Douglas-Fir Optimised Engineered Lumber (OEL™) Trial

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EXECUTIVE SUMMARY

The OEL™ (Optimised Engineered Lumber) technology produces structural products with known, uniform and reliable properties. There is financial advantage derived from the fact that all the merchantable OEL™ production output is certified structural grade (no downfall products), this compares with the output from traditional sawmilling where not all production achieves certification as structural grade product.

Wood Engineering Technology Ltd (WET) hold patents of the OEL™ process and are currently in the process of commercialising the OEL™ product. WET was sub-contracted by Scion to undertake this Douglas-fir trial for the Special Wood Product Partnership.

The intention of this project was to complete a scoping only study that took Douglas-fir thinning material through the OEL™ process followed by an assessment of the mechanical properties with the high level OEL™ economics developed.

Ernslaw One supplied 3m^3 of Douglas-fir thinning's logs these were young with an average age of 15 years, small end diameters (over bark) ranged from 19.5 – 36.5cm. large end diameters (over bark) ranged from 27.0 – 42.0cm, with an average Hitman value of 3.3km/sec. Wood Engineering Technology Ltd (WET) processed these into 71 pieces of 90x45x2930mm OEL™ and these were then supplied Scion for mechanical testing.

The results of the mechanical testing showed that the Douglas-fir OEL™ achieved the strength and stiffness properties of the New Zealand structural grade SG8. SG8 is the common grade used in house framing

The economic comparisons indicated the superior results of using OEL™ technology in converting 15-year-old average age production thinning Douglas fir logs into SG8 structural lumber (glulam), when compared with a saw log from full thirty-year rotation Radiata pine. This comparison applies to both Douglas fir logs that would normally be graded to saw logs or to pulp logs

INTRODUCTION

Optimised Engineered Lumber (OEL™)

The OEL™ process produces structural products with known, uniform, stable and reliable properties.

Essentially the OEL™ process starts with the production of metre long thin laminates that are of a known stiffness and strength. These laminates are then sorted into stiffness grades with the grade thresholds between the grades being determined from the layup and such that the target final section stiffness is achieved. The graded laminates are then finger-jointed together and then laid up in the predetermined sequence and glued together to form the final finger-jointed, laminated section as shown in Figure 1.

Wood Engineering Technology Ltd (WET) hold patents of the OEL™ process and are currently in the process of commercialising the OEL™ product. WET has been sub-contracted by Scion to undertake this Douglas-fir trial for the Special Wood Product Partnership.

Figure 1: *Douglas-fir 90x45 Optimised Engineered Lumber (OEL™)*

STUDY GOAL

The intention of this project was to complete a scoping only study that took Douglas-fir thinning material through the OEL™ process followed by an assessment of the mechanical properties. The high level OEL™ economics were also to be developed.

The outcome being to provide (or not) justification for further development, optimisation and potential commercialisation of this opportunity.

This scoping study as with any scoping study has limitations that would need to be further explored prior to commercialisation namely:

- Limited sample size.
- No replication across different forest resources, log types.
- No ability to tailor the processing to the Douglas-fir, i.e. The Radiata pine process parameters had to be used.
- Only room for one set of processing variables, i.e. No process optimisation possible.
- Only the major product properties are explored, in this case these were the primary mechanical properties. There are other properties that should be considered to develop this commercial opportunity namely:
    - Laminate bond quality
    - Timber treatment ability, ability to satisfy the H1.2 treatment class
    - Mechanical jointing properties (nail plate, nail, screw & bolt strengths)

LOG PROPERTIES

For this OEL™ trial Ernslaw One were asked to supply:

- 3m^3 of Douglas-fir thinning logs, the logs were to be cut to 3.3m long with a tidy square cut ends, the logs also needed to be debarked and cut into two half rounds.
- The logs were to be representative of the estate thinning's
- Record log information, age, shape, diameters, hitman etc..

Table 1 lists the log properties supplied. Figure 2 shows some photographs of the trial logs.

WET cut the 3.3m long logs into three 1.05m long logs to fit their process, the logs were supplied cut in half to help with processing in the WET pilot plant, this halving of logs is not a requirement in the final OEL™ commercial operation.

Table 1: *Douglas-fir Log properties as supplied by Ernslaw One*

Tree	**Log**	**Over Bark LED (mm)**	**Over Bark SED (mm)**	**Number of rings**	**log length, (m)**	**Hitman (km/sec)**	**BIX**
1	1	381.0	300.0	17.0	3.3	2.9	2.8
1	2	276.0	230.0	11.0	3.3	2.9	3.8
2	1	416.0	315.0	19.0	3.3	2.7	2.9
3	1	366.0	245.0	18.0	3.3	3.6	4.6
4	1	281.0	220.0	14.0	3.3	3.6	4.6
5	1	331.0	290.0	16.0	3.3	3.9	4.0
7	1	411.0	365.0	15.0	3.3	2.7	3.5
7	2	321.0	275.0	12.0	3.3	2.7	4.3
8	1	416.0	295.0	18.0	3.3	2.9	2.9
8	2	296.0	250.0	14.0	3.3	2.9	3.4
9	1	371.0	270.0	17.0	3.3	2.9	3.0
9	2	271.0	250.0	13.0	3.3	2.9	2.8
10	1	346.0	300.0	16.0	3.3	4.0	2.3
12	2	286.0	240.0	14.0	3.3	2.9	4.8
11	1	421.0	300.0	18.0	3.3	2.8	2.3
12	1	391.0	280.0	18.0	3.3	2.9	3.6
13	1	411.0	280.0	12.0	3.3	4.4*	5.3
13	2	281.0	195.0	9.0	3.3	4.3*	4.4
14	1	311.0	265.0	12.0	3.3	4.7*	3.8
15	1	381.0	260.0	12.0	3.3	4.3*	4.4
	Average	348.3	271.3	14.8	3.3	3.3	3.7
	Minimum	271.0	195.0	9.0	3.3	2.7	2.3
	Maximum	421.0	365.0	19.0	3.3	4.7	5.3
	Range	150.0	170.0	10.0	0.1	2.0	3.0
	STDev	54.49	37.80	2.86	0.02	0.69	0.87
	CoV%	15.65%	13.93%	19.41%	0.69%	20.51%	23.87%
	Count	20	20	20	20	20	20

* these appear high compared with the values above.

In summary the logs supplied were young with an average age of 15 years, small end diameters (over bark) ranged from 19.5 – 36.5cm. large end diameters (over bark) ranged from 27.0 – 42.0cm, with an average Hitman value of 3.3km/sec.

Figure 2: *Photographs of the Logs supplied*

Figure 2 (Cont): *Photographs of the Logs supplied*

OEL™ PROCESSING

Sawing

WET cut the 3.3m logs to a 1m length by cutting a piece 1.05m from the centre of each log to allow for chainsaw run off. The logs were slabbed off into 50mm slabs and docked square to a 1m length.

As the logs had been halved for quite an extended period the initial log halving cut was no longer straight. Thus when they were gang sawn into 1 m boards they are held against a fence set up such that the "first" saw blade makes a full cut down the "straight side". If the bowing (Figure 3) was any more than the 2.3mm kerf then they ended up with the first stick being unacceptably tapered and these had to be rejected. 44 sticks were rejected due to taper as they came off the gang saw. Note WET would expect with a fresh harvest (full logs within a week of being felled) might have resulted in no more than a loss of 3 sticks to this point in the process

Figure 3: *Bowed 50mm cants*

WET expected a 48.5% yield (based on an average SED of 330mm) ie 3598 sticks and achieved a yield of 3101 sticks, a yield of 42%. There are two possible reasons for this lower yield.

- Even at 1m length there are taper losses. The average taper over these logs is 26.3mm of diameter per m length. Radiata K logs average about 14mm/m. The high taper resulted in an extra 4% losses.
- The log diameter was low for the OEL process and smaller logs result in a higher proportion of sticks with wane which then had to be rejected. For the typical diameter processed the yield (@ 0.014 taper) would be about 44%.

The combination of high taper and small diameter would lead to an expected yield of 42.5% which compares the 42% achieved.

Drying

The 3101 sticks were supplied to Scion for drying. WET supplied Scion with its purpose built drying frame which is fabricated in a manner that restrains the sticks from moving whilst drying. The sticks were dried at 90/60°C for 9 hours plus steam reconditioning for 2.5 hours targeting a final moisture content of 6%. This schedule is based on an appearance-grade Radiata schedule and the literature suggested that Douglas-fir can be dried using conventional temperature Radiata schedules. Two sticks per kiln load were oven-dried to determine moisture content, the average moisture content of these sticks was 5.9%.

After drying the sticks were stored for 3 days at 40°C, 26°C wet bulb (EMC = 6%) then were block stacked and sent back to WET. It was observed that the drying quality was very good with no observed checking, collapse or distortion which is not unexpected as Douglas-fir is seen as being easy to dry. There is room for optimisation of drying schedule to reduce drying times, reduce brittleness (see next section of report).

Finger- jointing, thicknessing and laminating

WET did not un-pack the dried sticks until they were ready to process them, the dried sticks were kept block stacked in a sealed container in order to keep to the 6% moisture content. As the pilot plant recommissioning took longer than anticipated the sticks were stored 14 weeks which would not happen in a commercial operation.

This 14 week time period resulted in WET visually rejecting some sticks that had developed excessive bow or crook particularly at the ends which may not occur in the commercial operation. Some tapered sticks were also found during the thickness processing operation which may have affected the restraint provided to nearby sticks during drying.

The full OEL™ process has a machine process that culls sticks that are too weak or excessively distorted, however this was not available for this trial hence WET initially started by only undertaking a cursory visual cull and being quite generous with the amount of distortion which the process (but perhaps not the pilot machinery) could deal with. It was also found that some of the sticks were quite brittle and would simply fall apart during processing. After many stoppages and some gear breakages the visual cull became quite harsh with some 478 sticks being visually rejected some 15% versus about 2.7% for machine culled Radiata.

The finger-jointing worked reasonably well, some joints did not have the correct amount of glue applied, this however is a function of the pilot plant and would not be expected to occur in a commercial plant.

Generally the lamination worked well, with some glue application issues again these are a function of the pilot plant and would not be expected to occur in a commercial plant.

After curing the OEL™ was planed on four sides.

Finally WET supplied Scion with 71 pieces of 90x45x2930mm Douglas-fir OEL™ .

TESTING FOR MECHANICAL PROPERTIES

Scion carried out the mechanical tests on the Douglas-fir OEL™ 90x45 product supplied by WET.

1. The bending strength and stiffness specimens were tested to destruction in accordance with AS/NZS4063.1:2010. The Scion Grade 1 Baldwin Universal test machine was used for the bending tests.
2. The tension strength specimens were tested to destruction in accordance with AS/NZS4063.1:2010. The Scion tension test machine was used for the tension tests.
3. The compression strength specimens were tested to destruction in accordance with AS/NZS4063.1:2010. The Scion Grade 1 Baldwin Universal test machine was used for the compression tests.
4. The shear strength specimens were tested to destruction in accordance with AS/NZS4063.1:2010. The Scion Grade 1 Baldwin Universal test machine was used for the shear tests.
5. The strength and stiffness data was analysed in accordance with AS/NZS4063.2:2010.

All the testing was completed in the Timber Engineering laboratory of Scion, Rotorua, New Zealand. The testing was carried out over the period 23 June - 30 June 2016.

Mechanical Test Results

The characteristic strength and stiffness properties have been calculated using the calculations and procedures set out in AS/NZS4063.1:2010. The following Table 2 shows the characteristic strength and stiffness values for the Douglas-fir OEL™ 90x45 product with Table 3 listing the New Zealand characteristic grade stresses for the SG stress grades.

Table 4 shows a statistical summary of the strength and stiffness data with the Appendix listing the raw test data collected.

***Table 2**: AS/NZS4063.2:2010 Characteristic Strength Properties as Tested*

• **90x45 Douglas-fir** OEL™	**Bending Stiffness MoE As a Joist GPa**	**Bending Strength MoR As a Joist MPa**	**Tension Parallel Strength MPa**	**Compression Parallel Strength MPa**	**Shear Strength * MPa**
90x45 (Indicated SG grade)	8.64 (SG8)	16.54 (SG8)	10.55 (SG10)	38.28 (SG15)	Note 1

Note 1 – Only 4 samples failed in shear all of these either achieved or exceeded the SG8 value of 3.8MPa

***Table 3:** Characteristic stresses for machine graded timber NZS3603 A4*

Moisture Content – Dry (m/c = 16%)						
Species	**Grade**	**Bending Strength MPa**	**Compression Strength MPa**	**Tension Strength MPa**	**Bending Stiffness GPa**	**Lower bound Bending Stiffness GPa**
Radiata Pine & Douglas-fir	**SG 15**	41.0	35.0	23.0	15.2	11.5
	SG 12	28.0	25.0	14.0	12.0	9.0
	SG 10	20.0	20.0	8.0	10.0	7.5
	SG 8	14.0	18.0	6.0	8.0	5.4
	SG 6	10.0	16.0	4.0	6.0	4.0

Note: The shear strength for dry Radiata pine and Douglas-fir shall be taken as fs = 3.8 MPa.

***Table 4**: Douglas-fir OEL™ 90x45 Strength and Stiffness Statistical Summary as Tested*

90x45 Douglas-fir OEL™	Bending Stiffness MoE As a Joist GPa	Bending Strength MoR As a Joist MPa	Tension Parallel Strength MPa	Compression Parallel Strength MPa	Applied Shear Stress * MPa
Average	8.75	26.79	13.38	40.79	-
Minimum	6.72	16.54	9.11	30.52	-
Maximum	10.05	47.19	17.93	48.05	-
Range	3.33	30.65	8.81	17.53	-
STDev	0.87	7.08	1.97	3.54	-
CoV%	9.90%	26.42%	14.76%	8.67%	-
Count	30	30	30	30	-

***** Note only four of the 30 shear samples failed in shear, the other 26 failed in bending prior to the maximum shear strength being achieved.

The result of the mechanical testing showed that the Douglas-fir OEL™ achieved the strength and stiffness properties of the New Zealand structural grade SG8. SG8 is the common grade used in house framing.

OEL™ ECONOMICS

Prepared by Wood Engineering Technology Ltd, June 2016.

Conclusions regarding relative economics

Economic comparisons indicated the superior results of using OEL™ technology in converting average age 15-year-old production thinning Douglas fir logs into SG8 structural lumber (glulam), when compared with a saw log from full thirty-year rotation Radiata pine. This comparison applies to both Douglas fir logs that would normally be graded to saw logs or to pulp logs.

The OEL™ technology gives superior financial outcomes to that used of traditional sawmilling as all the merchantable production output is certified structural grade (as evidenced by the Scion test results in this trial) providing a higher total revenue at a similar total cost therefore a much enhanced return on capital employed. Generally, less than half of the output from traditional sawmilling achieves certification as structural grade product.

Trial design

The trial, using Douglas fir logs comprising production thinning's of 15 years average age (Trial Logs) generally of saw log grade with an average SED of 230mm, processed all logs through the Wood Engineering Technology Limited (WET) pilot plant into OEL™ engineered wood products. Scion then measured the resultant OEL™ output at their facility in Rotorua, and confirmed that all of the output exceeded the performance grade required for use as SG8 lumber.

Outcomes and assumptions

The economics were based on applying a saw grade log input cost range of $70-80/cum and a pulp grade log input cost of $45/cum. Yields of merchantable lamina sticks was reduced by an estimated amount of 5% compared with Radiata due to the presence of a quantity of brittle sticks, that were rejected in process. A further 11% conversion yield loss was applied against the use of pulp logs due to form and shape of the logs.

Financial comparisons

The economics below were derived from the results of one trial only, and more trials will be required to corroborate these calculations. Furthermore, it would be desirable to conduct more trials in order to understand the causation of the brittleness phenomenon, so as perhaps to be able to prevent this effect occurring.

Indicative WET Economics processing Douglas fir using the OEL™ Process (Prepared June 2016)

Key Assumptions:	**Radiata**	**Douglas fir**	**Douglas fir**	**Douglas fir**
1 cum log weighs 1 tonne	**OEL™ Process**	**OEL™ Process**	**OEL™ Process**	**OEL™ Process**
Log Grade	**S30**	**Saw**	**Trial logs**	**Pulp**
SED Average (mm)	300	260	230	230
Length	4.8m+	4.8m+	4.8m+	Random
Theoretical Yield - Actual Count (90X45)	47.5%	44.00%	40.00%	40.00%
Additional Douglas fir Losses - Brittle	0.0%	11.0%	11.0%	11.0%
Additional Douglas fir Losses - Pulp	0.0%	0.0%	0.0%	25.0%
Net Theoretical Yield - Actual Count (90X45)	47.5%	39.2%	35.6%	25.6%
NetTheoretical Yield - Nominal Count (100X50)	**58.6%**	**48.3%**	**44.0%**	**31.6%**
Log Price $/cum (Indicative prices May 2016)	104	80	70	45
Extra handling of small logs in yard	0	0	0	5
Total Indicative Log Price $/cum	**104**	**80**	**70**	**50**
Projected Wood Cost $/cum of Finished Product	**177**	**165**	**159**	**158**

CONCLUSION

This scoping study showed:

- That the low quality Douglas-fir thinning's can be successfully converted into OEL™.
- A recovery from log to finished product of 42% was achieved.
- The OEL™ achieved the bending stiffness, and bending, tension and compression and shear strengths of the common house framing grade of SG8.
- The economic assessment as provided by Wood Engineering Technology Limited showed the projected wood cost per m^3 for the Douglas-fir OEL™ being lower than that for Radiata OEL™.
- The OEL™ technology is considered superior to that used in traditional sawmilling because all of the output is converted into first grade structural product.
- There is an opportunity to optimise/tailor the OEL™ process around this Douglas-fir thinning material which should lift recoveries, improve the drying, finger-jointing and laminating processes in turn improving the economics.
- As this was just scoping study consideration should be given to
    - Increasing the sample size via replication across different forest resources, log types
    - Timber treatment ability, ability to satisfy the H1.2 treatment class
    - Mechanical jointing properties (nail plate, nail, screw & bolt strengths)

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REFERENCES

1. AS/NZS4063.1:2010, Characterization of structural timber Part 1: Test methods. Standards Australia/Standards New Zealand.

2. AS/NZS4063.2:2010, Characterization of structural timber Part 2: Determination of characteristic values. Standards Australia/Standards New Zealand.

APPENDIX A

Table A1: *Douglas-fir OEL 90x45 - Bending as a joist Strength and Stiffness*

Lab No	Client No:	Width mm	Depth mm	Slope N/mm	Max Load N	Bending Stiffness MoEj GPa	Bending Strength MoRj MPa
275480	31	45.12	88.56	317.92	6221	9.19	28.48
275481	32	45.00	88.94	346.35	7529	9.91	34.26
275482	33	44.96	88.84	289.78	7738	8.32	35.33
275483	34	44.80	89.14	344.99	6438	9.84	29.30
275484	35	45.05	88.89	281.53	6614	8.06	30.10
275485	36	45.03	88.69	348.64	8026	10.05	36.71
275486	37	44.78	88.79	291.06	5216	8.41	23.94
275487	38	44.88	88.82	275.12	5252	7.92	24.03
275488	39	44.89	88.73	293.90	6414	8.49	29.40
275489	40	44.86	88.70	340.53	3604	9.85	16.54
275490	41	45.03	88.06	283.98	3783	8.36	17.55
275491	42	44.67	88.62	300.18	5110	8.74	23.60
275492	43	44.72	88.03	265.66	4523	7.88	21.14
275493	44	44.84	88.23	335.12	10168	9.85	47.19
275494	45	44.77	87.99	328.59	5659	9.75	26.45
275495	46	44.79	88.11	314.06	4329	9.28	20.17
275496	47	44.86	88.11	330.44	9179	9.75	42.70
275497	48	44.81	87.99	294.54	5141	8.74	24.01
275498	49	45.05	87.96	325.83	4035	9.62	18.75
275499	50	44.85	88.05	304.11	7101	8.99	33.08
275500	51	44.78	88.01	300.75	4914	8.92	22.95
275501	52	44.76	88.10	272.65	4956	8.07	23.11
275502	53	44.84	88.13	286.51	5270	8.45	24.51
275503	54	44.96	88.09	278.95	5259	8.22	24.42
275504	55	44.80	88.07	287.35	5704	8.50	26.59
275505	56	44.85	87.96	277.90	4859	8.24	22.68
275506	57	45.25	88.28	291.58	5457	8.48	25.07
275507	58	45.04	88.25	229.63	6247	6.72	28.85
275508	59	44.93	88.10	310.00	4846	9.14	22.51
275509	60	44.98	88.01	229.99	4344	6.79	20.20

Table A2: *Douglas-fir OEL 90x45 Tension Strength*

Lab No	Client No:	Width mm	Depth mm	Max Load kN	Tension Strength MPa
275510	1	44.95	88.68	58.60	14.70
275511	2	44.79	88.61	46.85	11.80
275512	3	44.91	88.06	46.50	11.76
275513	4	44.80	88.05	58.00	14.70
275514	5	44.74	88.06	46.50	11.80
275515	6	44.98	88.11	64.35	16.24
275516	7	45.22	88.70	68.45	17.07
275517	8	45.06	88.60	60.65	15.19
275518	9	45.04	88.74	51.85	12.97
275519	10	44.92	88.05	50.65	12.81
275520	11	45.04	88.20	49.85	12.55
275521	12	44.89	88.48	61.20	15.41
275522	13	45.07	88.04	50.25	12.66
275523	14	44.84	88.11	56.77	14.37
275524	15	44.83	88.10	70.80	17.93
275525	16	44.82	88.01	51.75	13.12
275526	17	44.06	88.04	48.90	12.61
275527	18	44.22	88.56	36.30	9.27
275528	19	44.85	89.14	49.80	12.46
275529	20	45.04	87.98	57.80	14.59
275530	21	44.85	88.94	49.85	12.50
275531	22	44.98	88.66	61.00	15.30
275532	23	45.02	88.00	45.75	11.55
275533	24	44.93	88.14	54.50	13.76
275534	25	44.96	88.22	48.85	12.32
275535	26	44.92	88.70	55.75	13.99
275536	27	44.83	88.16	48.65	12.31
275537	28	44.94	88.14	36.10	9.11
275538	29	45.03	87.84	49.85	12.60
275539	30	44.54	89.06	54.90	13.84

Table A3: *Douglas-fir OEL 90x45 Compression Strength*

Lab No	Client No:	Width mm	Depth mm	Max Load N	Compression Strength MPa
275540	31	45.08	88.50	121767	30.52
275541	32	44.90	88.71	156651	39.33
275542	33	44.97	88.81	175816	44.02
275543	34	44.93	89.08	163447	40.84
275544	35	45.05	89.09	159333	39.70
275545	36	45.12	88.80	178943	44.66
275546	37	45.00	88.62	137116	34.38
275547	38	44.73	88.48	178578	45.12
275548	39	44.87	88.33	149747	37.78
275549	40	44.88	88.55	144560	36.38
275550	41	44.83	88.05	152906	38.74
275551	42	44.93	88.88	162789	40.76
275552	43	44.69	87.93	164219	41.79
275553	44	44.98	88.47	174398	43.83
275554	45	44.93	88.19	168491	42.52
275555	46	44.99	88.09	162818	41.08
275556	47	44.88	88.17	165769	41.89
275557	48	44.89	88.11	164677	41.63
275558	49	45.05	88.04	154950	39.07
275559	50	44.86	88.08	178402	45.15
275560	51	44.94	88.29	144133	36.33
275561	52	44.98	88.09	177884	44.89
275562	53	44.76	88.11	157411	39.91
275563	54	44.95	88.32	163848	41.27
275564	55	44.79	88.02	155304	39.39
275565	56	44.81	87.99	159612	40.48
275566	57	44.98	87.97	170796	43.16
275567	58	45.03	87.94	159023	40.16
275568	59	45.12	88.15	191095	48.05
275569	60	44.88	88.02	161249	40.82

Table A4: *Douglas-fir OEL 90x45, Shear as Joist*

Lab No	Client No:	Width mm	Length mm	Max Load N	Applied Shear Stress MPa	Shear / Bending Failure
275570	31	45.15	88.39	18.50		Bending
275571	32	45.12	89.04	16.45		Bending
275572	33	45.21	89.05	21.45	4.00	Shear
275573	34	45.00	89.19	19.05		Bending
275574	35	45.56	89.25	16.40		Bending
275575	36	45.08	89.31	23.40		Bending
275576	37	45.05	88.74	16.30		Bending
275577	38	44.73	89.02	13.20		Bending
275578	39	45.12	88.53	19.35		Bending
275579	40	44.97	88.82	19.90		Bending
275580	41	45.07	88.53	17.10		Bending
275581	42	44.84	88.96	19.95	3.75	Shear
275582	43	44.83	88.21	16.45		Bending
275583	44	44.83	88.26	19.85	3.76	Shear
275584	45	44.89	88.01	17.15		Bending
275585	46	45.00	88.06	24.35	4.61	Shear
275586	47	45.04	87.99	7.75		Bending
275587	48	44.85	88.26	26.00		Bending
275588	49	45.10	88.01	18.90		Bending
275589	50	44.94	88.10	16.40		Bending
275590	51	44.75	88.09	15.65		Bending
275591	52	44.81	88.23	16.85		Bending
275592	53	44.84	88.13	17.65		Bending
275593	54	45.08	88.05	20.05		Bending
275594	55	44.89	88.31	20.90		Bending
275595	56	44.86	87.96	23.40		Bending
275596	57	44.91	88.09	21.15		Bending
275597	58	45.06	88.41	17.55		Bending
275598	59	45.01	88.11	18.60		Bending
275599	60	44.99	88	17.75		Bending