPP substrate is sensitive to heat, where we identify a correlation between BOPP film shrinkage resulting in bad film appearance (i.e. wrinkles). Thus, it is difficult to laminate BOPP at high speed with compensation of high temperature. Working with low temperatures and low speed provides the desired lamination appearance, with acceptable LBS (>6N/inch).

The sealing test reveals that BOPP is non-sealable, suggests that this substrate may be processed only as top layer for in-to-in sealing flexible packaging applications only. Thus, only the seal area appearance was recorded (sealing the printed BOPP).

In the case of PET Gloss 1.2 and 0.8mil films there is a wide working window, 100-140°C at 40m/min.

Good visual lamination appearance was received with acceptable LBS (>6N/inch). The seal area appearance was found to have wider temperature window with the 1.2mil PET film than with the ultra-thin PET film.

Overall, we found that Nubelus thermal laminating films, BOPP and PET Gloss 1.2mil and ultra-thin (0.8mil) compatible films pass lamination appearance and bond lamination bond strength criteria.