KNAUF INSULATION FOR THE WORLD WE LIVE IN. | MANSON INSULATION

Earthwool® 1000° Pipe Insulation

Knauf Insulation Earthwool® 1000° Pipe Insulation is a molded, one-piece insulation made from inorganic glass fibers bonded with ECOSE® Technology. It is produced in 3' lengths with or without a factory-applied jacket. ASJ+ is the newest generation all-service jacket composed of aluminum foil, reinforced with a glass scrim bonded to a kraft paper interleaving, with an outer film layer. This jacket leaves no paper exposed, allowing for easier cleaning.

Manson ALLEY-K™ Pipe Insulation is available with or without the standard all service jacket (ASJ).

with ECOSE® TECHNOLOGY

Performance dashboard

Features & functionality

Excellent resistance to heat loss or gain, saving energy and lowering operating costs

Fast and easy installation reduces labor costs

ASJ+ facing is cleanable with a soapy wet cloth and has a self-sealing lap, which eliminates the need for additional material and tools

UL Environment validated formaldehyde-free

Visit Knauf and Manson for more product information
Earthwool® 1000° Pipe Insulation, ALLEY-K™

Environment & materials

Improved by:

Utilization of recycled glass

Knauf's original bio-based ECOSE® binder technology

Optimized compression packaging

Certification & rating systems:

HPD v2.2, 100ppm; C, S / BM1

UL GREENGUARD Gold certified

UL Validated recycled content

UL Validated formaldehyde-free

Audited, European Certification Board for Mineral Wool Products exoneration process

MasterFormat® 23 07 19

Thermal Insulation Guide Specification
For spec help, contact us or call 317 421 8727

See LCA, interpretation & rating systems

hpd VERSION 2.2 | UL VALIDATED | UL GREENGUARD GOLD | EUCEB

SM Transparency Report (EPD)™

VERIFICATION	LCA
3rd-party reviewed	✔
	Transparency Report (EPD)
3rd-party verified	✔
	Material evaluation
Self-declared	✔

Validity: 2023/05/15 – 2028/05/14

Decl #: KNA – 230515 – 001

This environmental product declaration (EPD) was externally verified by Harmony Environmental, LLC, according to ISO 21930:2017; UL Part A; UL Part B for Mechanical, Specialty, Thermal and Acoustical Insulation Products; and ISO 14025:2006.

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Management • Analysis • Communication
Beyond Sustainability, Striving for Harmony

SUMMARY

Reference PCR
UL PCR Part B: Mechanical, Specialty, Thermal, and Acoustic Insulation Product EPD Requirements v1.0, 09/19 - 09/24

Regions; system boundaries
North America; Cradle-to-installation with end of life

Declared unit / expected service life:

1 m of pipe insulation material, including packaging, with an expected service life (ESL) of 75 years; 1 m^2 of ASJ+ facer; 1 m of SSL; 1 m of butt strip

LCIA methodology: TRACI 2.1

LCA software; LCI database
LCA for Experts v10.7; LCA for Experts 2023

LCA conducted by: Sustainable Minds

Public LCA:
Knauf Earthwool® 1000° Pipe Insulation and Manson ALLEY-K Pipe Insulation

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LCA results & interpretation

Earthwool® 1000° Pipe Insulation ASJ+

Life cycle assessment

Scope and summary

○ Cradle to gate ✔ **Cradle to gate with options** ○ Cradle to grave

The system boundary is cradle-to-installation with end of life.

Application

Used to insulate iron, copper, stainless steel, PVC, and CPVC piping in both hot and cold systems. It can be used for both concealed and exposed piping systems, operating at temperatures ranging from 0°F to 1000°F (-18°C to 538°C). For outdoor use, additional weather protection is required.

Declared unit

This study includes Earthwool® 1000° Pipe Insulation available either unfaced or with a factory-applied ASJ+ jacket, and ALLEY-K™ Pipe Insulation available unfaced. The amount of insulation material in the faced and unfaced versions of the product is the same. The amount of self-sealing lap (SSL) is dependent on the length of insulation but not the diameter or thickness. The faced Earthwool® 1000° Pipe Insulation optionally includes a facer material (ASJ+) that is adhered to the surface of the fiberglass insulation during manufacture, and the amount of facer is dependent on diameter, thickness, and length. This facer is then connected to other sections using an added adhesive strip to the seams (butt strip), and the amount of butt strip is dependent on the outer diameter. For this reason, results are presented per several declared units.

Earthwool® 1000° Pipe Insulation and ALLEY-K™ Pipe Insulation: One meter (m) of pipe insulation material weighing 1.00 kg, including packaging, with an expected service life (ESL) of 75 years. At this declared unit, the density is 77.7 kg/m^3, the thickness is 4.49 cm, and the outer diameter is 12.57 cm.

ASJ+ facer: One square meter (m^2) of facer (0.156 kg).
Self-sealing lap (SSL): One meter (m) of fastening adhesive tape (0.0031 kg).
Butt strip: One meter (m) of sealing butt strip (0.0161 kg).

Manufacturing data

Reporting period: January 2019 – December 2019
Location: Shelbyville, IN

Default packaging, installation, and disposal scenarios

Pipe insulation is packaged into cardboard cartons and distributed to construction sites. Upon arrival, it unpackaged and installed with no additional materials required for installation. After installation, packaging is sent to be landfilled, recycled, or incinerated, while waste insulation is sent to a landfill. Some insulation material is assumed to be lost or wasted due to over-ordering, packaging damage, and other scrap-related reasons. Disposal rates for packaging waste treatment methods are designated as 75% to recycling, 20% to landfill, and 5% to incineration.

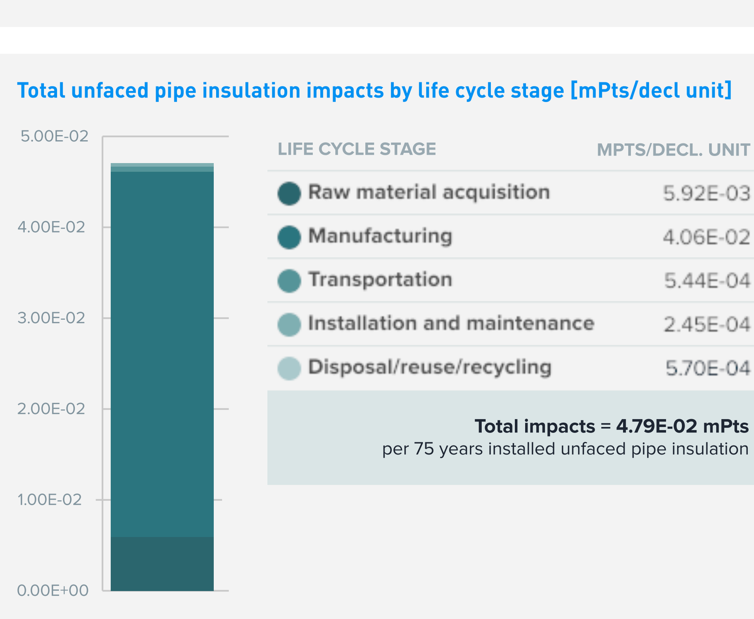
Sensitivity analysis

All energy was accounted for, although not all data was able to be assigned to specific manufacturing processes. Since energy is a major contributor to global warming, a sensitivity analysis was conducted by changing the amount of this uncategorized energy by ±100%. The result shows that changing uncategorized energy consumption by 100% changes the emissions in the manufacturing stage by 13%, which in turn changes the overall emissions across all life cycle stages by 11%.

Unfaced pipe insulation material composition

PART	MATERIAL	% WT.
Batch	Cullet	45-50%
Batch	Sand	10-13%
Batch	Borate	6-9%
Batch	Soda ash	6-9%
Batch	Silicate	2-5%
Batch	Oxides	2-5%
Binder	Sugars	3-6%
Binder	Catalyst	1-2%
Packaging	Cardboard	11.4%
	Others	<1%

Total unfaced pipe insulation impacts by life cycle stage [mPts/decl unit]



What's causing the greatest impacts

All life cycle stages

The manufacturing stage dominates the results for most impact categories. Contributing processes include the energy required to melt the glass and produce the glass fibers. Raw material production also constitutes a significant contribution to the impacts across all inventory and impact indicators. Outbound transport accounts for a notable impact only in the global warming and smog formation impact categories. Installation contributes a small fraction of the overall life cycle impact, with the only installation impacts being associated with packaging disposal. At the end of life, insulation is manually removed from the building and landfilled. For all products, waste is dominated by the final disposal of the product. Non-hazardous waste accounts for waste generated during manufacturing and installation. No substances required to be reported as hazardous are associated with the production of this product.

Raw materials acquisition and transportation

The raw material acquisition stage is the second highest contributor for most impact categories, but ozone depletion potential is almost entirely generated from this stage. The raw materials acquisition stage impact is largely due to the borax, manganese oxide, and soda ash in the batch and the sugars in the binder. Third-party verified ISO 14040/44 secondary LCI data sets contribute more than 80% of the total impacts to ozone depletion.

Manufacturing

The manufacturing stage has the most significant contribution to all impact categories, primarily due to the energy required to melt the glass and produce the glass fibers. Except for ozone depletion, the manufacturing stage is the highest contributor to all the impact categories. It accounts for over 50% of the impacts among nine categories.

Distribution

Outbound transportation is the second highest contributor to ecotoxicity impacts.

ASJ+ material composition

MATERIAL	% WT.
Paper	35-40%
Polypropylene	10-15%
Aluminum foil	10-15%
Fiberglass	10-15%
Synthetic polymer	10-15%
Alumina	<10%
Flame retardant	<5%
Antimony trioxide	<5%

SSL material composition

MATERIAL	% WT.
Polymer	75-85%
PET	15-25%

Butt strip material composition

MATERIAL	% WT.
Cellulose	25-30%
Synthetic polymer	25-30%
Adhesive	15-20%
Polypropylene	<10%
Fiberglass	<10%
Aluminum foil	<10%
Antimony trioxide	<5%
Coating	<1%

Knauf and Manson are committed to providing products that conserve energy and preserve natural resources.

- This product uses ECOSE® Technology, which is a bio-based binder adhesive instead of a fossil fuel-based binder. ECOSE® Technology represents a fossil fuel avoidance equivalent of 100,000 barrels of oil a year for Knauf products.
- Earthwool® 1000° Pipe Insulation and ALLEY-K™ Pipe Insulation are formaldehyde-free and made from sustainable resources such as recycled glass and sand.
- Our product contains a high degree of recycled content, which translates to 20% less glass melting energy and a 25% reduction in embodied carbon.
- Our utilization of recycled content reduces mining impacts by 60%. In fact, Knauf recycles 10 railcars of recycled glass a day.
- Knauf Insulation's glass is audited by a 3rd party to ensure biosoluble chemistry from a health and safety standpoint.

See how we make it greener

LCA results

LIFE CYCLE STAGE	RAW MATERIAL ACQUISITION	MANUFACTURING	DISTRIBUTION	INSTALLATION AND USE STAGE	DISPOSAL / REUSE / RECYCLING
Information modules: Included (X) | Excluded (MND)* *Module D is also excluded from this system boundary (MND).	**(X) A1 Raw materials acquisition** **(X) A2 Transportation**	**(X) A3 Manufacturing**	**(X) A4 Distribution**	**(X) A5 Installation** (MND) B1 Use (MND) B2 Maintenance (MND) B3 Repair (MND) B4 Replacement (MND) B5 Refurbishment (MND) B6 Operational energy use (MND) B7 Operational water use	**(X) C1 Deconstruction** **(X) C2 Transportation** **(X) C3 Waste processing** **(X) C4 Disposal**

SM Single Score

Learn about SM Single Score results

Impacts of 1 meter of pipe insulation material (unfaced)	5.92E-03 mPts	4.06E-02 mPts	5.44E-04 mPts	2.45E-04 mPts	5.70E-04 mPts
Materials or processes contributing >20% to total impacts in each life cycle stage	Batch material and binder material production.	Energy required to melt the glass and produce the glass fibers.	Truck and rail transportation used to transport product to building site.	Transportation to landfill and landfilling of packaging materials.	Transportation to landfill and landfilling of product at end of life.

TRACI v2.1 results for Earthwool® 1000° Pipe Insulation and ALLEY-K™ Pipe Insulation per declared unit (1m)

LIFE CYCLE STAGE	Unit	RAW MATERIAL ACQUISITION	MANUFACTURING	DISTRIBUTION	INSTALLATION AND USE STAGE	DISPOSAL / REUSE / RECYCLING
Ecological damage						
Acidification	kg SO_2 eq	1.13E-03	2.63E-03	1.51E-04	7.69E-05	1.17E-04
Eutrophication	kg N eq	2.42E-04	3.53E-04	1.29E-05	1.12E-05	6.78E-06
Global warming	kg CO_2 eq	2.07E-01	1.53E+00	2.94E-02	3.25E-02	2.61E-02
Ozone depletion	kg CFC-11 eq	9.78E-12	4.58E-14	6.56E-17	1.19E-16	8.39E-16
Human health damage						
Respiratory effects	kg $PM_{2.5}$ eq	8.98E-05	6.16E-04	7.37E-06	2.28E-06	7.87E-06
Smog	kg O_3 eq	1.14E-02	5.48E-02	5.17E-03	6.00E-04	2.26E-03
Additional environmental information						
Carcinogenics	CTU_h	18.0%	69.6%	1.1%	1.5%	9.8%
Non-carcinogenics	CTU_h	27.7%	53.2%	1.3%	2.1%	15.6%
Fossil fuel depletion	MJ, LHV	2.82E-01	2.76E+00	5.51E-02	9.23E-03	5.13E-02
Ecotoxicity	CTU_e	27.2%	66.2%	3.5%	0.5%	2.6%

See the additional content required by the ULE PCR for mechanical, specialty, thermal, and acoustic insulation on page 4 of the **Transparency Report PDF**.

TRACI v2.1 results for ASJ+ facer per declared unit (1m2)

LIFE CYCLE STAGE	Unit	RAW MATERIAL ACQUISITION	MANUFACTURING	DISTRIBUTION	INSTALLATION AND USE STAGE	DISPOSAL / REUSE / RECYCLING
Ecological damage						
Acidification	kg SO_2 eq	1.47E-03	0.00E+00	2.35E-05	0.00E+00	2.29E-05
Eutrophication	kg N eq	8.93E-05	0.00E+00	2.01E-06	0.00E+00	2.83E-05
Global warming	kg CO_2 eq	3.11E-01	0.00E+00	4.58E-03	0.00E+00	5.12E-03
Ozone depletion	kg CFC-11 eq	1.31E-10	0.00E+00	1.02E-17	0.00E+00	1.65E-16
Human health damage						
Respiratory effects	kg $PM_{2.5}$ eq	1.15E-04	0.00E+00	1.15E-06	0.00E+00	1.54E-06
Smog	kg O_3 eq	2.02E-02	0.00E+00	8.07E-04	0.00E+00	4.43E-04
Additional environmental information						
Carcinogenics	CTU_h	94.8%	0%	0.4%	0%	4.8%
Non-carcinogenics	CTU_h	91.7%	0%	0.3%	0%	8.0%
Fossil fuel depletion	MJ, LHV	8.90E-01	0.00E+00	8.59E-03	0.00E+00	1.01E-02
Ecotoxicity	CTU_e	96.4%	0%	0.7%	0%	2.9%

See the additional content required by the ULE PCR for mechanical, specialty, thermal, and acoustic insulation on page 4 of the **Transparency Report PDF**.

TRACI v2.1 results for self-sealing lap (SSL) per declared unit (1m)

LIFE CYCLE STAGE	Unit	RAW MATERIAL ACQUISITION	MANUFACTURING	DISTRIBUTION	INSTALLATION AND USE STAGE	DISPOSAL / REUSE / RECYCLING
Ecological damage						
Acidification	kg SO_2 eq	1.10E-05	0.00E+00	4.64E-07	0.00E+00	4.52E-07
Eutrophication	kg N eq	1.02E-06	0.00E+00	3.98E-08	0.00E+00	5.59E-07
Global warming	kg CO_2 eq	9.02E-03	0.00E+00	9.04E-05	0.00E+00	1.01E-04
Ozone depletion	kg CFC-11 eq	3.47E-16	0.00E+00	2.02E-19	0.00E+00	3.25E-18
Human health damage						
Respiratory effects	kg $PM_{2.5}$ eq	4.81E-07	0.00E+00	2.27E-08	0.00E+00	3.05E-08
Smog	kg O_3 eq	2.41E-04	0.00E+00	1.59E-05	0.00E+00	8.74E-06
Additional environmental information						
Carcinogenics	CTU_h	98.2%	0%	0.1%	0%	1.7%
Non-carcinogenics	CTU_h	97.3%	0%	0.1%	0%	2.6%
Fossil fuel depletion	MJ, LHV	3.72E-02	0.00E+00	1.70E-04	0.00E+00	1.99E-04
Ecotoxicity	CTU_e	96.2%	0%	0.7%	0%	3.0%

See the additional content required by the ULE PCR for mechanical, specialty, thermal, and acoustic insulation on page 4 of the **Transparency Report PDF**.

TRACI v2.1 results for butt strip per declared unit (1m)

LIFE CYCLE STAGE	Unit	RAW MATERIAL ACQUISITION	MANUFACTURING	DISTRIBUTION	INSTALLATION AND USE STAGE	DISPOSAL / REUSE / RECYCLING
Ecological damage						
Acidification	kg SO_2 eq	1.07E-04	0.00E+00	2.43E-06	0.00E+00	2.36E-06
Eutrophication	kg N eq	5.38E-06	0.00E+00	2.08E-07	0.00E+00	2.93E-06
Global warming	kg CO_2 eq	3.31E-02	0.00E+00	4.74E-04	0.00E+00	5.30E-04
Ozone depletion	kg CFC-11 eq	1.65E-15	0.00E+00	1.06E-18	0.00E+00	1.70E-17
Human health damage						
Respiratory effects	kg $PM_{2.5}$ eq	6.93E-06	0.00E+00	1.19E-07	0.00E+00	1.60E-07
Smog	kg O_3 eq	1.58E-03	0.00E+00	8.34E-05	0.00E+00	4.58E-05
Additional environmental information						
Carcinogenics	CTU_h	93.2%	0%	1.3%	0%	5.5%
Non-carcinogenics	CTU_h	95.3%	0%	0.2%	0%	4.5%
Fossil fuel depletion	MJ, LHV	1.19E-01	0.00E+00	8.88E-04	0.00E+00	1.04E-03
Ecotoxicity	CTU_e	93.2%	0%	1.3%	0%	5.5%

See the additional content required by the ULE PCR on page 4 of the **Transparency Report PDF**.

References

LCA Background Report
Knauf Earthwool® 1000° Pipe Insulation and Manson ALLEY-K™ Pipe Insulation LCA Background Report (public version), Knauf 2023

PCRs

ISO 21930:2017 serves as the core PCR along UL Part A.

ULE Part A: Life Cycle Assessment Calculation Rules and Report Requirements v4.0
March, 2022. PCR review conducted by Lindita Bushi, Chair (Athena Sustainable Materials Institute), Hugues Imbeault-Tétreault, Chair (Group AGECO), and Jack Geibig (Ecoform).

ULE Part B for Mechanical, Specialty, Thermal, and Acoustic Insulation Product EPD Requirements
September, 2019. PCR review conducted by Hugues Imbeault-Tétreault, Chair (Group AGECO), Thomas Gloria (Industrial Ecology Consultants), and Andre Omer Desjarlais (Oak Ridge National Laboratory).

UL Environment General Program Instructions v2.4, July 2018 (available upon request).

ISO 14025, "Sustainability in buildings and civil engineering works -- Core rules for environmental product declarations of construction products and services"

Developed using the TRACI v2.1 impact assessment methodology and LCA for Experts modeling software

Download PDF SM Transparency Report, which includes the additional EPD content required by the UL Environment PCR.

SM Transparency Reports (TR) are ISO 14025 Type III environmental declarations (EPD) that enable purchasers and users to compare the environmental performance of products on a life cycle basis. Environmental declarations from different programs (ISO 14025) may not be comparable. Comparison of the environmental performance of products using EPD information shall be based on the product's use and impacts at the building level, and therefore EPDs may not be used for comparability purposes when not considering the building energy use phase as instructed under this PCR. Full conformance with the PCR for Mechanical Thermal Insulation allows EPD comparability only when all stages of a life cycle have been considered. However, variations and deviations are possible. Example of variations: Different LCA software and background LCI datasets may lead to differences results for upstream or downstream of the life cycle stages declared.

Rating systems

The intent is to reward project teams for selecting products from manufacturers who have verified improved life-cycle environmental performance.

LEED BD+C: New Construction | v4 - LEED v4
Building product disclosure and optimization
Environmental product declarations

○ Industry-wide (generic) EPD	½product
✔ Product-specific Type III EPD	1 product

LEED BD+C: New Construction | v4.1 - LEED v4.1
Building product disclosure and optimization
Environmental product declarations

○ Industry-wide (generic) EPD	½ product
✔ Product-specific Type III EPD	1 product

BREEAM New Construction 2018
Mat 02 - Environmental impacts from construction products
Environmental Product Declarations (EPD)

○ Industry-average EPD	.5 point
○ Multi-product specific EPD	.75 points
✔ Product-specific EPD	1 point

SM Transparency Report (EPD)™

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3rd-party reviewed ✔	Transparency Report (EPD)
3rd-party verified ✔	Material evaluation
Self-declared ✔	

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How we make it greener

Earthwool® 1000° Pipe Insulation ASJ+

Collapse all

See LCA results by life cycle stage

RAW MATERIALS ACQUISITION

Utilize recycled content

By leveraging recycled content, we reduce the energy required to form glass fibers.

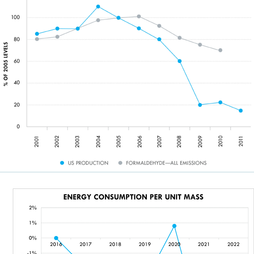
Pursue sequestration potential

Manson and Knauf's bio-based ECOSE Technology is derived from corn. While we don't grow the corn used in our products, the use of corn has a significant carbon sequestration impact on our processes. For instance, the use of corn actually offsets the carbon impact of some of the ancillary facers used on our products.

MANUFACTURING

Lead green chemistry efforts

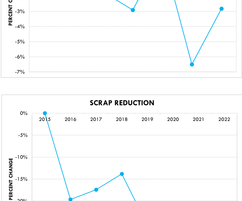
Following the launch of our ECOSE Technology in 2009, we had transformed all of our products and processes to this new technology. Using our bio-based ECOSE Technology has removed phenol and formaldehyde from our stack emissions. By 2012, the entire industry had followed our lead. This initiative not only established Manson and Knauf Insulation in a leadership position, but it had a transformative impact on our industry in general.

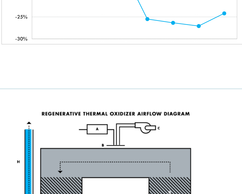


Reduce scrap generation and energy consumption

Continuous improvement is the methodology we utilize to engage the entire Knauf team in our manufacturing excellence and sustainment journey. Knauf Insulation, comprised of Knauf Insulation North America (KINA) and Knauf Insulation Europe Middle East, Asia, Asia Pacific (KI EMEA & APAC), share an overall global certification for ISO 45001 Health & Safety, ISO 14001 Environmental, ISO 50001 Energy, and ISO 9001 Quality through a third-party Certification Body.

KINA's Continuous Improvement Program, with all its tools and systems associated with it, provide a formal process where we are constantly monitoring our manufacturing and sustainability Key Performance Indicators (KPIs) with an eye towards improvement. This Continuous Improvement centric management system has proven to be effective in improving our sustainability by reducing scrap generation and energy consumption.

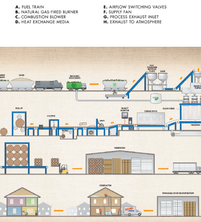




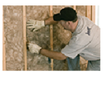
Green manufacturing Processes

1. Regenerative thermal oxidizers Manson and Knauf Insulation use regenerative thermal oxidizers (RTO) to capture and recycle much of the energy we used to cure our products. RTO is equipment used for the treatment of exhaust air. Our ovens exhaust into a ceramic heat exchange media to capture and reuse the heat in the exhausted air. Therefore, the amount of energy required to cure our product is reduced substantially.

2. Recycling As you can see below, everything we do starts with recycling. Our plant uses as much as 80% recycled content. While our only option is to landfill our products at end of life, that doesn't stop us from encouraging consumers to recycle other products, particularly glass bottles.



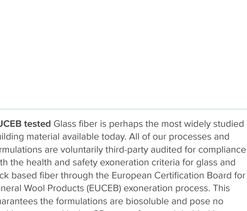
TRANSPORTATION



Leverage compression packaging

Glass is a high modulus material, which helps to facilitate compression packaging. We compress our insulation to fit up to five times more product on every truck. This compression means:

- More material can fit on one truck when compared to other insulation materials
- Fewer packages on a job
- Fewer deliveries needed



INSTALLATION AND MAINTENANCE

Be confident in glass fiber's safety

In the past, a label regarding the carcinogenic potential of insulation made from glass fibers was required on all packaging. Following forty years of research, fiberglass has been exonerated entirely. Knauf Insulation fiberglass is comprised of fibers that are biosoluble, meaning that the fibers dissolve in the body in a short period of time and exit the body with normal bodily functions. The scrutiny fiberglass has undergone is now seen as proof of its safety.

Meet and exceed green standards

GREENGUARD certified On the forefront of indoor air quality, Knauf Insulation was the first GREENGUARD certified product in 2002. This achievement led us to understand the impact our formaldehyde-free products could have on the indoor environment. The formaldehyde-free claim is third party validated by UL Environment.

EUCEB tested Glass fiber is perhaps the most widely studied building material available today. All of our processes and formulations are voluntarily third-party audited for compliance with the health and safety exoneration criteria for glass and rock based fiber through the European Certification Board for Mineral Wool Products (EUCEB) exoneration process. This guarantees the formulations are biosoluble and pose no health concerns. Having 35 years of research behind its safety, perhaps no other building material has been as thoroughly evaluated as fiberglass products. We believe a safe product is one that has been thoroughly evaluated.

Green building rating systems

Our products offer a vast array of potential credits for major green building rating systems, including: WELL, LEED v4, International Green Construction Code, Green Guide for Heath Care, NAHB Green Building Standard and more.

Visit the green building rating systems page to see all the credits you can earn using Manson and Knauf Insulation products

DISPOSAL

Promote Recycling

By taking a comprehensive approach of the benefits of recycling, Manson and Knauf Insulation advocates and promotes local recycling initiatives as well as actively participates in state and local government policy development. In addition, as a member of the North American Insulation Manufacturers Association (NAIMA) and Glass Recycling Coalition (GRC), we encourage regulatory and legislative initiatives that focus on glass recycling infrastructure deployment to increase the availability of post-consumer recycled glass.

GLASS RECYCLING COALITION MEMBER glassrecycles.org

SM Transparency Report (EPD)™

VERIFICATION	LCA
3rd-party reviewed	✔
	Transparency Report (EPD)
3rd-party verified	✔
	Material evaluation
Self-declared	✔

Validity: 2023/05/15 – 2028/05/14
Decl #: KNA – 230515 – 001

This environmental product declaration (EPD) was externally verified by Harmony Environmental, LLC, according to ISO 21930:2017; UL Part A; UL Part B for Mechanical, Specialty, Thermal and Acoustical Insulation Products; and ISO 14025:2006.

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Harmony Environmental, LLC Management • Analysis • Communication Beyond Sustainability, Striving for Harmony

SUMMARY

Reference PCR
UL PCR Part B: Mechanical, Specialty, Thermal, and Acoustic Insulation Product EPD Requirements v1.0 09/19 - 09/24

Regions; system boundaries
North America; Cradle-to-installation with end of life

Declared unit / expected service life:
1 m of pipe insulation material, including packaging, with an expected service life (ESL) of 75 years; 1 m^2 of ASJ+ facer; 1 m of SSL; 1 m of butt strip

LCIA methodology: TRACI 2.1

LCA software; LCI database
LCA for Experts v10.7; LCA for Experts 2023

LCA conducted by: Sustainable Minds

Public LCA:
Knauf Earthwool® 1000° Pipe Insulation and Manson ALLEY-K Pipe Insulation

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Shelbyville, IN 46176
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Contact us

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Earthwool® 1000° (ALLEY-K™) Pipe Insulation with optional ASJ+

Additional EPD content required by:
ULE PCR Part B: Mechanical, Specialty, Thermal, and Acoustic Insulation Product EPD Requirements

Data

Background This product-specific declaration was created by collecting production data from the Shelbyville, IN production location. Secondary data sources include those available in LCA for Experts 2023 databases.

Allocation The allocation methods used were examined according to the updated allocation rules in ISO 21930:2017. Since only facility-level data were available, allocation among the facility's other co-products was necessary to determine the input and output flows associated with the product. Allocation of materials and energy was done on a mass basis for all products except for the ASJ+ facing, SSL, and butt strip which were allocated based on product area, length, or number of pieces. Allocation of transportation was based on weight.

Cut-off criteria for the inclusion of mass and energy flows are 1% of renewable primary resource (energy) usage, 1% nonrenewable primary resource (energy) usage, 1% of the total mass input of that unit process, and 1% of environmental impacts. The total of neglected input flows per module does not exceed 5% of energy usage, mass, and environmental impacts. The only exceptions to these criteria are substances with hazardous and toxic properties, which must be listed even when the given process unit is under the cut-off criterion of 1% of the total mass. No known flows are deliberately excluded from this declaration; therefore, these criteria have been met. Biogenic carbon is included in reported results.

Quality Temporal and technological representativeness are considered to be high. Geographical representativeness is considered to be good. All relevant process steps for the product system were considered and modeled. The process chain is considered sufficiently complete with regards to the goal and scope of this study. The product system was checked for mass balance and completeness of the inventory. Capital equipment was excluded as required by the PCR. Otherwise, no data were knowingly omitted. For more information on data quality, see the LCA background report.

LCIA impact factors required by the PCR are global warming, ozone depletion, acidification, eutrophication, smog, and fossil fuel depletion; "These six impact categories are globally deemed mature enough to be included in Type III environmental declarations. Other categories are being developed and defined and LCA should continue making advances in their development. However, the EPD users shall not use additional measures for comparative purposes."

Relevant technical properties

PROPERTY (UNIT)	TEST	VALUE / PERFORMANCE
Design density of declared unit (size dependent) (kg/m³)	N/A	50 – 120
Corrosiveness	ASTM C665	Does not accelerate corrosion of steel
Corrosion	ASTM C1617	Pass
Maximum Service Temperature	ASTM C411 + ASTM C447	1000° F (538° C)
Water Vapor Permeance	ASTM E96, Procedure A	0.01 perms or less
Water Vapor Sorption (by weight)	ASTM C1104	Less than 5%
Shrinkage	ASTM C356	Negligible
Mold Growth	ASTM C1338	Pass
Surface Burning Characteristics (flame spread/smoke developed)	ASTM E84, UL 723, CAN/ULC S102	UL/ULC Classified FHC 25/50

Scenarios and additional technical information

PARAMETER	VALUE	UNIT
Transport to the building site [A4]		
Vehicle type	Truck and trailer	–
Fuel type	Diesel	–
Average distance from Shelbyville to installation site	1,094	km
Capacity utilization by mass	27	%
Gross density of products transported	Insulation: 64.1 ASJ+: 0.156 SSL: 0.097 Butt strip: 0.209	kg/m³
Capacity utilization volume factor	1	
Installation into the building [A5]		
Installation scrap assumed	7.6	%
Waste materials at the construction site before waste processing, generated by product installation	Insulation: 0.076 Others: N/A	kg
Mass of packaging waste (cardboard)	Cardboard: 0.058 Others: N/A	kg
GWP based in biogenic carbon content of paper packaging	-8.80E-02	kg CO_2e
End of life [C1-C4]		
Assumptions for scenario development	The product is dismantled and removed from the building manually. It is transported to a local facility where it requires no further processing before final disposition.	
Collection process	Collected with mixed construction waste	Insulation: 1.00 kg ASJ+: 0.156 kg SSL: 0.0031 kg Butt strip: 0.0161 kg
Disposal	Product for final deposition in landfill	Insulation: 1.00 kg ASJ+: 0.156 kg SSL: 0.0031 kg Butt strip: 0.0161 kg

Major system boundary exclusions

- Capital goods and infrastructure; maintenance of operation and support equipment;
- Manufacture & transport of packaging materials not associated with final product;
- Human labor and employee transport;
- Building operational energy and water use not associated with final product.

Major assumptions and limitations

- Due to the nature of insulation, it is anticipated that pipe insulation will last for the lifetime of the building, so the reference service life (RSL) is considered to be the same as the building estimated service life (ESL) of 75 years.
- Generic data sets used for material inputs, transport, and waste processing are considered good quality, but actual impacts from material suppliers, transport carriers, and local waste processing may vary.
- The impact assessment methodology categories do not represent all possible environmental impact categories.
- Characterization factors used within the impact assessment methodology may contain varying levels of uncertainty.
- LCA results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins or risks.

Flow diagram

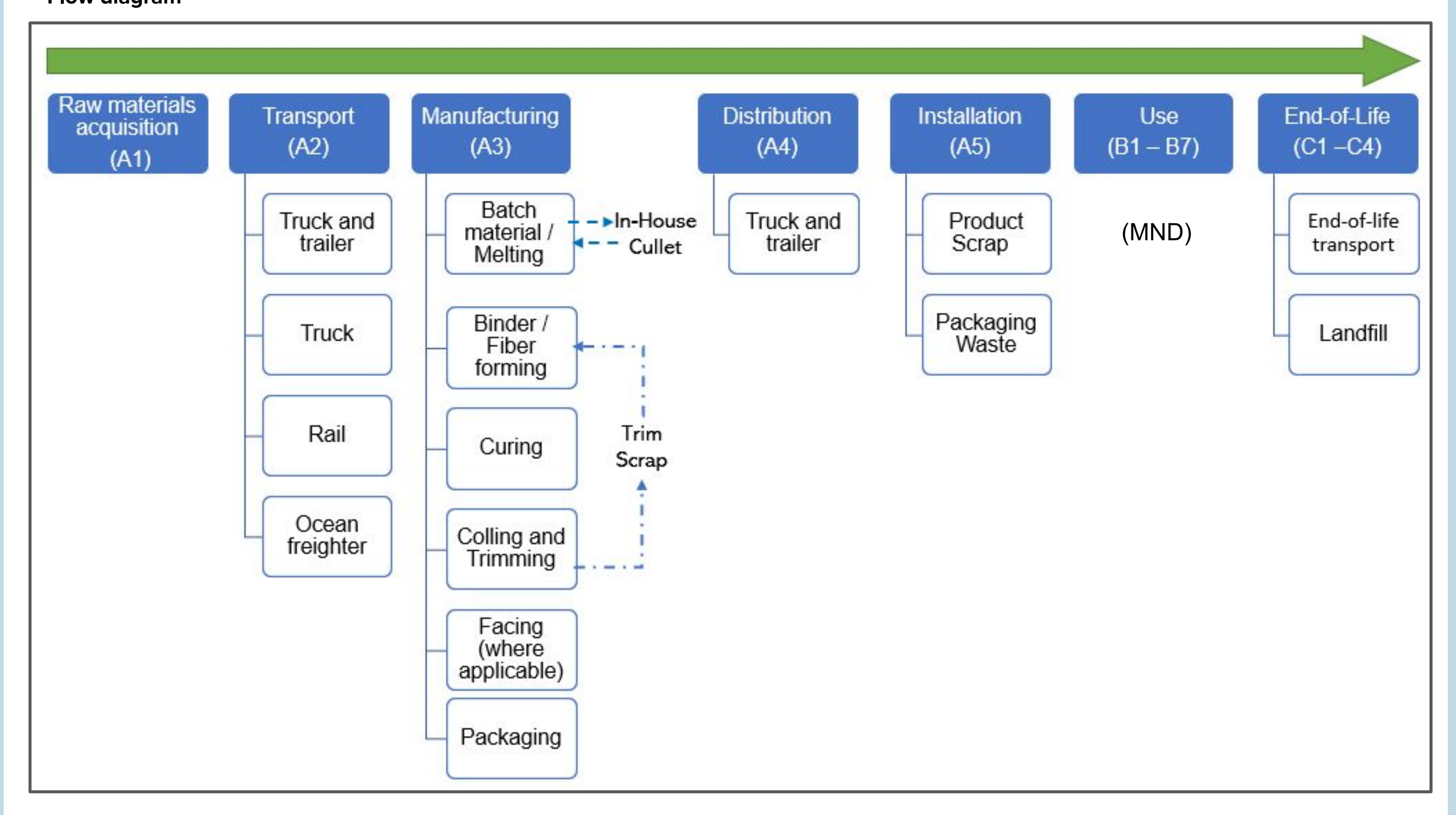

Table 1. Earthwool 1000° Pipe Insulation: LCIA results, resource use, output and waste flows, and carbon emissions & removals per declared unit (1 m at 1 kg)

Parameter	Unit	A1-A3	A4	A5	B1-B7	C1	C2	C3	C4	Total
LCIA results (per m of pipe insulation material, including packaging, with an expected service life (ESL) of 75 years)										
Ozone depletion	kg CFC-11 eq	9.83E-12	6.56E-17	1.19E-16	MND	0	2.12E-17	0	8.18E-16	9.83E-12
Global warming	kg CO_2 eq	1.74E+00	2.94E-02	3.25E-02	MND	0	9.51E-03	0	1.66E-02	1.82E+00
Smog	kg O_3 eq	6.62E-02	5.17E-03	6.00E-04	MND	0	6.48E-04	0	1.61E-03	7.42E-02
Acidification	kg SO_2 eq	3.76E-03	1.51E-04	7.69E-05	MND	0	2.84E-05	0	8.83E-05	4.10E-03
Eutrophication	kg N eq	5.95E-04	1.29E-05	1.12E-05	MND	0	2.91E-06	0	3.87E-06	6.26E-04
Respiratory effects	kg $PM_{2.5}$ eq	7.06E-04	7.37E-06	2.28E-06	MND	0	1.06E-06	0	6.81E-06	7.24E-04
Additional environmental information										
Carcinogenics	CTUh	87.7%	1.1%	1.5%	MND	0%	0.3%	0%	9.5%	100%
Non-carcinogenics	CTUh	80.9%	1.3%	2.1%	MND	0%	0.4%	0%	15.2%	100%
Ecotoxicity	CTUe	93.4%	3.5%	0.5%	MND	0%	1.1%	0%	1.4%	100%
Fossil fuel depletion	MJ surplus	3.04E+00	5.51E-02	9.23E-03	MND	0	1.78E-02	0	3.35E-02	3.15E+00
Resource use indicators										
Renewable primary energy used as energy carrier (fuel)	MJ, LHV	4.79E+00	1.62E-02	5.67E-03	MND	0	5.24E-03	0	3.12E-02	4.85E+00
Renewable primary resources with energy content used as material	MJ, LHV	3.86E-08	-1.32E-12	7.78E-13	MND	0	-4.27E-13	0	6.22E-12	3.86E-08
Non-renewable primary resources used as an energy carrier (fuel)	MJ, LHV	3.14E+01	4.16E-01	7.20E-02	MND	0	1.35E-01	0	2.66E-01	3.23E+01
Non-renewable primary resources with energy content used as material	MJ, LHV	8.91E-08	1.66E-09	2.32E-10	MND	0	5.36E-10	0	6.64E-10	9.22E-08
Secondary materials	kg	3.82E-01	0.00E+00	0.00E+00	MND	0	0.00E+00	0	0.00E+00	3.82E-01
Renewable secondary fuels	MJ, LHV	0.00E+00	0.00E+00	0.00E+00	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Non-renewable secondary fuels	MJ, LHV	0.00E+00	0.00E+00	0.00E+00	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Recovered energy	MJ, LHV	0.00E+00	0.00E+00	0.00E+00	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Use of net fresh water resources	m³	1.12E-02	5.63E-05	3.03E-05	MND	0	1.82E-05	0	3.30E-05	1.13E-02
Output flows and waste category indicators										
Hazardous waste disposed	kg	0.00E+00	0.00E+00	0.00E+00	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Non-hazardous waste disposed	kg	0.00E+00	0.00E+00	2.85E-02	MND	0	0.00E+00	0	7.05E-01	7.33E-01
High-level radioactive waste, conditioned, to final repository	kg	2.02E-06	1.21E-09	6.57E-10	MND	0	3.92E-10	0	3.29E-09	2.02E-06
Intermediate- and low-level radioactive waste, conditioned, to final repository	kg	1.69E-03	1.02E-06	5.75E-07	MND	0	3.30E-07	0	2.95E-06	1.69E-03
Components for re-use	kg	0.00E+00	0.00E+00	0.00E+00	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Materials for recycling	kg	0.00E+00	0.00E+00	8.54E-02	MND	0	0.00E+00	0	0.00E+00	8.54E-02
Materials for energy recovery	kg	0.00E+00	0.00E+00	0.00E+00	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Exported energy	MJ, LHV	0.00E+00	0.00E+00	0.00E+00	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Carbon emissions and removals										
Biogenic carbon removal from product	kg CO_2	4.22E-03	0.00E+00	0.00E+00	MND	0	0.00E+00	0	0.00E+00	4.22E-03
Biogenic carbon emission from product	kg CO_2	2.13E-02	0.00E+00	0.00E+00	MND	0	0.00E+00	0	1.37E-03	2.26E-02
Biogenic carbon removal from packaging	kg CO_2	1.73E-01	0.00E+00	0.00E+00	MND	0	0.00E+00	0	0.00E+00	1.73E-01
Biogenic carbon emission from packaging	kg CO_2	0.00E+00	0.00E+00	5.52E-03	MND	0	0.00E+00	0	0.00E+00	5.52E-03
Biogenic carbon emission from combustion of waste from renewable sources used in production processes	kg CO_2	0.00E+00	0.00E+00	8.81E-03	MND	0	0.00E+00	0	0.00E+00	8.81E-03
Calcination carbon emissions	kg CO_2	0.00E+00	0.00E+00	0.00E+00	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Carbonation carbon removals	kg CO_2	0.00E+00	0.00E+00	0.00E+00	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Carbon emissions from combustion of waste from non-renewable sources used in production processes	kg CO_2	0.00E+00	0.00E+00	0.00E+00	MND	0	0.00E+00	0	0.00E+00	0.00E+00

Table 2. ASJ+ facer: LCIA results, resource use, output and waste flows, carbon emissions & removals per declared unit (1 m²)

Parameter	Unit	A1-A3	A4	A5	B1-B7	C1	C2	C3	C4	Total
LCIA results (per m² of ASJ+ facer)										
Ozone depletion	kg CFC-11 eq	1.31E-10	1.02E-17	0	MND	0	4.16E-18	0	1.60E-16	1.31E-10
Global warming	kg CO_2 eq	3.11E-01	4.58E-03	0	MND	0	1.86E-03	0	3.26E-03	3.21E-01
Smog	kg O_3 eq	2.02E-02	8.07E-04	0	MND	0	1.27E-04	0	3.16E-04	2.14E-02
Acidification	kg SO_2 eq	1.47E-03	2.35E-05	0	MND	0	5.56E-06	0	1.73E-05	1.52E-03
Eutrophication	kg N eq	8.93E-05	2.01E-06	0	MND	0	5.70E-07	0	2.77E-05	1.20E-04
Respiratory effects	kg $PM_{2.5}$ eq	1.15E-04	1.15E-06	0	MND	0	2.09E-07	0	1.33E-06	1.17E-04
Additional environmental information										
Carcinogenics	CTUh	94.8%	0.4%	0%	MND	0%	0.2%	0%	4.6%	100%
Non-carcinogenics	CTUh	91.7%	0.3%	0%	MND	0%	0.1%	0%	7.9%	100%
Ecotoxicity	CTUe	96.40%	0.70%	0%	MND	0%	0.30%	0%	2.60%	100%
Fossil fuel depletion	MJ surplus	8.90E-01	8.59E-03	0	MND	0	3.50E-03	0	6.57E-03	9.09E-01
Resource use indicators										
Renewable primary energy used as energy carrier (fuel)	MJ, LHV	3.11E+00	2.53E-03	0	MND	0	1.03E-03	0	6.12E-03	3.12E+00
Renewable primary resources with energy content used as material	MJ, LHV	1.49E-10	-2.06E-13	0	MND	0	-8.37E-14	0	1.22E-12	1.50E-10
Non-renewable primary resources used as an energy carrier (fuel)	MJ, LHV	7.69E+00	6.49E-02	0	MND	0	2.64E-02	0	5.22E-02	7.84E+00
Non-renewable primary resources with energy content used as material	MJ, LHV	3.23E-08	2.59E-10	0	MND	0	1.05E-10	0	1.30E-10	3.28E-08
Secondary materials	kg	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Renewable secondary fuels	MJ, LHV	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Non-renewable secondary fuels	MJ, LHV	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Recovered energy	MJ, LHV	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Use of net fresh water resources	m³	3.63E-03	8.78E-06	0	MND	0	3.57E-06	0	6.47E-06	3.65E-03
Output flows and waste category indicators										
Hazardous waste disposed	kg	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Non-hazardous waste disposed	kg	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	1.56E-01	1.56E-01
High-level radioactive waste, conditioned, to final repository	kg	1.89E-07	1.89E-10	0	MND	0	7.69E-11	0	6.46E-10	1.90E-07
Intermediate- and low-level radioactive waste, conditioned, to final repository	kg	2.48E-04	1.59E-07	0	MND	0	6.48E-08	0	5.78E-07	2.49E-04
Components for re-use	kg	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Materials for recycling	kg	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Materials for energy recovery	kg	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Exported energy	MJ, LHV	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Carbon emissions and removals										
Biogenic carbon removal from product	kg CO_2	8.52E-02	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	8.52E-02
Biogenic carbon emission from product	kg CO_2	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	2.68E-04	2.68E-04
Biogenic carbon removal from packaging	kg CO_2	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Biogenic carbon emission from packaging	kg CO_2	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Biogenic carbon emission from combustion of waste from renewable sources used in production processes	kg CO_2	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Calcination carbon emissions	kg CO_2	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Carbonation carbon removals	kg CO_2	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Carbon emissions from combustion of waste from non-renewable sources used in production processes	kg CO_2	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00

Table 3. Self-sealing lap (SSL): LCIA results, resource use, output and waste flows, carbon emissions & removals per declared unit (1m)

Parameter	Unit	A1-A3	A4	A5	B1-B7	C1	C2	C3	C4	Total
LCIA results (per m of SSL)										
Ozone depletion	kg CFC-11 eq	3.47E-16	2.02E-19	0	MND	0	8.22E-20	0	3.17E-18	3.51E-16
Global warming	kg CO_2 eq	9.02E-03	9.04E-05	0	MND	0	3.68E-05	0	6.44E-05	9.21E-03
Smog	kg O_3 eq	2.41E-04	1.59E-05	0	MND	0	2.51E-06	0	6.23E-06	2.65E-04
Acidification	kg SO_2 eq	1.10E-05	4.64E-07	0	MND	0	1.10E-07	0	3.42E-07	1.19E-05
Eutrophication	kg N eq	1.02E-06	3.98E-08	0	MND	0	1.13E-08	0	5.47E-07	1.62E-06
Respiratory effects	kg $PM_{2.5}$ eq	4.81E-07	2.27E-08	0	MND	0	4.12E-09	0	2.64E-08	5.34E-07
Additional environmental information										
Carcinogenics	CTUh	98.2%	0.1%	0%	MND	0%	0.1%	0%	1.6%	100%
Non-carcinogenics	CTUh	97.3%	0.1%	0%	MND	0%	0.04%	0%	2.5%	100%
Ecotoxicity	CTUe	96.20%	0.70%	0%	MND	0%	0.30%	0%	2.70%	100%
Fossil fuel depletion	MJ surplus	3.72E-02	1.70E-04	0	MND	0	6.90E-05	0	1.30E-04	3.76E-02
Resource use indicators										
Renewable primary energy used as energy carrier (fuel)	MJ, LHV	1.03E-02	4.99E-05	0	MND	0	2.03E-05	0	1.21E-04	1.05E-02
Renewable primary resources with energy content used as material	MJ, LHV	3.50E-12	-4.06E-15	0	MND	0	-1.65E-15	0	2.41E-14	3.52E-12
Non-renewable primary resources used as an energy carrier (fuel)	MJ, LHV	2.68E-01	1.28E-03	0	MND	0	5.21E-04	0	1.03E-03	2.71E-01
Non-renewable primary resources with energy content used as material	MJ, LHV	3.00E-10	5.10E-12	0	MND	0	2.08E-12	0	2.57E-12	3.10E-10
Secondary materials	kg	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Renewable secondary fuels	MJ, LHV	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Non-renewable secondary fuels	MJ, LHV	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Recovered energy	MJ, LHV	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Use of net fresh water resources	m³	4.25E-05	1.73E-07	0	MND	0	7.05E-08	0	1.28E-07	4.29E-05
Output flows and waste category indicators										
Hazardous waste disposed	kg	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Non-hazardous waste disposed	kg	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	3.08E-03	3.08E-03
High-level radioactive waste, conditioned, to final repository	kg	2.22E-09	3.73E-12	0	MND	0	1.52E-12	0	1.28E-11	2.24E-09
Intermediate- and low-level radioactive waste, conditioned, to final repository	kg	2.35E-06	3.14E-09	0	MND	0	1.28E-09	0	1.14E-08	2.37E-06
Components for re-use	kg	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Materials for recycling	kg	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Materials for energy recovery	kg	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Exported energy	MJ, LHV	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Carbon emissions and removals										
Biogenic carbon removal from product	kg CO_2	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Biogenic carbon emission from product	kg CO_2	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Biogenic carbon removal from packaging	kg CO_2	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Biogenic carbon emission from packaging	kg CO_2	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Biogenic carbon emission from combustion of waste from renewable sources used in production processes	kg CO_2	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Calcination carbon emissions	kg CO_2	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Carbonation carbon removals	kg CO_2	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Carbon emissions from combustion of waste from non-renewable sources used in production processes	kg CO_2	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00

Table 4. Butt strip: LCIA results, resource use, output and waste flows, carbon emissions & removals per declared unit (1m)

Parameter	Unit	A1-A3	A4	A5	B1-B7	C1	C2	C3	C4	Total
LCIA results (per m of butt strip)										
Ozone depletion	kg CFC-11 eq	1.65E-15	1.06E-18	0	MND	0	4.30E-19	0	1.66E-17	1.67E-15
Global warming	kg CO_2 eq	3.31E-02	4.74E-04	0	MND	0	1.93E-04	0	3.37E-04	3.41E-02
Smog	kg O_3 eq	1.58E-03	8.34E-05	0	MND	0	1.31E-05	0	3.26E-05	1.71E-03
Acidification	kg SO_2 eq	1.07E-04	2.43E-06	0	MND	0	5.75E-07	0	1.79E-06	1.12E-04
Eutrophication	kg N eq	5.38E-06	2.08E-07	0	MND	0	5.89E-08	0	2.87E-06	8.52E-06
Respiratory effects	kg $PM_{2.5}$ eq	6.93E-06	1.19E-07	0	MND	0	2.16E-08	0	1.38E-07	7.21E-06
Additional environmental information										
Carcinogenics	CTUh	97.0%	0.2%	0%	MND	0%	0.1%	0%	2.7%	100%
Non-carcinogenics	CTUh	95.3%	0.2%	0%	MND	0%	0.1%	0%	4.4%	100%
Ecotoxicity	CTUe	93.20%	1.30%	0%	MND	0%	0.50%	0%	4.90%	100%
Fossil fuel depletion	MJ surplus	1.19E-01	8.88E-04	0	MND	0	3.62E-04	0	6.80E-04	1.21E-01
Resource use indicators										
Renewable primary energy used as energy carrier (fuel)	MJ, LHV	1.81E-01	2.61E-04	0	MND	0	1.06E-04	0	6.32E-04	1.82E-01
Renewable primary resources with energy content used as material	MJ, LHV	1.59E-11	-2.13E-14	0	MND	0	-8.66E-15	0	1.26E-13	1.60E-11
Non-renewable primary resources used as an energy carrier (fuel)	MJ, LHV	9.41E-01	6.71E-03	0	MND	0	2.73E-03	0	5.40E-03	9.56E-01
Non-renewable primary resources with energy content used as material	MJ, LHV	1.58E-09	2.67E-11	0	MND	0	1.09E-11	0	1.35E-11	1.63E-09
Secondary materials	kg	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Renewable secondary fuels	MJ, LHV	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Non-renewable secondary fuels	MJ, LHV	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Recovered energy	MJ, LHV	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Use of net fresh water resources	m³	3.62E-04	9.08E-07	0	MND	0	3.69E-07	0	6.69E-07	3.64E-04
Output flows and waste category indicators										
Hazardous waste disposed	kg	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Non-hazardous waste disposed	kg	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	1.61E-02	1.61E-02
High-level radioactive waste, conditioned, to final repository	kg	1.58E-08	1.95E-11	0	MND	0	7.95E-12	0	6.68E-11	1.59E-08
Intermediate- and low-level radioactive waste, conditioned, to final repository	kg	2.01E-05	1.65E-08	0	MND	0	6.70E-09	0	5.97E-08	2.02E-05
Components for re-use	kg	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Materials for recycling	kg	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Materials for energy recovery	kg	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Exported energy	MJ, LHV	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Carbon emissions and removals										
Biogenic carbon removal from product	kg CO_2	1.90E-03	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	1.90E-03
Biogenic carbon emission from product	kg CO_2	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	2.77E-05	2.77E-05
Biogenic carbon removal from packaging	kg CO_2	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Biogenic carbon emission from packaging	kg CO_2	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Biogenic carbon emission from combustion of waste from renewable sources used in production processes	kg CO_2	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Calcination carbon emissions	kg CO_2	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Carbonation carbon removals	kg CO_2	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00
Carbon emissions from combustion of waste from non-renewable sources used in production processes	kg CO_2	0.00E+00	0.00E+00	0	MND	0	0.00E+00	0	0.00E+00	0.00E+00

Scaling factors

Results in this report may be scaled to various pipe insulation diameters and thicknesses. In order to calculate results per one lineal foot of Earthwool® 1000° (ALLEY-K™) Pipe Insulation having a specific inside diameter (ID) and wall thickness with or without the ASJ+ facer, use the following equation:

Total results per lineal foot of pipe (1 ft) =

Unfaced pipe insulation

(Unfaced insulation impact Table 1) * (Unfaced insulation scaling factor Table 5, scaling factor INS) + (SSL impact Table 3) * (0.3048)

Plus ASJ+ facer with butt strip

(ASJ+ impact Table 2) * (ASJ+ scaling factor Table 5, scaling factor ASJ) + (Butt strip impact Table 4) * (Butt strip scaling factor Table 5, scaling factor BUT)

Table 5. Pipe insulation thicknesses for various iron and copper pipe sizes and their associated scaling factors

Iron pipe size (in)	Copper pipe size (in)	Nominal pipe insulation thickness (in)	Actual pipe insulation thickness (in)	Actual pipe insulation thickness (cm)	Scaling factor INS Pipe insulation scaling factor to one lineal foot of pipe from the declared unit (1m at 1kg)	Scaling factor ASJ ASJ+ scaling factor to one lineal foot of pipe from the declared unit (1m2)	Scaling factor BUT Butt strip scaling factor to one lineal foot of pipe from the declared unit (1m)
1/2	7/8	1/2	4.85E-01	1.23E+00	5.01E-02	4.49E-02	5.05E-02
	5/8	1/2	4.95E-01	1.26E+00	4.20E-02	3.93E-02	4.42E-02
3/4	1 1/8	1/2	4.95E-01	1.26E+00	6.02E-02	5.11E-02	5.75E-02
1	1 3/8	1/2	4.75E-01	1.21E+00	6.55E-02	5.60E-02	6.30E-02
1 1/4	1 5/8	1/2	5.15E-01	1.31E+00	7.70E-02	6.43E-02	7.23E-02
1 1/2		1/2	4.65E-01	1.18E+00	7.56E-02	6.79E-02	7.63E-02
2		1/2	4.60E-01	1.17E+00	9.21E-02	8.09E-02	9.10E-02
	2 1/8	1/2	4.85E-01	1.23E+00	8.12E-02	7.47E-02	8.41E-02
2 1/2		1/2	4.65E-01	1.18E+00	1.01E-01	9.29E-02	1.05E-01
	2 5/8	1/2	4.85E-01	1.23E+00	9.63E-02	8.65E-02	9.74E-02
3		1/2	4.60E-01	1.17E+00	1.16E-01	1.06E-01	1.20E-01
	3 1/8	1/2	4.85E-01	1.23E+00	1.02E-01	9.84E-02	1.11E-01
3 1/2		1/2	4.70E-01	1.19E+00	1.22E-01	1.18E-01	1.33E-01
	3 5/8	1/2	4.85E-01	1.23E+00	1.16E-01	1.10E-01	1.24E-01
4		1/2	5.00E-01	1.27E+00	1.45E-01	1.31E-01	1.48E-01
	4 1/8	1/2	4.85E-01	1.23E+00	1.24E-01	1.22E-01	1.37E-01
4 1/2		1/2	5.10E-01	1.30E+00	1.55E-01	1.44E-01	1.62E-01
5		1/2	4.75E-01	1.21E+00	1.60E-01	1.57E-01	1.76E-01
	5 1/8	1/2	4.85E-01	1.23E+00	1.51E-01	1.46E-01	1.64E-01
6		1/2	4.45E-01	1.13E+00	1.75E-01	1.80E-01	2.03E-01
	6 1/8	1/2	4.65E-01	1.18E+00	1.70E-01	1.69E-01	1.90E-01
7		1/2	4.50E-01	1.14E+00	1.73E-01	2.04E-01	2.30E-01
8		1/2	4.35E-01	1.10E+00	1.88E-01	2.28E-01	2.56E-01
9		1/2	4.90E-01	1.24E+00	2.35E-01	2.53E-01	2.85E-01
10		1/2	4.30E-01	1.09E+00	2.28E-01	2.78E-01	3.13E-01
1/2	7/8	1	9.45E-01	2.40E+00	9.70E-02	6.67E-02	7.50E-02
	5/8	1	1.08E+00	2.73E+00	1.03E-01	6.67E-02	7.50E-02
3/4	1 1/8	1	8.25E-01	2.10E+00	9.00E-02	6.67E-02	7.50E-02
1	1 3/8	1	1.02E+00	2.58E+00	1.35E-01	8.16E-02	9.18E-02
1 1/4	1 5/8	1	8.80E-01	2.24E+00	1.24E-01	8.16E-02	9.18E-02
1 1/2		1	1.01E+00	2.55E+00	1.62E-01	9.34E-02	1.05E-01
2		1	9.75E-01	2.48E+00	1.68E-01	1.05E-01	1.18E-01
	2 1/8	1	8.80E-01	2.24E+00	1.34E-01	9.34E-02	1.05E-01
2 1/2		1	9.75E-01	2.48E+00	1.92E-01	1.17E-01	1.32E-01
	2 5/8	1	8.80E-01	2.24E+00	1.55E-01	1.05E-01	1.18E-01
3		1	9.65E-01	2.45E+00	2.17E-01	1.30E-01	1.47E-01
	3 1/8	1	8.80E-01	2.24E+00	1.77E-01	1.17E-01	1.32E-01
3 1/2		1	1.26E+00	3.19E+00	3.30E-01	1.55E-01	1.75E-01
	3 5/8	1	9.10E-01	2.31E+00	2.07E-01	1.30E-01	1.47E-01
4		1	1.01E+00	2.55E+00	2.77E-01	1.55E-01	1.75E-01
	4 1/8	1	1.19E+00	3.02E+00	3.17E-01	1.55E-01	1.75E-01
4 1/2		1	1.26E+00	3.19E+00	3.92E-01	1.79E-01	2.01E-01
5		1	9.50E-01	2.41E+00	3.11E-01	1.79E-01	2.01E-01
	5 1/8	1	1.19E+00	3.02E+00	3.56E-01	1.79E-01	2.01E-01
6		1	9.20E-01	2.34E+00	3.30E-01	2.03E-01	2.28E-01
	6 1/8	1	1.17E+00	2.97E+00	4.06E-01	2.03E-01	2.28E-01
7		1	9.20E-01	2.34E+00	3.73E-01	2.26E-01	2.55E-01
8		1	9.70E-01	2.46E+00	4.42E-01	2.53E-01	2.85E-01
9		1	9.90E-01	2.51E+00	4.97E-01	2.77E-01	3.11E-01
10		1	9.05E-01	2.30E+00	5.00E-01	3.00E-01	3.38E-01
11		1	1.05E+00	2.65E+00	6.32E-01	3.30E-01	3.71E-01
12		1	1.04E+00	2.63E+00	6.75E-01	3.54E-01	3.98E-01
14		1	9.10E-01	2.31E+00	6.42E-01	3.77E-01	4.24E-01
15		1	9.10E-01	2.31E+00	6.84E-01	4.01E-01	4.51E-01
16		1	9.10E-01	2.31E+00	7.27E-01	4.24E-01	4.77E-01
17		1	9.10E-01	2.31E+00	7.69E-01	4.48E-01	5.04E-01
18		1	9.10E-01	2.31E+00	8.12E-01	4.72E-01	5.31E-01
19		1	9.10E-01	2.31E+00	8.55E-01	4.95E-01	5.57E-01
20		1	9.10E-01	2.31E+00	8.97E-01	5.19E-01	5.84E-01
21		1	9.10E-01	2.31E+00	9.40E-01	5.43E-01	6.10E-01
22		1	9.10E-01	2.31E+00	9.82E-01	5.66E-01	6.37E-01
23		1	9.10E-01	2.31E+00	1.03E+00	5.90E-01	6.64E-01
24		1	9.10E-01	2.31E+00	1.07E+00	6.14E-01	6.90E-01
25		1	9.10E-01	2.31E+00	1.11E+00	6.37E-01	7.17E-01
26		1	9.10E-01	2.31E+00	1.15E+00	6.61E-01	7.43E-01
27		1	9.10E-01	2.31E+00	1.20E+00	6.85E-01	7.70E-01
28		1	9.10E-01	2.31E+00	1.24E+00	7.08E-01	7.97E-01
29		1	9.10E-01	2.31E+00	1.28E+00	7.32E-01	8.23E-01
30		1	9.10E-01	2.31E+00	1.32E+00	7.56E-01	8.50E-01
1/2	7/8	1 1/2	1.51E+00	3.84E+00	1.70E-01	9.34E-02	1.05E-01
	5/8	1 1/2	1.39E+00	3.53E+00	1.42E-01	8.16E-02	9.18E-02
3/4	1 1/8	1 1/2	1.39E+00	3.53E+00	1.76E-01	9.34E-02	1.05E-01
1	1 3/8	1 1/2	1.52E+00	3.85E+00	2.20E-01	1.05E-01	1.18E-01
1 1/4	1 5/8	1 1/2	1.63E+00	4.14E+00	2.68E-01	1.17E-01	1.32E-01
1 1/2		1 1/2	1.51E+00	3.82E+00	2.57E-01	1.17E-01	1.32E-01
2		1 1/2	1.51E+00	3.82E+00	2.98E-01	1.30E-01	1.47E-01
	2 1/8	1 1/2	1.38E+00	3.51E+00	2.44E-01	1.17E-01	1.32E-01
2 1/2		1 1/2	1.79E+00	4.53E+00	4.22E-01	1.55E-01	1.75E-01
	2 5/8	1 1/2	1.41E+00	3.58E+00	2.71E-01	1.30E-01	1.47E-01
3		1 1/2	1.50E+00	3.80E+00	3.56E-01	1.55E-01	1.75E-01
	3 1/8	1 1/2	1.69E+00	4.29E+00	3.86E-01	1.55E-01	1.75E-01
3 1/2		1 1/2	1.76E+00	4.46E+00	4.78E-01	1.79E-01	2.01E-01
	3 5/8	1 1/2	1.44E+00	3.66E+00	3.08E-01	1.55E-01	1.75E-01
4		1 1/2	1.51E+00	3.82E+00	3.80E-01	1.79E-01	2.01E-01
	4 1/8	1 1/2	1.69E+00	4.29E+00	4.14E-01	1.79E-01	2.01E-01
4 1/2		1 1/2	1.76E+00	4.46E+00	4.98E-01	2.03E-01	2.28E-01
5		1 1/2	1.45E+00	3.68E+00	4.30E-01	2.03E-01	2.28E-01
	5 1/8	1 1/2	1.69E+00	4.29E+00	4.84E-01	2.03E-01	2.28E-01
6		1 1/2	1.42E+00	3.61E+00	4.82E-01	2.26E-01	2.55E-01
	6 1/8	1 1/2	1.67E+00	4.24E+00	5.50E-01	2.26E-01	2.55E-01
7		1 1/2	1.49E+00	3.77E+00	5.70E-01	2.53E-01	2.85E-01
8		1 1/2	1.47E+00	3.73E+00	6.27E-01	2.77E-01	3.11E-01
9		1 1/2	1.49E+00	3.78E+00	6.96E-01	3.00E-01	3.38E-01
10		1 1/2	1.53E+00	3.89E+00	7.92E-01	3.30E-01	3.71E-01
11		1 1/2	1.55E+00	3.92E+00	8.63E-01	3.54E-01	3.98E-01
12		1 1/2	1.54E+00	3.90E+00	9.22E-01	3.77E-01	4.24E-01
14		1 1/2	1.41E+00	3.58E+00	9.13E-01	4.01E-01	4.51E-01
15		1 1/2	1.41E+00	3.58E+00	9.72E-01	4.24E-01	4.77E-01
16		1 1/2	1.41E+00	3.58E+00	1.03E+00	4.48E-01	5.04E-01
17		1 1/2	1.41E+00	3.58E+00	1.09E+00	4.72E-01	5.31E-01
18		1 1/2	1.41E+00	3.58E+00	1.15E+00	4.95E-01	5.57E-01
19		1 1/2	1.41E+00	3.58E+00	1.21E+00	5.19E-01	5.84E-01
20		1 1/2	1.41E+00	3.58E+00	1.27E+00	5.43E-01	6.10E-01
21		1 1/2	1.41E+00	3.58E+00	1.32E+00	5.66E-01	6.37E-01
22		1 1/2	1.41E+00	3.58E+00	1.38E+00	5.90E-01	6.64E-01
23		1 1/2	1.41E+00	3.58E+00	1.44E+00	6.14E-01	6.90E-01
24		1 1/2	1.41E+00	3.58E+00	1.50E+00	6.37E-01	7.17E-01
25		1 1/2	1.41E+00	3.58E+00	1.56E+00	6.61E-01	7.43E-01
26		1 1/2	1.41E+00	3.58E+00	1.62E+00	6.85E-01	7.70E-01
27		1 1/2	1.41E+00	3.58E+00	1.68E+00	7.08E-01	7.97E-01
28		1 1/2	1.41E+00	3.58E+00	1.74E+00	7.32E-01	8.23E-01
29		1 1/2	1.41E+00	3.58E+00	1.79E+00	7.56E-01	8.50E-01
30		1 1/2	1.41E+00	3.58E+00	1.85E+00	7.79E-01	8.76E-01
1/2	7/8	2	2.01E+00	5.11E+00	2.77E-01	1.17E-01	1.32E-01
	5/8	2	1.92E+00	4.86E+00	2.32E-01	1.06E-01	1.20E-01
3/4	1 1/8	2	1.89E+00	4.80E+00	2.71E-01	1.17E-01	1.32E-01
1	1 3/8	2	2.05E+00	5.19E+00	3.32E-01	1.30E-01	1.47E-01
1 1/4	1 5/8	2	1.91E+00	4.85E+00	3.22E-01	1.30E-01	1.47E-01
1 1/2		2	2.32E+00	5.88E+00	4.62E-01	1.55E-01	1.75E-01
2		2	2.04E+00	5.17E+00	4.33E-01	1.55E-01	1.75E-01
	2 1/8	2	2.19E+00	5.56E+00	4.49E-01	1.55E-01	1.75E-01
2 1/2		2	2.29E+00	5.80E+00	5.66E-01	1.79E-01	2.01E-01
	2 5/8	2	1.94E+00	4.93E+00	4.21E-01	1.55E-01	1.75E-01
3		2	2.00E+00	5.07E+00	5.21E-01	1.79E-01	2.01E-01
	3 1/8	2	2.19E+00	5.56E+00	5.52E-01	1.79E-01	2.01E-01
3 1/2		2	2.26E+00	5.73E+00	5.93E-01	2.03E-01	2.28E-01
	3 5/8	2	1.94E+00	4.93E+00	4.55E-01	1.79E-01	2.01E-01
4		2	2.01E+00	5.09E+00	5.48E-01	2.03E-01	2.28E-01
	4 1/8	2	2.19E+00	5.56E+00	5.82E-01	2.03E-01	2.28E-01
4 1/2		2	2.26E+00	5.73E+00	6.87E-01	2.26E-01	2.55E-01
5		2	1.95E+00	4.95E+00	6.19E-01	2.26E-01	2.55E-01
	5 1/8	2	2.19E+00	5.56E+00	6.73E-01	2.26E-01	2.55E-01
6		2	1.99E+00	5.04E+00	7.21E-01	2.53E-01	2.85E-01
	6 1/8	2	2.24E+00	5.68E+00	7.88E-01	2.53E-01	2.85E-01
7		2	1.99E+00	5.04E+00	8.03E-01	2.77E-01	3.11E-01
8		2	1.97E+00	5.00E+00	8.81E-01	3.00E-01	3.38E-01
9		2	2.12E+00	5.37E+00	1.04E+00	3.30E-01	3.71E-01
10		2	2.03E+00	5.16E+00	1.09E+00	3.54E-01	3.98E-01
11		2	2.05E+00	5.19E+00	1.18E+00	3.77E-01	4.24E-01
12		2	2.04E+00	5.17E+00	1.26E+00	4.01E-01	4.51E-01
14		2	1.91E+00	4.85E+00	1.28E+00	4.24E-01	4.77E-01
15		2	1.91E+00	4.85E+00	1.36E+00	4.48E-01	5.04E-01
16		2	1.91E+00	4.85E+00	1.44E+00	4.72E-01	5.31E-01
17		2	1.91E+00	4.85E+00	1.51E+00	4.95E-01	5.57E-01
18		2	1.91E+00	4.85E+00	1.59E+00	5.19E-01	5.84E-01
19		2	1.91E+00	4.85E+00	1.67E+00	5.43E-01	6.10E-01
20		2	1.91E+00	4.85E+00	1.75E+00	5.66E-01	6.37E-01
21		2	1.91E+00	4.85E+00	1.83E+00	5.90E-01	6.64E-01
22		2	1.91E+00	4.85E+00	1.91E+00	6.14E-01	6.90E-01
23		2	1.91E+00	4.85E+00	1.99E+00	6.37E-01	7.17E-01
24		2	1.91E+00	4.85E+00	2.07E+00	6.61E-01	7.43E-01
25		2	1.91E+00	4.85E+00	2.15E+00	6.85E-01	7.70E-01
26		2	1.91E+00	4.85E+00	2.23E+00	7.08E-01	7.97E-01
27		2	1.91E+00	4.85E+00	2.31E+00	7.32E-01	8.23E-01
28		2	1.91E+00	4.85E+00	2.39E+00	7.56E-01	8.50E-01
29		2	1.91E+00	4.85E+00	2.47E+00	7.79E-01	8.76E-01
30		2	1.91E+00	4.85E+00	2.55E+00	8.03E-01	9.03E-01
1	1 3/8	2 1/2	2.61E+00	6.62E+00	4.37E-01	1.57E-01	1.76E-01
1 1/4	1 5/8	2 1/2	2.47E+00	6.27E+00	4.28E-01	1.57E-01	1.76E-01
1 1/2		2 1/2	2.82E+00	7.15E+00	5.58E-01	1.79E-01	2.01E-01
2		2 1/2	2.54E+00	6.44E+00	5.32E-01	1.79E-01	2.01E-01
	2 1/8	2 1/2	2.69E+00	6.83E+00	5.47E-01	1.79E-01	2.01E-01
2 1/2		2 1/2	2.79E+00	7.07E+00	6.71E-01	2.03E-01	2.28E-01
	2 5/8	2 1/2	2.44E+00	6.20E+00	5.22E-01	1.79E-01	2.01E-01
3		2 1/2	2.50E+00	6.34E+00	6.31E-01	2.03E-01	2.28E-01
	3 1/8	2 1/2	2.69E+00	6.83E+00	6.59E-01	2.03E-01	2.28E-01
3 1/2		2 1/2	2.76E+00	7.00E+00	7.82E-01	2.26E-01	2.55E-01
	3 5/8	2 1/2	2.44E+00	6.20E+00	6.23E-01	2.03E-01	2.28E-01
4		2 1/2	2.51E+00	6.36E+00	7.37E-01	2.26E-01	2.55E-01
	4 1/8	2 1/2	2.69E+00	6.83E+00	7.71E-01	2.26E-01	2.55E-01
4 1/2		2 1/2	2.82E+00	7.16E+00	9.26E-01	2.53E-01	2.85E-01
5		2 1/2	2.52E+00	6.39E+00	8.58E-01	2.53E-01	2.85E-01
	5 1/8	2 1/2	2.76E+00	7.00E+00	9.12E-01	2.53E-01	2.85E-01
6		2 1/2	2.49E+00	6.31E+00	9.54E-01	2.77E-01	3.11E-01
	6 1/8	2 1/2	2.74E+00	6.95E+00	1.02E+00	2.77E-01	3.11E-01
7		2 1/2	2.49E+00	6.31E+00	1.06E+00	3.00E-01	3.38E-01
8		2 1/2	2.60E+00	6.59E+00	1.23E+00	3.30E-01	3.71E-01
9		2 1/2	2.62E+00	6.64E+00	1.34E+00	3.54E-01	3.98E-01
10		2 1/2	2.53E+00	6.43E+00	1.41E+00	3.77E-01	4.24E-01
11		2 1/2	2.55E+00	6.46E+00	1.53E+00	4.01E-01	4.51E-01
12		2 1/2	2.54E+00	6.44E+00	1.63E+00	4.24E-01	4.77E-01
14		2 1/2	2.41E+00	6.12E+00	1.66E+00	4.48E-01	5.04E-01
15		2 1/2	2.41E+00	6.12E+00	1.76E+00	4.72E-01	5.31E-01
16		2 1/2	2.41E+00	6.12E+00	2.09E+00	4.95E-01	5.57E-01
17		2 1/2	2.41E+00	6.12E+00	1.96E+00	5.19E-01	5.84E-01
18		2 1/2	2.41E+00	6.12E+00	2.06E+00	5.43E-01	6.10E-01
19		2 1/2	2.41E+00	6.12E+00	2.16E+00	5.66E-01	6.37E-01
20		2 1/2	2.41E+00	6.12E+00	2.26E+00	5.90E-01	6.64E-01
21		2 1/2	2.41E+00	6.12E+00	2.36E+00	6.14E-01	6.90E-01
22		2 1/2	2.41E+00	6.12E+00	2.46E+00	6.37E-01	7.17E-01
23		2 1/2	2.41E+00	6.12E+00	2.56E+00	6.61E-01	7.43E-01
24		2 1/2	2.41E+00	6.12E+00	2.66E+00	6.85E-01	7.70E-01
25		2 1/2	2.41E+00	6.12E+00	2.77E+00	7.08E-01	7.97E-01
26		2 1/2	2.41E+00	6.12E+00	2.87E+00	7.32E-01	8.23E-01
27		2 1/2	2.41E+00	6.12E+00	2.97E+00	7.56E-01	8.50E-01
28		2 1/2	2.41E+00	6.12E+00	3.07E+00	7.79E-01	8.76E-01
29		2 1/2	2.41E+00	6.12E+00	3.17E+00	8.03E-01	9.03E-01
30		2 1/2	2.41E+00	6.12E+00	3.27E+00	8.26E-01	9.30E-01
1	1 3/8	3	3.08E+00	7.81E+00	5.76E-01	1.79E-01	2.01E-01
1 1/2		3	3.32E+00	8.42E+00	7.26E-01	2.03E-01	2.28E-01
2		3	3.04E+00	7.71E+00	7.00E-01	2.03E-01	2.28E-01
	2 1/8	3	3.19E+00	8.10E+00	7.15E-01	2.03E-01	2.28E-01
2 1/2		3	3.29E+00	8.34E+00	8.60E-01	2.26E-01	2.55E-01
	2 5/8	3	2.94E+00	7.47E+00	6.90E-01	2.03E-01	2.28E-01
3		3	3.00E+00	7.61E+00	8.20E-01	2.26E-01	2.55E-01
	3 1/8	3	3.19E+00	8.10E+00	8.48E-01	2.26E-01	2.55E-01
3 1/2		3	3.32E+00	8.43E+00	1.02E+00	2.53E-01	2.85E-01
	3 5/8	3	2.94E+00	7.47E+00	8.12E-01	2.26E-01	2.55E-01
4		3	3.07E+00	7.80E+00	9.76E-01	2.53E-01	2.85E-01
	4 1/8	3	3.26E+00	8.27E+00	1.01E+00	2.53E-01	2.85E-01
4 1/2		3	3.32E+00	8.43E+00	1.16E+00	2.77E-01	3.11E-01
5		3	3.02E+00	7.66E+00	1.09E+00	2.77E-01	3.11E-01
	5 1/8	3	3.26E+00	8.27E+00	1.15E+00	2.77E-01	3.11E-01
6		3	2.99E+00	7.58E+00	1.21E+00	3.00E-01	3.38E-01
	6 1/8	3	3.24E+00	8.22E+00	1.28E+00	3.00E-01	3.38E-01
7		3	3.11E+00	7.90E+00	1.40E+00	3.30E-01	3.71E-01
8		3	3.10E+00	7.86E+00	1.53E+00	3.54E-01	3.98E-01
9		3	3.12E+00	7.91E+00	1.67E+00	3.77E-01	4.24E-01
10		3	3.03E+00	7.70E+00	1.76E+00	4.01E-01	4.51E-01
11		3	3.05E+00	7.73E+00	1.89E+00	4.24E-01	4.77E-01
12		3	3.04E+00	7.71E+00	2.01E+00	4.48E-01	5.04E-01
14		3	2.91E+00	7.39E+00	2.07E+00	4.72E-01	5.31E-01
15		3	2.91E+00	7.39E+00	2.19E+00	4.95E-01	5.57E-01
16		3	2.91E+00	7.39E+00	2.31E+00	5.19E-01	5.84E-01
17		3	2.91E+00	7.39E+00	2.43E+00	5.43E-01	6.10E-01
18		3	2.91E+00	7.39E+00	2.55E+00	5.66E-01	6.37E-01
19		3	2.91E+00	7.39E+00	2.67E+00	5.90E-01	6.64E-01
20		3	2.91E+00	7.39E+00	2.79E+00	6.14E-01	6.90E-01
21		3	2.91E+00	7.39E+00	2.91E+00	6.37E-01	7.17E-01
22		3	2.91E+00	7.39E+00	3.04E+00	6.61E-01	7.43E-01
23		3	2.91E+00	7.39E+00	3.16E+00	6.85E-01	7.70E-01
24		3	2.91E+00	7.39E+00	3.28E+00	7.08E-01	7.97E-01
25		3	2.91E+00	7.39E+00	3.40E+00	7.32E-01	8.23E-01
26		3	2.91E+00	7.39E+00	3.52E+00	7.56E-01	8.50E-01
27		3	2.91E+00	7.39E+00	3.64E+00	7.79E-01	8.76E-01
28		3	2.91E+00	7.39E+00	3.76E+00	8.03E-01	9.03E-01
29		3	2.91E+00	7.39E+00	3.88E+00	8.26E-01	9.30E-01
30		3	2.91E+00	7.39E+00	4.01E+00	8.50E-01	9.56E-01
1 1/2		3 1/2	3.82E+00	9.69E+00	9.15E-01	2.26E-01	2.55E-01
2		3 1/2	3.54E+00	8.98E+00	8.89E-01	2.26E-01	2.55E-01
	2 1/8	3 1/2	3.69E+00	9.37E+00	9.04E-01	2.26E-01	2.55E-01
2 1/2		3 1/2	3.85E+00	9.78E+00	1.10E+00	2.53E-01	2.85E-01
	2 5/8	3 1/2	3.44E+00	8.74E+00	8.79E-01	2.26E-01	2.55E-01
3		3 1/2	3.56E+00	9.04E+00	1.06E+00	2.53E-01	2.85E-01
	3 1/8	3 1/2	3.76E+00	9.54E+00	1.09E+00	2.53E-01	2.85E-01
3 1/2		3 1/2	3.82E+00	9.70E+00	1.25E+00	2.77E-01	3.11E-01
	3 5/8	3 1/2	3.51E+00	8.90E+00	1.05E+00	2.53E-01	2.85E-01
4		3 1/2	3.57E+00	9.07E+00	1.21E+00	2.77E-01	3.11E-01
	4 1/8	3 1/2	3.76E+00	9.54E+00	1.24E+00	2.77E-01	3.11E-01
4 1/2		3 1/2	3.82E+00	9.70E+00	1.41E+00	3.00E-01	3.38E-01
5		3 1/2	3.52E+00	8.93E+00	1.35E+00	3.00E-01	3.38E-01
	5 1/8	3 1/2	3.76E+00	9.54E+00	1.40E+00	3.00E-01	3.38E-01
6		3 1/2	3.61E+00	9.17E+00	1.56E+00	3.30E-01	3.71E-01
	6 1/8	3 1/2	3.86E+00	9.80E+00	1.62E+00	3.30E-01	3.71E-01
7		3 1/2	3.61E+00	9.17E+00	1.71E+00	3.54E-01	3.98E-01
8		3 1/2	3.60E+00	9.13E+00	1.85E+00	3.77E-01	4.24E-01
9		3 1/2	3.62E+00	9.18E+00	2.01E+00	4.01E-01	4.51E-01
10		3 1/2	3.53E+00	8.97E+00	2.12E+00	4.24E-01	4.77E-01
11		3 1/2	3.55E+00	9.00E+00	2.28E+00	4.48E-01	5.04E-01
12		3 1/2	3.54E+00	8.98E+00	2.42E+00	4.72E-01	5.31E-01
14		3 1/2	3.41E+00	8.66E+00	2.49E+00	4.95E-01	5.57E-01
15		3 1/2	3.41E+00	8.66E+00	2.63E+00	5.19E-01	5.84E-01
16		3 1/2	3.41E+00	8.66E+00	2.78E+00	5.43E-01	6.10E-01
17		3 1/2	3.41E+00	8.66E+00	2.92E+00	5.66E-01	6.37E-01
18		3 1/2	3.41E+00	8.66E+00	3.06E+00	5.90E-01	6.64E-01
19		3 1/2	3.41E+00	8.66E+00	3.20E+00	6.14E-01	6.90E-01
20		3 1/2	3.41E+00	8.66E+00	3.34E+00	6.37E-01	7.17E-01
21		3 1/2	3.41E+00	8.66E+00	3.49E+00	6.61E-01	7.43E-01
22		3 1/2	3.41E+00	8.66E+00	3.63E+00	6.85E-01	7.70E-01
23		3 1/2	3.41E+00	8.66E+00	3.77E+00	7.08E-01	7.97E-01
24		3 1/2	3.41E+00	8.66E+00	3.91E+00	7.32E-01	8.23E-01
25		3 1/2	3.41E+00	8.66E+00	4.05E+00	7.56E-01	8.50E-01
26		3 1/2	3.41E+00	8.66E+00	4.20E+00	7.79E-01	8.76E-01
27		3 1/2	3.41E+00	8.66E+00	4.34E+00	8.03E-01	9.03E-01
28		3 1/2	3.41E+00	8.66E+00	4.48E+00	8.26E-01	9.30E-01
29		3 1/2	3.41E+00	8.66E+00	4.62E+00	8.50E-01	9.56E-01
1 1/2		4	4.38E+00	1.11E+01	1.15E+00	2.53E-01	2.85E-01
2		4	4.10E+00	1.04E+01	1.13E+00	2.53E-01	2.85E-01
	2 1/8	4	4.26E+00	1.08E+01	1.14E+00	2.53E-01	2.85E-01
2 1/2		4	4.35E+00	1.10E+01	1.33E+00	2.77E-01	3.11E-01
	2 5/8	4	4.01E+00	1.02E+01	1.12E+00	2.53E-01	2.85E-01
3		4	4.06E+00	1.03E+01	1.29E+00	2.77E-01	3.11E-01
	3 1/8	4	4.26E+00	1.08E+01	1.32E+00	2.77E-01	3.11E-01
3 1/2		4	4.32E+00	1.10E+01	1.51E+00	3.00E-01	3.38E-01
	3 5/8	4	4.01E+00	1.02E+01	1.28E+00	2.77E-01	3.11E-01
4		4	4.07E+00	1.03E+01	1.46E+00	3.00E-01	3.38E-01
	4 1/8	4	3.76E+00	9.54E+00	1.24E+00	2.77E-01	3.11E-01
4 1/2		4	3.82E+00	9.70E+00	1.41E+00	3.30E-01	3.71E-01
5		4	4.14E+00	1.05E+01	1.69E+00	3.30E-01	3.71E-01
	5 1/8	4	3.76E+00	9.54E+00	1.40E+00	3.00E-01	3.38E-01
6		4	4.11E+00	1.04E+01	1.86E+00	3.54E-01	3.98E-01
	6 1/8	4	3.86E+00	9.80E+00	1.62E+00	3.30E-01	3.71E-01
7		4	4.11E+00	1.04E+01	2.03E+00	3.77E-01	4.24E-01
8		4	4.10E+00	1.04E+01	2.19E+00	4.01E-01	4.51E-01
9		4	4.12E+00	1.05E+01	2.37E+00	4.24E-01	4.77E-01
10		4	4.03E+00	1.02E+01	2.50E+00	4.48E-01	5.04E-01
11		4	4.05E+00	1.03E+01	2.68E+00	4.72E-01	5.31E-01
12		4	4.04E+00	1.02E+01	2.84E+00	4.95E-01	5.57E-01

14		4	3.91E+00	9.93E+00	2.94E+00	5.19E-01	5.84E-01
15		4	3.91E+00	9.93E+00	3.10E+00	5.43E-01	6.10E-01
16		4	3.91E+00	9.93E+00	3.26E+00	5.66E-01	6.37E-01
17		4	3.91E+00	9.93E+00	3.43E+00	5.90E-01	6.64E-01
18		4	3.91E+00	9.93E+00	3.59E+00	6.14E-01	6.90E-01
19		4	3.91E+00	9.93E+00	3.75E+00	6.37E-01	7.17E-01
20		4	3.91E+00	9.93E+00	3.92E+00	6.61E-01	7.43E-01
21		4	3.91E+00	9.93E+00	4.08E+00	6.85E-01	7.70E-01
22		4	3.91E+00	9.93E+00	4.24E+00	7.08E-01	7.97E-01
23		4	3.91E+00	9.93E+00	4.40E+00	7.32E-01	8.23E-01
24		4	3.91E+00	9.93E+00	4.57E+00	7.56E-01	8.50E-01
25		4	3.91E+00	9.93E+00	4.73E+00	7.79E-01	8.76E-01
26		4	3.91E+00	9.93E+00	4.89E+00	8.03E-01	9.03E-01
27		4	3.91E+00	9.93E+00	5.06E+00	8.26E-01	9.30E-01
28		4	3.91E+00	9.93E+00	5.22E+00	8.50E-01	9.56E-01
2		4 1/2	4.63E+00	1.17E+01	1.37E+00	2.78E-01	3.13E-01
	2 1/8	4 1/2	4.78E+00	1.21E+01	1.39E+00	2.78E-01	3.13E-01
2 1/2		4 1/2	4.38E+00	1.11E+01	1.34E+00	2.78E-01	3.13E-01
	2 5/8	4 1/2	4.53E+00	1.15E+01	1.36E+00	2.78E-01	3.13E-01
3		4 1/2	4.56E+00	1.16E+01	1.55E+00	3.00E-01	3.38E-01
	3 1/8	4 1/2	4.26E+00	1.08E+01	1.32E+00	2.77E-01	3.11E-01
3 1/2		4 1/2	4.32E+00	1.10E+01	1.51E+00	3.00E-01	3.38E-01
	3 5/8	4 1/2	4.51E+00	1.14E+01	1.54E+00	3.00E-01	3.38E-01
4		4 1/2	4.70E+00	1.19E+01	1.81E+00	3.30E-01	3.71E-01
	4 1/8	4 1/2	4.26E+00	1.08E+01	1.50E+00	3.00E-01	3.38E-01
4 1/2		4 1/2	4.45E+00	1.13E+01	1.76E+00	3.30E-01	3.71E-01
5		4 1/2	4.64E+00	1.18E+01	1.99E+00	3.54E-01	3.98E-01
	5 1/8	4 1/2	4.38E+00	1.11E+01	1.75E+00	3.30E-01	3.71E-01
6		4 1/2	4.61E+00	1.17E+01	2.18E+00	3.77E-01	4.24E-01
	6 1/8	4 1/2	4.36E+00	1.11E+01	1.92E+00	3.54E-01	3.98E-01
7		4 1/2	4.61E+00	1.17E+01	2.37E+00	4.01E-01	4.51E-01
8		4 1/2	4.60E+00	1.17E+01	2.56E+00	4.24E-01	4.77E-01
9		4 1/2	4.62E+00	1.17E+01	2.76E+00	4.48E-01	5.04E-01
10		4 1/2	4.55E+00	1.15E+01	2.92E+00	4.72E-01	5.31E-01
11		4 1/2	4.55E+00	1.15E+01	3.11E+00	4.95E-01	5.57E-01
12		4 1/2	4.54E+00	1.15E+01	3.29E+00	5.19E-01	5.84E-01
14		4 1/2	4.41E+00	1.12E+01	3.41E+00	5.43E-01	6.10E-01
15		4 1/2	4.41E+00	1.12E+01	3.59E+00	5.66E-01	6.37E-01
16		4 1/2	4.41E+00	1.12E+01	3.77E+00	5.90E-01	6.64E-01
17		4 1/2	4.41E+00	1.12E+01	3.96E+00	6.14E-01	6.90E-01
18		4 1/2	4.41E+00	1.12E+01	4.14E+00	6.37E-01	7.17E-01
19		4 1/2	4.41E+00	1.12E+01	4.32E+00	6.61E-01	7.43E-01
20		4 1/2	4.41E+00	1.12E+01	4.51E+00	6.85E-01	7.70E-01
21		4 1/2	4.41E+00	1.12E+01	4.69E+00	7.08E-01	7.97E-01
22		4 1/2	4.41E+00	1.12E+01	4.88E+00	7.32E-01	8.23E-01
23		4 1/2	4.41E+00	1.12E+01	5.06E+00	7.56E-01	8.50E-01
24		4 1/2	4.41E+00	1.12E+01	5.24E+00	7.79E-01	8.76E-01
25		4 1/2	4.41E+00	1.12E+01	5.43E+00	8.03E-01	9.03E-01
26		4 1/2	4.41E+00	1.12E+01	5.61E+00	8.26E-01	9.30E-01
27		4 1/2	4.41E+00	1.12E+01	5.79E+00	8.50E-01	9.56E-01
2		5	5.10E+00	1.30E+01	1.61E+00	3.00E-01	3.38E-01
	2 1/8	5	5.26E+00	1.33E+01	1.63E+00	3.00E-01	3.38E-01
2 1/2		5	5.48E+00	1.39E+01	1.93E+00	3.30E-01	3.71E-01
	2 5/8	5	5.03E+00	1.28E+01	1.62E+00	3.01E-01	3.39E-01
3		5	5.19E+00	1.32E+01	1.89E+00	3.30E-01	3.71E-01
	3 1/8	5	5.38E+00	1.37E+01	1.92E+00	3.30E-01	3.71E-01
3 1/2		5	4.95E+00	1.26E+01	1.86E+00	3.30E-01	3.71E-01
	3 5/8	5	5.13E+00	1.30E+01	1.88E+00	3.30E-01	3.71E-01
4		5	5.20E+00	1.32E+01	2.11E+00	3.54E-01	3.98E-01
	4 1/8	5	4.88E+00	1.24E+01	1.84E+00	3.30E-01	3.71E-01
4 1/2		5	4.95E+00	1.26E+01	2.06E+00	3.54E-01	3.98E-01
5		5	5.14E+00	1.31E+01	2.31E+00	3.77E-01	4.24E-01
	5 1/8	5	5.38E+00	1.37E+01	2.37E+00	3.77E-01	4.24E-01
6		5	5.11E+00	1.30E+01	2.52E+00	4.01E-01	4.51E-01
	6 1/8	5	5.36E+00	1.36E+01	2.59E+00	4.01E-01	4.51E-01
7		5	5.11E+00	1.30E+01	2.73E+00	4.24E-01	4.77E-01
8		5	5.10E+00	1.29E+01	2.94E+00	4.48E-01	5.04E-01
9		5	5.12E+00	1.30E+01	3.16E+00	4.72E-01	5.31E-01
10		5	5.03E+00	1.28E+01	3.34E+00	4.95E-01	5.57E-01
11		5	5.05E+00	1.28E+01	3.55E+00	5.19E-01	5.84E-01
12		5	5.04E+00	1.28E+01	3.76E+00	5.43E-01	6.10E-01
14		5	4.91E+00	1.25E+01	3.89E+00	5.66E-01	6.37E-01
15		5	4.91E+00	1.25E+01	4.10E+00	5.90E-01	6.64E-01
16		5	4.91E+00	1.25E+01	4.30E+00	6.14E-01	6.90E-01
17		5	4.91E+00	1.25E+01	4.51E+00	6.37E-01	7.17E-01
18		5	4.91E+00	1.25E+01	4.71E+00	6.61E-01	7.43E-01
19		5	4.91E+00	1.25E+01	4.92E+00	6.85E-01	7.70E-01
20		5	4.91E+00	1.25E+01	5.12E+00	7.08E-01	7.97E-01
21		5	4.91E+00	1.25E+01	5.33E+00	7.32E-01	8.23E-01
22		5	4.91E+00	1.25E+01	5.53E+00	7.56E-01	8.50E-01
23		5	4.91E+00	1.25E+01	5.74E+00	7.79E-01	8.76E-01
24		5	4.91E+00	1.25E+01	5.94E+00	8.03E-01	9.03E-01
25		5	4.91E+00	1.25E+01	6.14E+00	8.26E-01	9.30E-01
26		5	4.91E+00	1.25E+01	6.35E+00	8.50E-01	9.56E-01
2		6	5.73E+00	1.45E+01	1.96E+00	3.30E-01	3.71E-01
2 1/2		6	6.48E+00	1.64E+01	2.56E+00	3.77E-01	4.24E-01
	2 5/8	6	6.13E+00	1.56E+01	2.25E+00	3.54E-01	3.98E-01
3		6	6.19E+00	1.57E+01	2.52E+00	3.77E-01	4.24E-01
	3 1/8	6	6.38E+00	1.62E+01	2.54E+00	3.77E-01	4.24E-01
3 1/2		6	5.95E+00	1.51E+01	2.48E+00	3.77E-01	4.24E-01
	3 5/8	6	6.13E+00	1.56E+01	2.51E+00	3.77E-01	4.24E-01
4		6	6.20E+00	1.57E+01	2.78E+00	4.01E-01	4.51E-01
	4 1/8	6	6.38E+00	1.62E+01	2.81E+00	4.01E-01	4.51E-01
4 1/2		6	5.95E+00	1.51E+01	2.73E+00	4.01E-01	4.51E-01
5		6	6.14E+00	1.56E+01	3.02E+00	4.24E-01	4.77E-01
	5 1/8	6	6.38E+00	1.62E+01	3.08E+00	4.24E-01	4.77E-01
6		6	6.11E+00	1.55E+01	3.27E+00	4.48E-01	5.04E-01
	6 1/8	6	6.36E+00	1.62E+01	3.34E+00	4.48E-01	5.04E-01
7		6	6.11E+00	1.55E+01	3.52E+00	4.72E-01	5.31E-01
8		6	6.10E+00	1.55E+01	3.77E+00	4.95E-01	5.57E-01
9		6	6.12E+00	1.55E+01	4.03E+00	5.19E-01	5.84E-01
10		6	6.03E+00	1.53E+01	4.25E+00	5.43E-01	6.10E-01
11		6	6.05E+00	1.54E+01	4.51E+00	5.66E-01	6.37E-01
12		6	6.04E+00	1.53E+01	4.76E+00	5.90E-01	6.64E-01
14		6	5.91E+00	1.50E+01	4.93E+00	6.14E-01	6.90E-01
15		6	5.91E+00	1.50E+01	5.18E+00	6.37E-01	7.17E-01
16		6	5.91E+00	1.50E+01	5.43E+00	6.61E-01	7.43E-01
17		6	5.91E+00	1.50E+01	5.67E+00	6.85E-01	7.70E-01
18		6	5.91E+00	1.50E+01	5.92E+00	7.08E-01	7.97E-01
19		6	5.91E+00	1.50E+01	6.16E+00	7.32E-01	8.23E-01
20		6	5.91E+00	1.50E+01	6.41E+00	7.56E-01	8.50E-01
21		6	5.91E+00	1.50E+01	6.66E+00	7.79E-01	8.76E-01
22		6	5.91E+00	1.50E+01	6.90E+00	8.03E-01	9.03E-01
23		6	5.91E+00	1.50E+01	7.15E+00	8.26E-01	9.30E-01
24		6	5.91E+00	1.50E+01	7.40E+00	8.50E-01	9.56E-01

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