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Use of Multiple Reactor Technology to Produce Enhanced Single Site Catalyzed Polyethylenes for Film Applications

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Outline

- Benefits/Issues with existing Single Site/Metallocene Catalyzed Polyethylenes
- Introduction to Multiple Reactor Technology
- Pilot Plant Experiment
- Commercial Plant Production
- Conclusions
- Acknowledgements

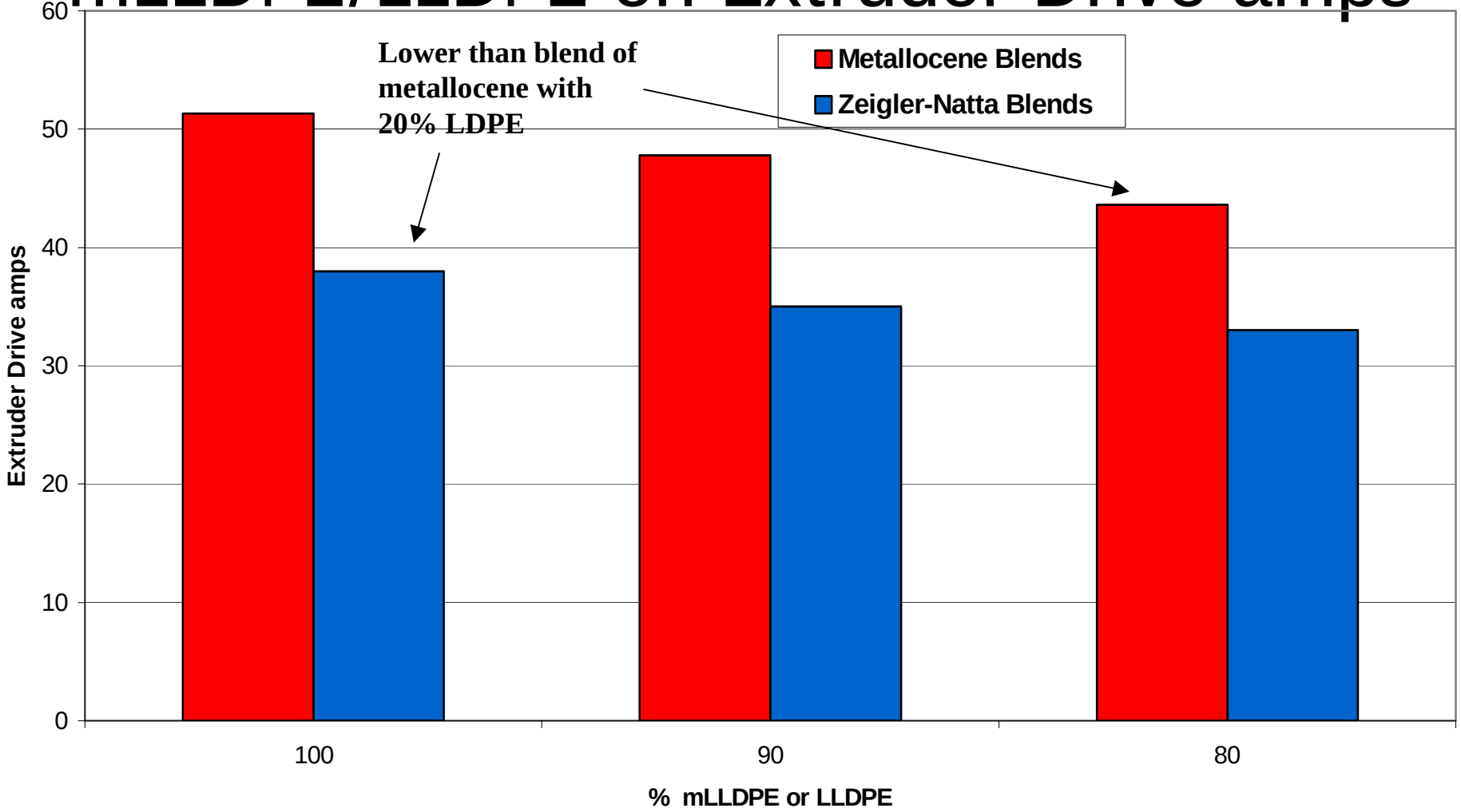
Benefits/Issues with existing Single Site/Metallocene catalyzed Polyethylenes

- Existing commercial single site and metallocene catalyzed products offer excellent impact properties, sealing characteristics, and low hexane extractables. These materials have found a place in a wide range of film applications as a result of these properties.
- Two key issues that have limited substantial growth in the marketplace has been the processing characteristics and poor tear strength of these materials.

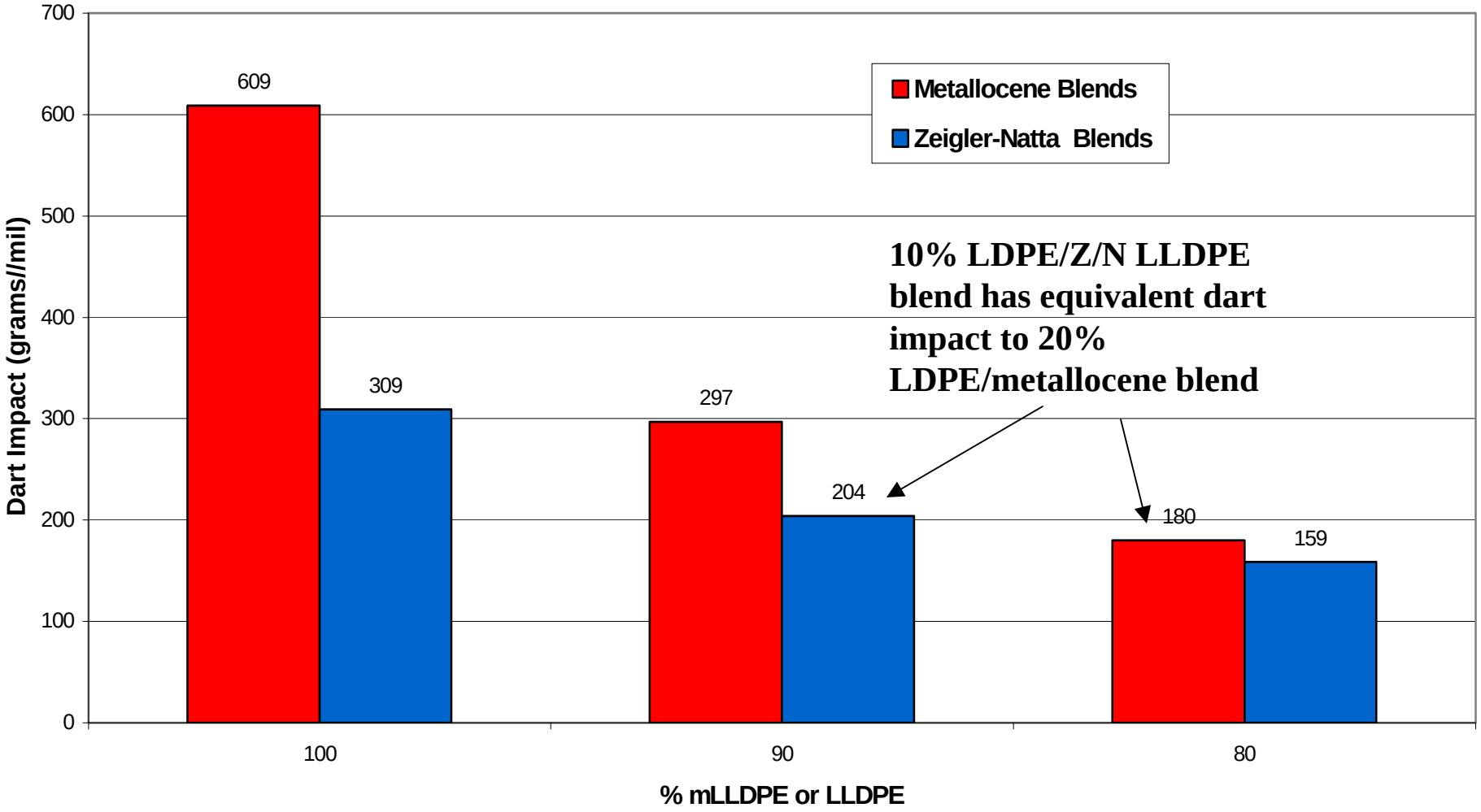
Benefits/Issues with existing Single Site/Metallocene catalyzed Polyethylenes

- The poor processing characteristics of these materials has been combated by blending LDPE at 10-20% to reduce motor load, head pressure parameters and enhance bubble stability.
- Blending of LDPE significantly reduces dart impact properties and further reduces tear properties.

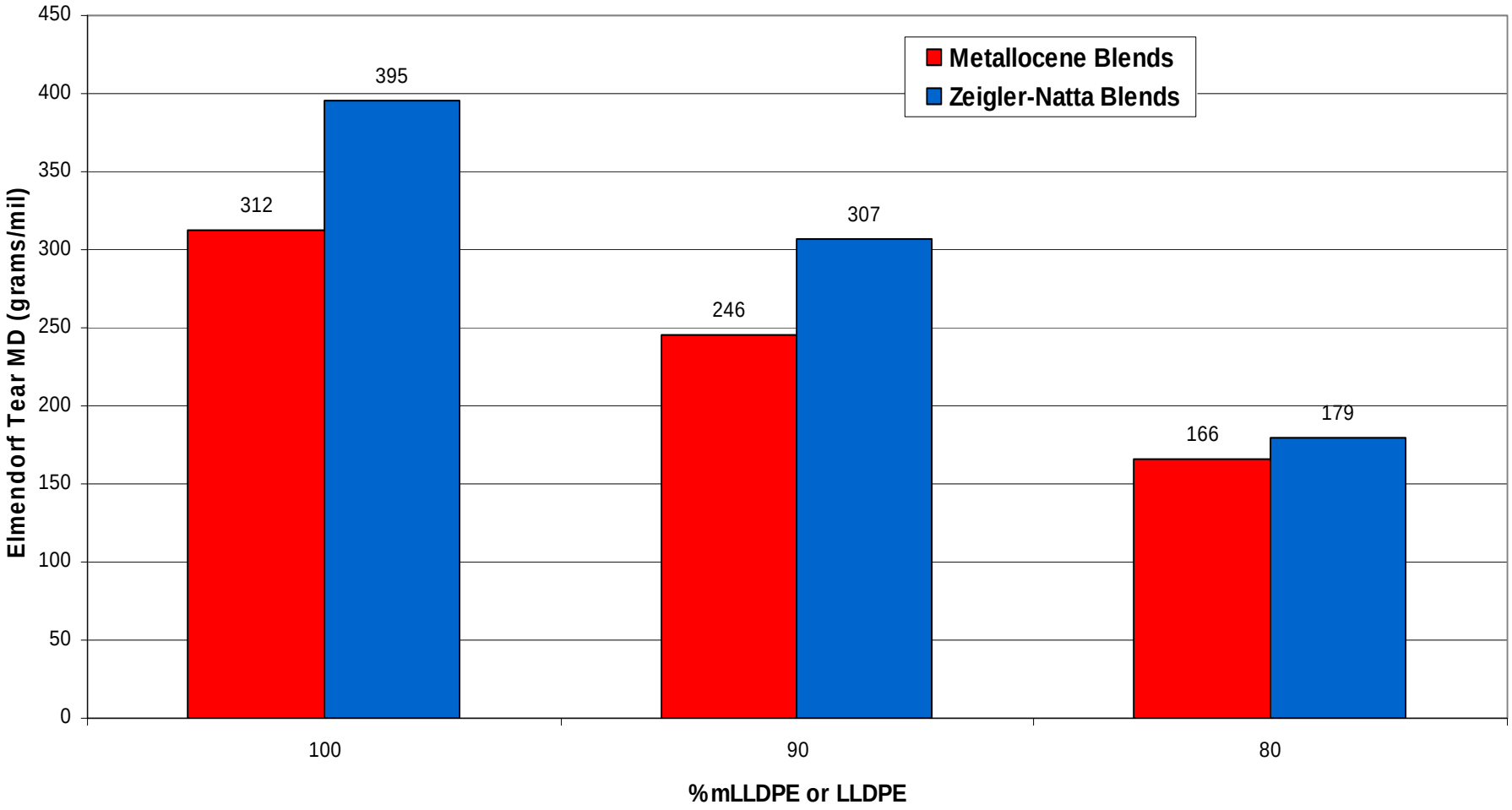
Effect of Blending LDPE with mLLDPE/LLDPE on Extruder Drive amps



Effect of Blending LDPE with mLLDPE/LLDPE on Dart Impact



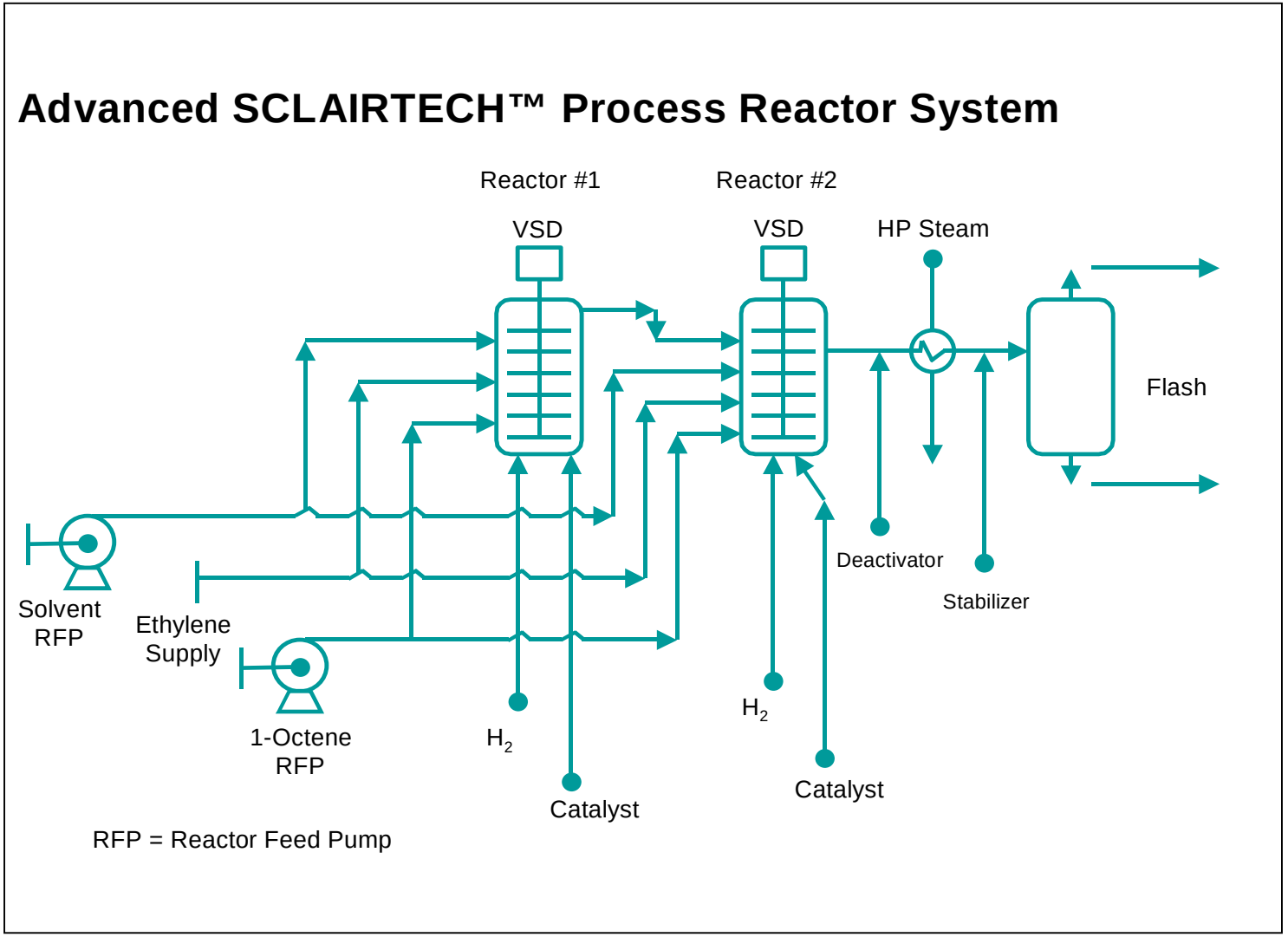
Effect of Blending LDPE with mLLDPE/LLDPE on MD Elmendorf Tear



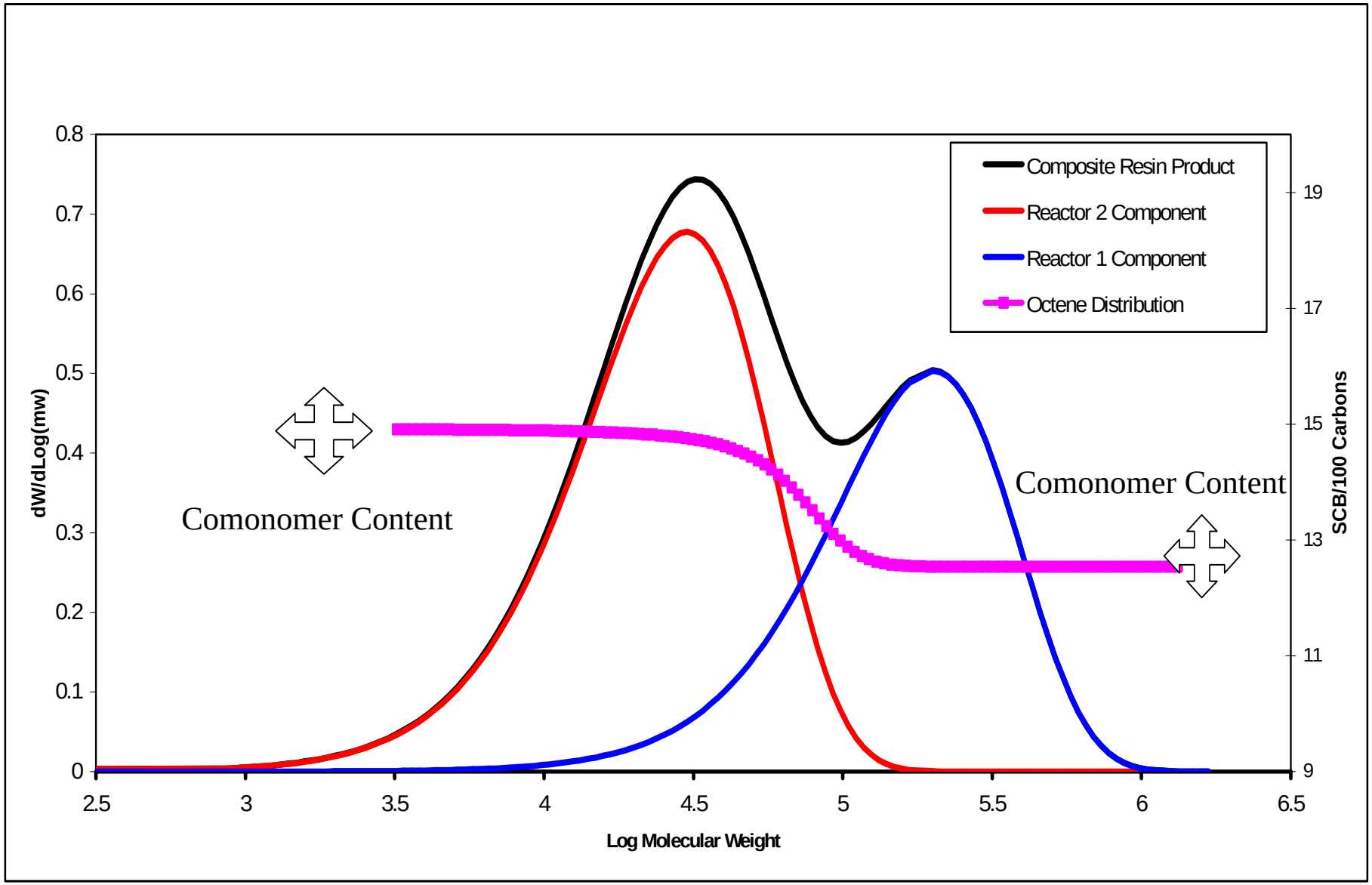
Opportunity

- If the processing properties of mLLDPE or single site catalyzed LLDPE's (sLLDPE) could be improved, the dependency on LDPE could be reduced or eliminated thus preserving the superior impact properties.
- How could one improve the processability of sLLDPE materials yet maintain the other properties which has made these materials so desirable?

Use of Multiple Reactors



Flexibility in Molecular Design

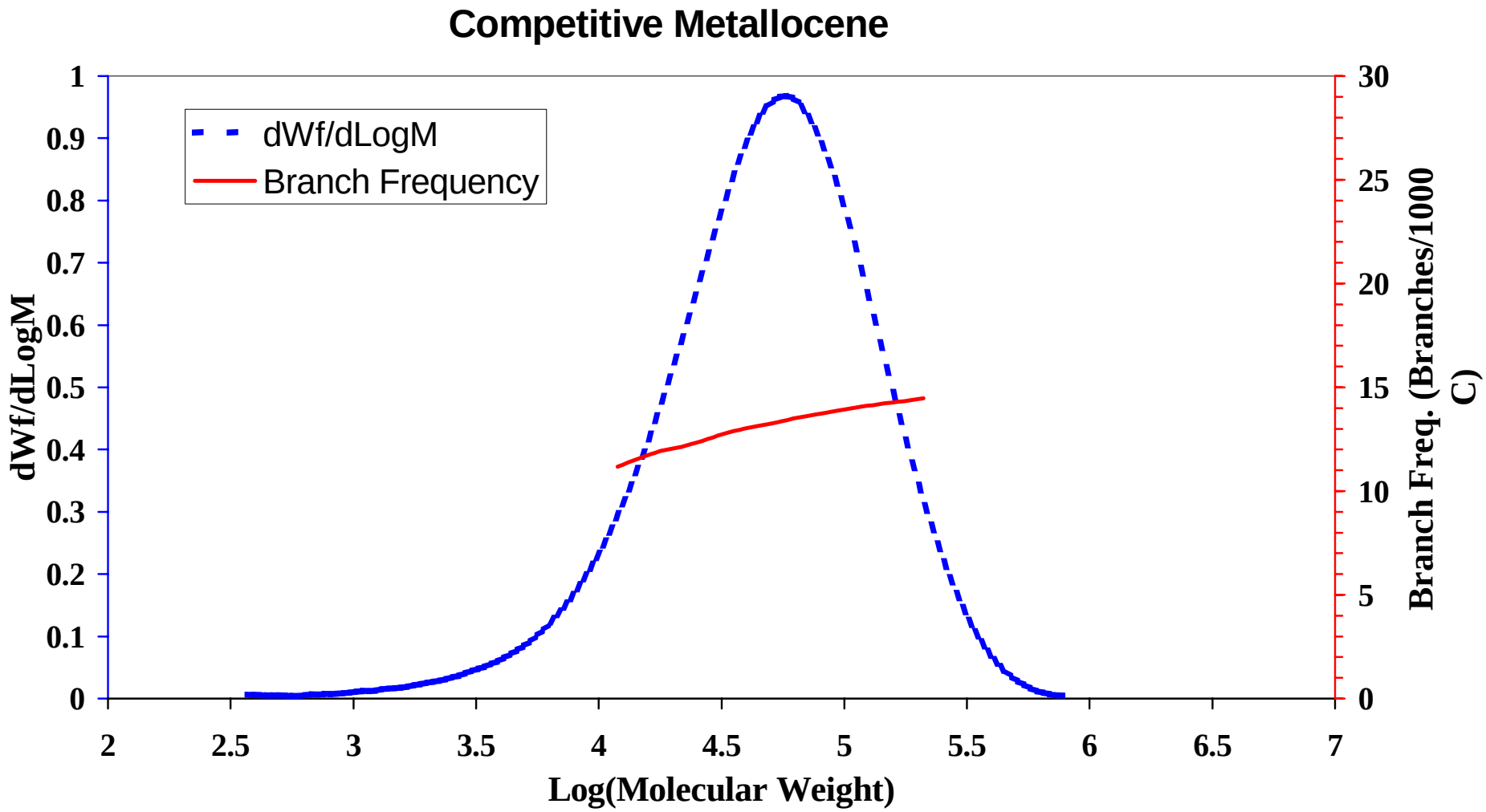


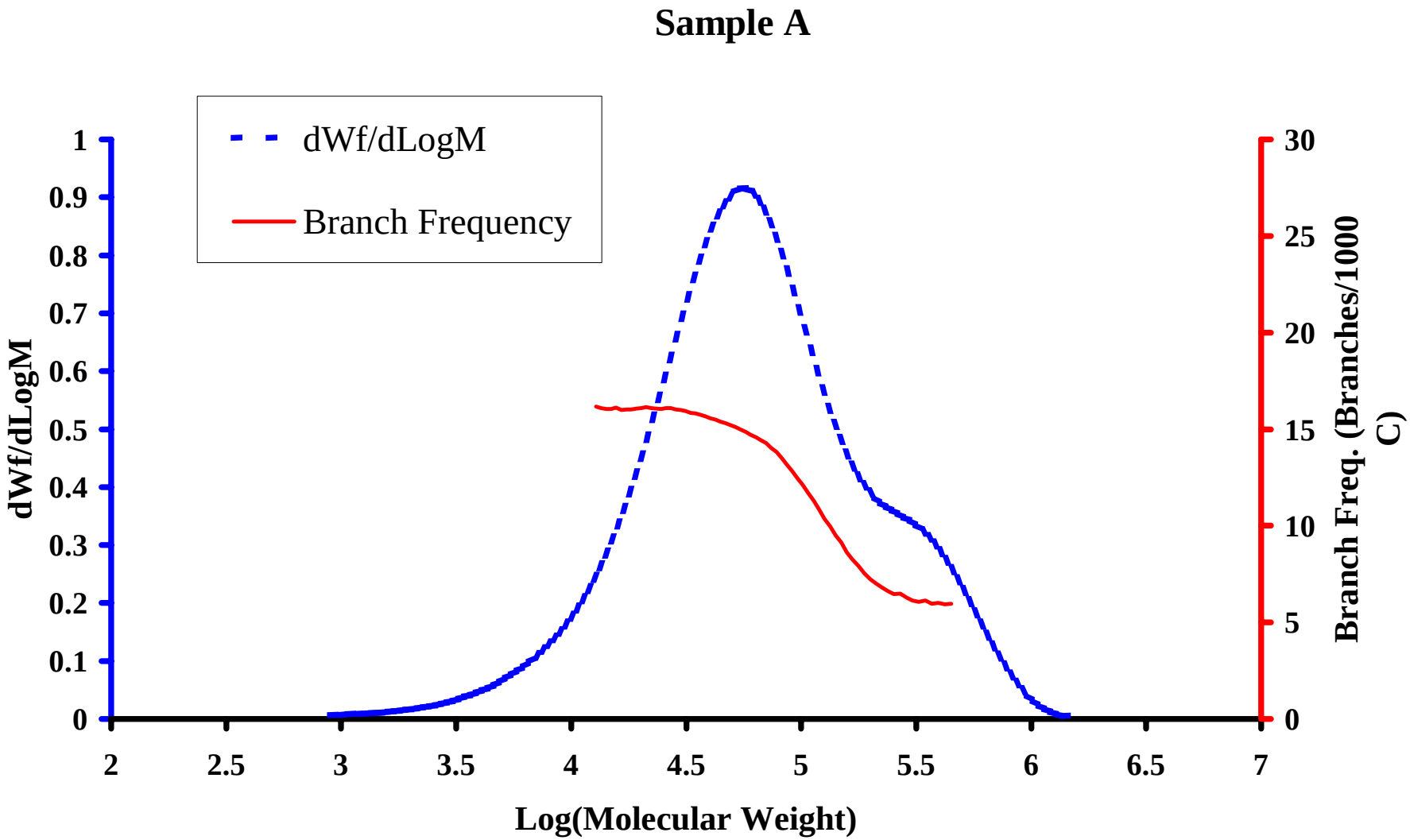
Experiment

- Sample materials produced on a pilot scale plant utilizing a variety of manufacturing strategies.
- Pilot plant materials compared to commercially available metallocene product.
- Resins characterized for basic parameters and MWD and branch frequency.
- Blown film evaluation to assess materials for processability and maximum output rate.
- Films collected and evaluated for toughness properties.

Materials

	Melt Index ($I_{2.16}$)(grams/10 min.)	Density (grams/cc)	Flow Ratio ($I_{10}/I_{2.16}$)	Polydispersity	MWD Modality
Competitive Metallocene	1.08	0.918	6.4	1.97	Unimodal
SAMPLE A	0.66	0.9163	9.15	2.74	Pseudo-Bimodal
SAMPLE B	0.57	0.9169	9.7	2.81	Bimodal
SAMPLE C	0.61	0.9165	10.2	3.22	Bimodal
SAMPLE D	0.58	0.9159	8.7	3.08	Pseudo-Bimodal
SAMPLE E	0.71	0.9164	8.56	3.5	Bimodal
SAMPLE F	0.58	0.9165	10.9	6.35	Bimodal


Competitive Metallocene
dWf/dLogM
Branch Frequency
dWf/dLogM
Branch Freq. (Branches/1000 C)
Log(Molecular Weight)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
30
25
20
15
10
5
0
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7


Sample A
dWf/dLogM
Branch Frequency
dWf/dLogM
Branch Freq. (Branches/1000 C)
Log(Molecular Weight)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
30
25
20
15
10
5
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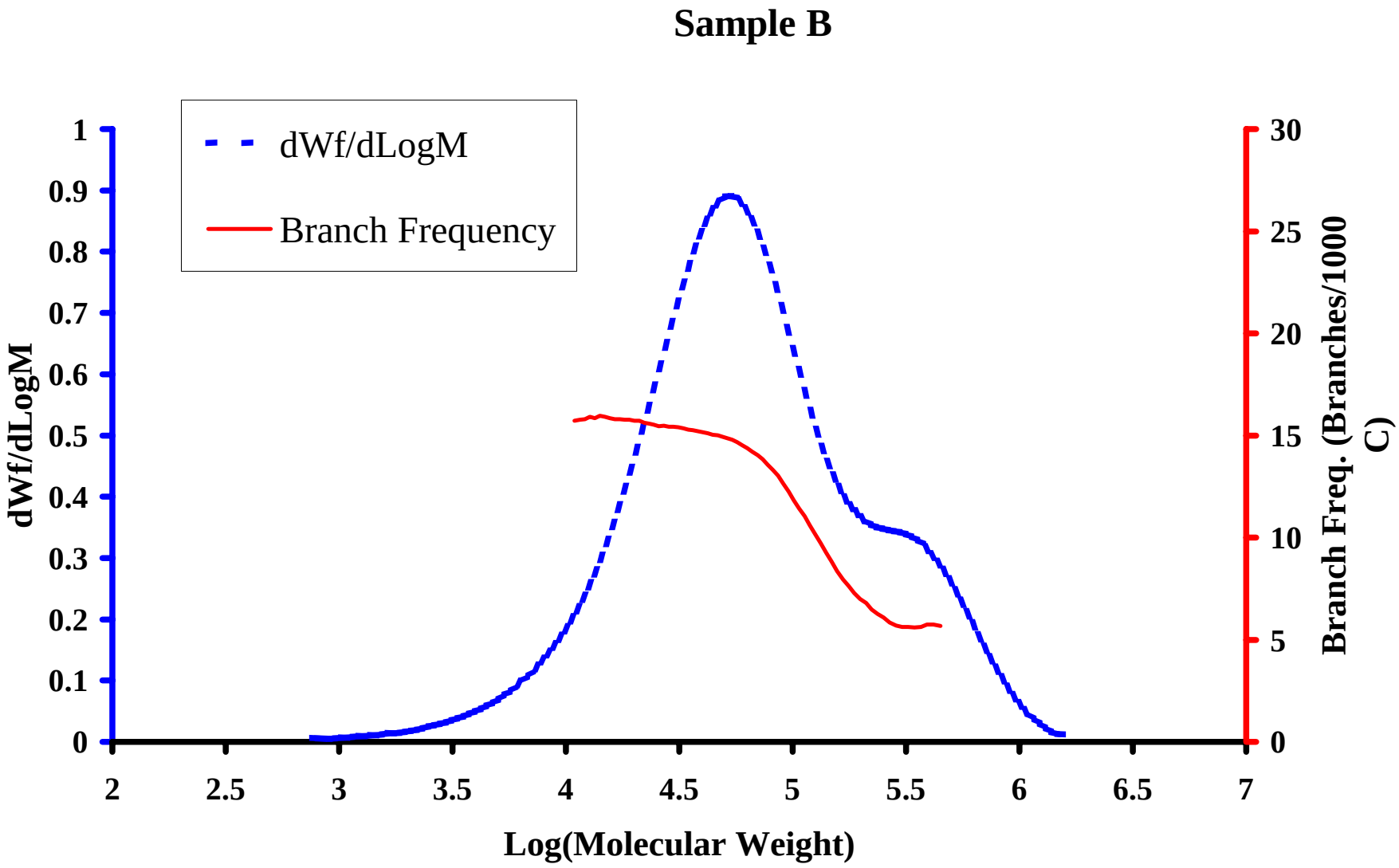
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7


Sample B
dWf/dLogM
Branch Frequency
dWf/dLogM
Branch Freq. (Branches/1000 C)
Log(Molecular Weight)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
30
25
20
15
10
5
0
2
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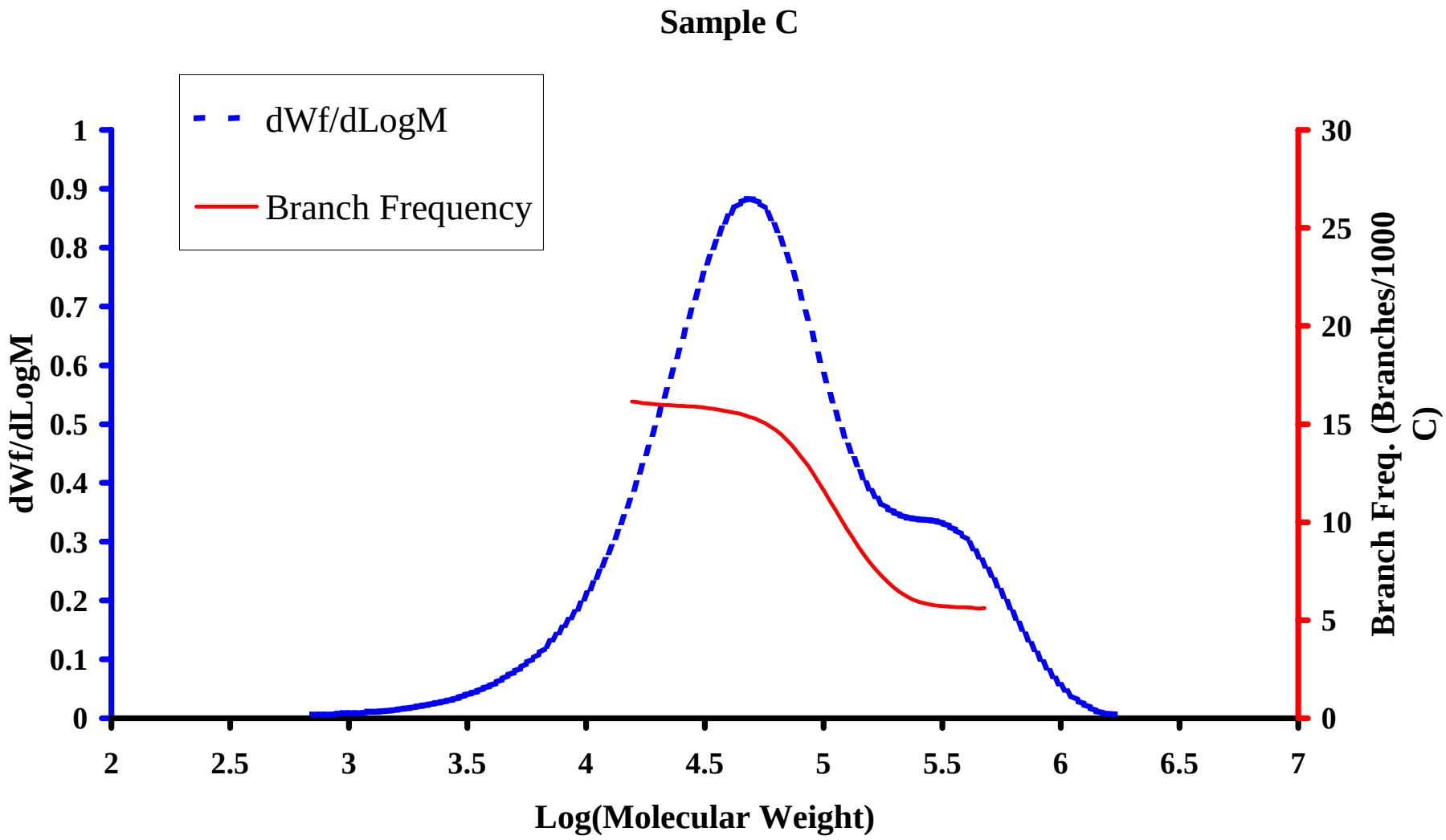
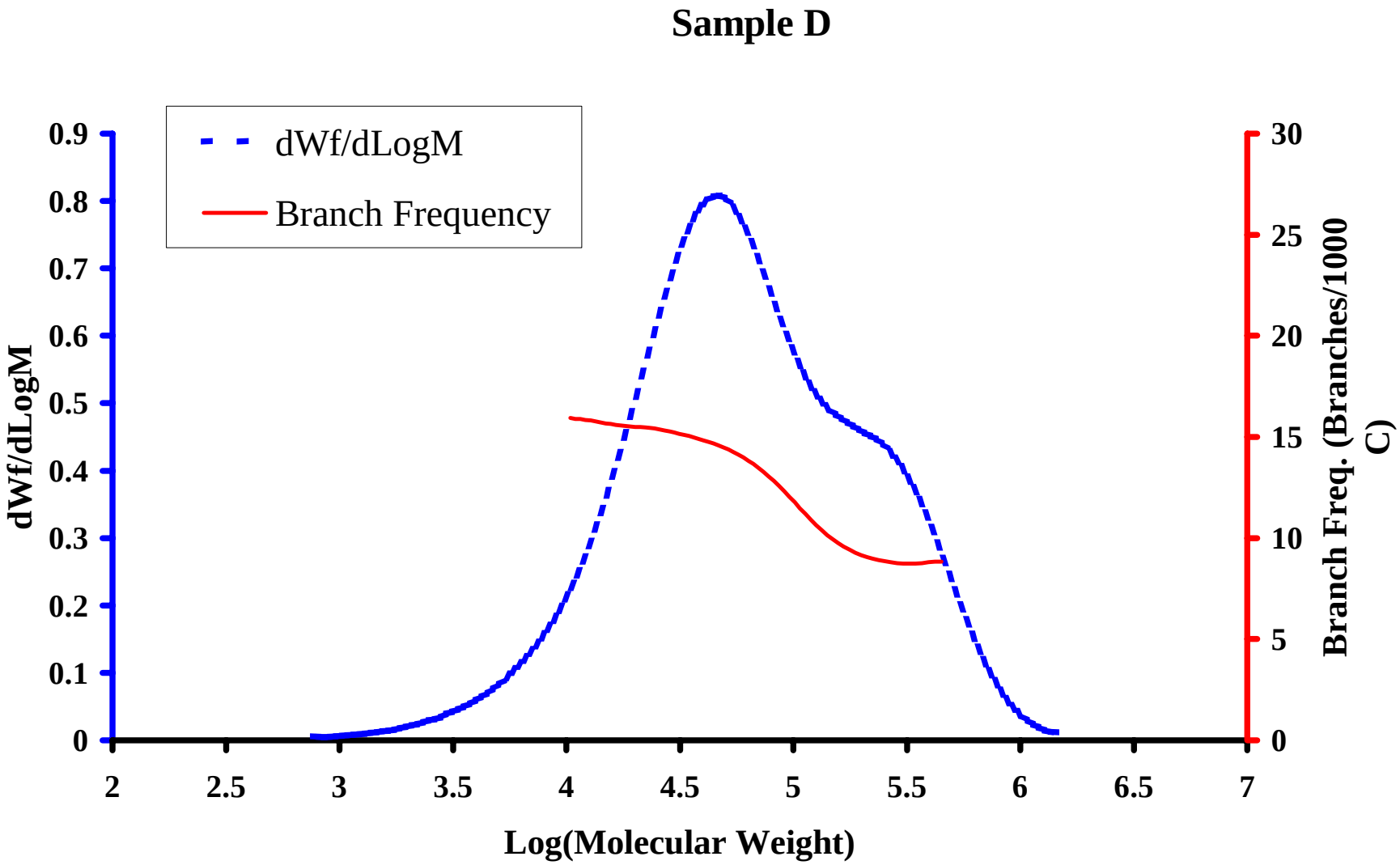
4
4.5
5
5.5
6
6.5
7


Sample C
dWf/dLogM
Branch Frequency
dWf/dLogM
Branch Freq. (Branches/1000 C)
Log(Molecular Weight)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
5
10
15
20
25
30
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7


Sample D
dWf/dLogM
Branch Frequency
dWf/dLogM
Branch Freq. (Branches/1000 C)
Log(Molecular Weight)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
30
25
20
15
10
5
0
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2.5
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6.5
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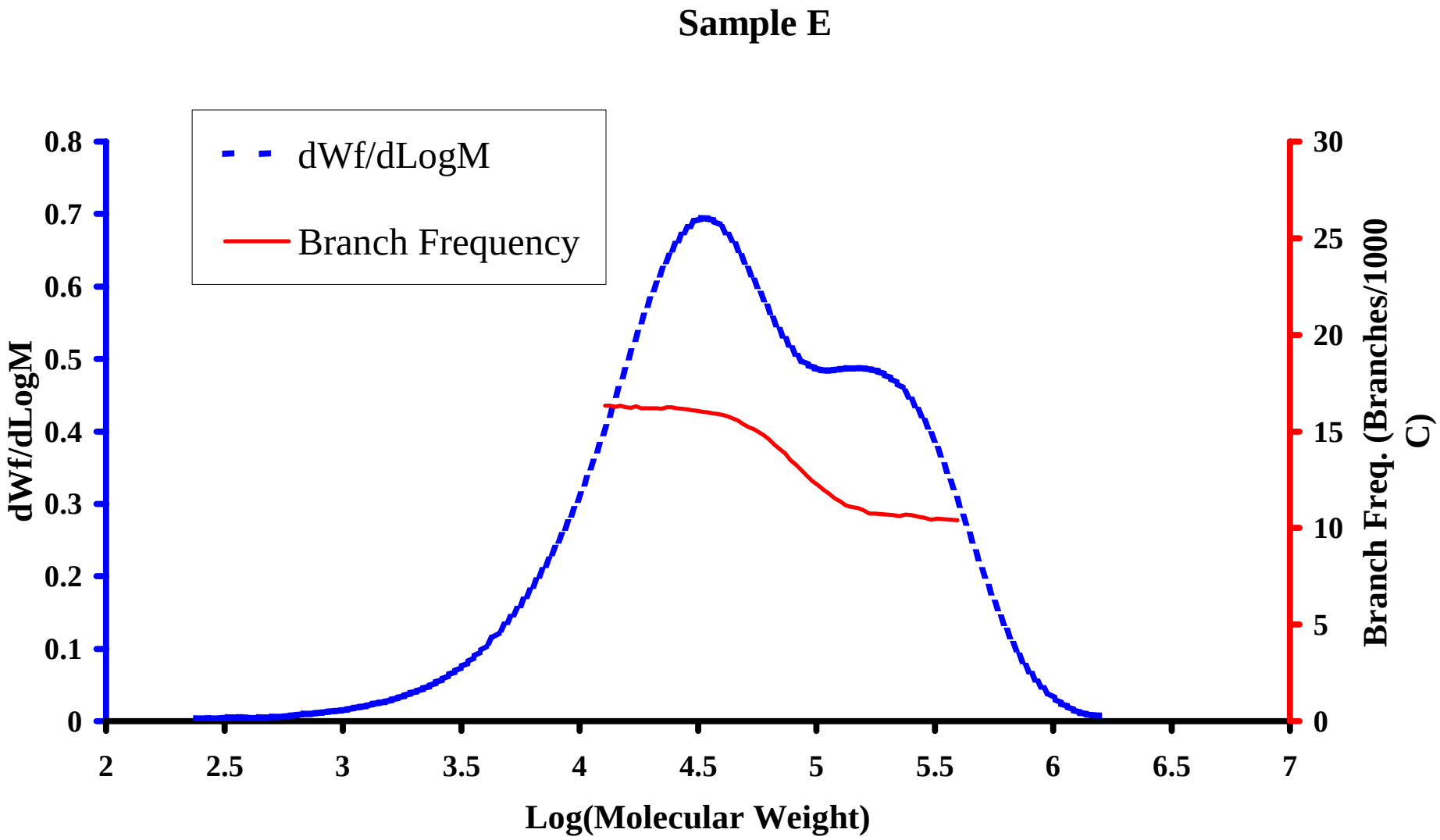
Sample E
dWf/dLogM
Branch Frequency
dWf/dLogM
Branch Freq. (Branches/1000 C)
Log(Molecular Weight)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
30
25
20
15
10
5
0
2
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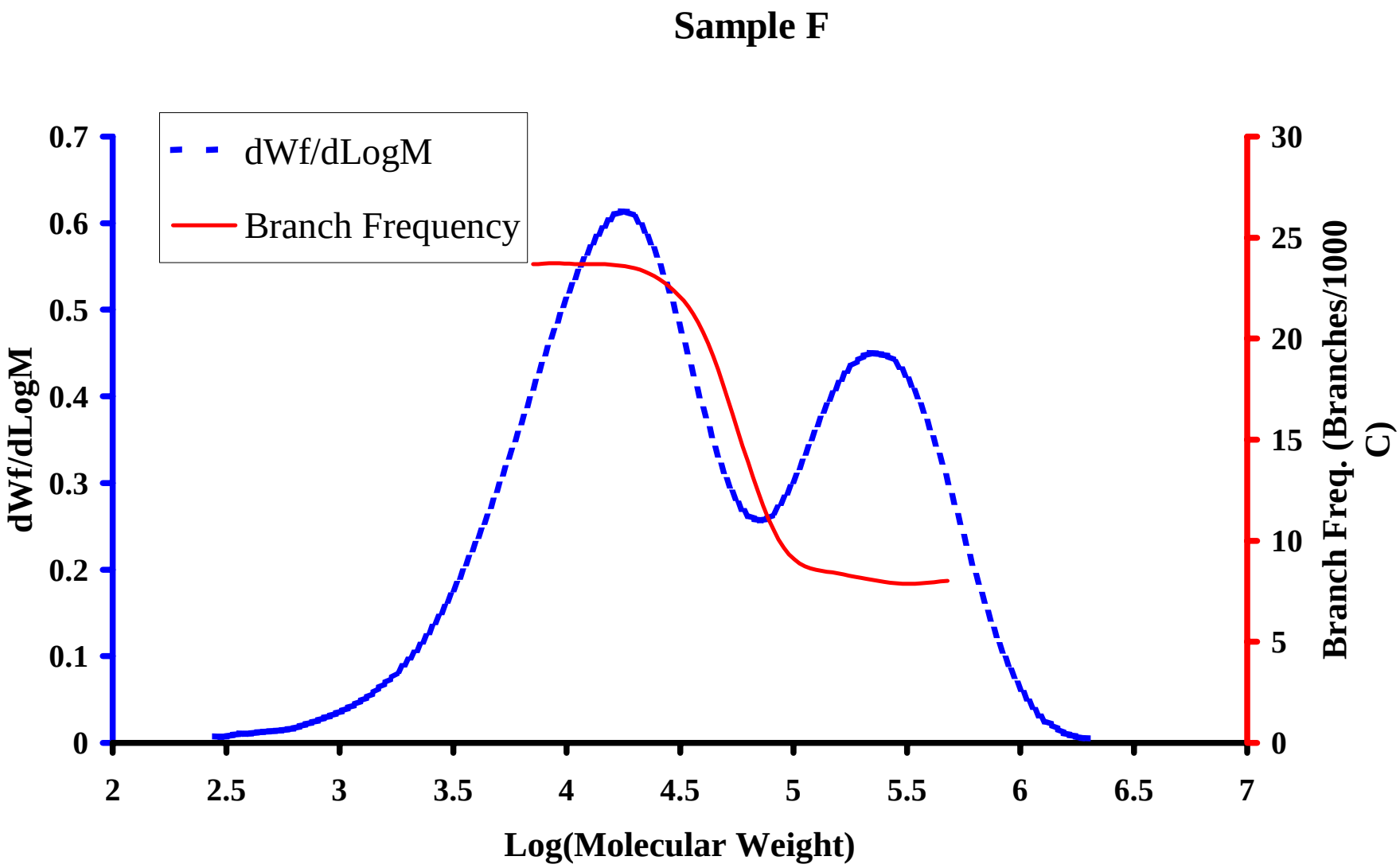
Sample F
dWf/dLogM
Branch Frequency
dWf/dLogM
Branch Freq. (Branches/1000 C)
Log(Molecular Weight)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
30
25
20
15
10
5
0
2
2.5
3
3.5
4
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5
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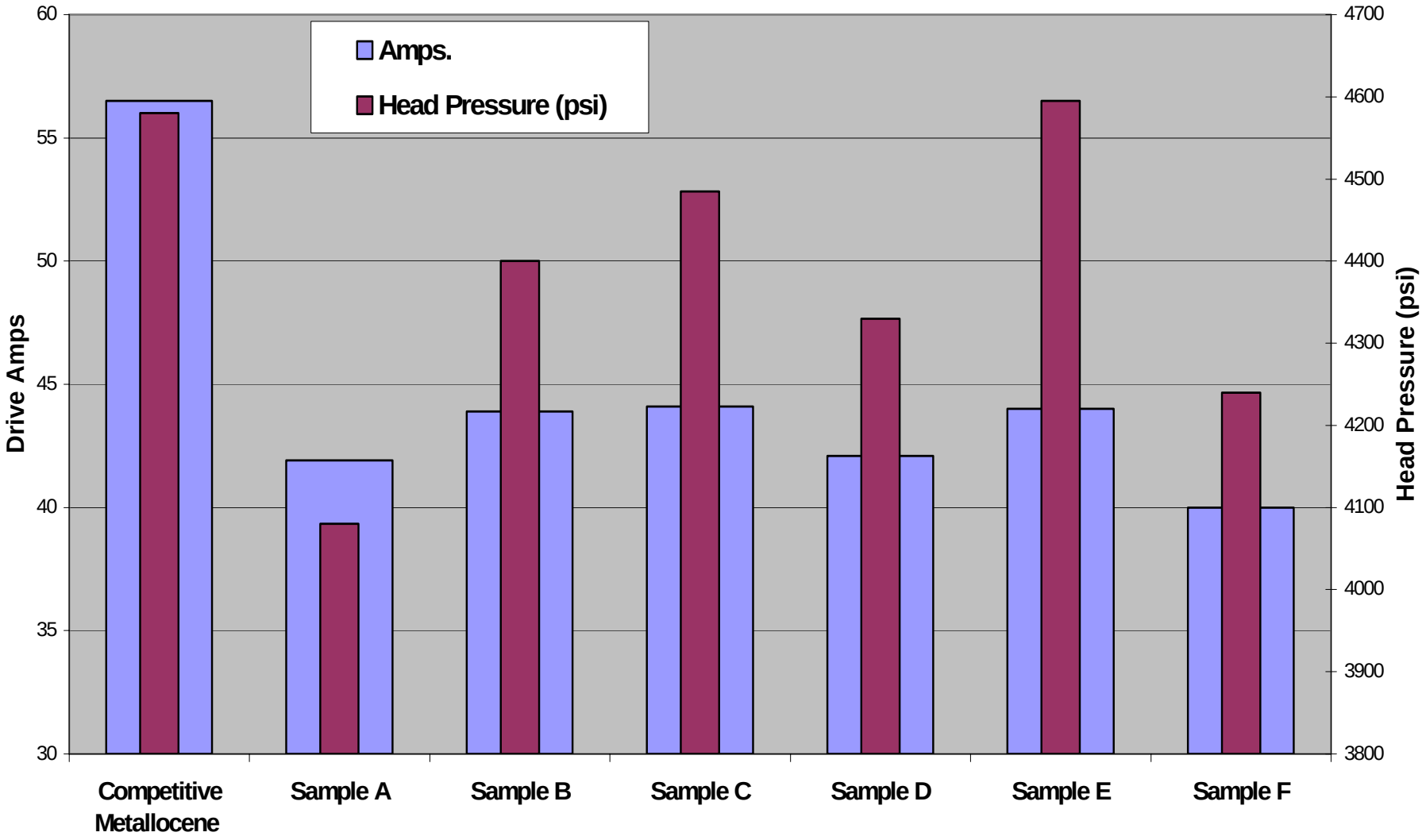
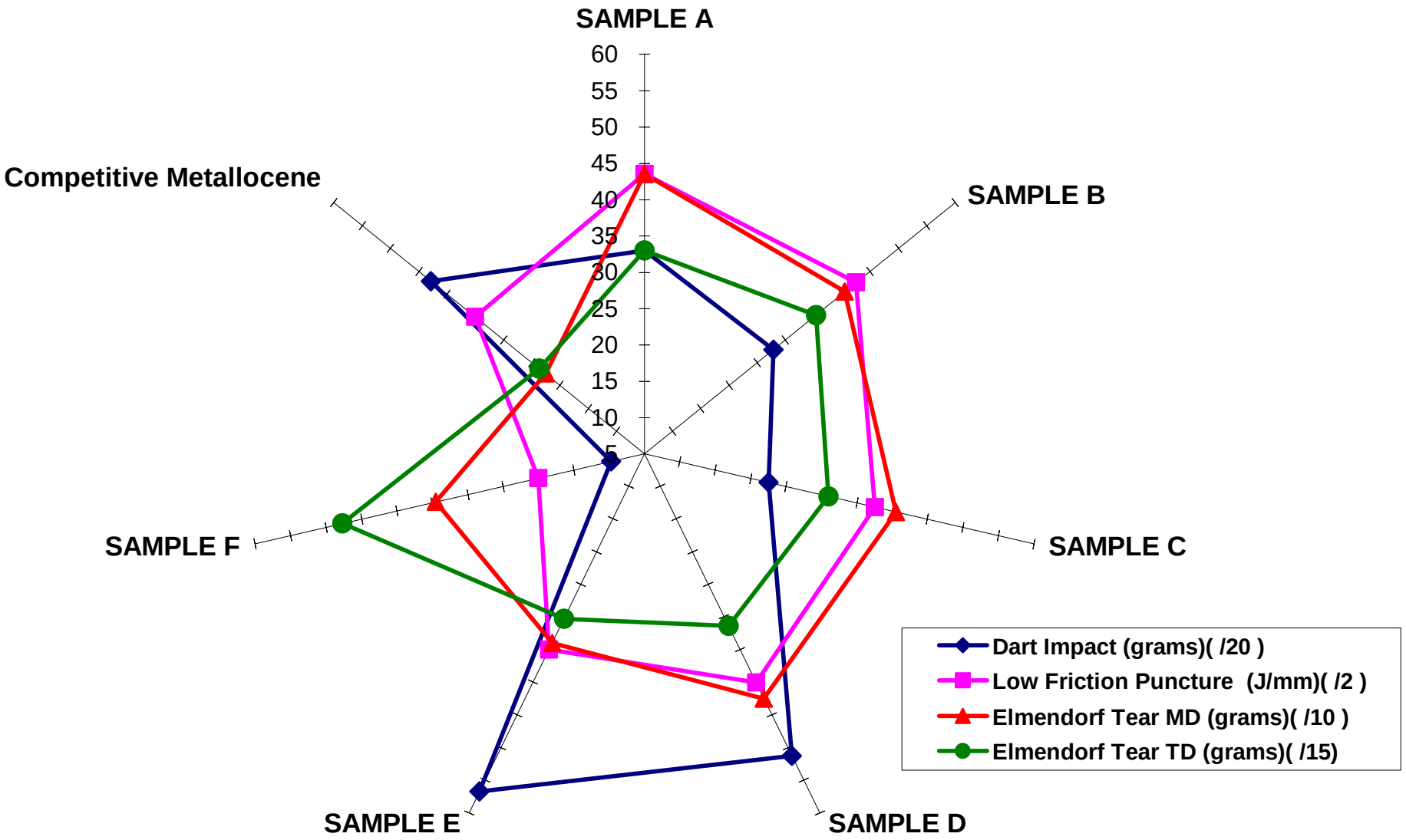
6.5
7

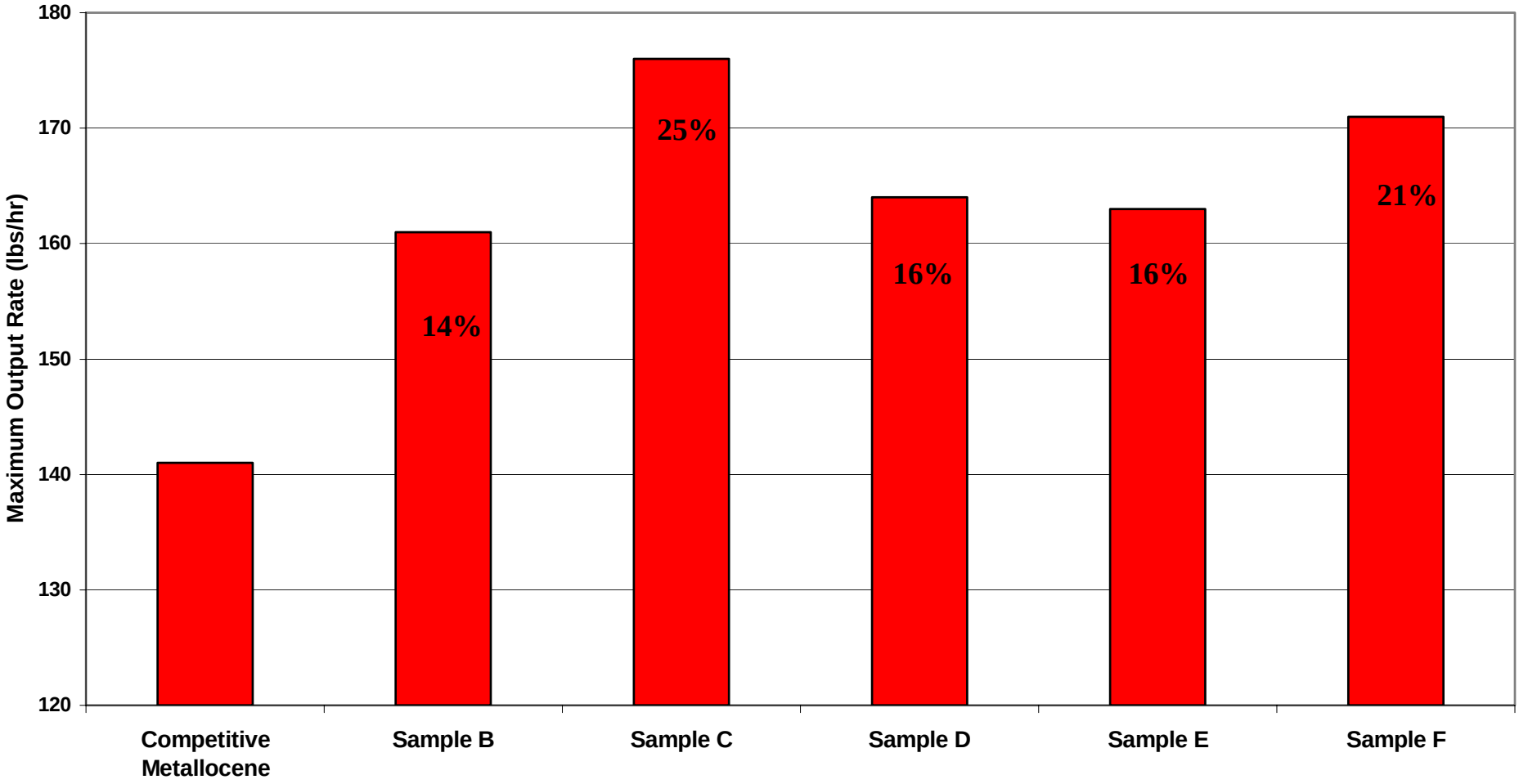
Extrusion Parameters



Physical Properties



Maximum Output Rate
(Bubble Stability the Limiting Factor)



Summary of Pilot Plant Evaluation

- Pilot plant material vs. Commercial Metallocene
  - Reduced drive amp requirements
  - Similar or lower head pressure
  - Improved melt strength results in a higher maximum output rate thus reducing or eliminating the need for blending LDPE
  - Superior tear properties
  - Enhanced puncture resistance
  - Dart impact performance varies with resin design

Pilot Plant to Commercial Plant

- A product for production on commercial facility was designed based upon the pilot plant experiment.
- Target similar parameters:

  Melt Index: 0.60 grams/10 min.

  Density: 0.917 grams/cc

  Formulated with slip, AB, PPA

Commercial Material vs. Pilot Plant vs. Commercial Z-N

	Pilot Plant	Commercial Plant	Commercial Plant	Commercial Plant
	SSC	SSC	SSC	Z-N
	Sample E	SURPASS™	SURPASS™	
Melt Index (grams/10 min.)	0.71	0.52	0.57	0.51
Density (grams/cc)	0.9164	0.9183	0.9180	0.9170
Output Rate (lbs/hr)	100	100	100	100
Pressure (psi)	4595	4807	4996	5607
Amps	44	41	42	47
Dart Impact (grams/mil)	1135	755	845	590
MD Elmendorf Tear (grams/mil)	340	425	415	380
Low Friction Puncture (J/mm)	70	78	78	49

Conclusions

- Materials can be tailored in dual reactor system such that the need or amount of LDPE required to improve processability is reduced or eliminated.
- Elimination of LDPE blending allows the processor to take advantage of the superior properties offered by these dual reactor single site catalyzed materials.

Conclusions

- Dual reactor technology enables a significant degree of molecular tailoring, allowing polymer scientists to manipulate molecular weight distribution and/or comonomer branching distribution of single site catalyzed materials over a wider range.
- Single site catalyzed materials produced in a dual reactor process can be designed to offer enhanced processability, melt strength, and tear properties yet maintain the impact properties expected of single site catalyzed materials.

Acknowledgements

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