MEASURING HOT TACK OF HEATSEALABLE WEBS

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ABSTRACT

Hot tack of HEATSEALABLE webs is measured by a new machine that tracks strength development of a heatseal as it cools during the first half-second after the dies open at conclusion of a heatsealing cycle. The cooling curve thereby generated is displayed on the screen of a computer. Seal strength reached after 250 milliseconds, or other period of cooling, can be used as an index of hot tack behavior for comparison with other materials and with performance on form-fill packaging machines. It is important that laboratory comparisons of hot tack performance of materials be made under similar cooling conditions. Several packaging materials were evaluated using the new machine.

PERSPECTIVE: HOT TACK vs ULTIMATE SEAL STRENGTH

The strength of all heatseals formed by hot-die heatsealers behaves in broadly the same way: The hot seal is initially relatively weak when the dies are opened at conclusion of the sealing cycle, but as the heatseal cools it gains strength rapidly. In a matter of seconds it reaches ambient temperature, and — for most materials[1] — its ultimate strength.

HOT TACK VARIABLES

The term "Hot Tack" refers to the strength of the hot seal during the first 500 to 1000 milliseconds after the dies open. Seal strength changes rapidly as the seal cools, starting at millisecond zero. Hot Tack is a variable that is a function, not only of time, but of ambient cooling conditions affecting transfer of heat from the seal to its environment. Figures 2 – 5 and Table I show development of seal strength at different cooling rates. Commercially, rate of seal cooling can be affected by both packaging-machine and product variables.

THE COOLING CURVE

Ideally, if one could measure both the strength of the hot seal and simultaneously its temperature during the first few hundred milliseconds of the heatseal's life, hot tack performance of a material could be described by a curve of seal strength vs seal temperature — the cooling curve of the material.

Dynamically, seal strength can be accurately measured under test conditions, but seal temperature is very difficult to determine precisely when it is changing rapidly. Sensors can be placed at the seal interface, but introduce a much greater mass and heat capacity than the polymer they are measuring. This causes a serious lag in temperature reading.

We are therefore left with the second-best choice in measuring the cooling curve of the material: Track the increase of strength of the heatseal with time, while controlling cooling conditions at a constant and measured level.

THE HOT TACK INDEX

The curve of hot seal strength vs cooling time portrays the hot tack behavior of a material graphically, but is awkward to compare with curves of other materials or with those generated at other sealing temperatures. Since curves for most materials are generally of the same shape, an index number related to the rate of increase of seal strength with cooling time can be used.

The Theller model HT Heatsealer used in these experiments generates two index numbers — a standard index for comparison with other laboratories, and a user-selected index that can be chosen for a particular applications. The standard index is the strength of the hot seal at 250 milliseconds after die opening, determined by the computer from the cooling time. curve. Obviously, the 250 ms index — or any value of peeling force measured at a specified time — will be greatly affected by cooling rate (Table I). To be valid, comparisons of hot tack performance of materials must be made at the same cooling conditions.

ULTIMATE SEAL STRENGTH

If the cooling-time curve is followed to its completion — to the point the heatseal reaches ambient temperature — it levels off at its Ultimate Seal Strength. This is the strength of the heatseal as normally determined by peel testing on a tensile machine — usually minutes, hours or longer after the seal has been made.

In our work, Ultimate Seal Strength is measured by the same model HT sealer used for hot tack — employing a special mode in which the machine's integral air cooling system operates at maximum, in combination with a delay time (cooling time) set by the operator but usually about 10 sec to allow the heatseal to reach ambient temperature (Fig. 6).

THE HEATSEALING CYCLE

In hot tack testing, the same considerations apply with respect to heatsealing conditions that must be observed in ultimate strength testing — since the only difference between the two procedures is the time interval between conclusion of the sealing cycle and the point in time when the strength of the seal is measured. These considerations are discussed in detail in Reference 1. To summarize:

[1] Seal Strength of some materials continues to change for hours or days after cooling to ambient temperature — due to progressive crystallization.

Sealing Temperature means temperature at the interface between the two surfaces being sealed. This will be equal to die temperature only if two conditions are strictly observed:

1. Both dies are maintained at the same temperature. (A consequence of this requirement is that heatsealability — measured by either ultimate strength or hot tack — cannot be measured using a sealer with only one heated die).
2. Sufficient dwell time is allowed to permit the interface to reach the known temperature of the dies. For films up to about 76 microns (3 mil), 1000 ms is usually ample.

Sealing Pressure must be high enough to flatten the sample to the point where maximum molecular contact is made between the two surfaces — given their specific micro-topography. Heatsealing is a process of diffusion of chain ends from each surface into the other (Ref.2), and it takes place only in areas of molecular contact. Additional pressure does not affect seal strength. We usually seal at about 400 kPa (60psi).

Sealing Dies should be flat. Serrated and other styles can introduce complicating variables that should be studied separately.

COMPARING LABORATORY HOT TACK MEASUREMENTS WITH COMMERCIAL PERFORMANCE

To perform satisfactorily on a commercial form-fill machine, a packaging material must be capable of developing heatseals strong enough to support the product against both its own weight and the stresses it may be subject to immediately upon release from the dies or grippers of the machine. Depending on circumstances of machine type, speed, heatseal grippers, cooling facilities, etc. — and product characteristics such as weight, density, temperature, heat transfer (liquid?) — the material's ability to develop seal strength after only limited cooling may be critical.

Obviously there is no standard set of sealing or handling conditions that could be used in the laboratory to simulate the wide range of conditions encountered commercially. Since the behavior of a material under any set of field conditions is dependent on its basic properties, it makes sense in a laboratory test to characterize the material by measuring those properties. In the case of heatsealability, the basic property is heatseal strength as a function of sealing temperature — and this applies to hot seal strength as well as to ultimate strength.

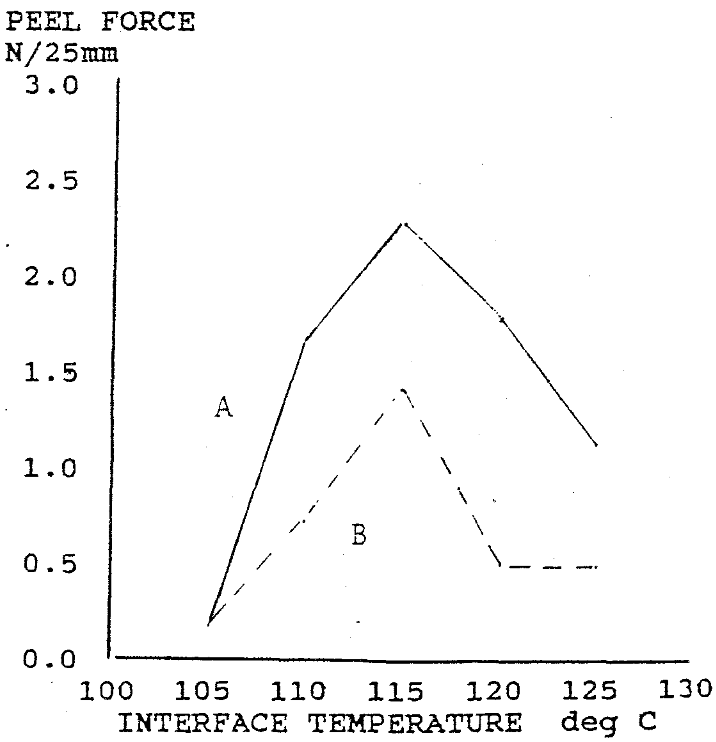
If this approach is adopted — characterize materials by seal strength vs sealing temperature — one finds that attempting to use commercial conditions of die temperature and dwell time as laboratory test conditions for materials evaluation is completely misdirected.

In production, it is desirable to run as fast as possible — everything considered — which means keeping sealing dwell time to a minimum. Since the interface, where the seal is to be formed, must reach a temperature characteristic of the material to develop the necessary strength, the die temperature must be raised to compensate as dwell time is reduced. How much the temperature is raised is determined by the operator by trial and error. There is no problem with this procedure in production, but it is inadequate as an analytical method because although die temperature is known, it gives no information at all on the actual sealing temperature at the interface — which is the critical property determining seal strength.

In the laboratory test procedure, enough dwell time is used for the seal strength to reach a plateau level (Ref.1), where additional dwell time results in no further increase in strength. This is the equilibrium condition, where the interface has reached the known temperature of the dies. Seal strength — both ultimate and hot tack — can then be determined as a function of sealing temperature at any dwell time in the plateau region.

This procedure was used to compare the hot tack of two liquid-packaging films: Film A was run successfully by a commercial packing plant, but Film B was rejected because of excessive seal failure on the machine. Both films were 76 microns (3.0 mils), but from different manufacturers. They were single-layer, unprinted, of undisclosed composition. Figure 1 shows the curve of Hot Tack vs Sealing Temperature for each material, clearly indicating the superior performance of Film A.

Fig. 1. Hot Tack of Liquid-Packaging Films



Data plotted in Fig. 1 are the 250 ms strength values as determined by the computer from cooling curves recorded at each sealing temperature. Original data are shown in Table II (Appendix). Triplicate tests were made at each temperature — with very good reproducibility.

Both materials showed a seal strength maximum at 115° C. At that temperature and below, the hot seal peeled apart and measured force was the strength of the seal itself at 250 ms cooling time.

At 120° and above, the observed force dropped — but as recorded in Table II it was the film itself that broke, and the seal remained for the most part intact. At these higher temperatures the strength of the material had deteriorated to the point it was weaker than the seal.

Figures 7 – 10 show representative cooling curves for both films at 115° C sealing temperature, where hot seal strength reaches its maximum, and at 120°, where net strength has dropped due to thermal weakening of the film itself.

REFERENCES

1. Theller, H.W., *Proceedings, TAPPI 1991 PLC Conference*, "Testing Flexible Web Materials for Heatsealability," p67.

2. Theller, H.W., *Journal of Plastic Film and Sheeting*, "Heatsealability of Flexible Web Materials in Hot-Bar Sealing Applications," 5(1): 66(1989).

TABLES

Table I Effect of Cooling Conditions on Hot Seal Strength

AIR SETTING	OBSERVATIONS N/25MM @ 250 ms					MEAN N	SDEV N
Off	1.90	2.03	1.84	1.95	1.95	1.93	.07
1	2.14	2.31	2.12	2.20	2.17	2.19	.07
5	2.76	2.50	2.58	2.50	2.39	2.55	.14
10	3.23	2.71	2.79	2.90	2.58	2.84	.25

Material: HDPE/SURLYN; 56 microns (2.2mil)
Sealing Conditions: 90° C; 448 kPa (65psi); 1000 ms dwell

Table II. Liquid packaging films: Hot Tack Evaluation of Commercially Acceptable and Rejected Films

INTERFACE TEMP - C	OBSERVATIONS N/25MM @ 250 ms			MEAN N	S DEV N	COMMENTS
Film A:	Acceptable					
105	0.19	0.16	0.22	0.19	0.03	Peel
110	1.68	1.68	1.68	1.68	0.0	"
115	2.25	2.25	2.31	2.27	0.03	"
120	1.95	1.76	1.63	1.78	0.16	Film break @ seal edge
125	0.95	1.25	1.17	1.12	0.16	" " " " "
Film B	Rejected (low hot seal strength)					
105	0.19	0.19	0.22	0.20	0.02	Peel
110	0.76	0.79	0.62	0.72	0.09	"
115	1.19	1.49	1.49	1.39	0.17	"
120	0.54	0.43	0.52	0.50	0.06	Film break @ seal edge
125	0.46	0.41	0.65	0.51	0.13	" " " " "

Materials: Both samples were commercial liquid-packaging films, 76 microns (3.0 mils), from different manufacturers. They were single-layer, unprinted, composition undisclosed.

Sealing Conditions: Dwell time: 1000 ms; Pressure: 448 kPa (65psi); 1/2-mil Mylar carrier sheet.

Fig. 2. Effect of Cooling Conditions on Hot Tack of HDPE/Surlyn: No Induced Air Circulation

TEST DATA: HEATSEALING/SEAL STRENGTH

LINE	SAMPLE			HEATSEALING				PEEL			
NO.	DESCRIP	MILS	REP	TEMP			AVG	Newtons at		BLOWERS	CLAMPS
				UPPER	LOWER	DWELL	PSI	250 mS	500 mS	TEMP SET	CM/MIN
1				90.0	90.0	999	66.1	1.90	2.58	0	100
2				90.1	90.0	1002	66.0	2.03	2.93	0	100
3				90.1	90.1	998	66.2	1.84	2.71	0	100
4				90.2	90.1	1001	66.5	1.95	2.82	0	100
5				90.0	90.1	1000	66.3	1.95	2.93	0	100
6											

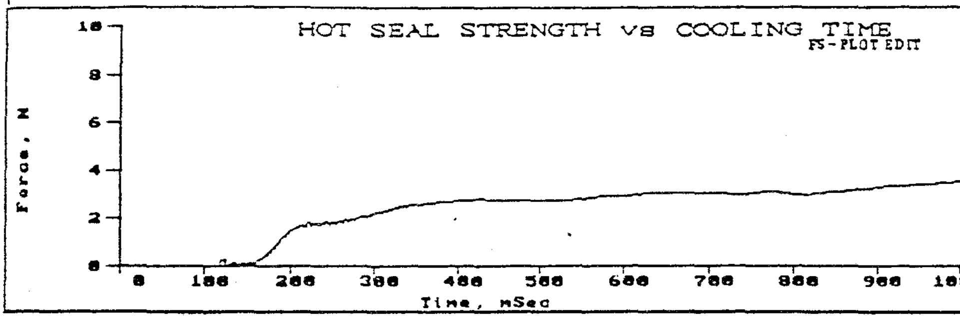


Fig. 3. Effect of Cooling Conditions on Hot Tack of HDPE/Surlyn: 3 M/sec Air Circulation

TEST DATA: HEATSEALING/SEAL STRENGTH

LINE	SAMPLE			HEATSEALING				PEEL			
NO.	DESCRIP	MILS	REP	TEMP			AVG	Newtons at		BLOWERS	CLAMPS
				UPPER	LOWER	DWELL	PSI	250 mS	500 mS	TEMP SET	CM/MIN
1				89.8	89.8	996	67.0	2.14	3.77	1	100
2				90.0	89.9	999	66.9	2.31	3.37	1	100
3				90.0	90.0	998	66.1	2.12	3.77	1	100
4				90.0	90.1	1002	66.6	2.20	3.58	1	100
5				90.1	90.1	1000	66.8	2.17	3.15	1	100
6											

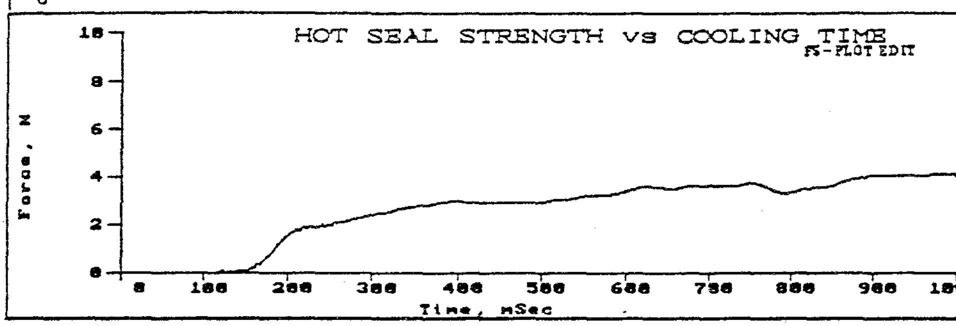


Fig. 4. Effect of Cooling Conditions on Hot Tack of HDPE/Surlyn: 4 M/sec Air Circulation

TEST DATA: HEATSEALING/SEAL STRENGTH

LINE	SAMPLE			HEATSEALING				PEEL			
NO.	DESCRIP	MILS	REP	TEMP			AVG	Newtons at		BLOWERS	CLAMPS
				UPPER	LOWER	DWELL	PSI	250 mS	500 mS	TEMP SET	CM/MIN
1				90.1	90.1	1000	66.0	2.76	4.66	5	100
2				90.0	90.0	999	66.5	2.50	4.10	5	100
3				90.0	90.0	1000	66.4	2.58	4.31	5	100
4				90.0	90.0	1001	66.5	2.50	4.12	5	100
5				89.9	90.0	1000	66.8	2.39	3.61	5	100
6											

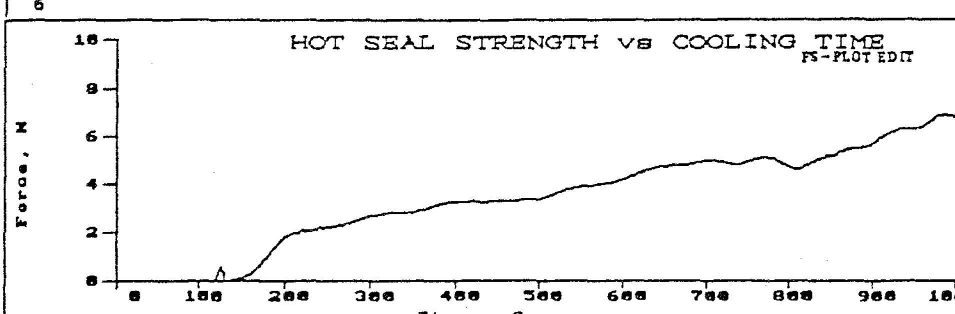


Fig. 5. Effect of Cooling Conditions on Hot Tack of HDPE/Surlyn: 7 M/sec Air Circulation

TEST DATA: HEATSEALING/SEAL STRENGTH

LINE NO.	SAMPLE DESCRIP	MILS	REP	HEATSEALING TEMP UPPER	LOWER	DWELL	AVG PSI	PEEL Newtons at 250 mS	500 mS	BLOWERS TEMP SET	CLAMP S CM/MIN
1				89.9	90.0	999	66.4	3.23	7.32	10	100
2				90.0	90.0	1001	66.7	2.71	5.75	10	100
3				90.0	89.9	1000	66.3	2.79	5.97	10	100
4				90.0	89.9	1000	66.3	2.90	5.40	10	100
5				90.0	90.0	999	66.6	2.58	4.94	10	100
6											

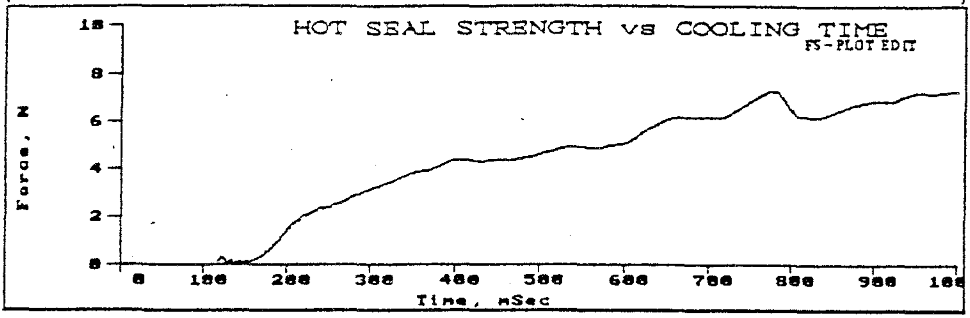


Fig. 6. Ultimate Seal Strength of HDPE/Surlyn: Seal Profile after 10-sec Stabilization Period

TEST DATA: HEATSEALING/SEAL STRENGTH

LINE NO.	SAMPLE DESCRIP	MILS	REP	HEATSEALING TEMP UPPER	LOWER	DWELL	AVG PSI	PEEL GRAMS MAX F	BLOWERS TEMP SET	CLAMP S CM/MIN
31				194.5	194.4	1081	54.9	1381	10	30
32				194.7	194.8	921	57.9	1471	10	30
33				194.9	194.8	998	57.9	1526	10	30
34			AVG	194.7	194.7	1000	56.9	1459	10	30
35			sd	0.2	0.2	65	1.4	59	0	0
36										

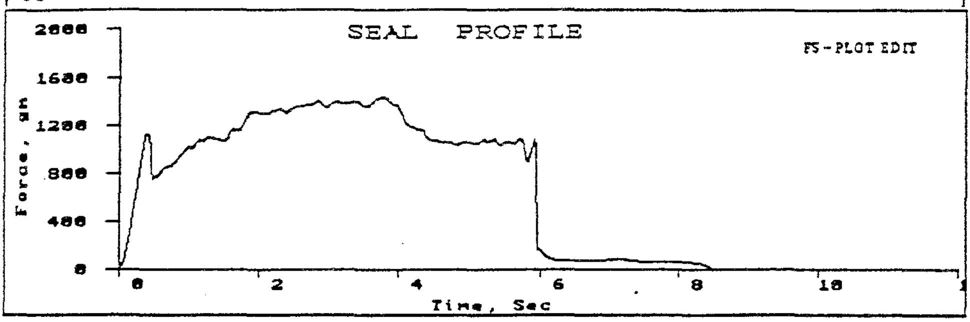


Fig. 7. Hot Tack of Good Liquid-Packaging Film @ 115 C Sealing Temperature

TEST DATA: HEATSEALING/SEAL STRENGTH

LINE NO.	SAMPLE DESCRIP	MILS	REP	HEATSEALING TEMP UPPER	LOWER	DWELL	AVG PSI	PEEL Newtons at 250 mS	500 mS	BLOWERS TEMP SET	CLAMP S CM/MIN
23	A			115.0	115.0	999	66.6	2.25	2.77	5	100
24				114.9	115.0	1001	65.8	2.25	2.66	5	100
25				115.0	115.0	1000	66.1	2.31	2.55	5	100
26											
27											
28											

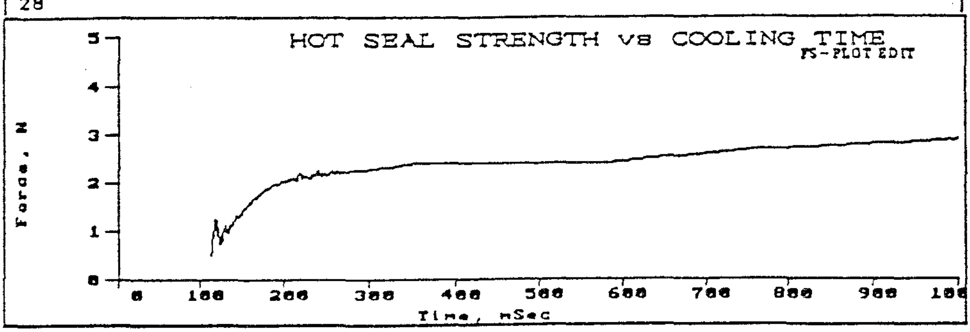


Fig. 8. Hot Tack of Poor Liquid-Packaging Film @ 115 C Sealing Temperature

TEST DATA: HEATSEALING/SEAL STRENGTH

LINE NO.	SAMPLE DESCRIP	MILS	REP	HEATSEALING TEMP UPPER	LOWER	DWELL	AVG PSI	PEEL Newtons at 250 mS	500 mS	BLOWERS TEMP SET	CLAMPS CM/MIN
26											
27											
28	B			114.9	115.1	1000	65.9	1.19	1.90	$	100
29				114.9	114.9	1002	66.7	1.49	2.06	$	100
30				115.0	115.1	999	66.2	1.49	2.01	$	100
31											

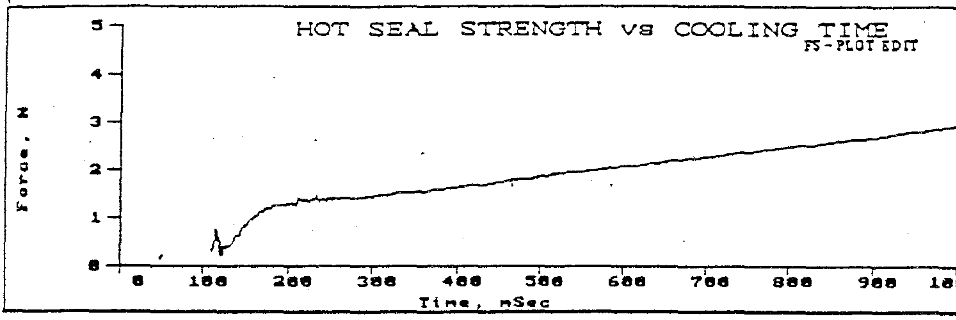


Fig. 9. Hot Tack of Good Liquid-Packaging Film @ 120 C Sealing Temperature

TEST DATA: HEATSEALING/SEAL STRENGTH

LINE NO.	SAMPLE DESCRIP	MILS	REP	HEATSEALING TEMP UPPER	LOWER	DWELL	AVG PSI	PEEL Newtons at 250 mS	500 mS	BLOWERS TEMP SET	CLAMPS CM/MIN
31											
32											
33	A			120.0	120.0	999	66.6	1.95	1.55	$	100
34				119.9	119.9	999	65.7	1.76	1.41	$	100
35				120.0	120.1	1002	66.3	1.63	1.19	$	100
36											

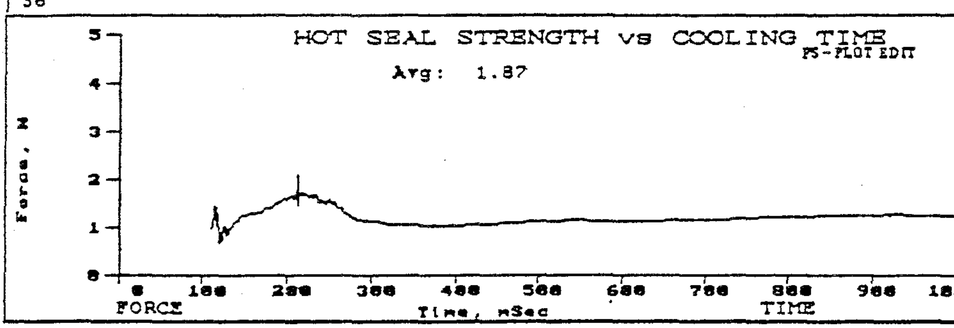


Fig. 10. Hot Tack of Poor Liquid-Packaging Film @ 120 C Sealing Temperature

TEST DATA: HEATSEALING/SEAL STRENGTH

LINE NO.	SAMPLE DESCRIP	MILS	REP	HEATSEALING TEMP UPPER	LOWER	DWELL	AVG PSI	PEEL Newtons at 250 mS	500 mS	BLOWERS TEMP SET	CLAMPS CM/MIN
36											
37											
38	B			120.0	120.0	999	66.5	0.54	0.62	$	100
39				119.9	119.9	1000	65.8	0.43	0.54	$	100
40				119.9	119.9	999	66.2	0.52	0.62	$	100
41