

Coal Plastic Composite Pipe Infrastructure Components (D-E0031982)

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U.S. DOE-NETL Resource Sustainability Project Review Meeting

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Project Overview

Project Specifics

- DOE/NETL Cooperative Agreement No. DE FE-0031982
- DOE Project Manager: Jason Montgomery
- Principal Investigator (PI): Jason Trembly
- Participants: CONSOL Energy, Engineered Profiles, and Clear Skies Consulting

Project Budget

- Federal: \$500,000
- Non-Federal: \$125,000

Project Duration

- January 1, 2021– December 31, 2022



DOE-NETL Carbon Ore Processing Program

Coal Plastic Composites

Background

- In past 3 years, OHIO and industrial partners have developed CPC materials for decking applications
 - DE-FE0031809
- Successfully matured technology from TRL4 to TRL8
- Meets or exceeds ASTM and IBC requirements
- Performance advantages
 - Equivalent or greater strength
 - Greater resistance to oxidation
 - Lower flammability
 - Better price point
 - Lower embodied energy and emissions



Deck Constructed with CPC Boards

CPC Pricing with Commercial Products

Manufacturer	Product	End User Pricing (\$/linear ft)
DE-FE0031809	CPC	1.29
Trex	WPC	1.75-5.78
Choicedek	WPC	3.67
TimberTech	WPC	4.48-6.68

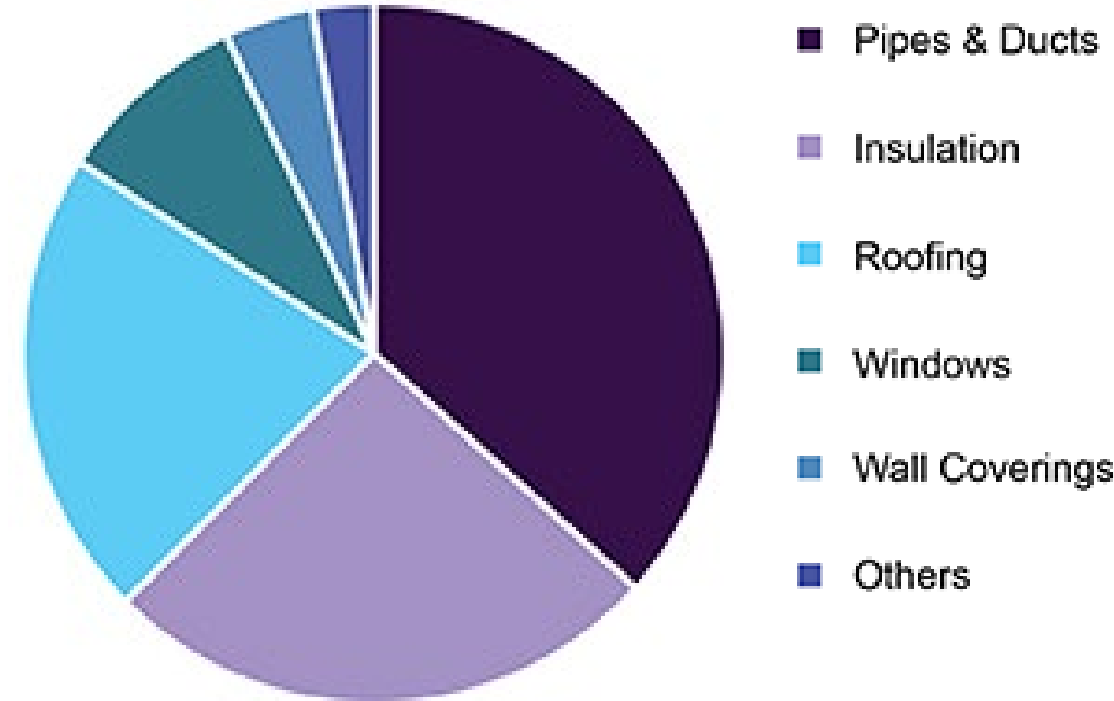
Pipe Materials Market

Overview

- Pipe is the largest thermoplastic resin market segment
- In 2019, the U.S. plastic pipe and fitting market had a value of \$20 billion, and it is expected to grow at 2.5% annually through 2026
- Sewage and drainage account for the largest market segment (35%)

Coal Plastic Composite for Pipe

- Favorable physical properties including high thermal and thermo-oxidative stability
- Upcycles the value of coal (~0.04-0.03 \$/lb), as HDPE and PVC pipe materials sell for ~\$2.20-3.70/lb.
- Replacing CaCO_3 (\$0.13-0.22/lb) or carbon black (~\$1.00/lb) with coal offers attractive cost savings
- Must meet rigorous ASTM performance requirements for compounds and pipe materials



Building/construction plastic market share

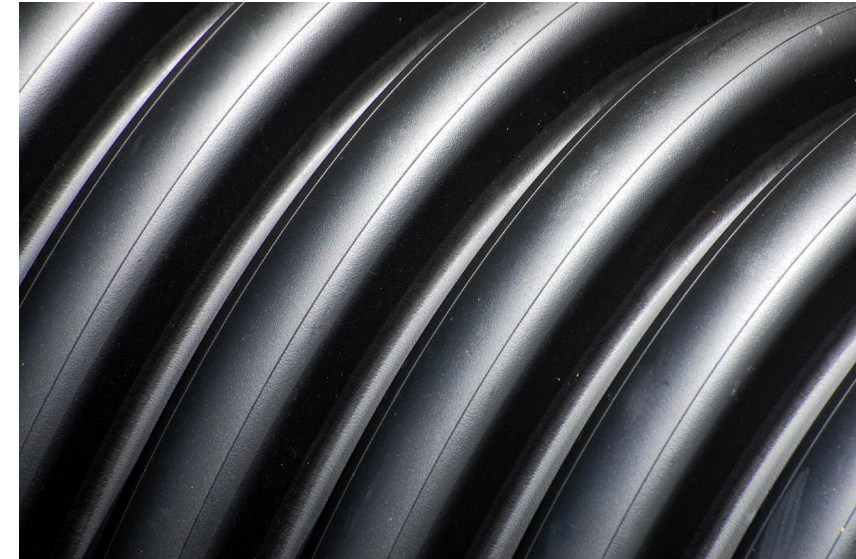
Project Objectives

Overall: Develop coal plastic composite (CPC) pipes for use in home, industrial, and infrastructure applications.

- Consist of ≥ 51 wt.% coal and > 70 wt.% carbon
- Offer performance, cost, and environmental benefits

Phase I Objectives

- Develop CPC compounds that meet ASTM specifications
- Analyze existing market applications
- Conduct costing and technology gap analyses



Project Scope

Project Milestones

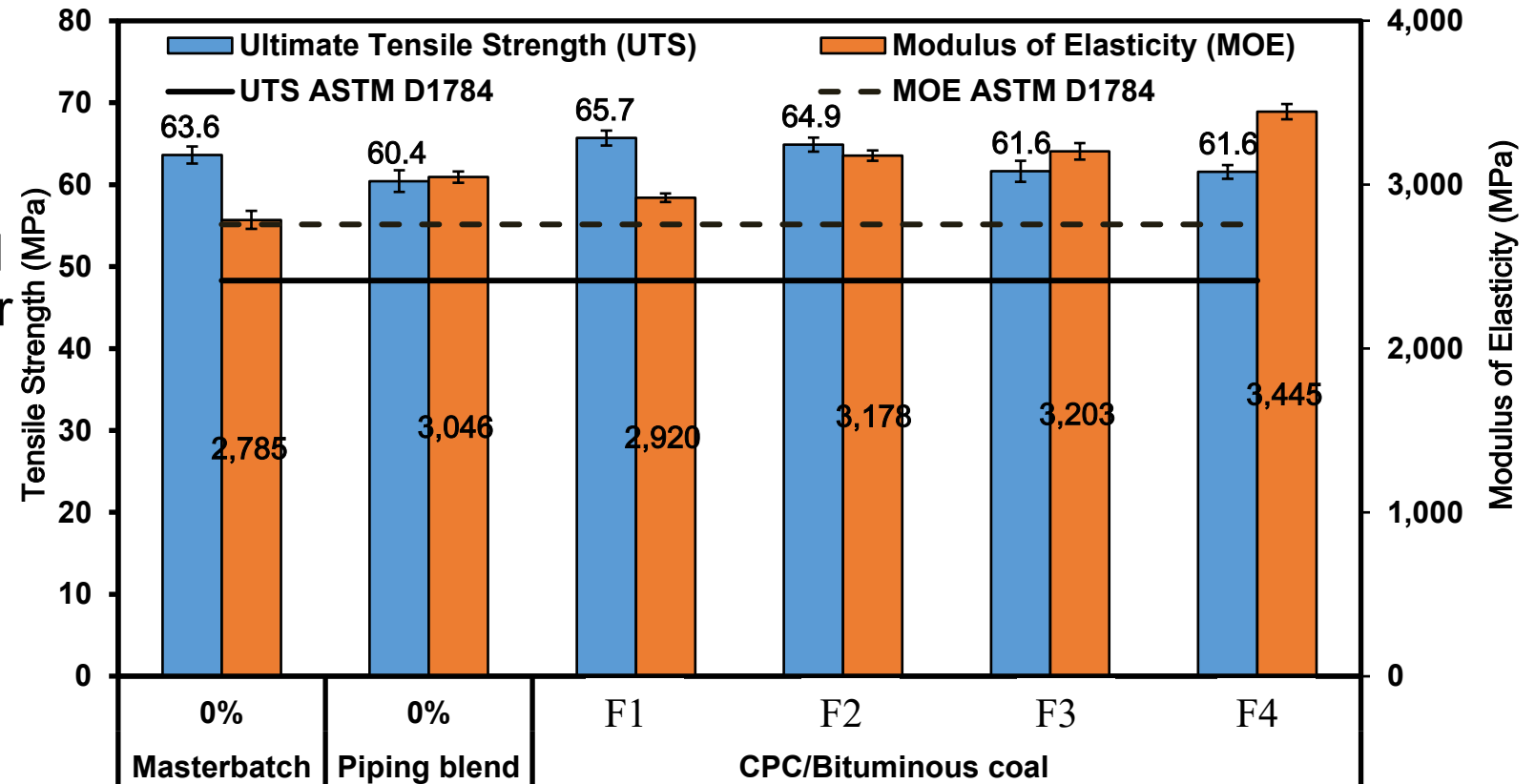
Description	Planned Completion Date	Actual Completion Date
CPC Formulation Performance Report	January 31, 2022	January 31, 2022
Techno-economic and Market Analyses	July 31, 2002	July 28, 2022
Technology-gap Analysis	December 31, 2022	

Project Success Criteria

- Demonstrate the ability of CPC pipe formulations containing greater than 51 wt.% coal meet ASTM plastic pipe compound attribute requirements,
- Demonstrate continuously-manufactured CPC pipes meet ASTM plastic pipe attribute requirements, and
- Demonstrate manufacturing CPC pipes containing at least 51 wt.% coal.

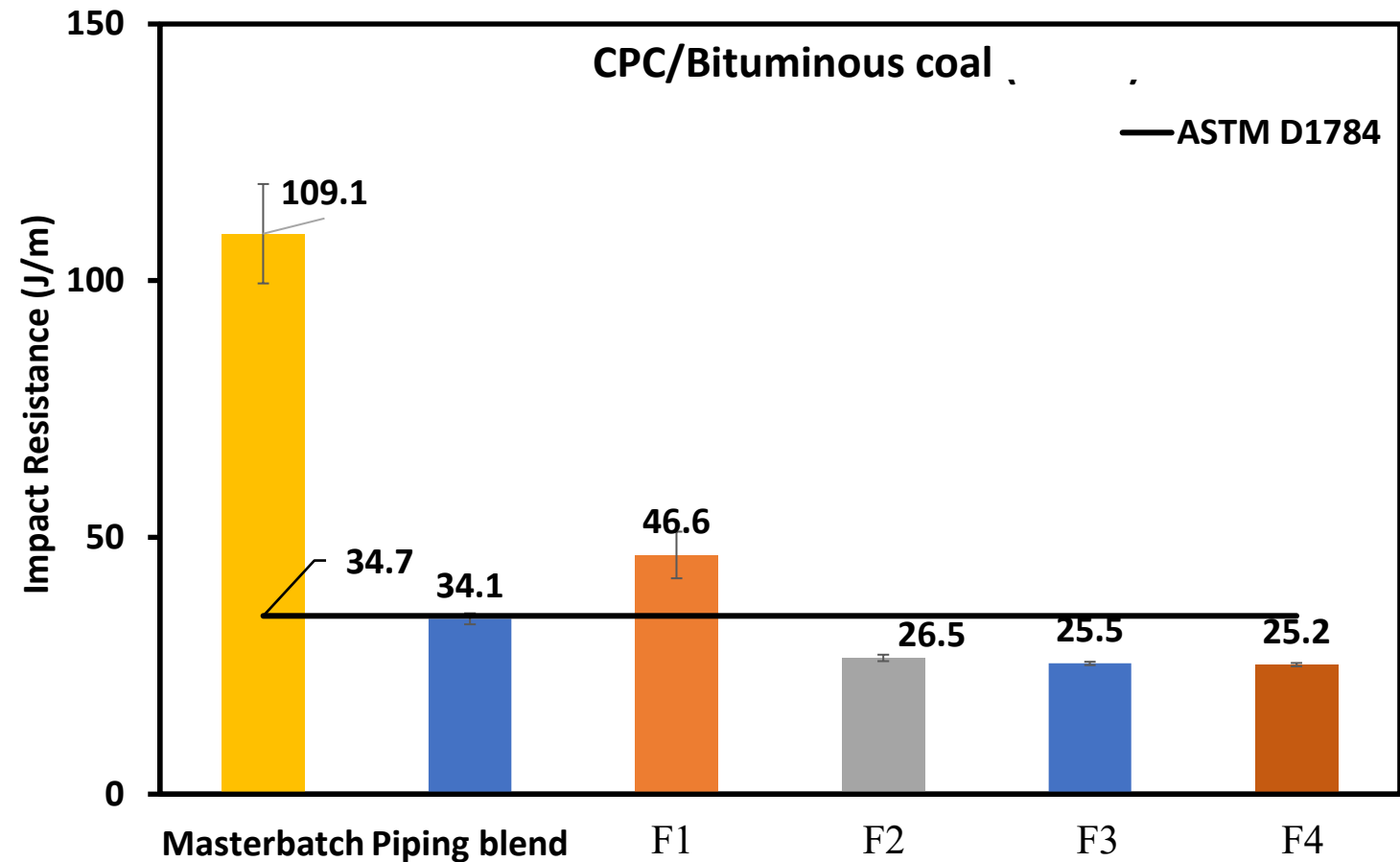
CPC Compounds: Tensile Properties

- Tensile properties for CPC pipe formulations with different coal types and particle size distributions were investigated
- CPC formulations meet or exceed tensile properties requirements for class 12454 per ASTM D1784
- UTS for F4 was comparable to commercial pipe material blend
- MOE for F4 was slightly higher than commercial pipe material blend



CPC Compounds: Impact Resistance

- Impact resistance for CPC pipe formulations with different coal types and particle size distributions were investigated
- CPC formulation with F1 coal exceeds the impact resistance requirement for class 12454 per ASTM D1784
- Reduction in impact was attributed to stiffening of polymer chains and coal agglomeration at the higher coal content



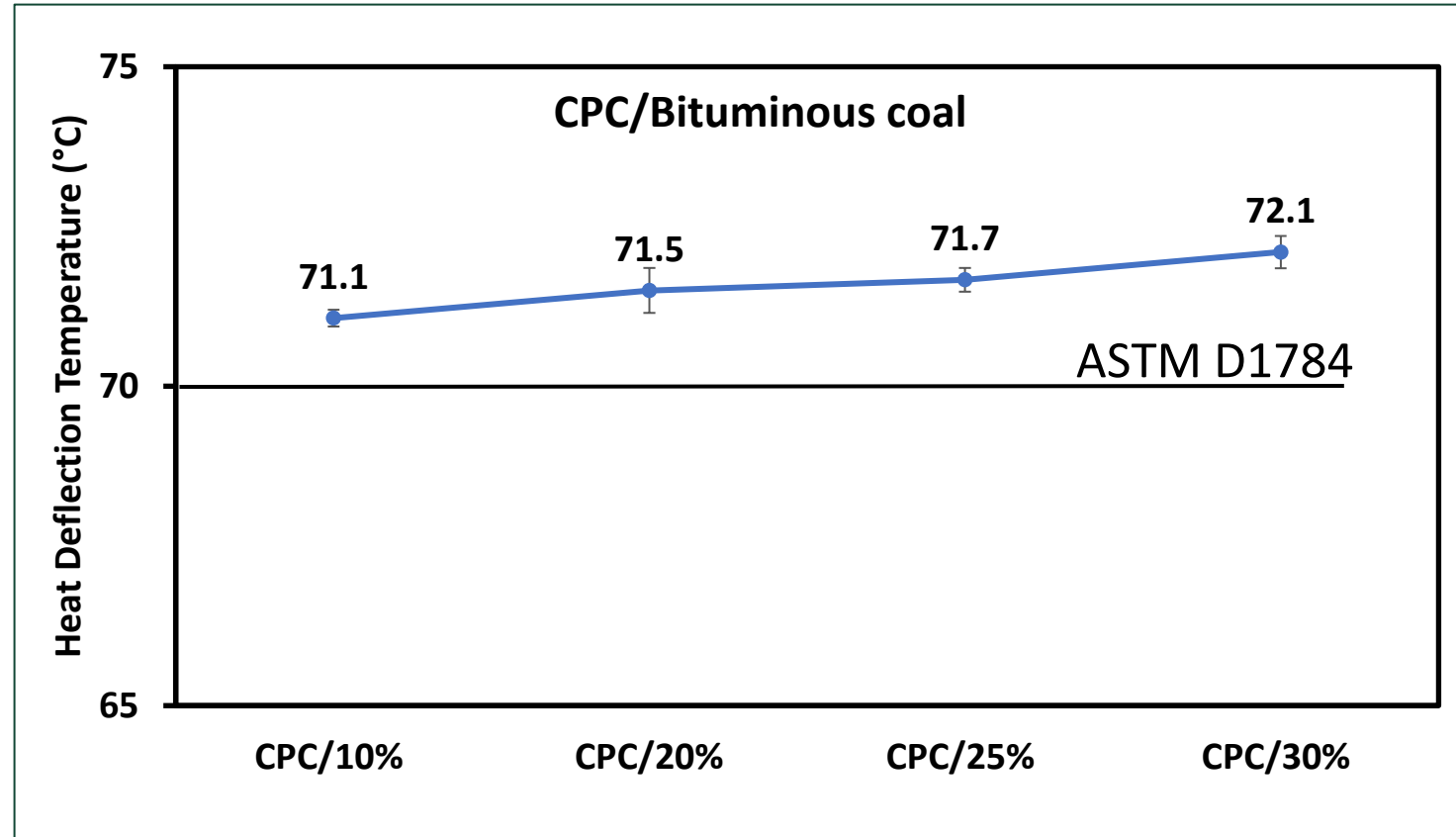
CPC Compounds

Heat Deflection Temperature (HDT)

- HDT for CPC pipe formulations with different coal types and particle size distributions were investigated
- CPC formulations (1000 wt.%) exceeds HDT requirement for class 12454 as per ASTM D1784

Flammability

- Burning extent values were below 25 mm and burning times were less than 10 s when tested as per ASTM D635
- All CPC compounds meet flammability requirements for class 12454 as per ASTM D1784



EHS Evaluation

Heavy Metal Leaching

- EPA Method 1311
- Determines ability to safely dispose of materials in MSW landfills
- CPC Passes, all metals below detectable levels

Respirable Dust

- NIOSH Method 0600
- CPC Passes, well below coal standards and construction dust standards

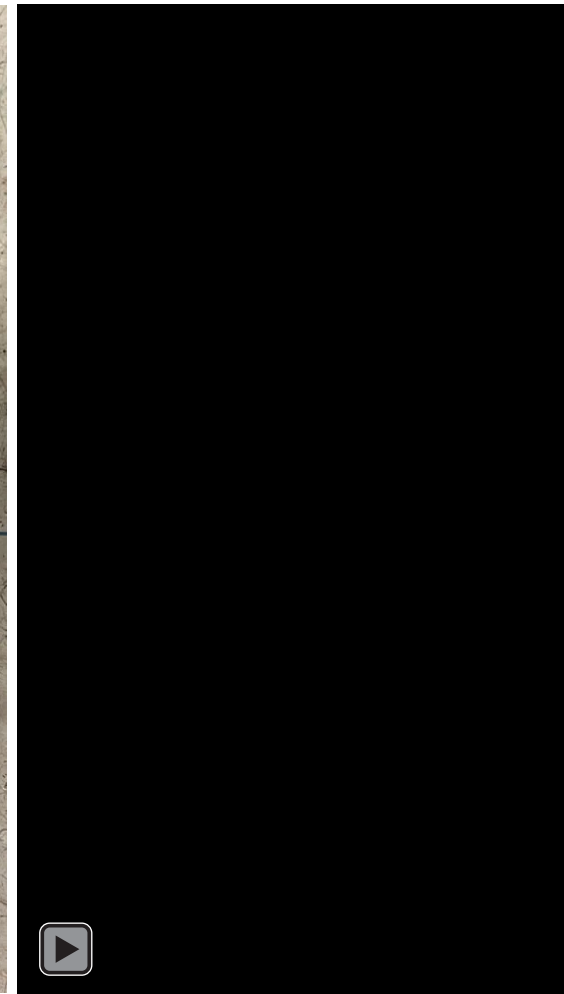
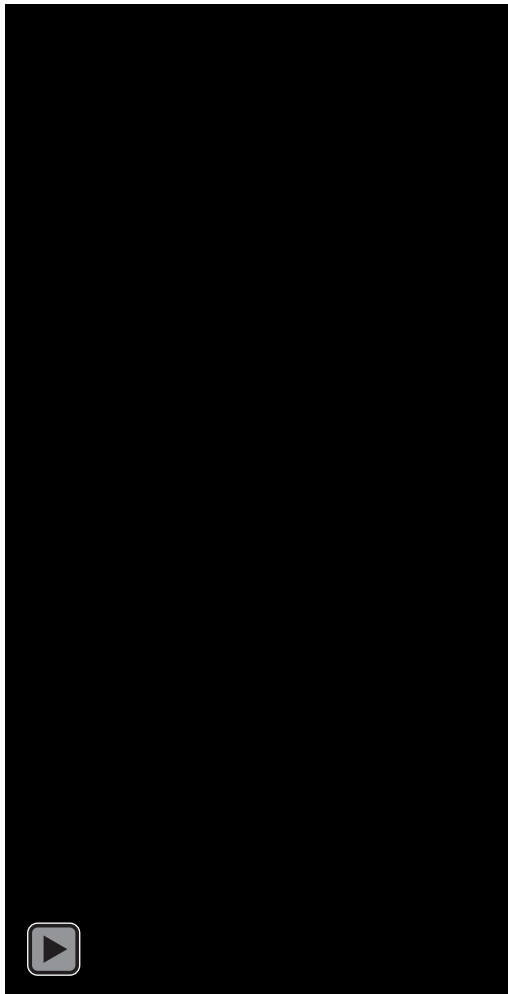
EPA Method 1311 Results

Metal	CPC (mg•L ⁻¹)	EPA Limit (mg•L ⁻¹)
As	<0.05	5.0
Ba	<0.05	100.0
Cd	<0.05	1.0
Cr	<0.05	5.0
Pb	<0.05	5.0
Se	<0.05	1.0

Continuous CPC Pipe Manufacturing

- Pipe testing completed for 1.25" CPC pipe
- CPC pipe (2" or greater) should meet ASTM requirements for sewer pipe and fittings applications

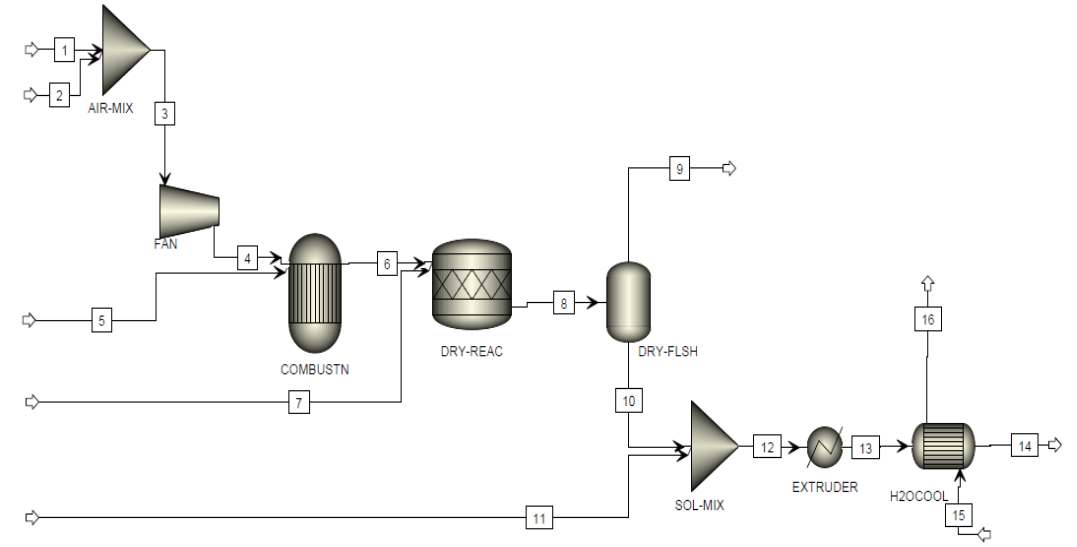
	ASTM D2665	ASTM D2729
Pipe type	Drain, Waste, Vent Pipe	Sewer Pipe and Fittings
Cell classification	12454	12454
Impact resistance (ASTM D2444)	60 ft.lbf	35 ft.lbf
Pipe stiffness	600 psi	59 psi



Techno-economic Analysis

Base Assumptions

- n^{th} plant design
- 12.5 ton/hr manufacturing capacity
- Feedstocks: PVC and Pitt No.8
- Cost Categories
 - CAPEX and Fixed/Variable OPEX
- Manufacturer's Sales Price (30% IRR)
 - PVC Pipe: \$2.48/ft
 - CPC Pipe: \$2.13/ft
 - Current Pricing: \$3.17/ft



Future Development

Pipe Formulations

- PVC-based formulation R&D has been the primary focus of project efforts
- Polyethylene-based formulation R&D to be evaluated during project remainder

Pipe Manufacturing

- Preliminary CPC pipe manufacturing scaleup demonstrated at Engineered Profiles
 - 1¼ in Schedule 40 pipe
 - Meets ASTM D2729 performance requirements
 - ASTM D2729 requires ≥ 2 in pipe



**1¼ in Schedule 40 PVC pipe made
with CPC formulation**

Summary

- CPC materials demonstrate potential for use in pipe infrastructure applications
 - CPC formula developed which meets ASTM specs for D2729
 - CPC formulations successfully used in manufacturing 1¼ in Schedule 40 pipe
 - Initial pipe Meets ASTM D2729 requirements for sewer pipe and fittings
 - Techno-economic analysis indicates CPC materials offer cost savings over existing PVC materials
- Project team competencies were integral in overcoming challenges in a timely manner
- CPC pipe technology matured to TRL5

Acknowledgements

- U.S. DOE/NETL
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Questions

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