

Failure Assessment Of Guardrail Extruder Terminals



January 11, 2012

ET-2000 and ET-Plus are
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Failure Assessment Of Guardrail Extruder Terminals

This presentation is the sole opinion of SPIG Industries based on an empirical analysis of guardrail terminal impacts throughout a number of states.

January 11, 2012

ET-2000 and ET-Plus are
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ET-Plus Background



The ET-2000 is the first extruding type guardrail end terminal and was accepted by FHWA in August 1995.

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ET-Plus Background



The ET-2000 is the first extruding type guardrail end terminal and was accepted by FHWA in August 1995.

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ET-Plus Background

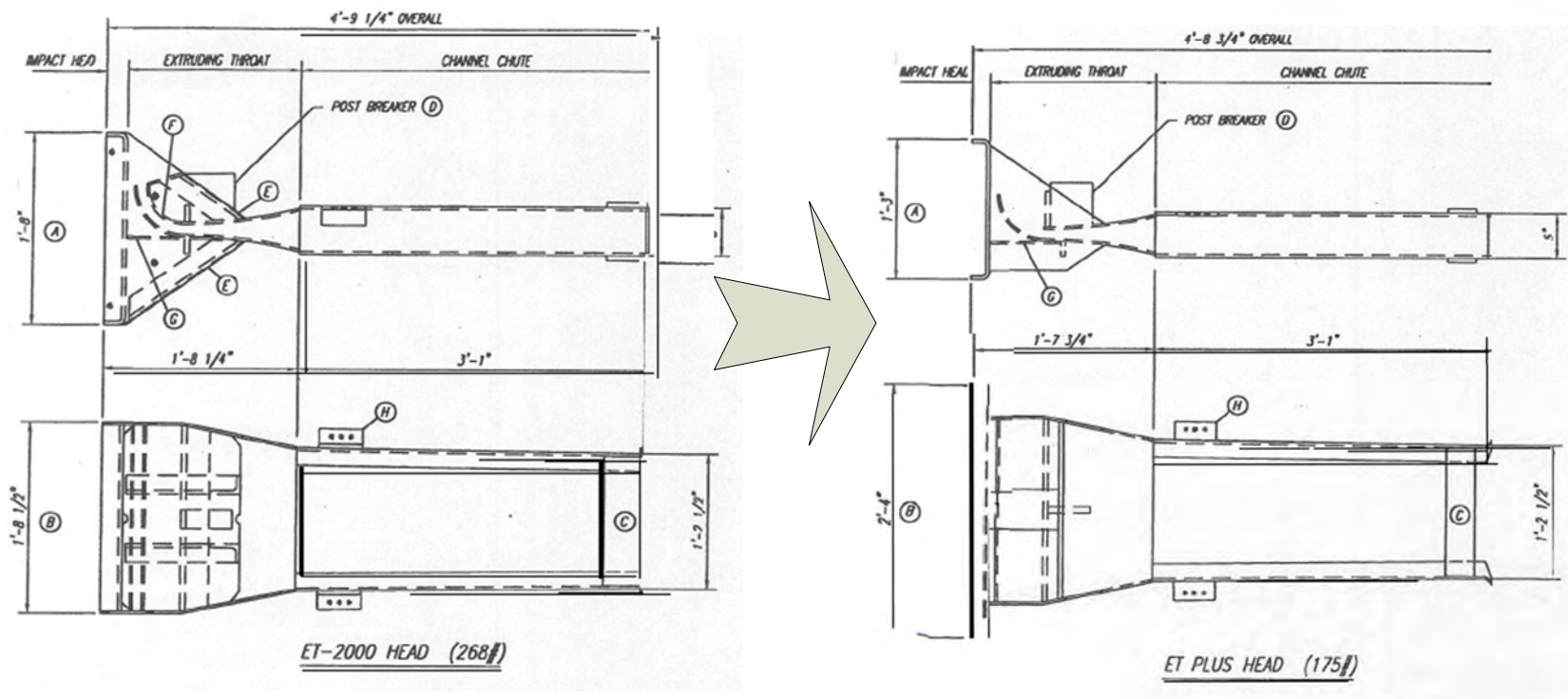


The ET-2000 is the first extruding type guardrail end terminal and was accepted by FHWA in August 1995.

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ET-Plus Background

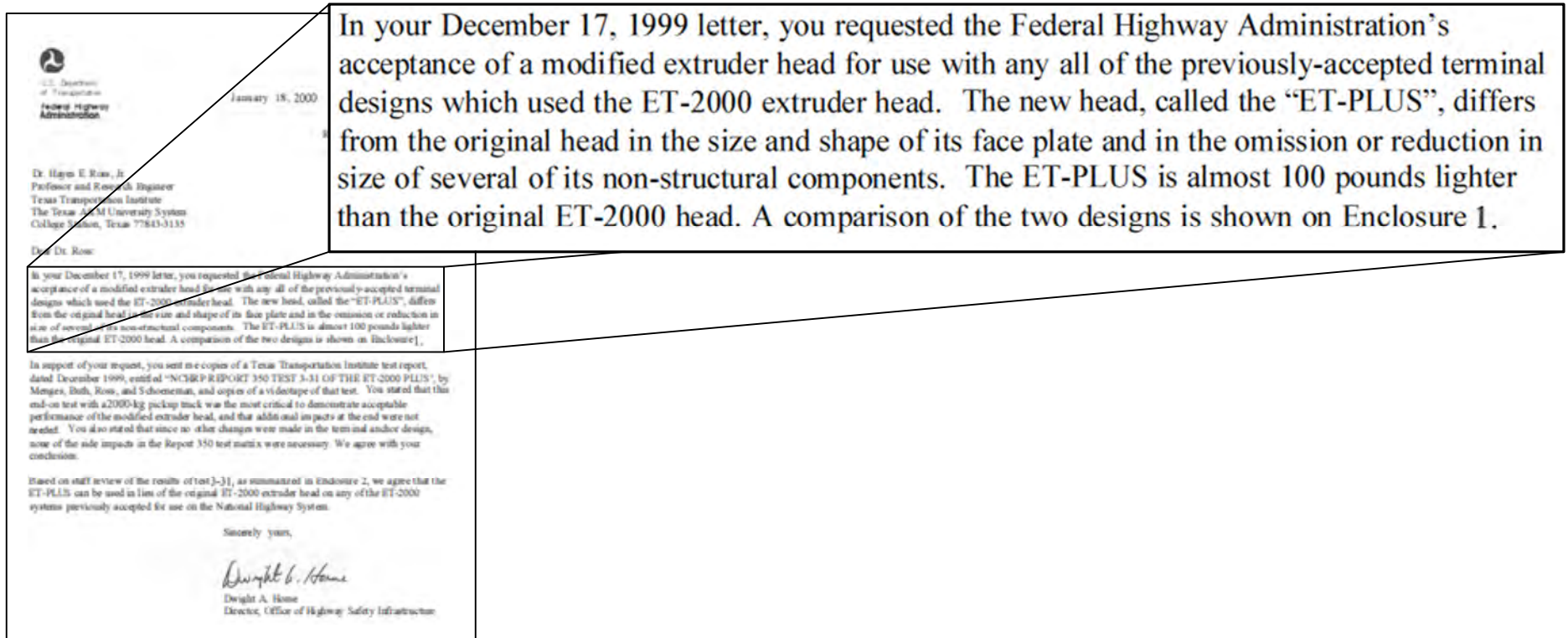


The early production model ET-PLUS was a redesign based on the ET-2000 that eliminated 93 pounds of weight and reduced the number of parts.

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ET-Plus Background



The ET-Plus was approved by the FHWA in January of 2000.

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ET-Plus Background



The early production model of ET-Plus was produced from about 1999 to 2005 and had a change in the post breaker shape from square to triangular sometime in 2001.

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ET-Plus Background



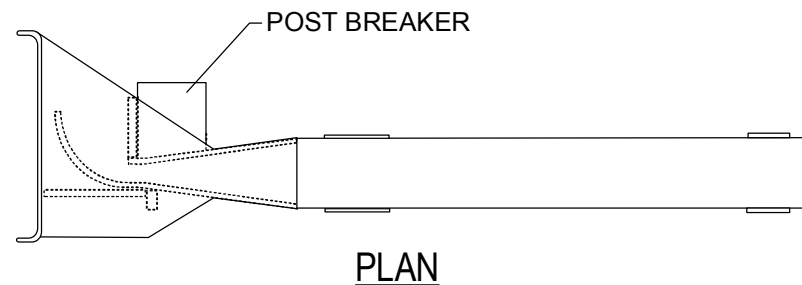
The early production model of ET-Plus was produced from about 1999 to 2005 and had a change in the post breaker shape from square to triangular sometime in 2001.

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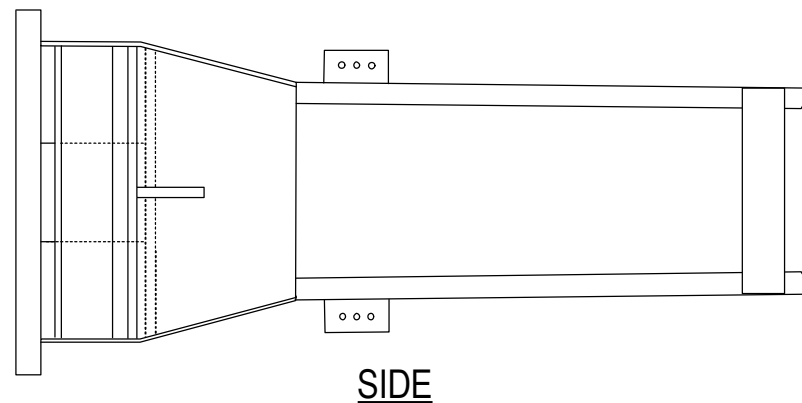
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ET-Plus Background

The top drawing is a plan view of an early production ET-Plus with a square post breaker.

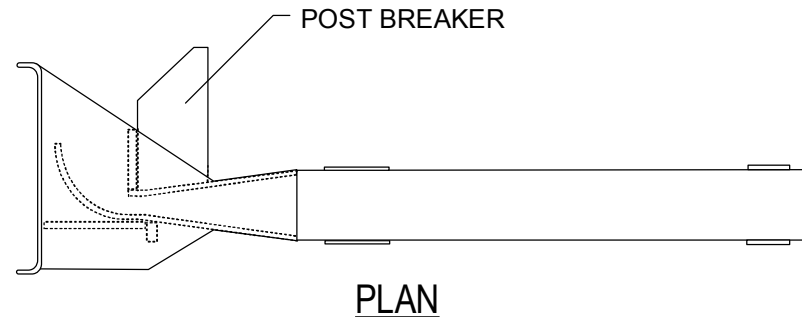


The bottom drawing is a side view of the same early production ET-Plus.

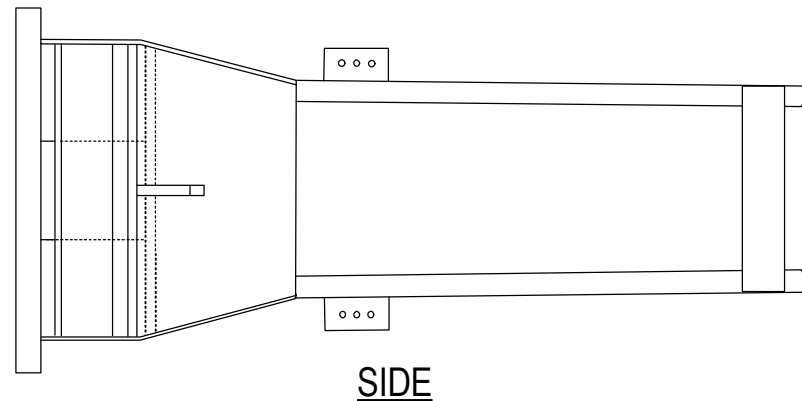


ET-Plus Background

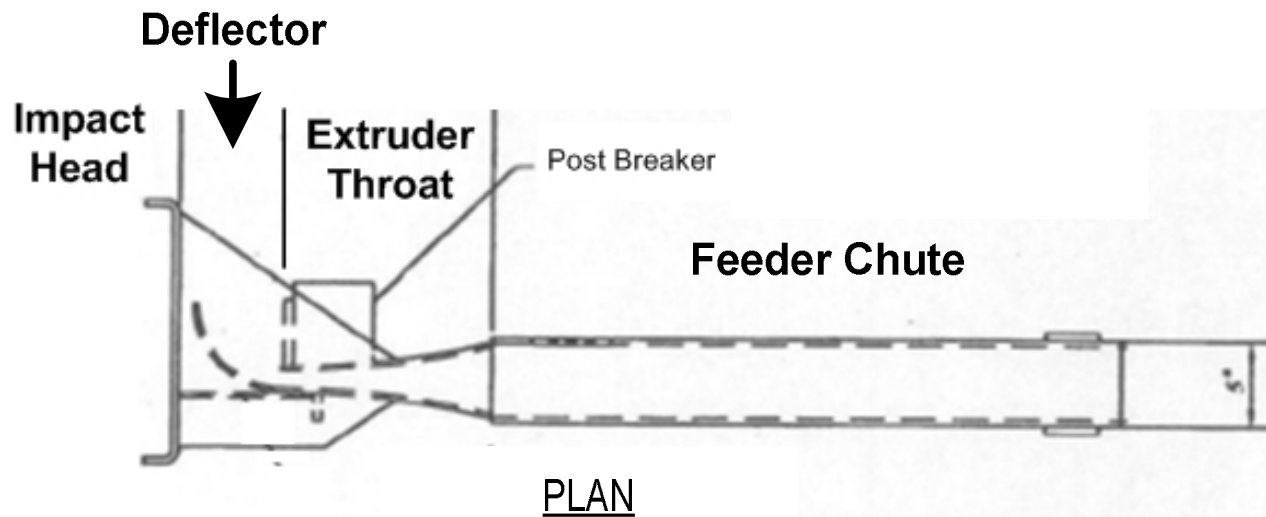
The top drawing is a plan view of an early production ET-Plus with a triangular post breaker.



The bottom drawing is a side view of the same ET-Plus.

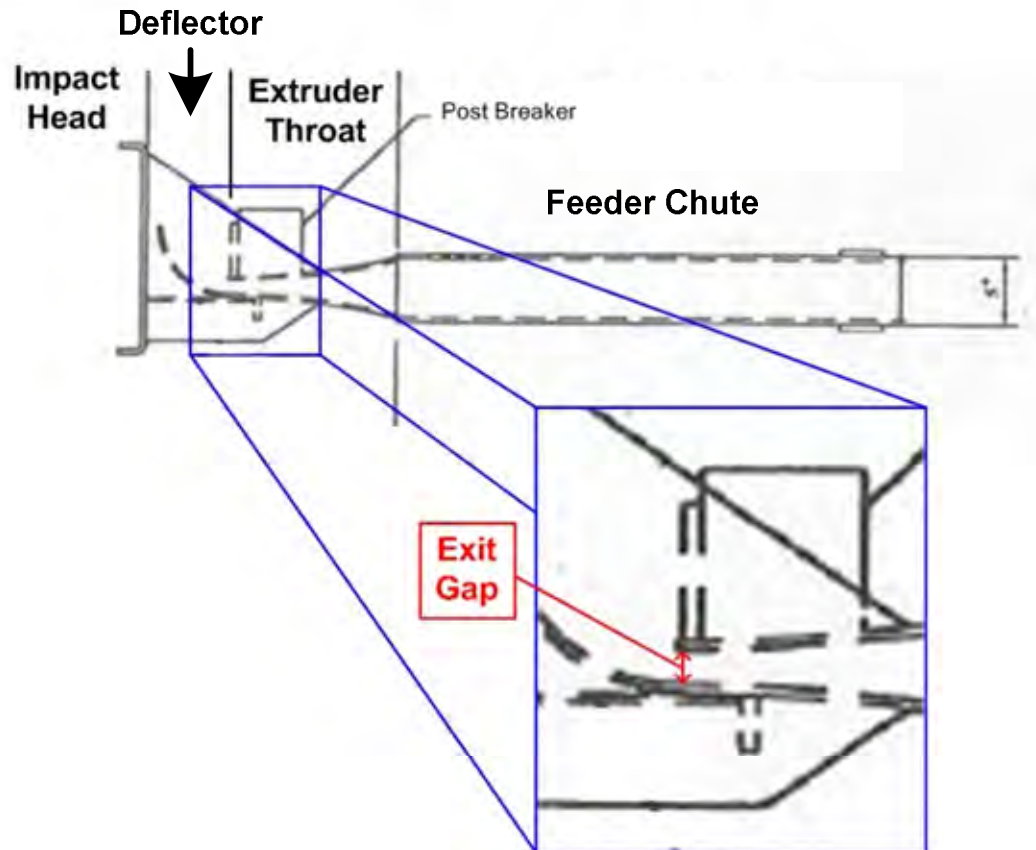


Parts Of Early Production ET-Plus



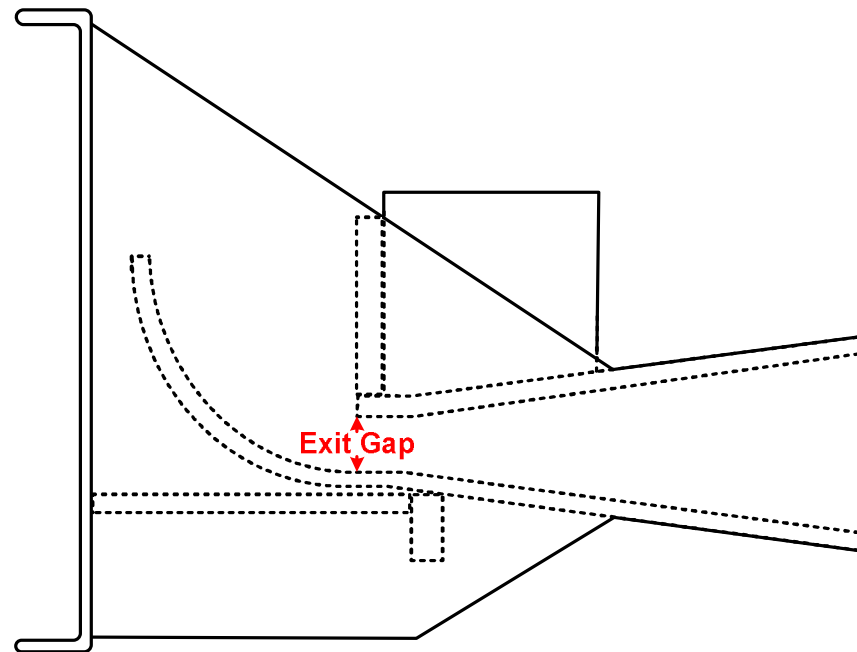
The early production ET-Plus has four basic sections: impact head, deflector, extruder throat and feeder chute.

Parts Of Early Production ET-Plus



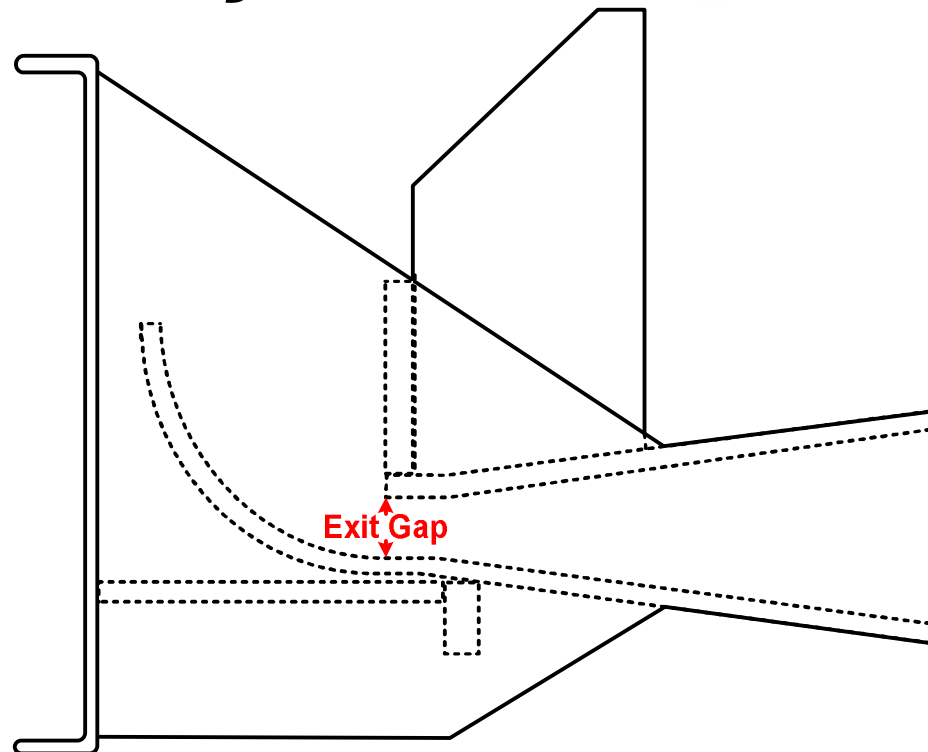
The end of the extruder throat has an exit gap.

Parts Of Early Production ET-Plus



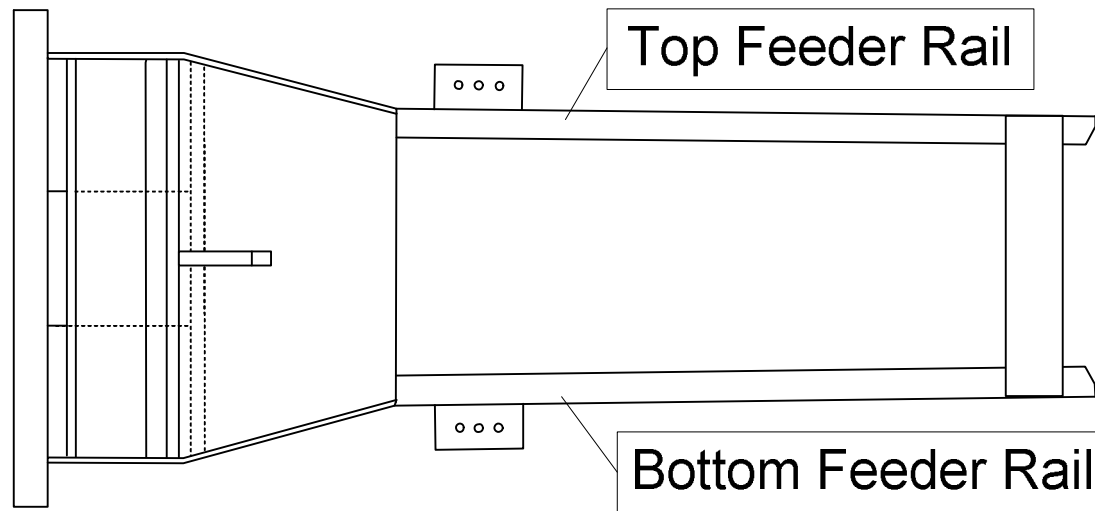
The exit gap of an early production ET-Plus square post breaker had manufacturing variances between 1.35 to 1.6 inches.

Parts Of Early Production ET-Plus



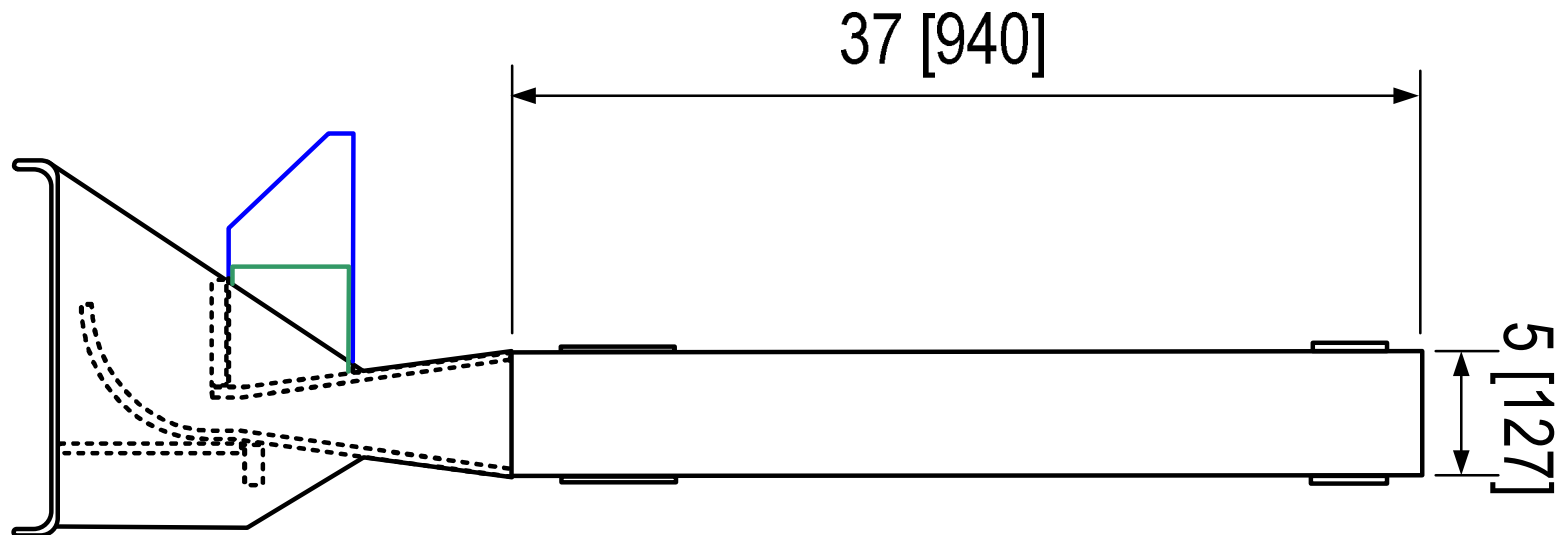
The exit gap of an early production ET-Plus triangle post breaker had manufacturing variances between 1.1 to 1.5 inches.

Parts Of Early Production ET-Plus



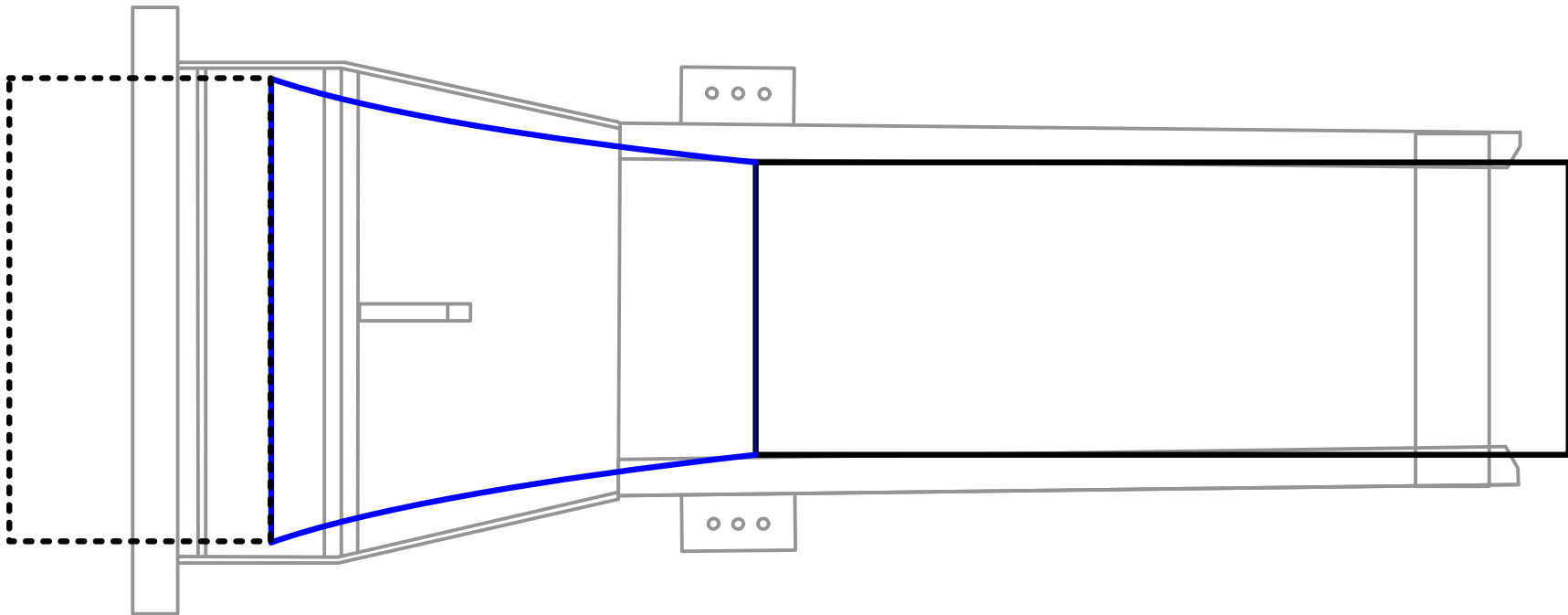
This is a side view of the ET-Plus showing the top feeder rail and the bottom feeder rail of the feeder chute.

Parts Of Early Production ET-Plus



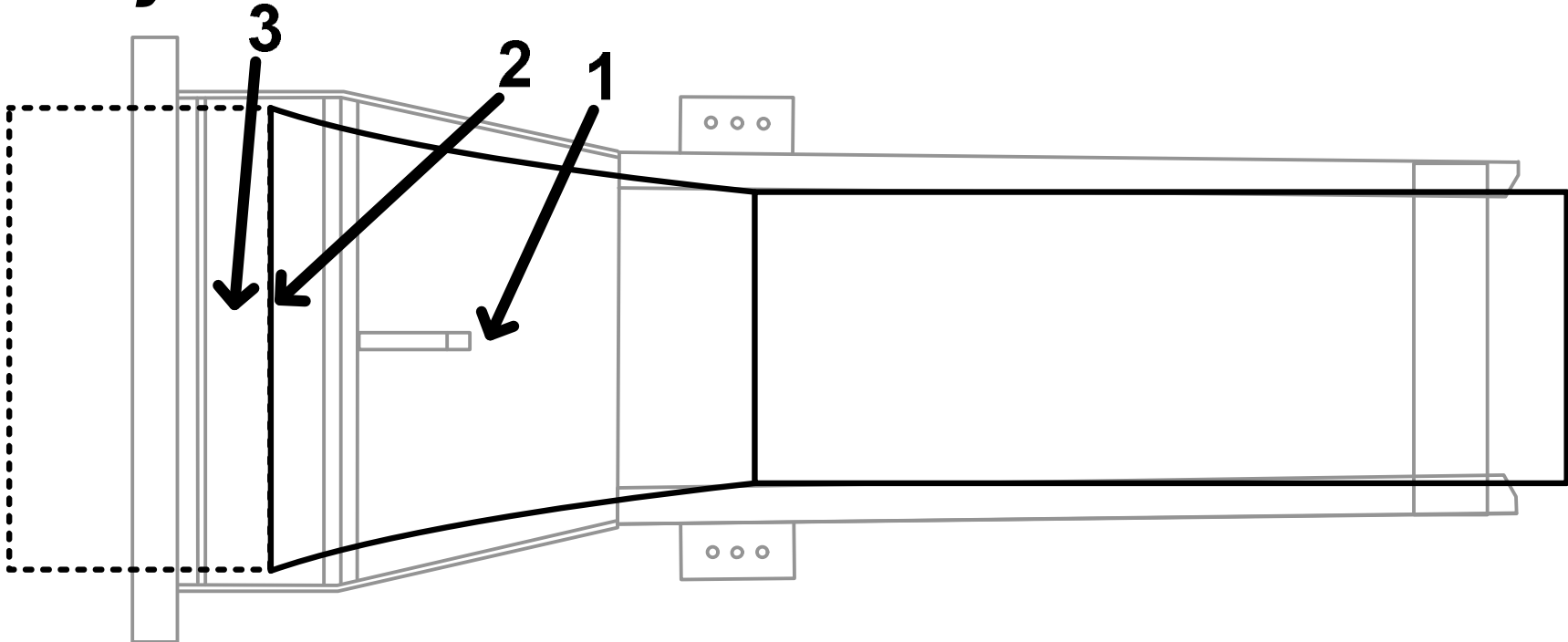
This is a plan view of an early production ET-Plus showing the feeder chute had a width of 5 inches and a length of 37 inches with either the **triangular** post breaker or the **square** post breaker.

Early Production ET-Plus Performance



The extruding type guardrail terminal creates a **dynamic compression plume** as the terminal moves down the guardrail.

Early Production ET-Plus Performance

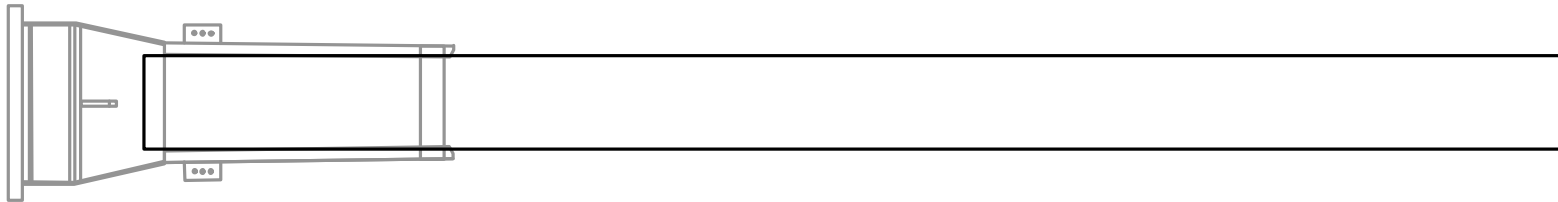


The extruding type guardrail terminal 1) plumes the guardrail, 2) flattens the guardrail, and then 3) deflects the flattened guardrail.

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Early Production ET-Plus Performance

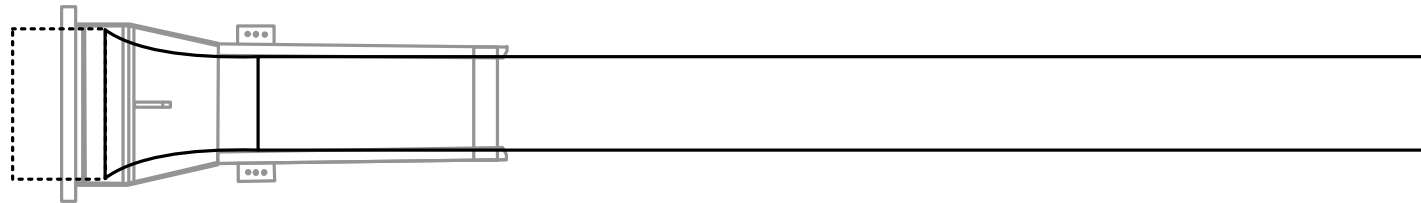


The extruding type guardrail terminal creates a dynamic compression plume as the terminal moves down the guardrail.

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Early Production ET-Plus Performance

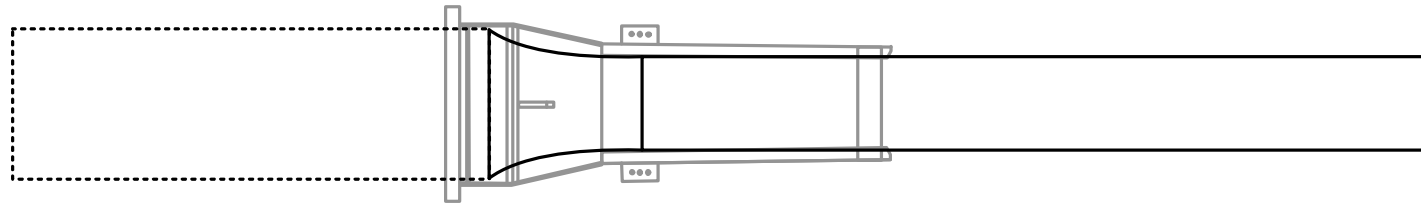


The extruding type guardrail terminal creates a dynamic compression plume as the terminal moves down the guardrail.

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Early Production ET-Plus Performance



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Early Production ET-Plus Performance

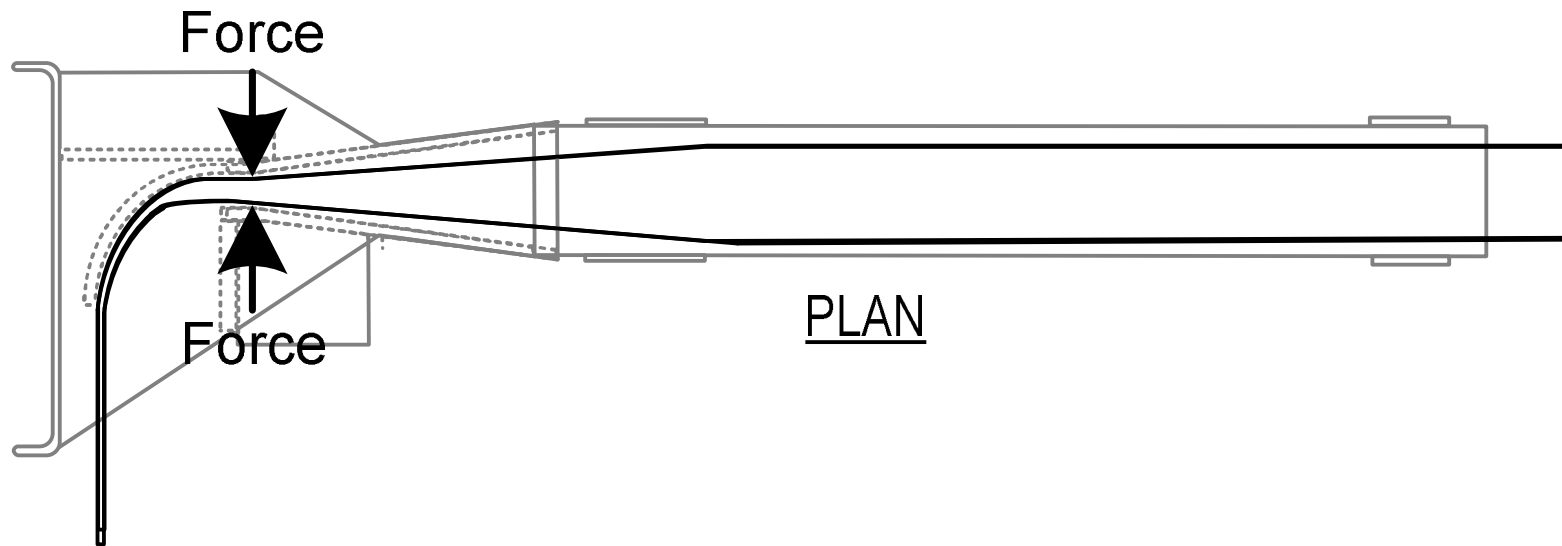


The extruding type guardrail terminal creates a dynamic compression plume as the terminal moves down the guardrail.

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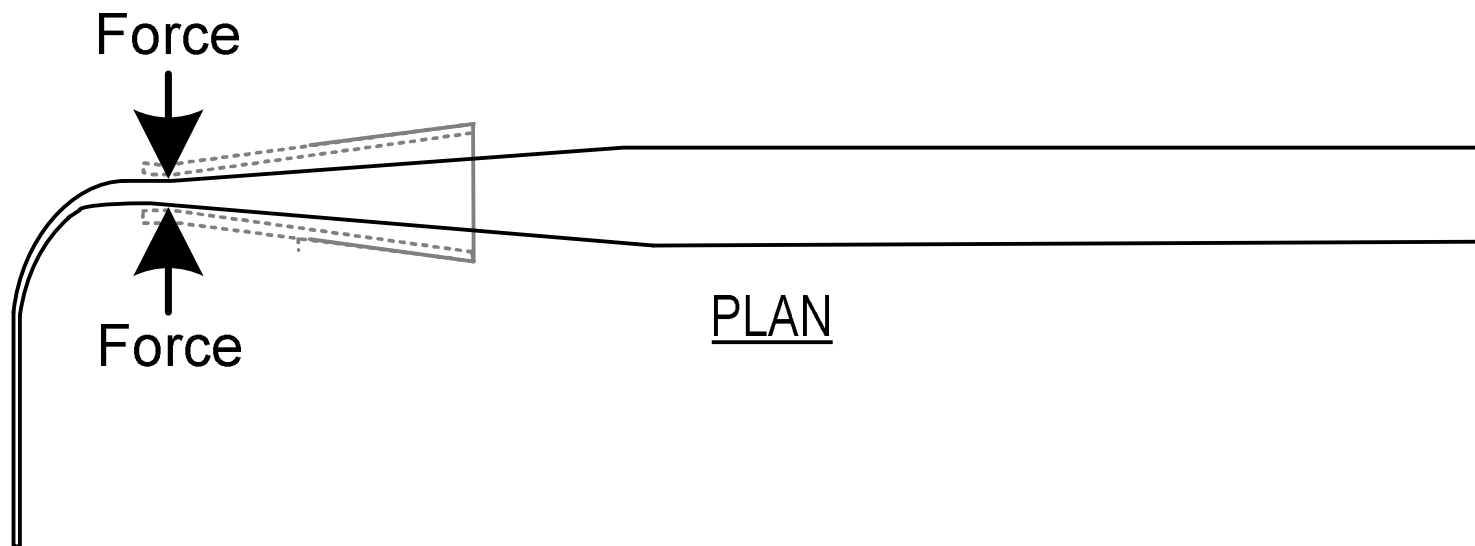
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Early Production ET-Plus Performance



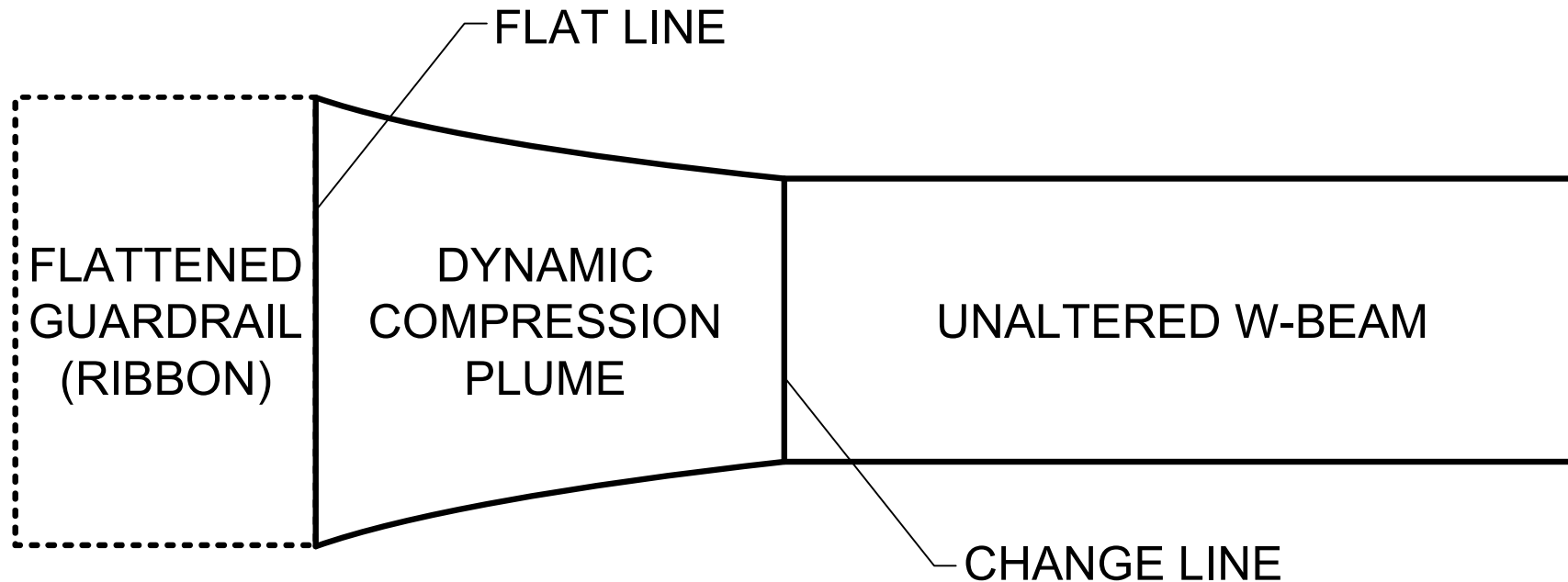
The guardrail is compressed by horizontal forces from the extruder throat and subsequently flattened by the deflector into a ribbon.

Early Production ET-Plus Performance



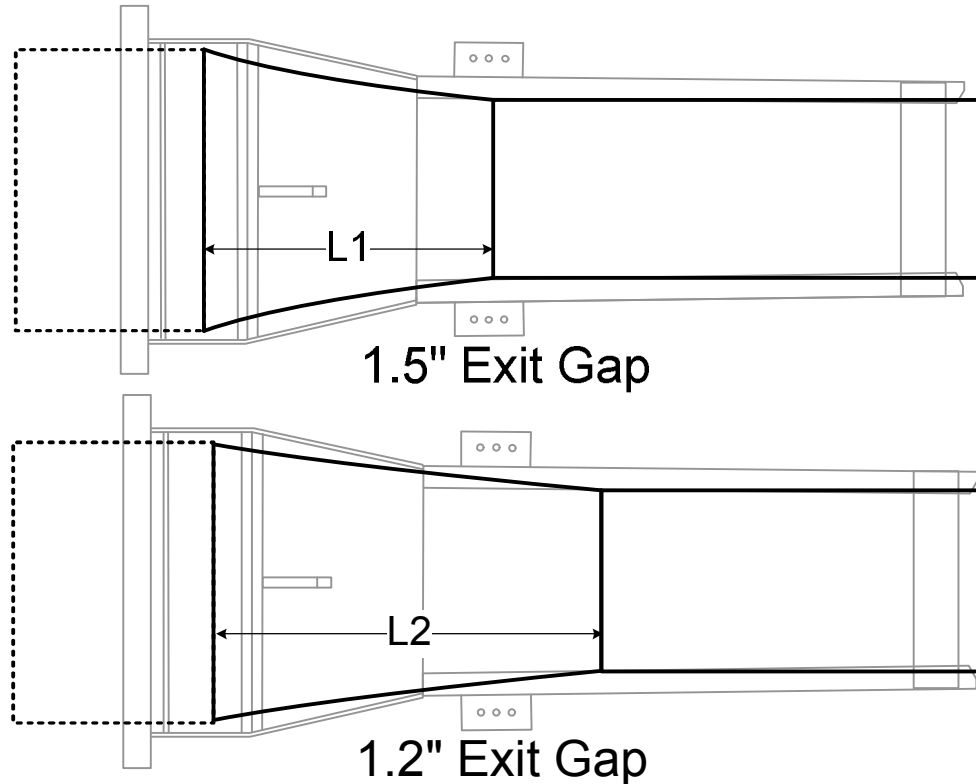
Most of the horizontal compressing forces are adjacent to the exit gap of the extruder throat that create the dynamic compression plume.

Early Production ET-Plus Performance



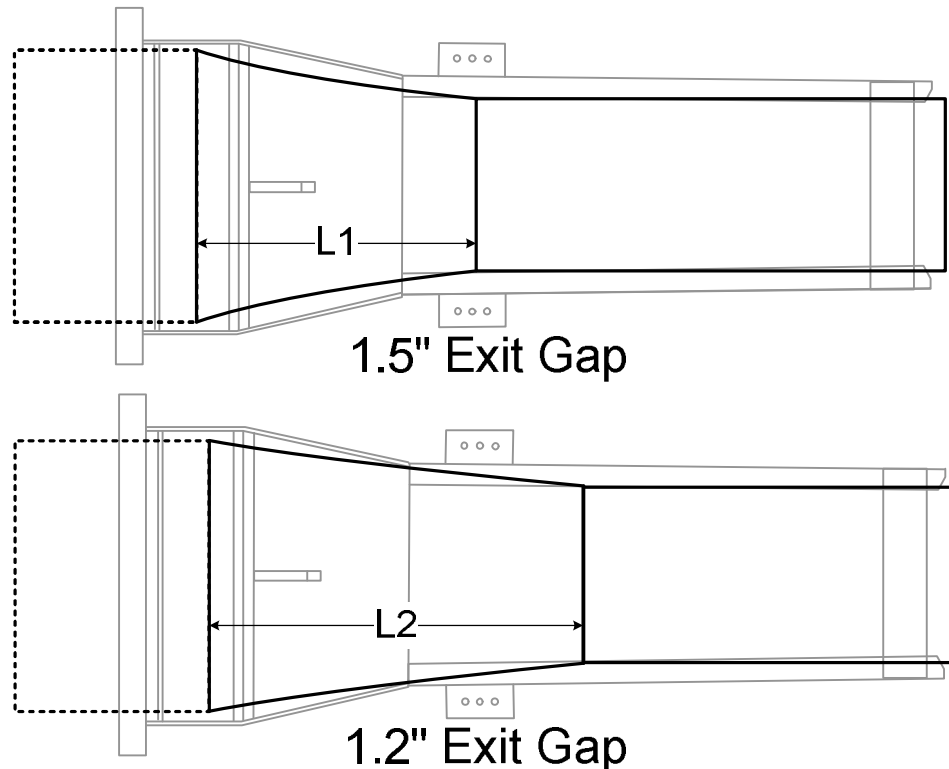
The dynamic compression plume is located between the change line and the flat line as the terminal moves along the guardrail during an impact.

Early Production ET-Plus Performance



As shown above, a smaller exit gap creates a larger or longer dynamic compression plume.

Early Production ET-Plus Performance



The early production ET-Plus could easily handle a dynamic compression plume from a 1.5 inch exit gap as well as a larger dynamic compression plume from a 1.2 inch exit gap.

Early Production ET-Plus Performance



The early production ET-Plus work.*

* Those with exit gaps less than 1.35 inches may fail at a guardrail splice since guardrail bolts have an overall length of 1.5 inches.

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Early Production ET-Plus Performance



The early production ET-Plus work.*

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Early Production ET-Plus Performance



The early production ET-Plus work.*

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Early Production ET-Plus Performance



A glancing blow on an early production ET-Plus and it worked.

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Early Production ET-Plus Performance



An early production ET-Plus that worked until the guardrail splice.

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Early Production ET-Plus Performance



The rest of the debris.

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Early Production ET-Plus Performance

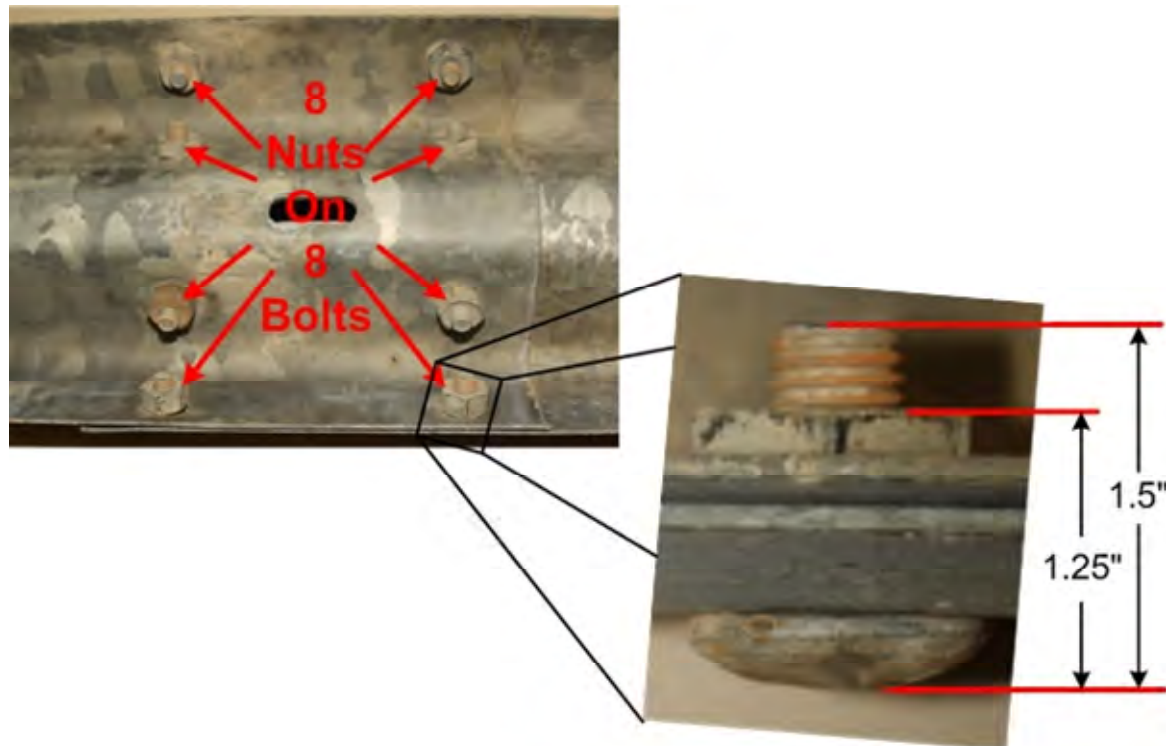


The exit gap for the extruder throat was 1.17 inches. If the exit gap had been 1.35 the splice could have gone through.

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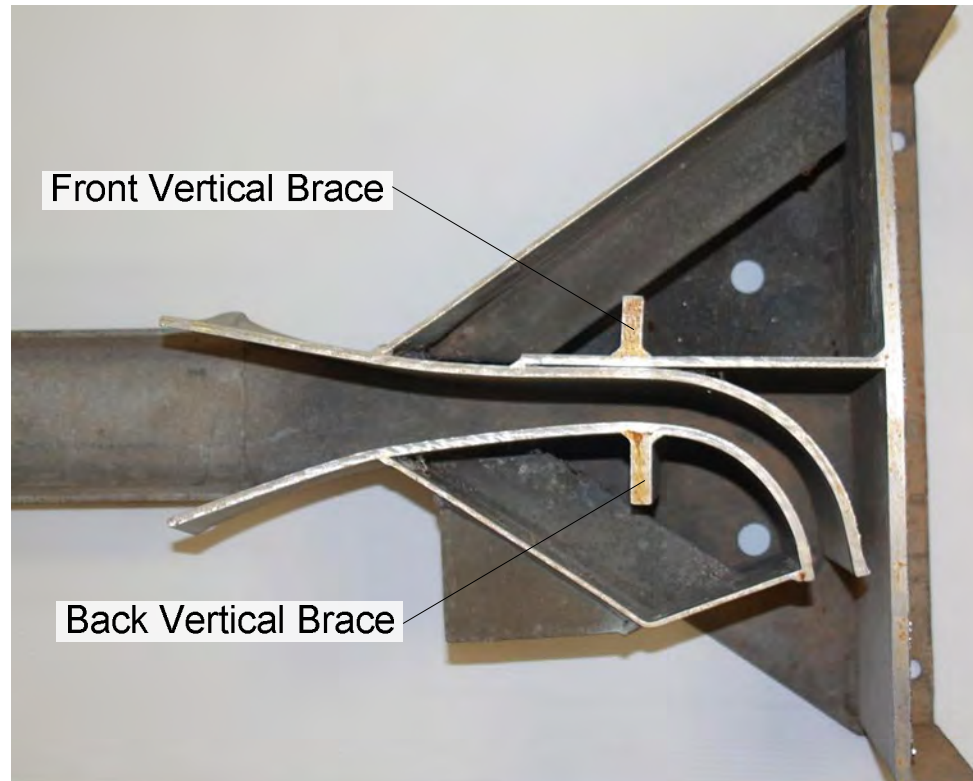
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Early Production ET-Plus Performance



There are 8 guardrail splice bolts, which are grade 5 and have an overall length of 1.5 inches.

Early Production ET-Plus Performance



The front and back vertical braces of the ET-2000 deformed to allow the 1.5 guardrail bolts through the exit gap.

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Early Production ET-Plus Performance



A 1.5 inch bolt has hard time getting through a 1.17 inch gap and bending the 4 inch wide $\frac{1}{2}$ inch thick steel back vertical brace of the ET-Plus.

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Redesign Into Current Production

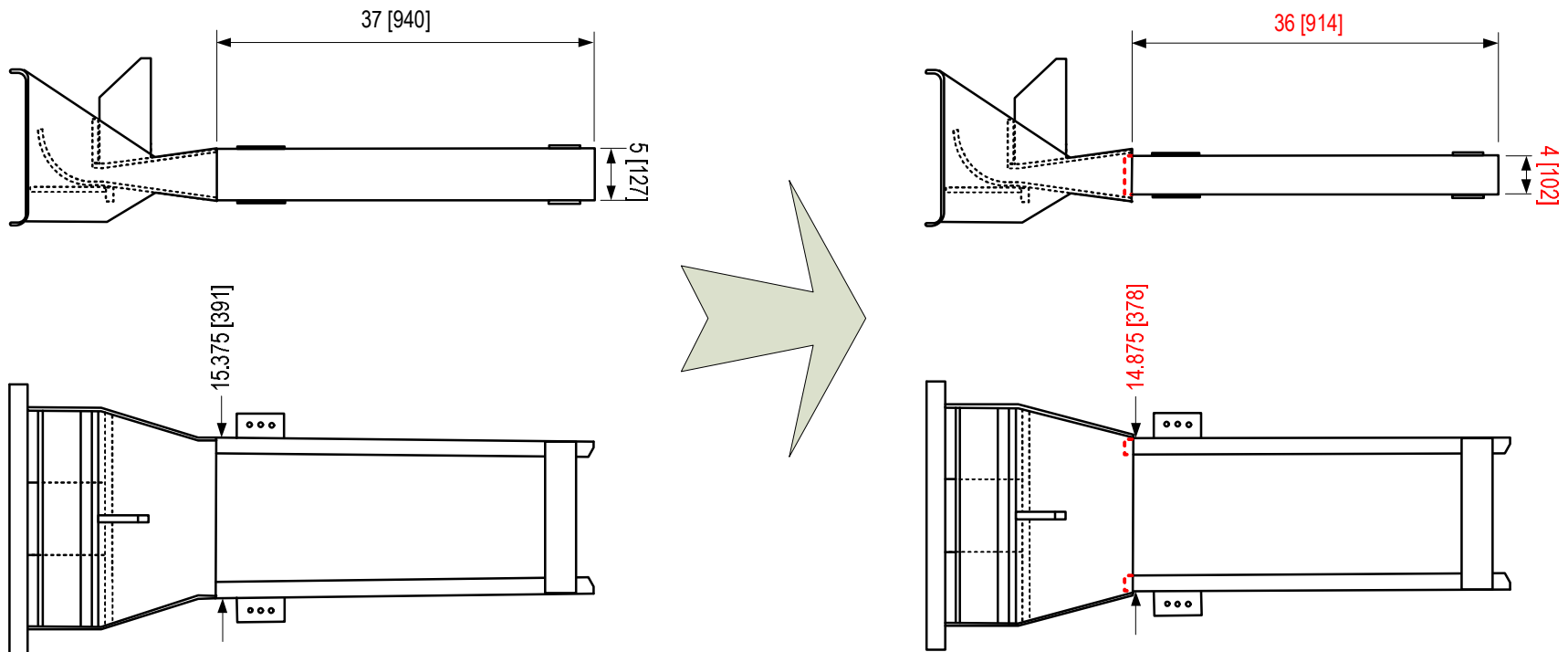


The current production ET-Plus with a feeder chute having 4 inch wide rails started to appear in 2005.

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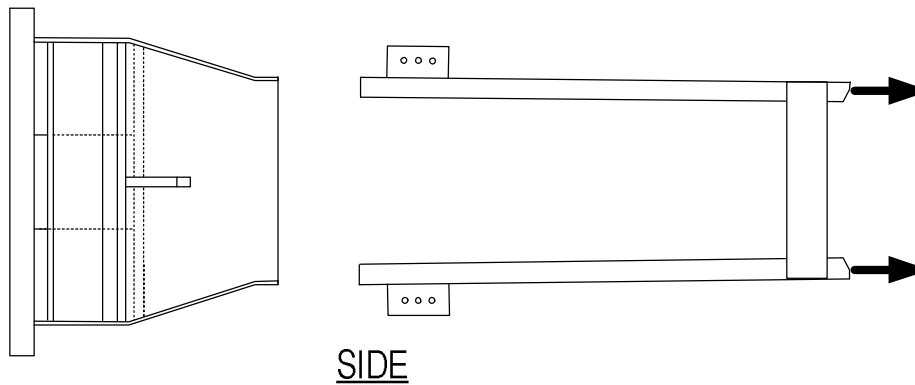
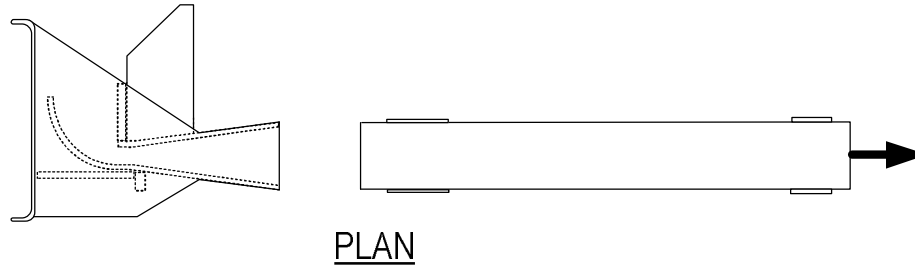
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Redesign Into Current Production



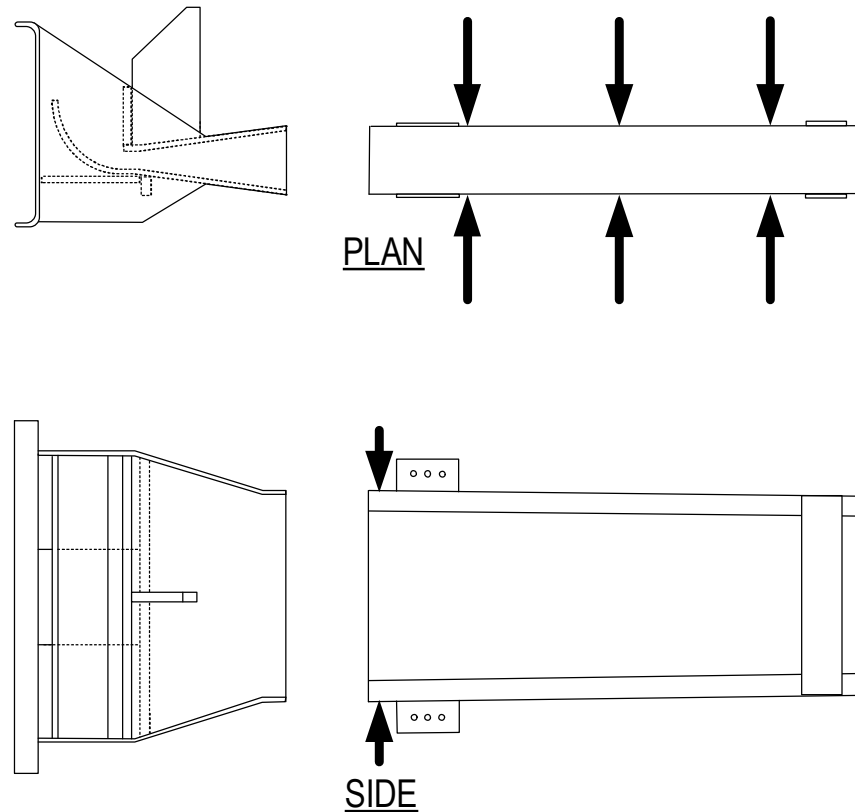
The following explains how a 2005 redesign changed an early production ET-Plus into a current production ET-Plus.

Redesign Into Current Production



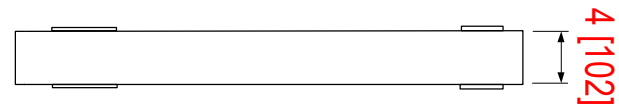
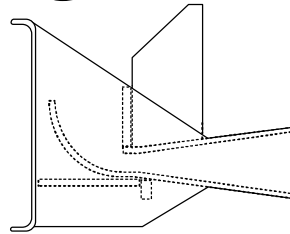
First, remove the feeder chute from the extruder throat.

Redesign Into Current Production

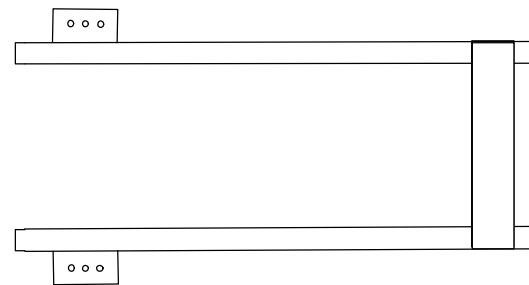
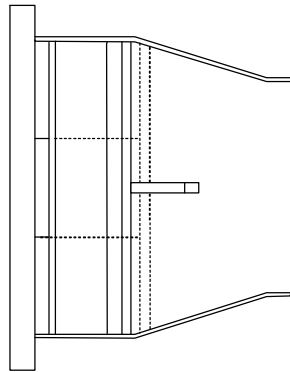


Reduce feeder chute width and height between rails.

Redesign Into Current Production



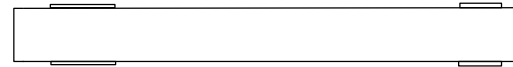
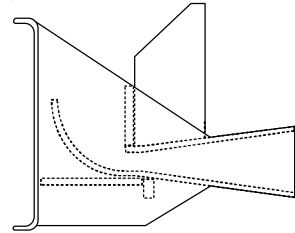
PLAN



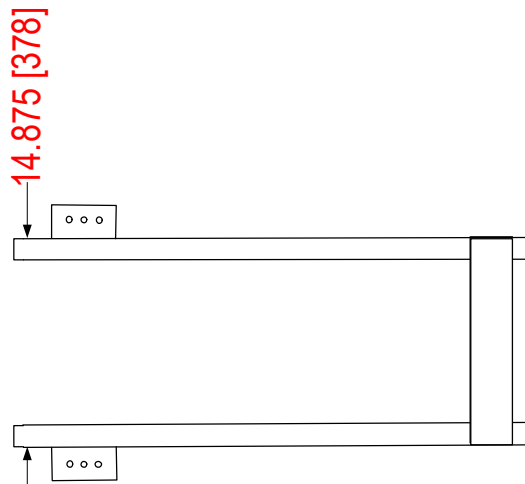
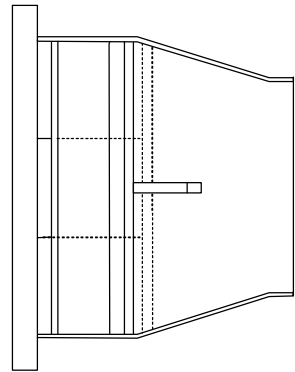
SIDE

More specifically, reduce feeder chute width from 5 to 4 inches.

Redesign Into Current Production



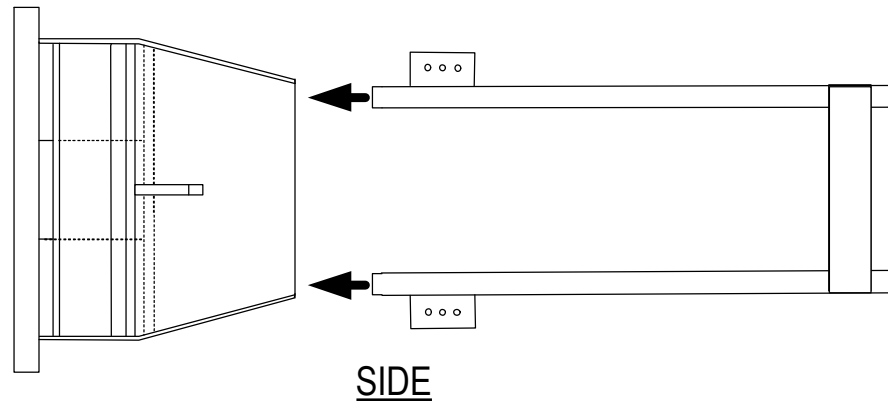
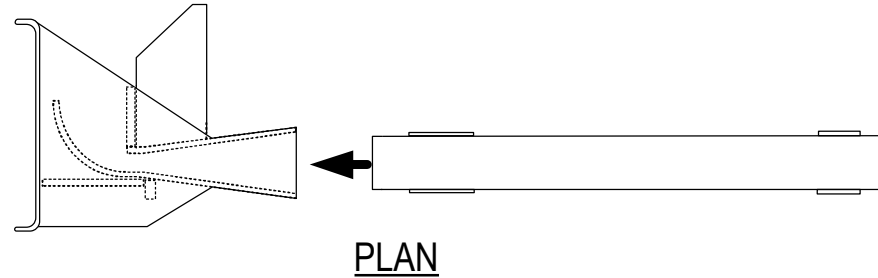
PLAN



SIDE

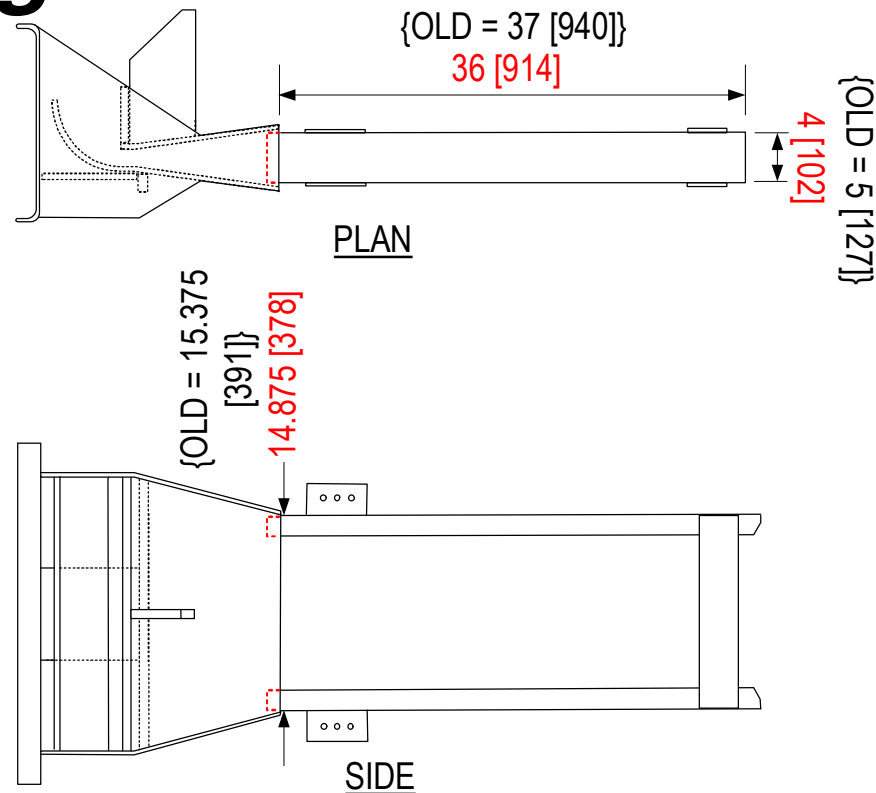
Reduce rail height from 15.375 to 14.875 inches.

Redesign Into Current Production



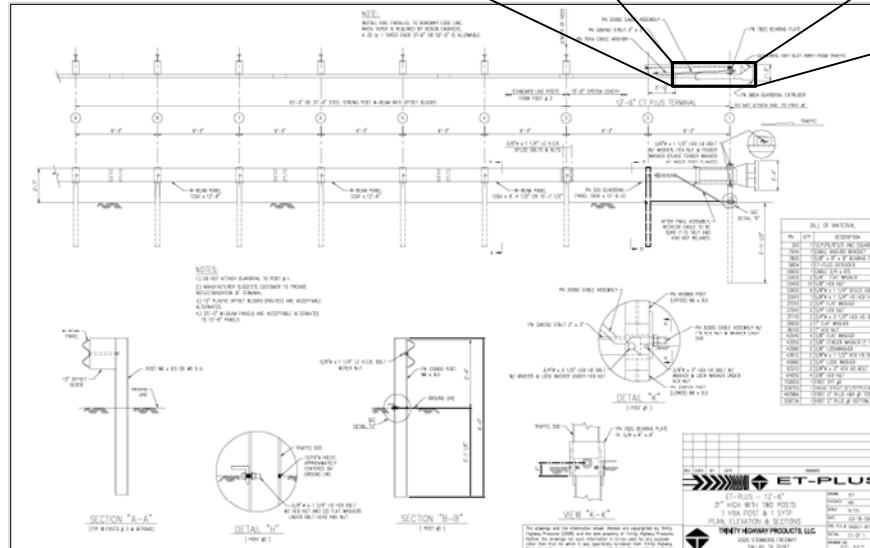
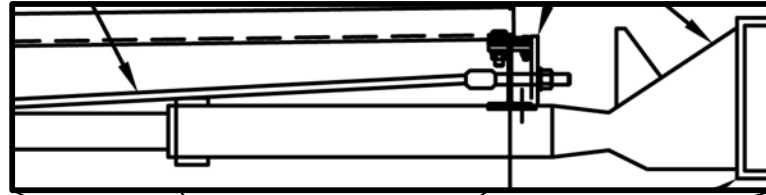
Insert rails .75 inches deep into extruder throat.

Redesign Into Current Production



The result is that the impact plate, deflector and extruder throat are the same as an earlier production ET-Plus but the feeder chute is shorter, narrower and intrudes into the extruder throat.

Redesign Into Current Production

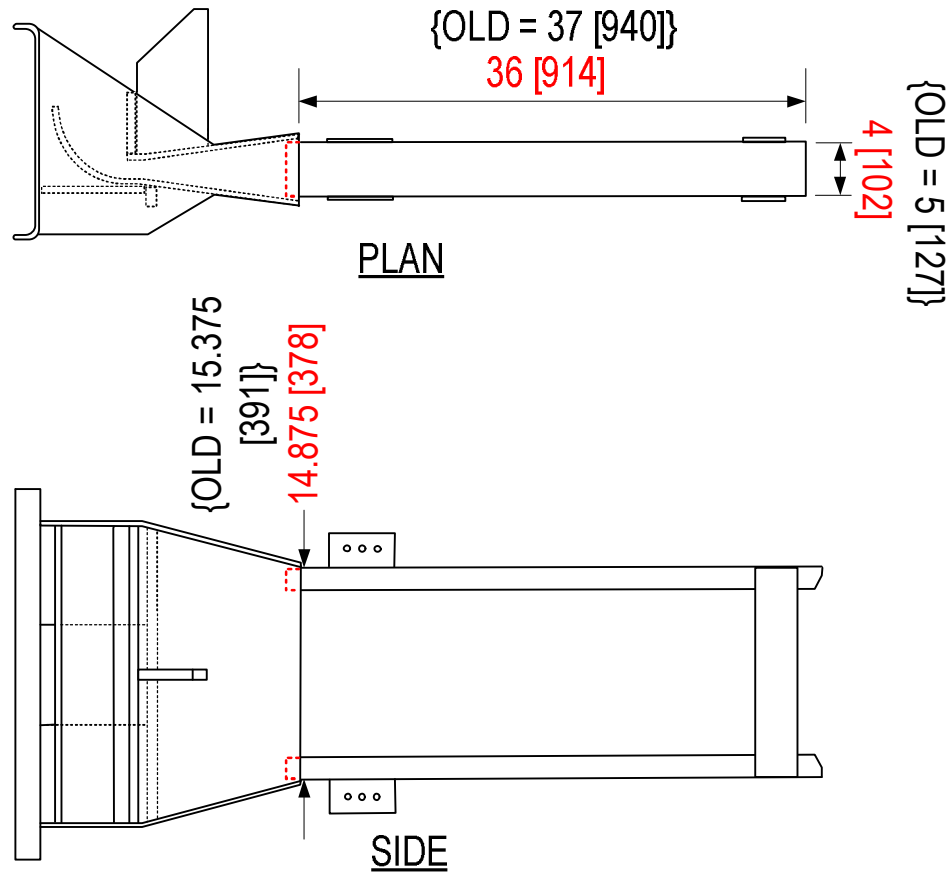


A design approval request sent to FHWA in October 2009 for a system having 31 inch high guardrail showed the ET-Plus as having a feeder chute with 5 inch wide feeder rails.

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Differences Between Productions

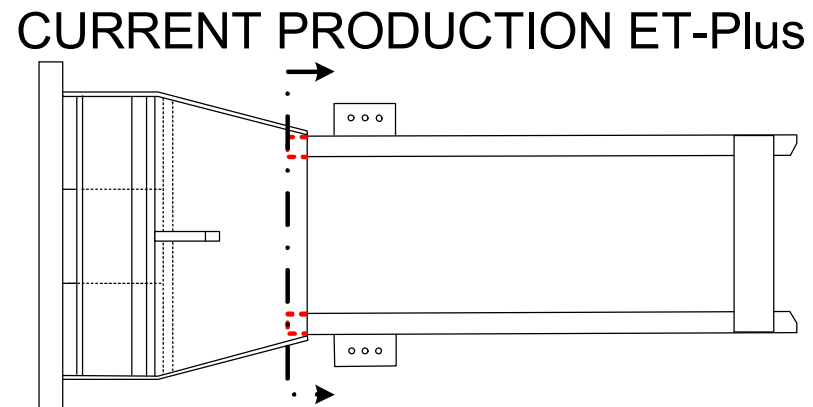
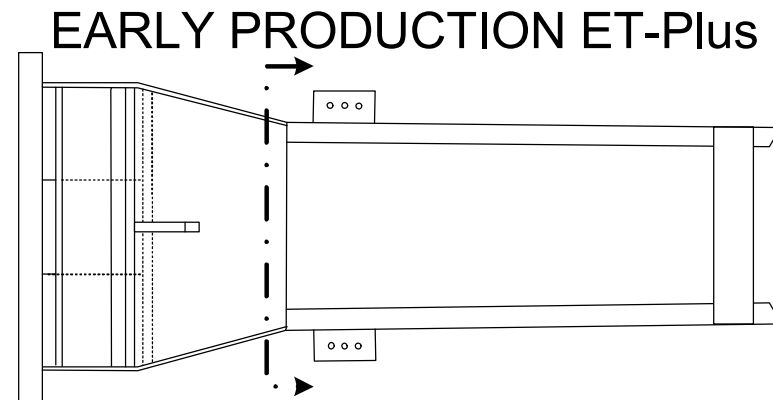


Differences of dimensions of feeder chute between productions.

Differences Between Productions

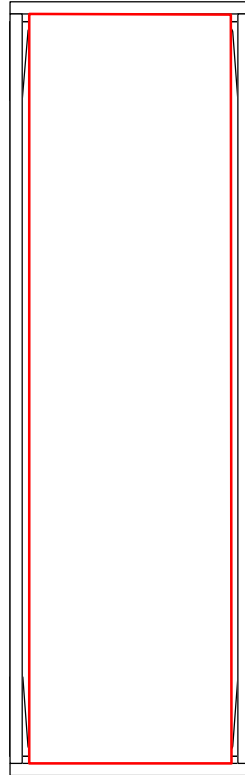
The insertion of the feeder chute into the extruder throat has caused changes to critical dimensions within the extruder throat that adversely effect performance.

Note positions for following cross-sections at .75 inches into the extruder throat from feeder chute for both.

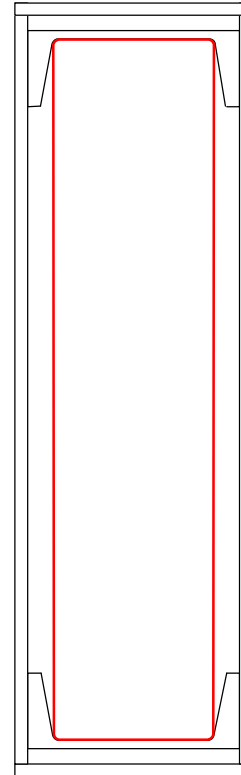


Differences Between Productions

EARLY PRODUCTION
ET-Plus



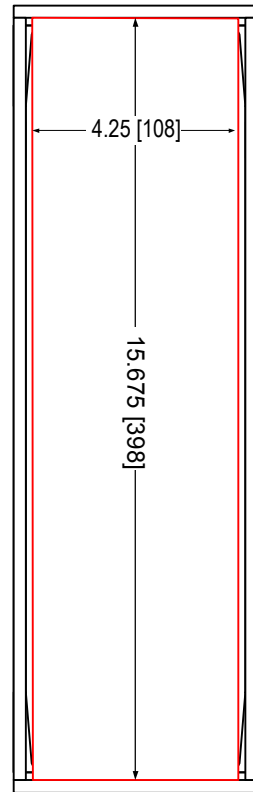
CURRENT PRODUCTION
ET-Plus



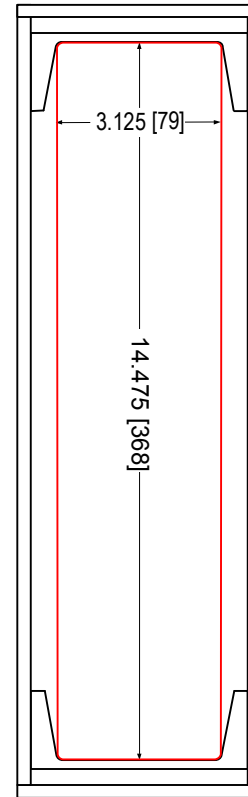
Less **area** for guardrail in the extruder throat where the feeder chute ends in the extruder throat.

Differences Between Productions

EARLY PRODUCTION
ET-Plus



CURRENT PRODUCTION
ET-Plus



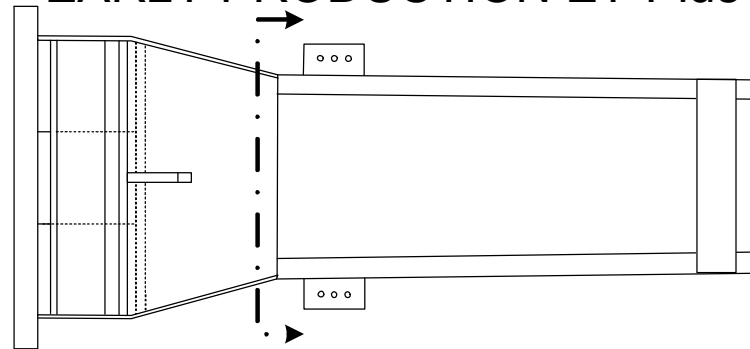
Dimensions at .75 inches within extruder throat are different.

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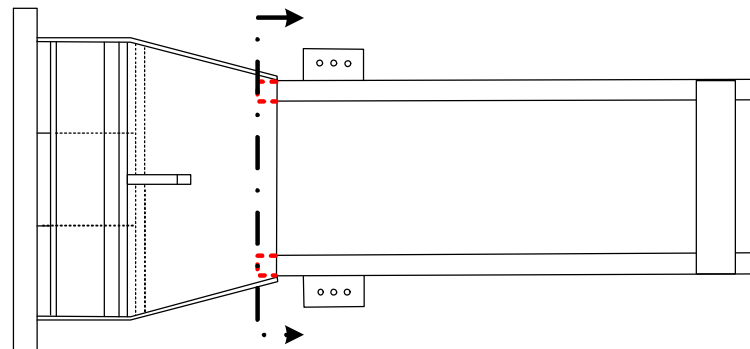
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Differences Between Productions

EARLY PRODUCTION ET-Plus



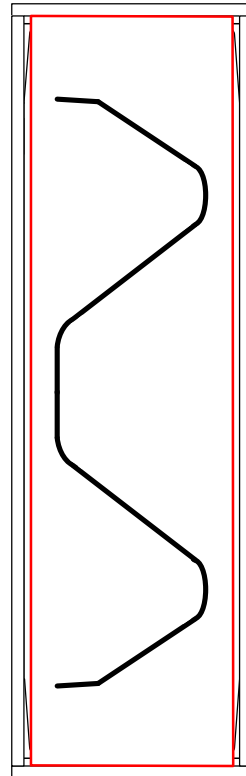
CURRENT PRODUCTION ET-Plus



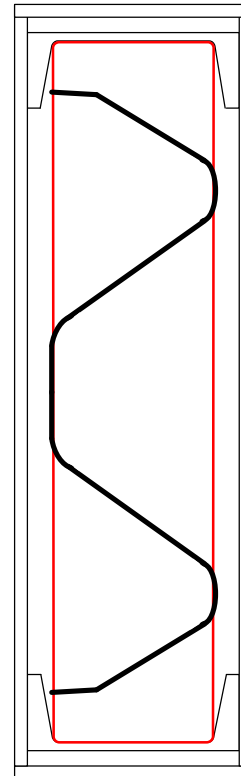
Note positions of the cross-sections again.

Differences Between Productions

EARLY PRODUCTION
ET-Plus

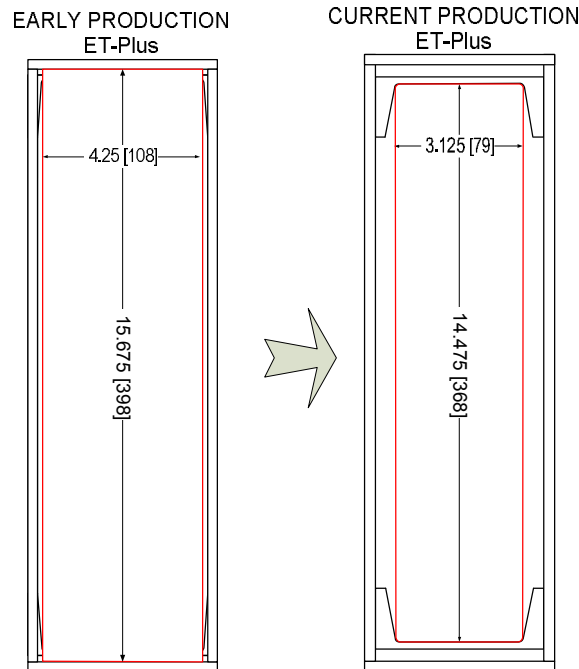


CURRENT PRODUCTION
ET-Plus



Change of **area** relative to guardrail without a dynamic compression plume.

Differences Between Productions

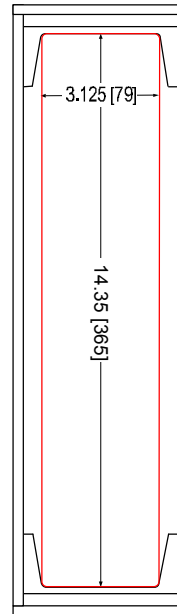


4.25" to 3.125" = ~26% WIDTH REDUCTION
15.675" to 14.475" = ~7.6% HEIGHT REDUCTION
67" to 45" = ~33% REDUCTION IN AREA

The ~7.6% height reduction at .75 inches inside of the extruder throat from the feeder chute can drastically impact performance.

Differences Between Productions

CURRENT PRODUCTION
ET-Plus



15.675" to 14.35" = ~8.5% HEIGHT REDUCTION

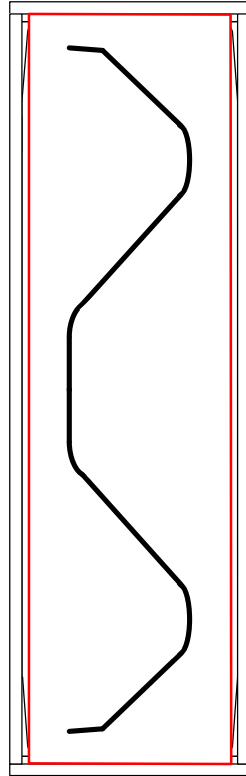
Some current production ET-Plus out on the highways now show a ~8.5% height reduction at .75 inches inside of the extruder throat from the feeder chute.

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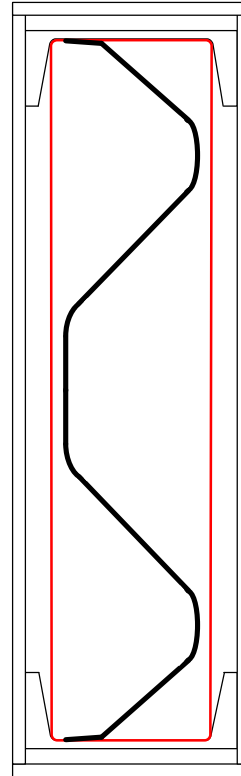
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Differences Between Productions

EARLY PRODUCTION
ET-Plus

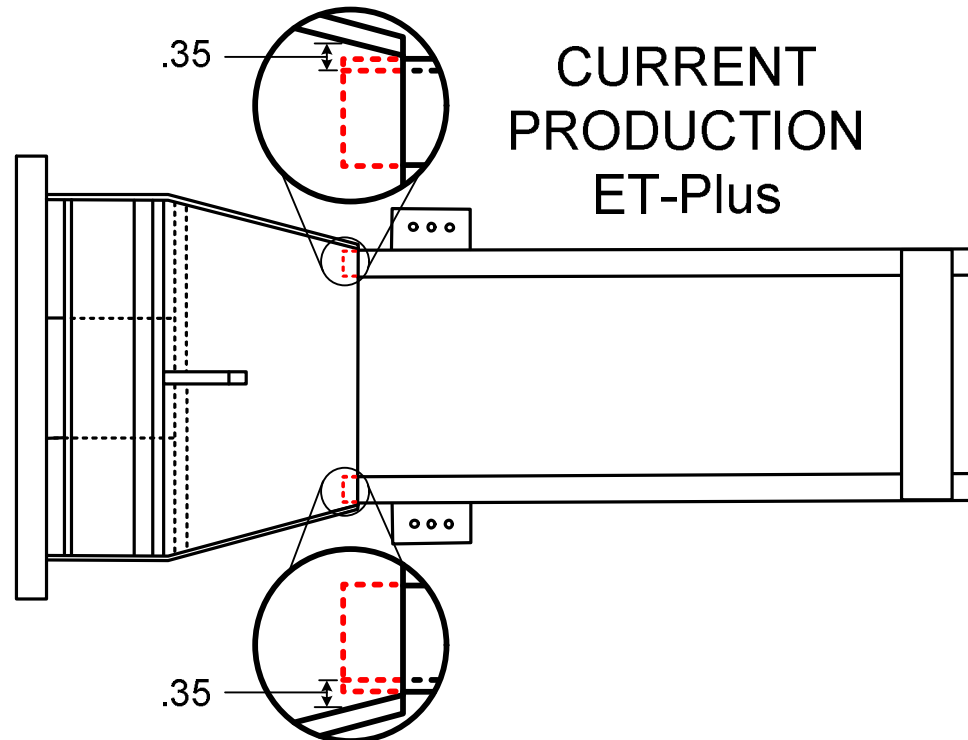


CURRENT PRODUCTION
ET-Plus



The shorter height of the current production ET-Plus limits the expansion of the dynamic compression plume.

Differences Between Productions

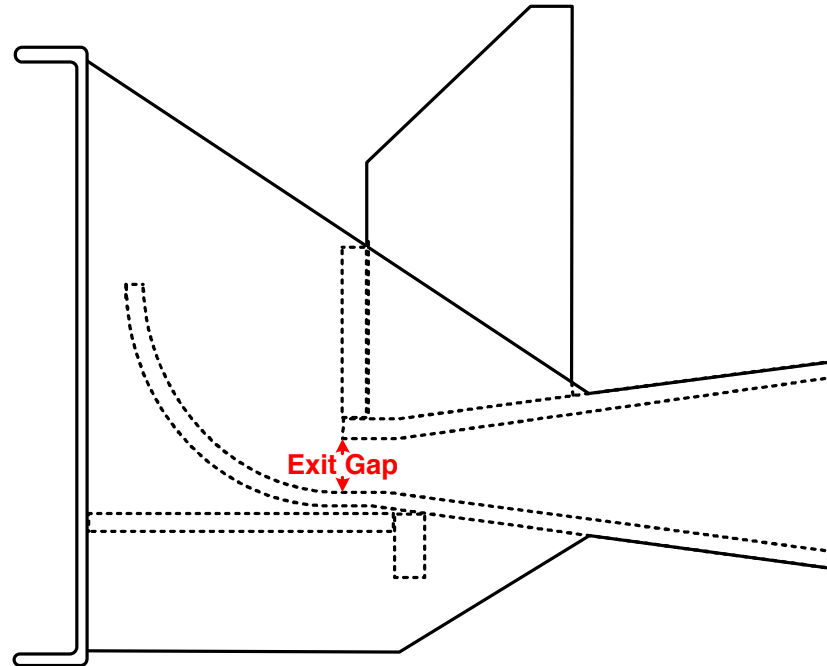


There are ~.35 inch ledges near the top and bottom of the extruder throat at .75 inches inside of the extruder throat from due to the feeder chute intrusion that can drastically impact performance.

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Differences Between Productions



The exit gap of current production ET-PLUS now has manufacturing variances between 1 to 1.2 inches.

Current Production Fails To Feed

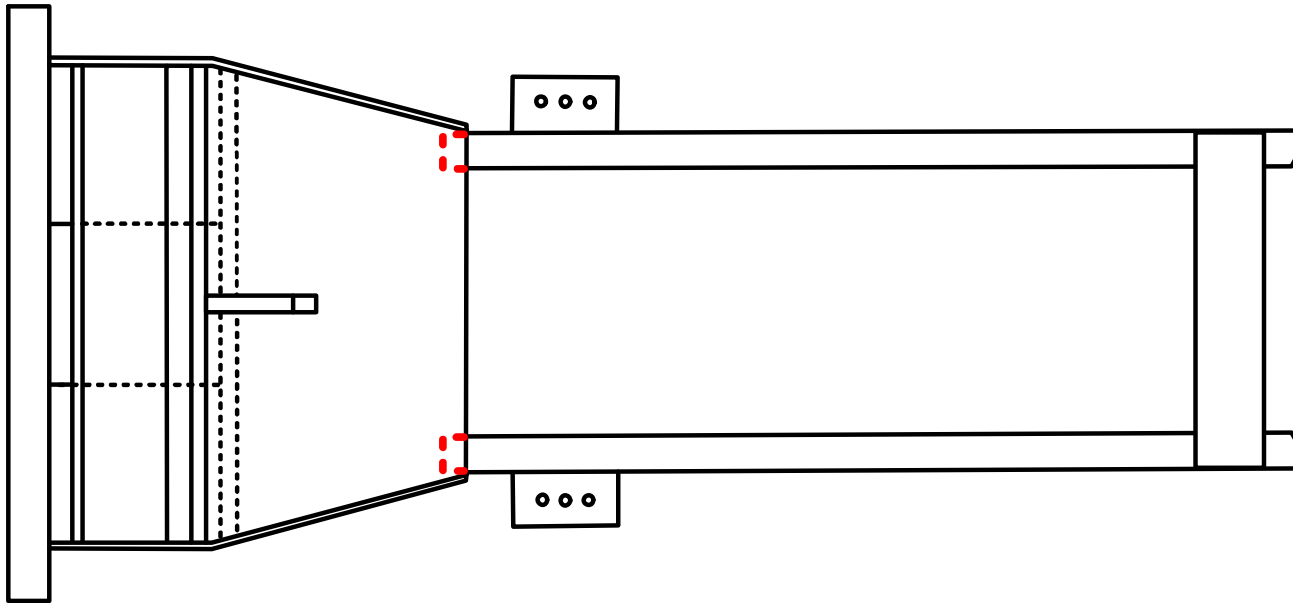


The current production ET-Plus started to appear in 2005.

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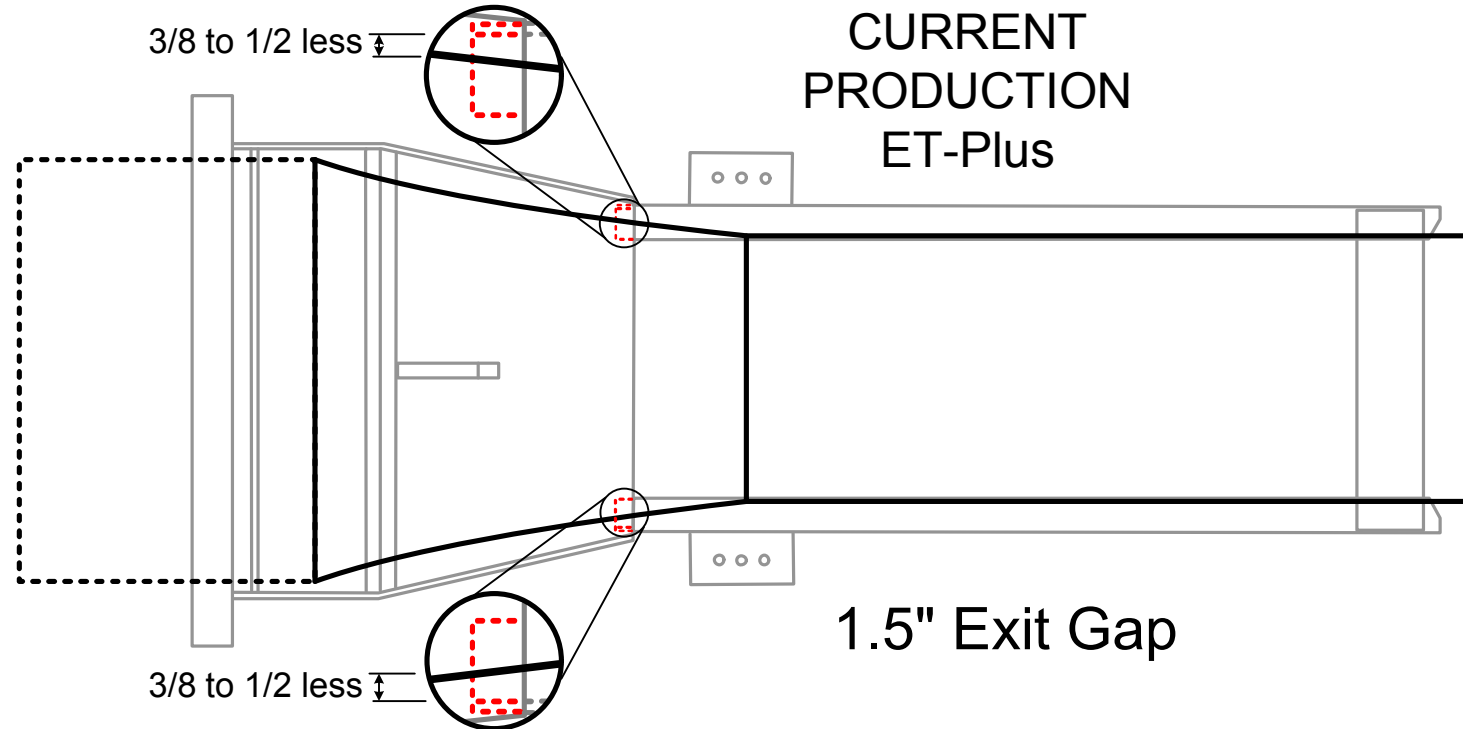
SPIG

Current Production Fails To Feed



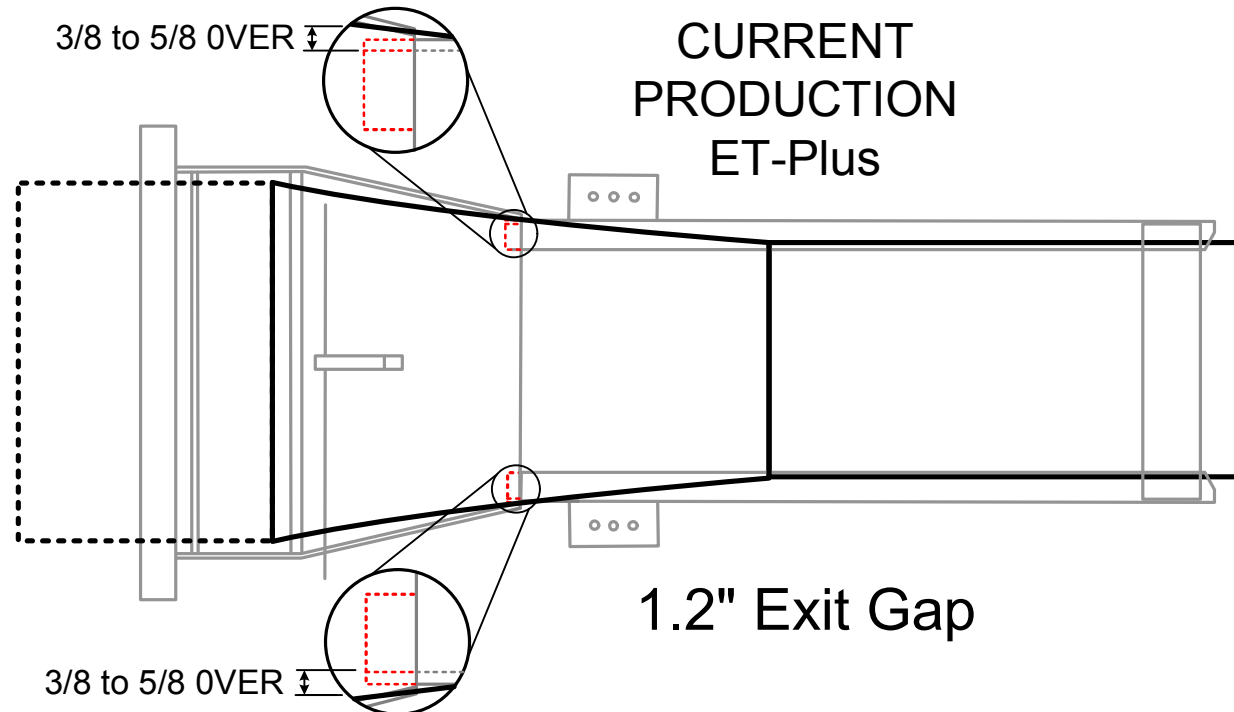
The height reduction of at least 1.2 inches at .75 inches within the extruder throat coupled with reduction in the exit gap of the extruder throat to below 1.3 inches cause the guardrail to “Throat Lock” in the extruder throat during an impact.

Current Production Fails To Feed



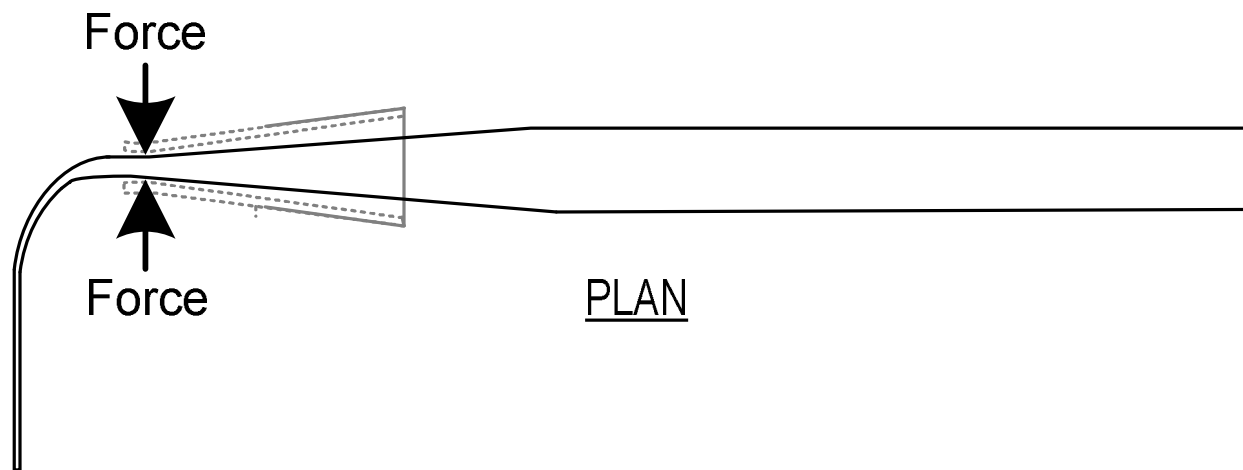
When the exit gap of the extruder throat is 1.5 inches, the resultant dynamic compression plume is well within the top and bottom feed rails within the extruder throat.

Current Production Fails To Feed



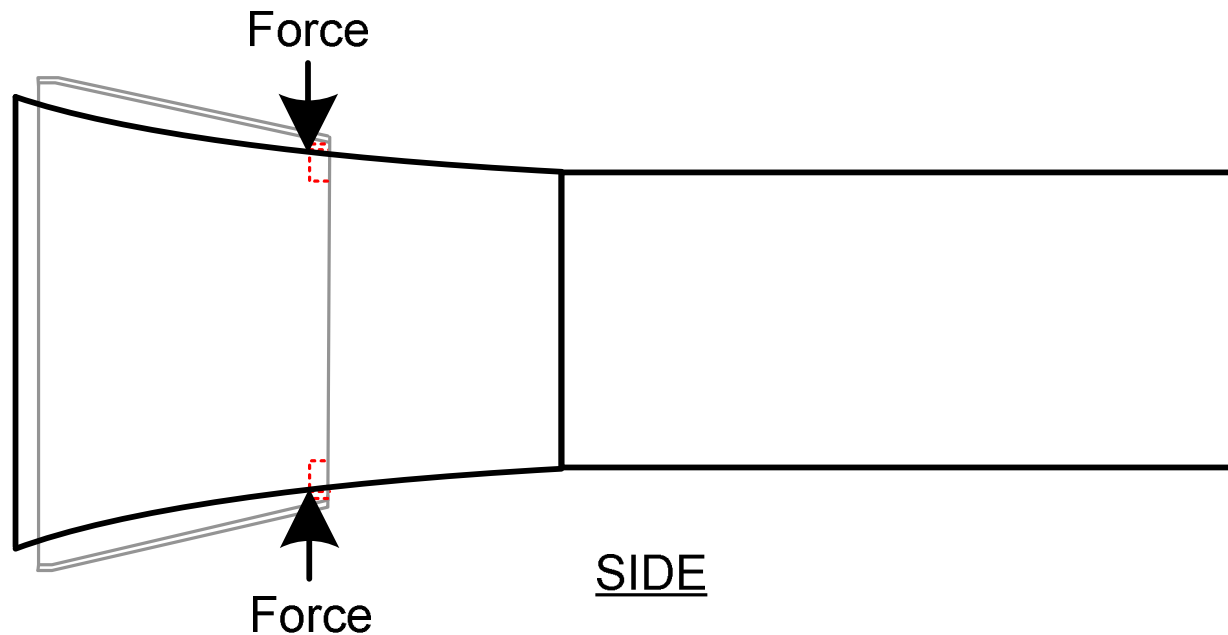
When the exit gap of the extruder throat is 1.2 inches, the resultant dynamic compression plume is beyond the top and bottom feed rails within the extruder throat by $\frac{3}{4}$ to 1.25 inches.

Current Production Fails To Feed



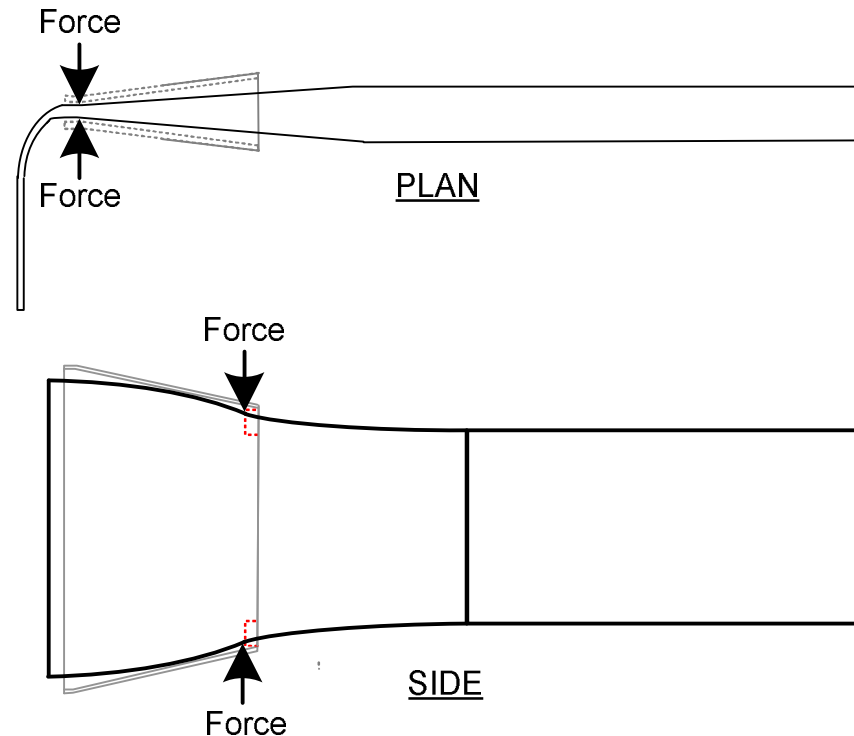
Thus, in addition to the horizontal compressing forces from the extruder throat that create the dynamic compression plume,...

Current Production Fails To Feed



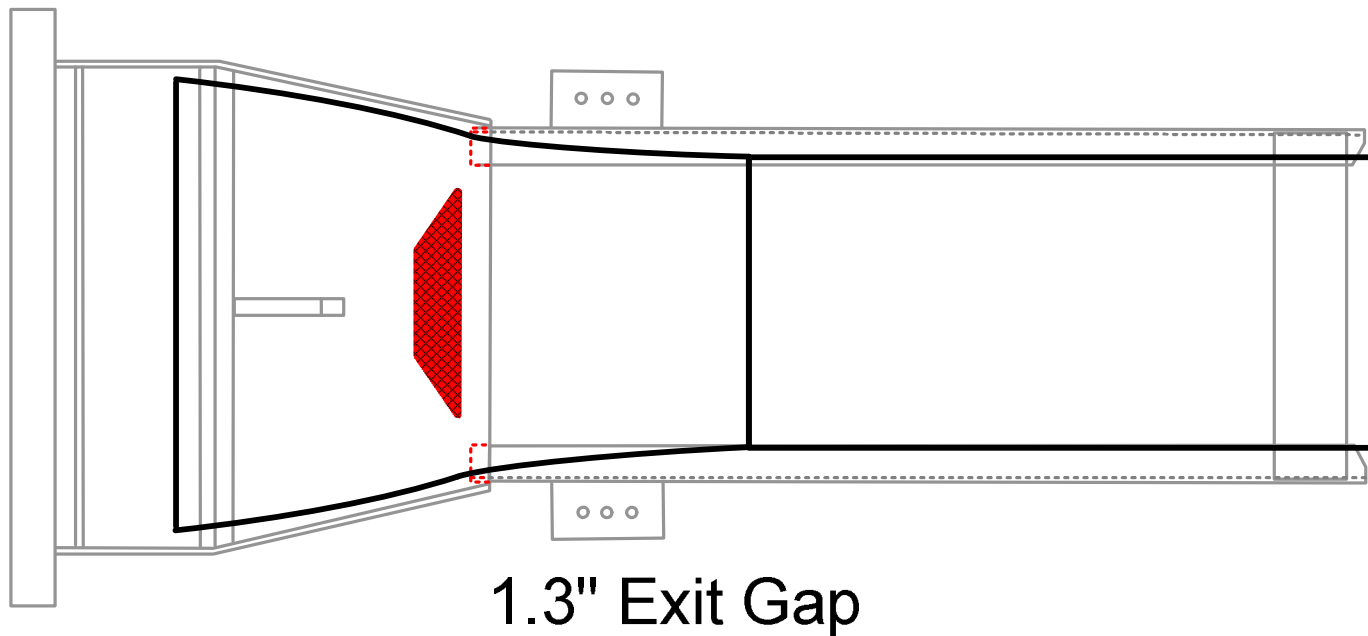
...there are also vertical constraining forces on the dynamic compression plume due to the ends of the feeder rails intruding into the extruder throat by $\frac{3}{4}$ inches.

Current Production Fails To Feed



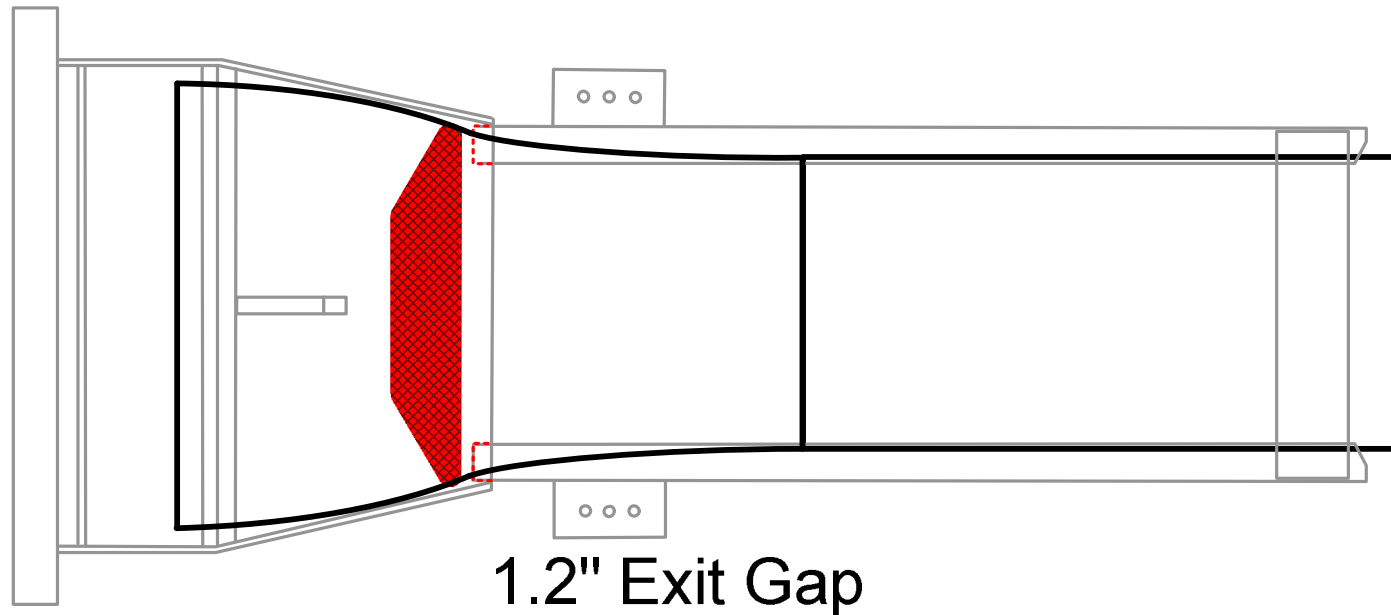
The vertical constraining forces from the ends of the feeder rails deforms the natural shape of the dynamic compression plume resulting from the horizontal compressing forces.

Current Production Fails To Feed



The deformation of the natural dynamic compression plume creates a contortion zone in the guardrail within the extruder throat.

Current Production Fails To Feed



The contortion zone of a current production ET-Plus with 1.2 inch exit gap will span across the distance between ends of the feeder rails in the extruder throat so as to cause the guardrail to lock up in the extruder throat during an impact.

Current Production Fails To Feed



This is an example of throat lock that occurred in a current production ET-Plus with 1.2 inch exit gap during an impact.

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Current Production Fails To Feed

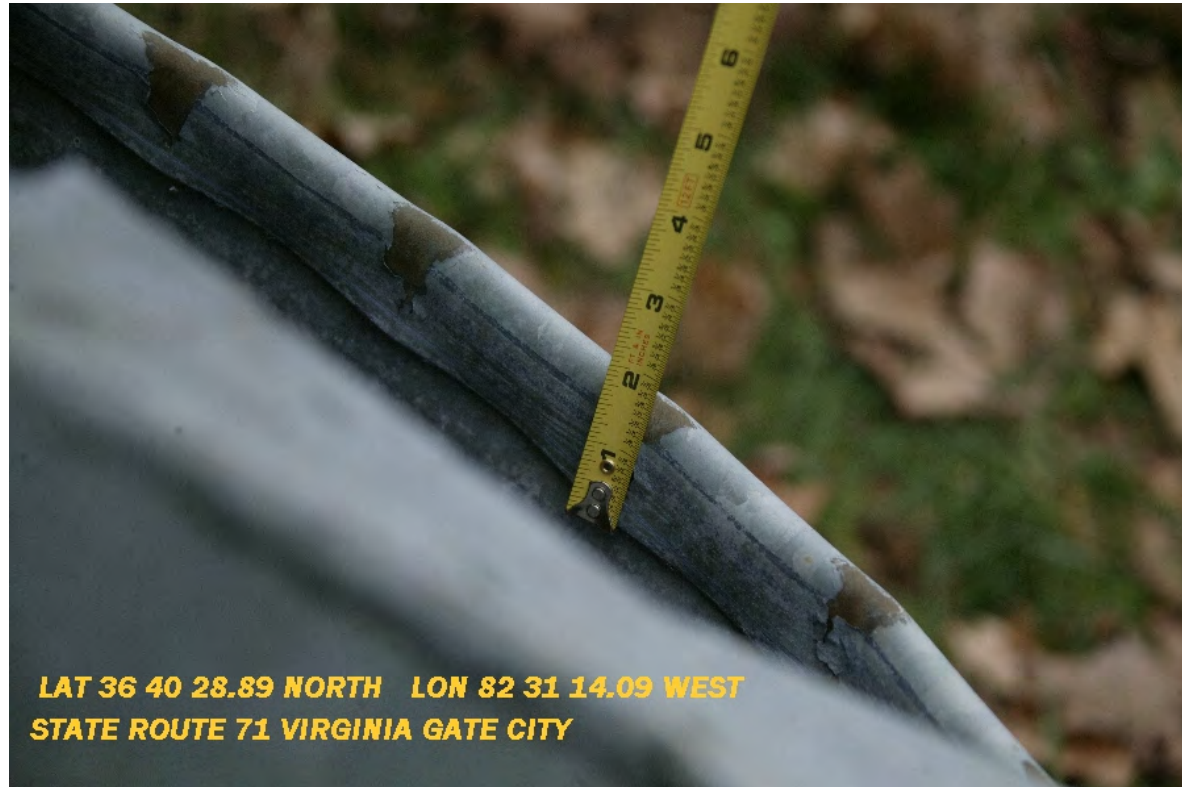


This is an example of a current production ET-Plus with 1.2 inch exit gap that did not throat lock because...

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Current Production Fails To Feed



...the rail bent over at the top of the guardrail.

Current Production Fails To Feed



Then, this current production ET-Plus failed at the guardrail splice.

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Current Production Fails To Feed

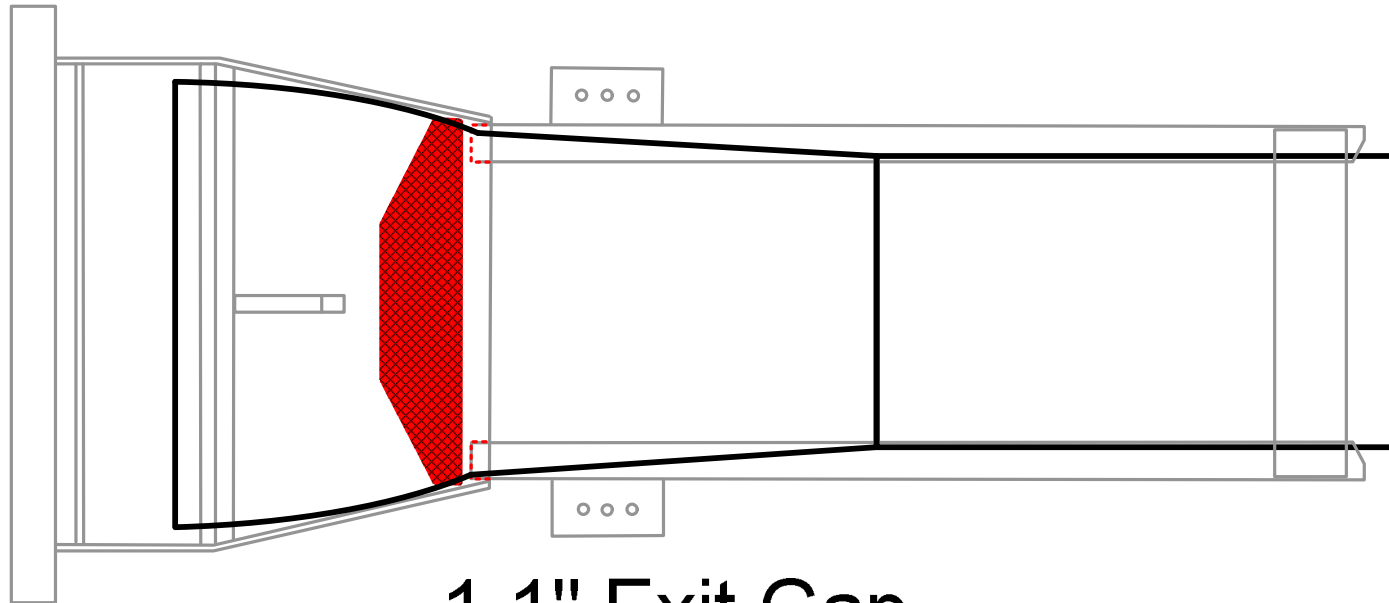


This guardrail bent over at the bottom, fed through the extruder throat some distance, and then throat locked.

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Current Production Fails To Feed



1.1" Exit Gap

The contortion zone of a current production ET-Plus with 1.1 inch exit gap is even larger and thus is more likely to throat lock quicker during an impact.

Current Production Fails To Feed



This is an example of throat lock that occurred in a current production ET-Plus with 1.1 inch exit gap during an impact.

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Current Production Fails To Feed



This is an example of throat lock that occurred in a current production ET-Plus with 1.1 inch exit gap during an impact.

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Current Production Fails To Feed

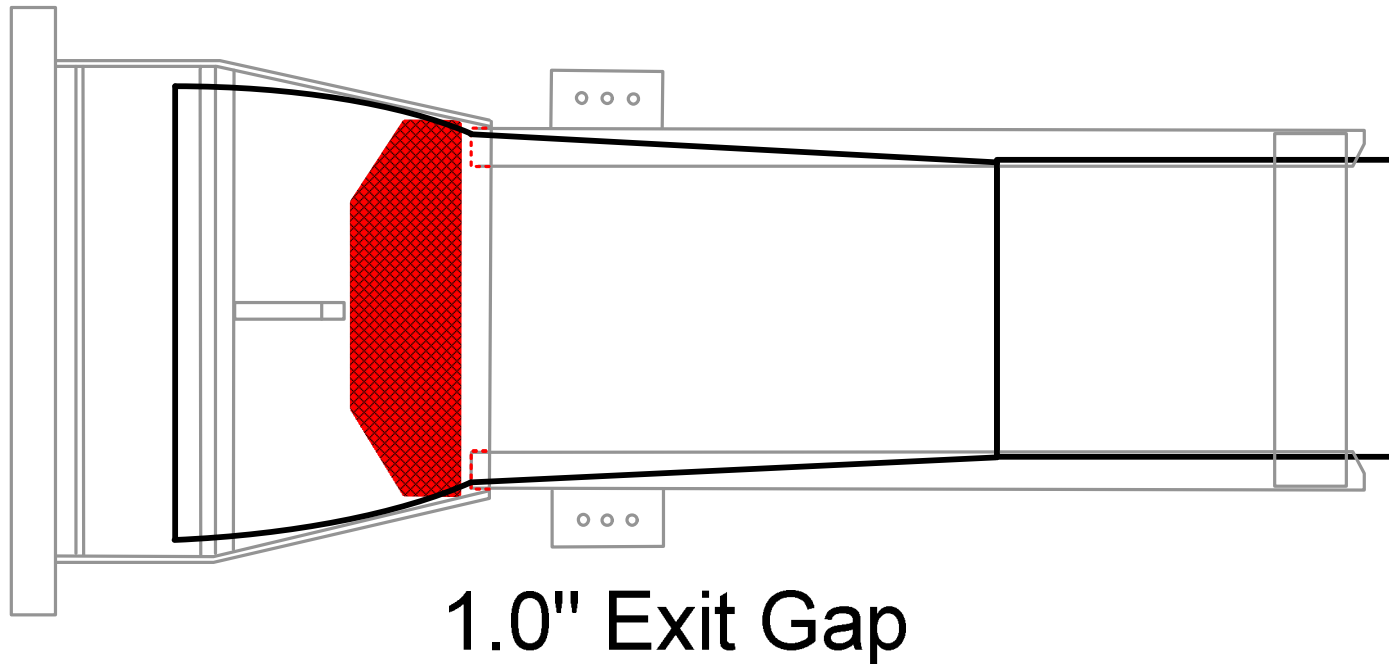


Note edge stress on guardrail ribbon of this throat locked current production ET-Plus with 1.1 inch exit gap.

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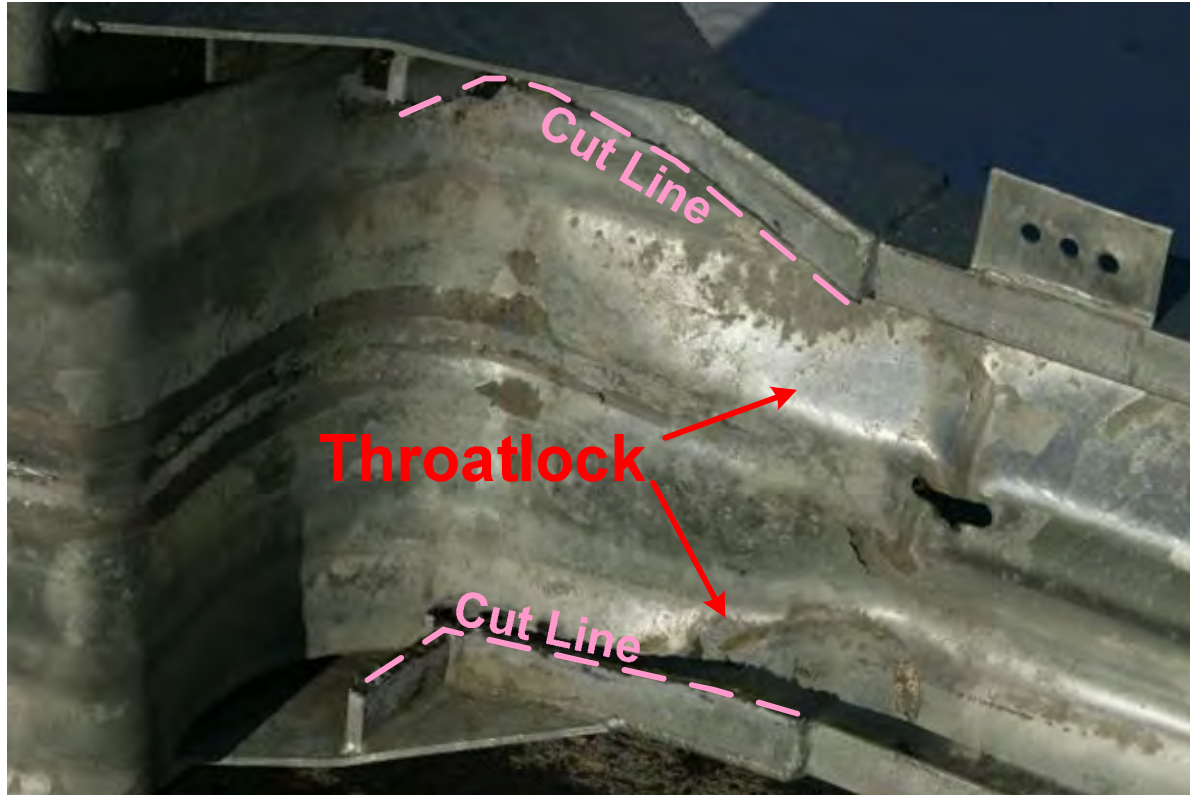
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Current Production Fails To Feed



The contortion zone of a current production ET-Plus with 1.0 inch exit gap is the largest.

Current Production Fails To Feed



This is a current production ET-Plus that has been cut apart to show throat locked guardrail in the extruder throat.

Other Thoughts



The blockout's lack of resilience may further contribute to throat lock in that the guardrail is allowed to flex.

Other Thoughts



The early release of the tension cable by the hinged breakaway post may also contribute to throat lock by not holding the guardrail tight at initial compression/deflection.

Conclusion

- **A current production ET-Plus having an exit gap of less than 1.3 inches will have the guardrail throat lock in the extruder throat when impacted.**

Addendum



In this December 2011 picture of a throat locked current production ET-Plus with a 1.0 exit gap, the memorial is for...

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Addendum



... young lady killed in a 2008 accident involving another current production ET-Plus with 1.0 inch exit gap.

Addendum



This current production ET-Plus has an exit gap of 1.0 inch and the guardrail is throat locked in the extruder throat.

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Thank you
Questions ?

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Appendix



Guardrail compression in feeder chute of throat locked head.

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Guardrail bulge in feeder chute of throat locked head.

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Kinking guardrail at splice because of throat locked head.

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Appendix

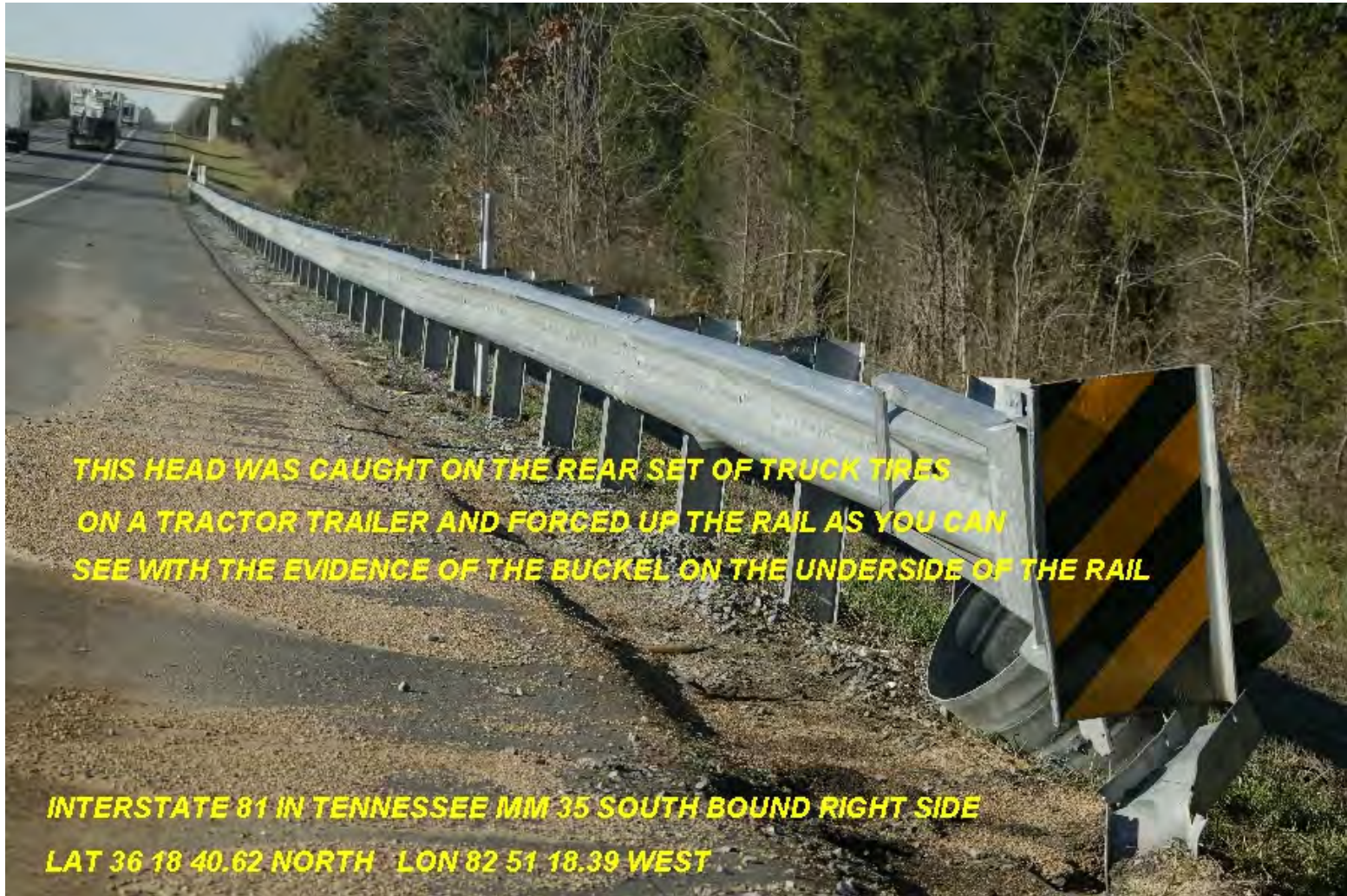


Guardrail compression in feeder chute of throat locked head.

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Appendix



Appendix



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Appendix



Remnants of plume outside in the feeder chute.

Appendix



Remnants of plume outside in the feeder chute.

Appendix



Not even two feet.

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Appendix



Ran a good bit but...

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Appendix



...guardrail still throat locked in the extruder throat.

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