Project Notes:

Project Title: Developing a Mobile Thermal Disposal System for On-Site Construction Wood Waste
Name: Prendergast, Ryan

Note Well: There are NO SHORT-cuts to reading journal articles and taking notes from them. Comprehension is paramount. You will most likely need to read it several times, so set aside enough time in your schedule.

Contents:

Knowledge Gaps:

This list provides a brief overview of the major knowledge gaps for this project, how they were resolved and where to find the information.

Knowledge Gap	Resolved By	Information is located	Date resolved
What is the average amount of Emissions produced from Trucks on Roads When Bringing Materials To a Landfill?	Research Article	Article #2 Notes	9-6-25
What is the temperature of burning wood? What type of safety precautions need to take place to keep all people safe around a fire burning in a metal container?	Research Article	Article #3 Notes	9-11-25
What are the effects on the o-zone when wood is burned	Research Article	Article #4 Notes	9-16-25
How does wood being left to sit in a landfill negatively affect the environment?	Research Article	Article #5 Notes	9-20-25
I want to make the final product both affordable and durable. What metals can I use to get the most amount of durability and how much more will that cost compared to the less durable option? Can I find a metal that	Review Article	Article #6 Notes	9-24-25

will work better for my application (heat applied directly from burning wood)?			
How can the metal hopper be designed to evenly distribute the heat from the burning wood? How do different layouts of metal distribute heat through a system when immense heat is within the metal?	Research Article	Article #7 Notes	9-28-25
Should something go wrong, what are my different options to put out the fire? How do methods like a fire extinguisher, water, and other methods compare?	Research Article	Article #8 Notes	10-2-25
What goes into something that is magnetized? Can I magnetize something that is just metal? How long does that magnetism last? How can I incorporate this to my design to make all the metal parts inside the wood get filtered out?	Research Article	Article #9 Notes	10-6-25
What wheels (or other method for movement) should I use for my project? What would work best when moving about 100 lbs that must support operating at high temperatures? What types of rubber and	Review Article	Article #10 Notes	10-10-25

other materials are there to choose from?			
How can my product work ergonomically? How can I design my product to encourage safe lifting to prevent injuries?	Journal Article	Article #11 Notes	10-18-25
I want to add spray paint to my final product to give it a nice finish. What should I look for in a spray paint to ensure it will continue to work at high temperatures? How will spray paint affect the tolerancing of my product? Should I disassemble everything and spray paint or just spray the final product?	Overview Article	Article #12 Notes	10-24-25
A product on a construction site needs to be durability. What forces might a product like this most likely experience on a construction site?	Journal Article	Article #13 Notes	10-30-25
How can an electric motor be integrated to the design to help it move? How can I use the motor to optimize efficiency and ease of use on the job site. How often would I have to charge it or change a battery?	Conference Article	Article #14 Notes	11-5-25
If I were to add an electric motor to assist with driving the	Journal Article	Article #15 Notes	11-11-25

product and a hydraulic system to assist with dumping, how will this affect my manufacturing costs? How much more would I have to charge for my product to add these premiums, and would it interest more (or less due to cost) people in the product? Would it be worth making two different tiers of devices, one with a motor and hydraulic system and one without?			
How would a hydraulic dump work? How do hydraulics work in general and are they worth adding to my design?	Conference Article	Article #16 Notes	11-23-25
If I add things like a motor and hydraulics, what type of maintenance am I looking at each year and how much will it likely cost. By how much does a motor and hydraulics increase the price of the product?	Journal Article	Article #17 Notes	11-29-25
What metals will work best for my project? What factors should I look at for casting and manufacturing methods? How does the molecular structure of atoms play a roll?	Review Video	Article #18 Notes	12-5-25
I simulated 5 different metals and found that	Journal Article	Article #19 Notes	12-11-25

the thermal gradient was the same for all for all of them. I want to investigate why I may have gotten these results.			
What should I do with the leftover ash? How has wood ash been used in the past and how can I incorporate it into my project?	Review Article	Article #20 Notes	12-14-25

Literature Search Parameters:

These searches were performed between 9-1-2025 and 2/12/2025.
List of keywords and databases used during this project.

Database/search engine	Keywords	Summary of search
Google	total transferring factor	Used to determine the total emissions for transportation of freight
Google	pyrolysis	The thermochemical decomposition of dry, organic materials in the absence of oxygen
Google	petrochemical	Chemical derived from petroleum (oil) or natural gas. It Is used as a building block for a wide range of products (plastics, synthetic rubbers, fabrics, and cosmetics).
Google	muffle material analysis	Type of furnace that preforms high-temperature material analysis by providing controlled, enclosed environments.
Google	calciner	Another type of furnace. This one uses high temperatures in a controlled atmosphere to chemically alter materials.
Google	creep-rupture	Failure of a material due to prolonged exposure to constant stress at elevated temperatures, even when stress is below the material's yield strength.

Tags:

Tag Name

Article #0 Notes: Blank Sample

Article notes should be on separate sheets

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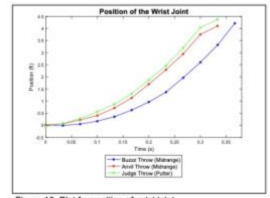
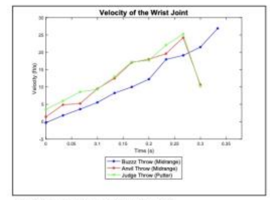
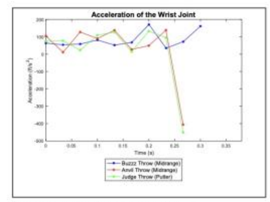
Source Title	
Source citation (APA Format)	
Original URL	
Source type	
Keywords	
#Tags	
Summary of key points + notes (include methodology)	
Research Question/Problem/ Need	
Important Figures	
VOCAB: (w/definition)	
Cited references to follow up on	
Follow up Questions	
Why I Researched	

Article #1 Notes: Analysis of Flight and Mechanics of Disc Golf Equipment

Source Title	Analysis of Flight and Mechanics of Disc Golf Equipment
Source citation (APA Format)	Stawarski, C. (2022). *Analysis of Flight and Mechanics of Disc Golf Equipment* (Honors thesis, Syracuse University). Renée Crown University Honors Thesis Projects. https://surface.syr.edu/honors_capstone/1714
Original URL	https://surface.syr.edu/cgi/viewcontent.cgi?article=2613&context=honors_capstone
Source type	Thesis
Keywords	Flight path, disc golf, spin rate, velocity, friction, air resistance, release angle
#Tags	#DiscGolf, #AerospaceEngineering, #Thesis, #FlightMechanics, #ThrowingDevice, #DiscFlight
Summary of key points + notes (include methodology)	Dr. Stawarski attempted to design a device to replicate a human's throwing of a disc golf disc. He did this in order to have a reliable way to test new discs and compare them properly. Video analysis was used to get the spin rate and exit velocity of the average disc golf player, which the machine would then be able to replicate. In the end, he was not able to get the machine to work because of friction and the differences between the machine and a human arm.
Research Question/Problem/ Need	Can Disc Golf manufactures use a device to regulate the statistics given to each disc so they are comparable between companies?

Important Figures	 *Figure 6: Path of disc through throwing motion*  *Figure 7: Path of wrist through throwing motion*  *Figure 8: Path of elbow through throwing motion*  *Figure 9: Path of shoulder through throwing motion*  *Figure 10: Plot for position of wrist joint*  *Figure 11: Plot for velocity of wrist joint*  *Figure 12: Plot for acceleration of wrist joint* Figure 6-9 shows the path different body parts take throughout a standard right hand backhand throw. This is used to help calculate the forces acting on the disc. Figures 10-12 show the same data seen in figures 6-9 but plotted on a graph.
VOCAB: (w/definition)	PDGA - Professional Disc Golf Association RHBH - Right Hand Backhand RHFH - Right Hand Forehand LHBH - Left Hand Backhand LHFH - Left Hand Forehand FPS - Frames Per Second RPM - Revolutions Per Minute Angle of attack – one of key parameters of a disc's release, defining its orientation relative to the direction of travel. Exit Velocity – Speed at which the disc leaves the thrower's hand or the throwing device. Fade – tendency for a disc to turn to the left at the end of flight, scale 0-5 for RHBH throw.
Cited references to follow up on	***https://link.springer.com/content/pdf/10.1007/s12283-023-00420-w.pdf*** https://infinitediscs.com/blog/disc-buying-guide/ https://discgolfunited.com/blog/post/disc-golf-flight-numbers
Follow up Questions	How can the machine test discs outdoors while removing/accounting for natural variables such as wind? How can performance estimates be better outlined to ensure that they are more accurate, resulting in a more successful product? What would be a better launch device other than wheels so that the launch better

	represents the theoretical calculations?
Why I Researched	Understand fundamentals of aerodynamics when applied to Disc Golf. See if 3D printable discs will be a good project.

Article #2 Notes: Analyzing the Freight Characteristics and Carbon Emission of Construction Waste Hauling Trucks: Big Data Analytics of Hong Kong

Source Title	Analyzing the Freight Characteristics and Carbon Emission of Construction Waste Hauling Trucks: Big Data Analytics of Hong Kong
Source citation (APA Format)	Wei, X., Ye, M., Yuan, L., Bi, W., & Lu, W. (2022). Analyzing the Freight Characteristics and Carbon Emission of Construction Waste Hauling Trucks: Big Data Analytics of Hong Kong. *International Journal of Environmental Research and Public Health*, *19*(4), 2318. https://doi.org/10.3390/ijerph19042318
Original URL	https://pmc.ncbi.nlm.nih.gov/articles/PMC8872571/pdf/ijerph-19-02318.pdf
Source type	Journal Article
Keywords	Freight Characteristics, Construction waste hauling trucks (CWHTs), Carbon emission, big data
#Tags	#CWHT #HongKong #FreightPerformance #CarbonEmission #BigDataAnalytics #UrbanLogistics #WasteManagement #SustainableTransport
Summary of key points + notes (include methodology)	Research Problem: Below Methodology: 1. Data collection – uses a big dataset from the Hong Kong Environmental Protection Department (HKEPD) for May 2015. Which includes 112,942 different construction waste transport trips. The dataset consists of 3 different parts: a. Construction waste disposal records b. Billing account information c. Vehicle information 2. Data processing – data was processed to match construction sites (origin) with disposal facilities (destinations). Geographic coordinates for each site and facility were obtained using

	Google Maps Geocoding Service, and trip lengths/durations were extracted using Auto Navi Map API. Outliers were removed and missing data was completed using mean values. 3. Analysis – Paper analysis freight performance metrics including vehicle type, transport weight, trip length, and trip duration. 4. Carbon Emission Measurement – "Bottom Up" method was used to calculate carbon emissions. This involved estimating energy consumption for both loaded and unloaded round trips by multiplying trip length by average energy consumption values based on gross vehicle weight. Energy consumption was then converted to carbon emissions (CO_2, NH_4, N_2O) using a total transferring factor derived from carbon emission factors and global warming potential (GWP) values. Key Findings: Daily trips – May 2015: 4,544 daily trips resulted with 307.64 tons of CO_2 emissions on working days. 553 trips resulted with 28.78 tons of CO_2 emissions on non working days. Vehicle usage – heavy trucks most used for trips to public fills while medium trucks are preferred for trips to landfill/sorting facilities. Trip length + duration – average trip length was about 26 km with most trips being short/medium distance (<30 km)/ Average trip duration is 36.15 min. Trip length found to be most influential factor for carbon emissions. Note: "trip" is from construction site to disposal facility, not round trip. Efficiency – trips to public fills had highest carbon emission (bad) efficiency while trips to landfill facilities had the lowest (good).
Research Question/Problem/ Need	There is a lack of documentation regarding the impact of construction waste hauling trucks (CWHTs) on urban transport systems and the environment. The article aims to analyze the freight characteristics and carbon emissions of these trucks to provide data for transport planning and emission reduction policies.

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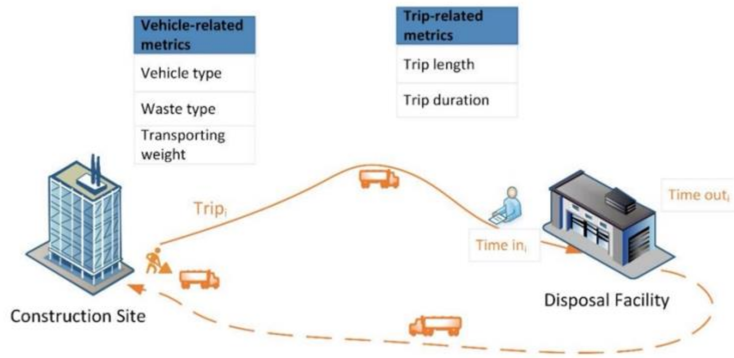

Figure 1: Diagram visually categorizes metrics analyzed in study.

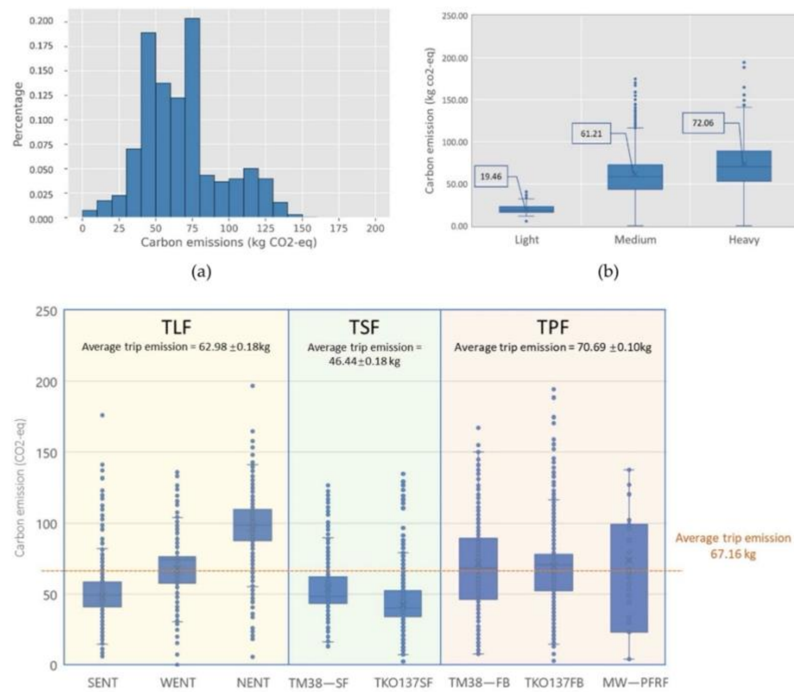

Figure 8: Carbon emission of CWHTs. Figure presents the distribution of carbon emissions per trip and by vehicle/trip type. It indicates that heavier trucks and TPF trips (trips to public fills) generate more emissions per trip.
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<td>VOCAB: (w/definition)</td>
<td>Carbon dioxide equivalents – standard unit for measuring carbon footprints. Quantifies total global warming potential of various greenhouse gases.
Permitted gross vehicle weight (PGVW) – max allowable weight for a vehicle, including load. Article uses PGVW to classify trucks into light, medium, and heavy trucks.
Bottom Up method – Method for estimating carbon emissions by calculating</td>
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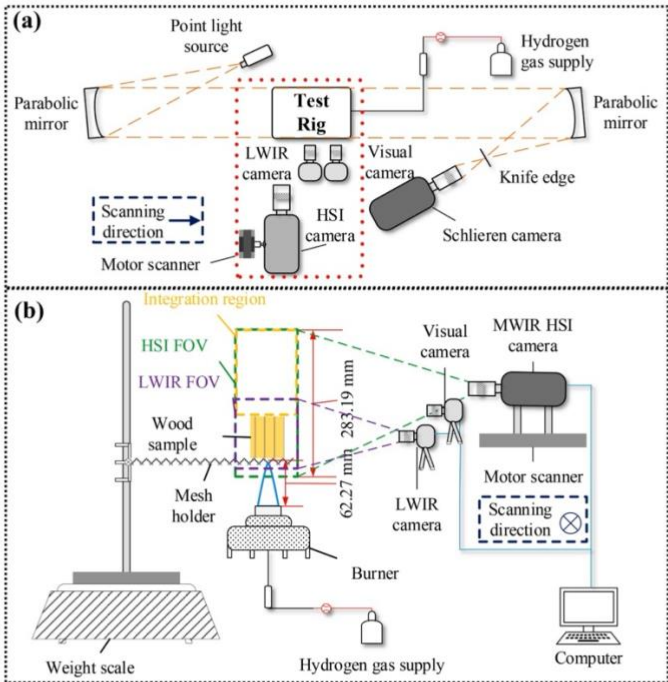
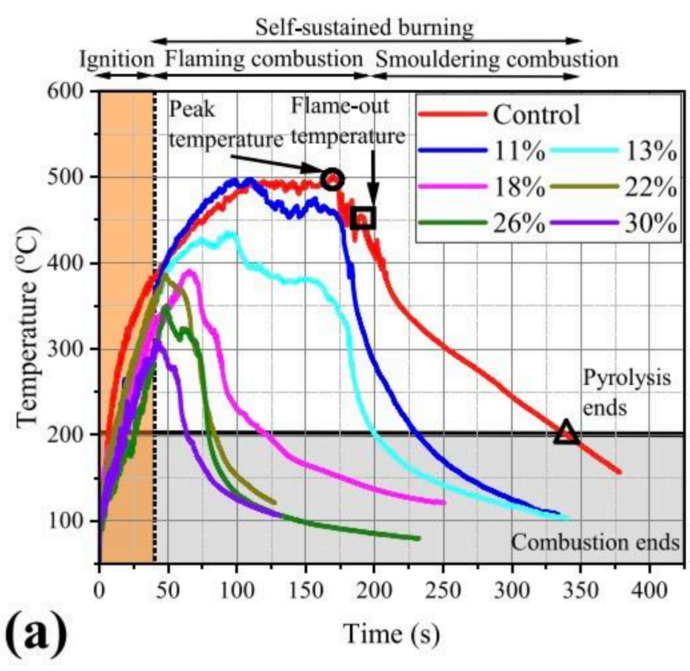
	fuel consumption and then applying regional carbon emission factors.
Cited references to follow up on	Beliën, J.; Boeck, L.D.; Ackere, J.V. Municipal Solid Waste Collection and Management Problems: A Literature Review. Transp. Sci. 2014, 48, 78–102. [CrossRef] Lu, W. Big data analytics to identify illegal construction waste dumping: A Hong Kong study. Resour. Conserv. Recycl. 2019, 141, 264–272. [CrossRef] Hao, H.; Geng, Y.; Li, W.; Guo, B. Energy consumption and GHG emissions from China's freight transport sector: Scenarios through 2050. Energy Policy 2015, 85, 94–101. [CrossRef]
Follow up Questions	How much less emotions will occur if we burn wood instead of transport with trucks that produce emissions? How much less space will be taken up if wood is burned instead of dumped?
Why I Researched	Baseline and selling point of why my product will work.

Article #3 Notes: Characterisation of wood combustion and emission under varying moisture contents using multiple imaging techniques

Source Title	Characterisation of wood combustion and emission under varying moisture contents using multiple imaging techniques
Source citation (APA Format)	Lai, Y., Liu, X., Davies, M., Fisk, C., Holliday, M., King, D., Zhang, Y., & Willmott, J. (2024). Characterisation of wood combustion and emission under varying moisture contents using multiple imaging techniques. *Fuel*, *373*, 132397. https://doi.org/10.1016/j.fuel.2024.132397
Original URL	https://www.sciencedirect.com/science/article/pii/S001623612401545X?ref=pdf_download&fr=RR-3&rr=9868068f289942b3
Source type	Journal Article
Keywords	Wood combustion Multiple imaging system MWIR hyperspectral imaging LWIR thermal imaging Moisture content Combustion dynamics
#Tags	#WoodCombustion, #MoistureContent, #HyperspectralImaging, #ThermalImaging, #CombustionDynamics, #Biomass, #Emissions, #EnergyScience
Summary of key points + notes (include methodology)	Methodology: Experimental Setup - The study used a pioneering multi-imaging system, which included four synchronized cameras: a visual camera, a Schlieren camera, a Long-Wavelength Infrared (LWIR) thermal imaging camera, and a Mid-Wavelength Infrared (MWIR) Hyperspectral Imaging (HSI) system. Sample Preparation - Natural oak wood was cut into cuboid samples. It was pre-dried at 100°C for 12 hours, then submerged in distilled water for 4–10 hours to achieve varying moisture contents (ranging from 0% to 30%). The samples were then vacuum-sealed for 48 hours to ensure uniform internal moisture. Combustion Process: Each wood sample was ignited for 40 seconds using a hydrogen burner (to avoid interfering with carbon-based spectral data). After

	ignition, the fuel supply was cut off, and the sample burned in a self-sustained manner. Data Analysis - The experiment recorded weight loss, thermal profiles, and spectral radiance of gas emissions. The ratio of spectral radiance was used to estimate relative changes in gas species. Key Findings: Combustion Efficiency - Higher moisture content led to decreased fuel consumption, with samples leaving a greater proportion of unburnt material. Gas Emissions - During the initial combustion stages, samples with higher moisture content showed higher ratios of CH_4 /CO_2 and CO/CO_2. This indicates reduced efficiency and incomplete combustion. Combustion Stages - High moisture content caused a quicker, more direct transition from flaming to smouldering combustion. Water evaporation suppressed the thermal pyrolysis of flammable gases. Drier samples sustained a longer flaming stage. Thermal Profiles - Samples with higher moisture content reached peak temperatures more quickly, but these peaks were lower than in drier samples. The duration of the high-temperature plateau (flaming combustion) was inversely proportional to moisture content. The self-sustained burning lifetime was also significantly reduced in wetter samples.
Research Question/Problem/ Need	Previous studies on wood combustion often focused on specific aspects like emissions or thermal efficiency, but lacked an approach to monitor the entire process. The complex dynamics of combustion stages must be better explored to get a better understanding of how wood burning and emissions are linked.

Important Figures	 Figure 1: Illustrates the experimental setup with the four imaging systems. Helps understand methodology.  Figure 4A: Shows the side surface temperature of wood samples over time, shown by their different moisture levels and peak temperatures. Drier samples peaked around 500C. Wetter Samples Peaked around 300C. 180C difference in peak temperature between 0% and 30%.

VOCAB: (w/definition)	Anisotropic - Material like wood that has properties that vary with direction. This makes it challenging to standardize moisture content. Hyperspectral Imaging (HSI) - An imaging technique that collects and processes information from across the electromagnetic spectrum. The MWIR HSI system used in the study imaged the emissions from the burning wood. Pyrolysis - The thermal decomposition of wood, which produces combustible gases. Smouldering - A form of combustion without a flame. Slower reaction. The study found that wetter samples transitioned to this stage more quickly. Spectral Radiance - The amount of radiation emitted by a source per unit area and solid angle. Used to quantify the emissions of gas species from the burning wood.
Cited references to follow up on	Dzurenda L, Banski A. The effect of firewood moisture content on the atmospheric thermal load by flue gases emitted by a boiler. Sustainability (Switzerland) 2019; 11(2). https://doi.org/10.3390/su11010284. Sjostr ¨ om ¨ J, Blomqvist P. Direct measurements of thermal properties of wood pellets: elevated temperatures, fine fractions and moisture content. Fuel 2014;134: 460–6. https://doi.org/10.1016/j.fuel.2014.05.088.
Follow up Questions	Do these peak temperatures change with different types of wood and different amounts? How can I test temperature of wood burning myself without expensive imaging equipment?
Why I Researched	Wanted to determine the peak temperatures of wood burning to see how strong I have to make my design. This will determine which kind of metal I decide to use.

Article #4 Notes: Quantifying greenhouse gas emissions from wood fuel use by households

Source Title	Quantifying greenhouse gas emissions from wood fuel use by households
Source citation (APA Format)	Flammini, A., Adzmir, H., Karl, K., & Tubiello, F. N. (2023). Quantifying greenhouse gas emissions from wood fuel use by households. *Earth System Science Data*, *15*(5), 2179–2187. https://doi.org/10.5194/essd-15-2179-2023
Original URL	https://essd.copernicus.org/articles/15/2179/2023/essd-15-2179-2023.pdf
Source type	Journal Article
Keywords	greenhouse gas emissions wood fuel non-renewable wood fuel harvesting agri-food value chain carbon offsets wood fuel consumption
#Tags	#GreenhouseGasEmissions #WoodFuel #HouseholdEmissions #NonRenewableBiomass #ClimateChange #SustainableForestry
Summary of key points + notes (include methodology)	Methodology: Data Sources - The study uses country-level data from the United Nations Statistics Division (UNSD) and the International Energy Agency (IEA) on household wood fuel use. Data gaps for certain countries, like China, were filled using data from the IEA. Emission Calculation - GHG emissions were calculated using the IPCC Tier 1 guidelines with the formula: $E_{i,g}=A_{i,y}\cdot f_{w}\cdot NRBf_{i}\cdot EF_{g}$. Variables: A (Activity Data) - Volume of wood fuel consumed in cubic meters, sourced from the UNSD Energy Statistics database. A calorific value

	of 11.2 GJ m^{-3} was applied to convert volume to energy. f_w (Share for Cooking) - Assumed to be 100% for tropical countries and 84.7% for non-tropical countries. NRBf (Non-Renewable Biomass Fraction) - Sourced from an evolution of the FAO's Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) model. A single NRBf value was used for each country for all years in the study. EF (Emission Factor) - IPCC (2006) default values were used for each gas (CH4 and N2O). Key Findings: Global Emissions - In 2019, annual emissions from non-renewable wood fuel for household food preparation were approximately 745 million tonnes which is about 6% higher than 1990 levels. Regional Trends - Emission increases were primarily driven by countries in sub-Saharan Africa, southern Asia, and Latin America. Significant decreases were observed in eastern and South-East Asia. Contribution to Food Systems - Emissions from non-renewable wood fuel constitute a significant portion of the total agri-food sector emissions, representing 36.3% of emissions from household food systems in 2019.
Research Question/Problem/ Need	The journal article aims to address the need to quantify greenhouse gas (GHG) emissions from wood fuel used by households, which are often overlooked or considered carbon-neutral. The study focuses on emissions from non-renewable wood fuel, which is wood harvested at a rate exceeding forest regrowth. The research aims to fill this gap in research and provide a more accurate picture of household emissions from wood burning.

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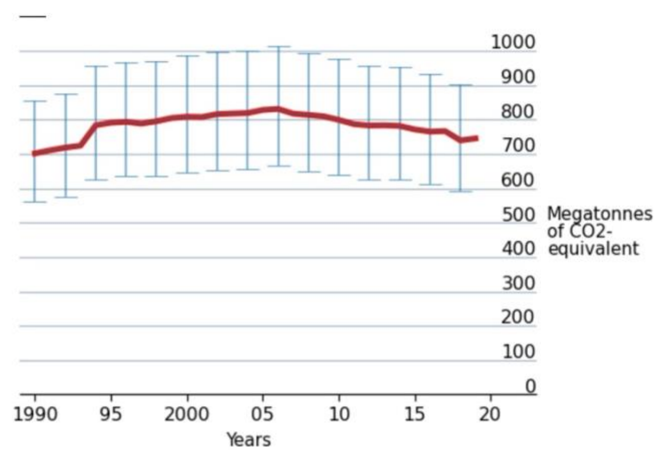

Figure 1: Shows the global GHG emissions from non-renewable wood fuel use from 1990 to 2019. The uncertainty range is shown with the vertical bars on the chart. They show the max and min possible emission estimates due to limitations with data.

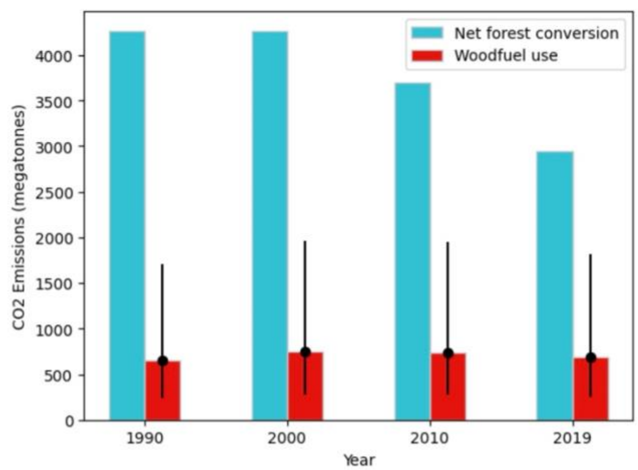

Figure 4: Compares trends of CO_2 emissions from net forest conversion and non-renewable wood fuel use. The graph shows that household wood fuel emissions were between 15% and 23% of global net forest conversion emissions from 1990 to 2019.
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Non-renewable biomass (NRB) - Woody biomass harvested at a rate that results in a long-term loss of carbon stocks, as the extraction rate is too high to allow for full regrowth.

NRB_f (Non-renewable biomass fraction) - The fraction or percentage of wood harvested that is considered non-renewable.

Calorific Value - The amount of energy released as heat during the complete combustion of a substance. The study uses an average calorific value of 11.2 GJ m^{-3} for wood fuel.
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Cited references to follow up on	Flammini, A., Pan, X., Tubiello, F. N., Qiu, S. Y., Rocha Souza, L., Quadrelli, R., Bracco, S., Benoit, P., and Sims, R.: Emissions of greenhouse gases from energy use in agriculture, forestry and fisheries: 1970–2019, Earth Syst. Sci. Data, 14, 811–821, https://doi.org/10.5194/essd-14-811-2022, 2022b. World Bank: Wood-Based Biomass Energy Development for SubSaharan Africa: Issues and Approaches, https://openknowledge. worldbank.org/handle/10986/26149 (last access: 24 April 2023), 2011. Flammini, A., Adzmir, H., Karl, K., and Tubiello, F.: Country greenhouse gas emissions from the non-renewable fraction of woodfuel used in households (1.0), Zenodo [data set], https://doi.org/10.5281/zenodo.7310933, 2022a.
Follow up Questions	Are there ways to minimize the amount of CO_2 released?
Why I Researched	I want to see if burning the wood is more effective than transporting + storing. Now I know both sides of the equation. Later on I will use math to determine what is better for the atmosphere.

Article #5 Notes: Decomposition of forest products buried in landfills

Source Title	Decomposition of forest products buried in landfills
Source citation (APA Format)	Wang, X., Padgett, J. M., Powell, J. S., & Barlaz, M. A. (2013). Decomposition of forest products buried in landfills. *Waste Management*, *33*(10), 2267–2276. https://doi.org/10.1016/j.wasman.2013.07.009
Original URL	https://www.sciencedirect.com/science/article/abs/pii/S0956053X13003371?via%3Dihub
Source type	Journal Article
Keywords	Landfills Municipal solid waste Forest products Anaerobic decomposition Biogenic carbon storage
#Tags	#Landfills #WasteManagement #ForestProducts #AnaerobicDecomposition #CarbonStorage
Summary of key points + notes (include methodology)	Methodology: Materials - Researchers buried samples of various wood and paper products, including hardwood (HW), softwood (SW), plywood (PW), oriented strand board (OSB), particleboard (PB), medium-density fiberboard (MDF), newsprint (NP), corrugated container (CC), and copy paper (CP). Site Selection - Samples were buried in two commercial landfills, Uwharrie Environmental Landfill in North Carolina and Maplewood Landfill in Virginia, both of which used leachate recirculation to accelerate decomposition. Burial and Excavation - Samples were buried in June 2007 and May 2009. They were excavated after approximately 1.5 and 2.5 years. Analysis - Excavated samples were analyzed for cellulose (C), hemicellulose (H), lignin (L), volatile solids (VS), and organic carbon (OC). Metrics - The extent of decomposition was evaluated using a holocellulose decomposition index (HOD), while a carbon storage factor (CSF) was used to

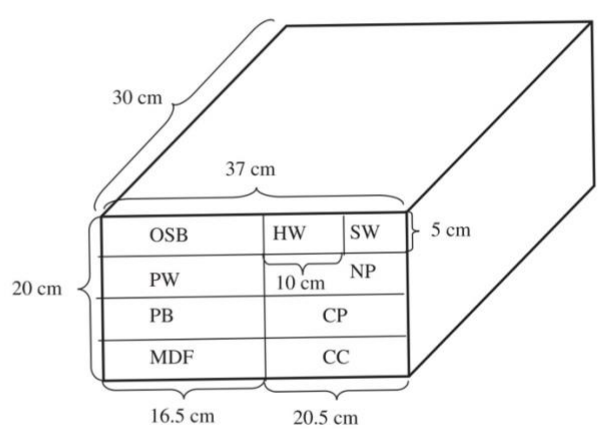
	quantify carbon storage. Key Findings: Decomposition Rates - The decomposition of paper products was significantly higher than that of wood products. Paper - Holocellulose (C+H) loss was up to 81% for newsprint (NP), 95% for copy paper (CP), and 96% for corrugated container (CC). No CP or CC samples were recognizable in one landfill, suggesting complete biodegradation. Wood - C+H loss for most wood types was only 0-10%. Oriented strand board made from hardwood (OSB-HW) showed the most loss, up to 38%. Carbon Storage - The carbon storage factors (CSFs) for wood products ranged from 0.34 to 0.47 g OCg^{-1} dry material. For paper products, CSFs ranged from 0.02 to 0.27 g OCg^{-1} dry material. These values indicate that wood products store significantly more carbon over time than paper products. Decomposition Indicators - Lignin content plays a crucial role, as it is recalcitrant and acts as a barrier to the biodegradation of cellulose and hemicellulose. Visual inspection was found to be an unreliable indicator of decomposition alone; chemical characterization was necessary to quantify biodegradation.
Research Question/Problem/ Need	How does decomposition of wood and paper products occur in landfills? To what degree does decomposition take place? This is important for estimating national methane emissions, calculating carbon storage credits, and assessing the life-cycle greenhouse gas impacts of these products.
Important Figures	

Figure 1: Schematic shows the design of the metal cages used in the Maplewood landfill. It illustrates how different wood and paper materials were compartmentalized for burial.

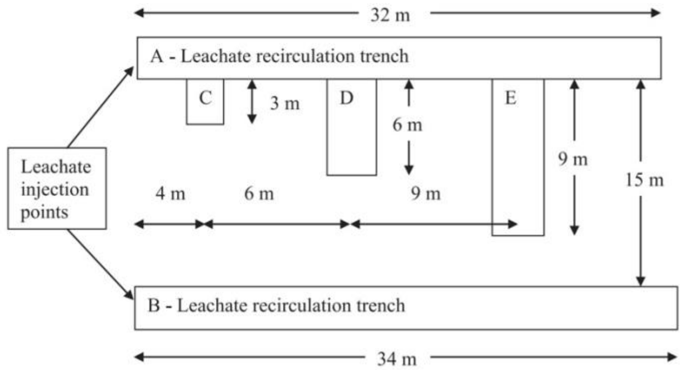


Figure 2: Shows the leachate recirculation trenches at the Uwharrie landfill. It shows the injection points.

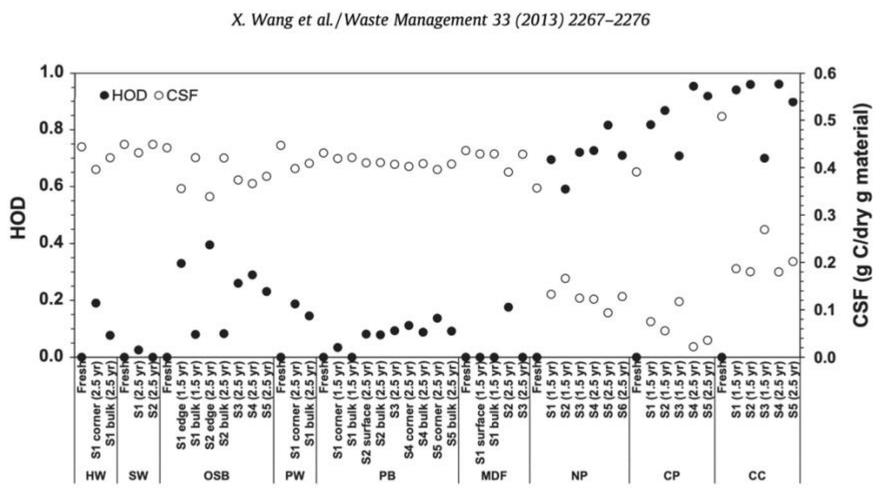


Figure 5: Scatter plot displays the holocellulose decomposition indices (HODs) and carbon storage factors (CSFs) for samples excavated from the Uwharrie landfill. It shows the relationship between decomposition and carbon storage.

VOCAB: (w/definition)

Anaerobic decomposition - The breakdown of organic materials by microorganisms in the absence of oxygen. In landfills, this process generates biogenic methane and carbon dioxide.

Biogenic carbon sink - The portion of biogenic carbon in wood and paper products that does not decompose in a landfill and thus remains sequestered.

Cellulose (C) and Hemicellulose (H) - Major polymeric components of wood and paper that

	are microbially converted to methane and carbon dioxide under anaerobic conditions. Holocellulose decomposition index (HOD) - A calculated index that quantifies the extent of decomposition of cellulose and hemicellulose. An HOD of 0 indicates no degradation, while 1.0 means all holocellulose has degraded. Lignin (L) - A complex polymer in wood that is highly resistant to anaerobic degradation. It acts as a barrier to the decomposition of cellulose and hemicellulose. Carbon storage factor (CSF) - The mass of carbon that remains un-degraded per initial dry mass of a material. It decreases as a material decomposes. Leachate recirculation - A landfill operation technique where the liquid that has passed through the waste (leachate) is collected and reinjected into the landfill to accelerate decomposition.
Cited references to follow up on	http://refhub.elsevier.com/S0956-053X(13)00337-1/h0005 http://refhub.elsevier.com/S0956-053X(13)00337-1/h0030
Follow up Questions	How much wood is deposited in landfills every year? Is the amount of wood going to landfills increasing? If so, what is a good plan for when there is so much wood that decomposition can never catch up?
Why I Researched	I am trying to determine the level (quantified level) of a problem that wood is in landfills.

Article #6 Notes: Heat resistant alloys: Selection and failure avoidance

Source Title	Heat resistant alloys: Selection and failure avoidance
Source citation (APA Format)	Wilson, J., Wachowiak, D., Pollard, S., & Huang, A. (2008). Heat resistant alloys: Selection and failure avoidance. *Stainless Steel World*, 2267–2276. https://www.rolledalloys.com/wp-content/uploads/Heat-Resistant-Alloys-Selection-and-Failure-Avoidance-rolled-alloys.pdf
Original URL	https://www.rolledalloys.com/wp-content/uploads/Heat-Resistant-Alloys-Selection-and-Failure-Avoidance-rolled-alloys.pdf
Source type	Review Article
Keywords	Heat resistant alloys High temperature corrosion Mechanical failure Creep-rupture strength Distortion Oxidation (Scaling)
#Tags	#HeatResistantAlloys #MaterialsSelection #Corrosion #MechanicalFailure #CreepRupture #ThermalFatigue #HighTemperatureApplications #MaterialAnnalysis
Summary of key points + notes (include methodology)	Heat-resistant stainless steels and nickel-based alloys are commonly used in the petrochemical, metal treating, power generation, and incineration industries. These components require replacement every now and then, making the extension of their useful life an important way to dramatically reduce maintenance costs, especially with rising alloy costs. Heat-resistant alloy fabrications typically fail due to either high-temperature corrosion (like oxidation) or mechanical failure (like creep or distortion). Maximum operating temperatures are typically based on when the rate of scaling from oxidation becomes unacceptable (often several hundred degrees below the alloy's melting point).

Scaling rates were tested using cyclic oxidation over 3000 hours.

Creep-Rupture Strength must be considered for long-term service at temperatures above 1000°F. Values are reported as average stress to rupture for 10,000 hours at various temperatures.

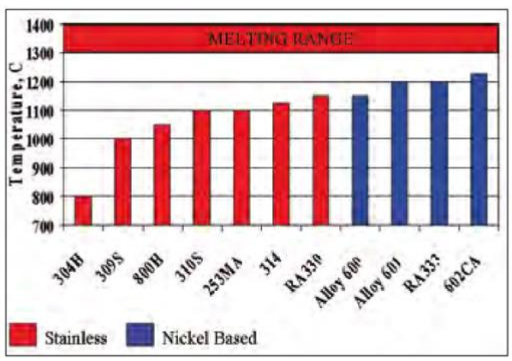
Distortion and warpage are common due to the alloys' low thermal conductivity and high rates of thermal expansion.

Research Question/Problem/ Need

What are the most common failures due to heat in stainless steel and nickel based alloys?

The paper's goal is to reduce maintenance costs by understanding and addressing common causes for failure in heat-resistant stainless steel and nickel-based alloys. It seeks to enable people to understand the balance of price and durability so they can make educated decisions for themselves when choosing an alloy.

Important Figures



Suggested temperature limits for some heat resistant alloys.
Suggested maximum operating temperatures are well below the 1300°C to 1400°C melting range.

Table 2: 10,000 Hour, average stress for rupture, psi (MPa)[1]

Alloy	1700°F=927°C	1800°F=982°C	1900°F=1038°C	2000°F=1093°C
310 Stainless	940 (6.5)	660 (4.6)	-	-
253MA	1,650 (11.4)	1,150 (7.9)	860 (5.9)	680 (4.7)
Alloy 800H	1,900 (13.1)	1,200 (8.3)	-	-
RA330	1,050 (7.2)	630 (4.3)	400 (2.8)	280 (1.9)
Alloy 600	1,650 (11.4)	450 (3.1)	-	-
Alloy 601	-	1,200 (8.3)	-	620 (4.3)
602CA	2,180 (15.0)	1,490 (10.3)	990 (6.8)	670 (4.6)

Over 10,000 hours, the data table shows the average stress required

	for a rupture in psi and MPa. The table shows long-term strength data for various alloys, demonstrating the rapid decrease in strength with increasing temperature.
VOCAB: (w/definition)	Oxidation (Scaling): High-temperature corrosion where an alloy reacts with oxygen, forming a protective oxide scale (primarily chromium-based). The scaling rate determines the alloy's max service temperature. Creep: A mechanical failure mode involving the slow, permanent deformation of a material under continuous stress at temperatures above 1000 Creep-Rupture Strength: The stress required to cause a material to fracture after a specific long-term period (like 10,000 hours) at a given high temperature. Distortion: A mechanical failure occurs due to uneven heating, poor thermal conductivity, and high thermal expansion.
Cited references to follow up on	Special Metals Publication SMC 047 (2004 rev). Andersson, “High Temperature Properties and Corrosion Resistance of a 21 Cr-11Ni Stainless Steel Alloyed with Silicon, Nitrogen, and Rare Earths”, Paper 129, Corrosion 1979. J. Wilson, D.C. Agarwal, “Case histories of successful application of alloy 602CA (UNS06025) in high temperature environments” paper 05423, Corrosion 2005.
Follow up Questions	Beyond creep and distortion, what are the characteristics and avoidance strategies for Thermal fatigue and Metal dusting/carbon rot mentioned as other common failure modes? How do the chemical compositions of key alloys like 602CA (high strength) and 310 Stainless (lower strength) account for their differences in creep-rupture performance?
Why I Researched	Burn barrel will be a metal hopper to put the wood into while it burns. That metal has to be able to resist the fire which is about 2000°F. I wanted to determine how different layouts of metal distribute heat through a system when immense heat is within the metal. I wanted to look at the science of heat transfer throughout systems with the source of heat being internal..

Article #7 Notes: Comparative Study of Heat Transfer Simulation and Effects of Different Scrap Steel Preheating Methods

Source Title	Comparative Study of Heat Transfer Simulation and Effects of Different Scrap Steel Preheating Methods
Source citation (APA Format)	Xiao, P., Jin, Y., Zhu, L., Wang, C., & Zhu, R. (2024). Comparative Study of Heat Transfer Simulation and Effects of Different Scrap Steel Preheating Methods. *Metals, 14*(8), 913. https://doi.org/10.3390/met14080913
Original URL	https://www.mdpi.com/2075-4701/14/8/913
Source type	Journal Article
Keywords	Converter steelmaking Temperature field Numerical simulation High scrap ratio
#Tags	#Steelmaking #ScrapPreheating #WasteHeatRecovery #ShaftFurnace #EnergyEfficiency #CarbonReduction #NumericalSimulation
Summary of key points + notes (include methodology)	China's steel industry relies on blast furnaces (more than 90% of steel production). To meet the global objective of reducing carbon emissions and to enhance efficiency, there is a strategy to increase the scrap ratio in converters. Increasing the scrap ratio lessens the heat input in the converter. This improves scrap preheating technologies to maintain the tapping temperature. Current scrap preheating is primarily done using horizontal tunnel furnaces, which have the side effects of high energy consumption and low efficiency. The study designed and numerically simulated a new three-stage vertical shaft furnace for scrap preheating to address the low efficiency and high energy consumption of traditional horizontal furnaces.

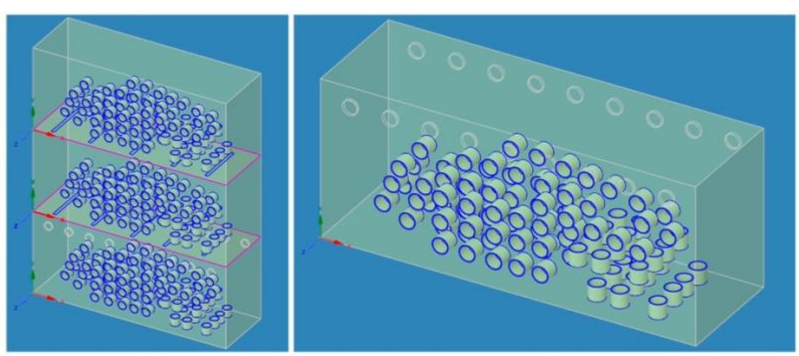
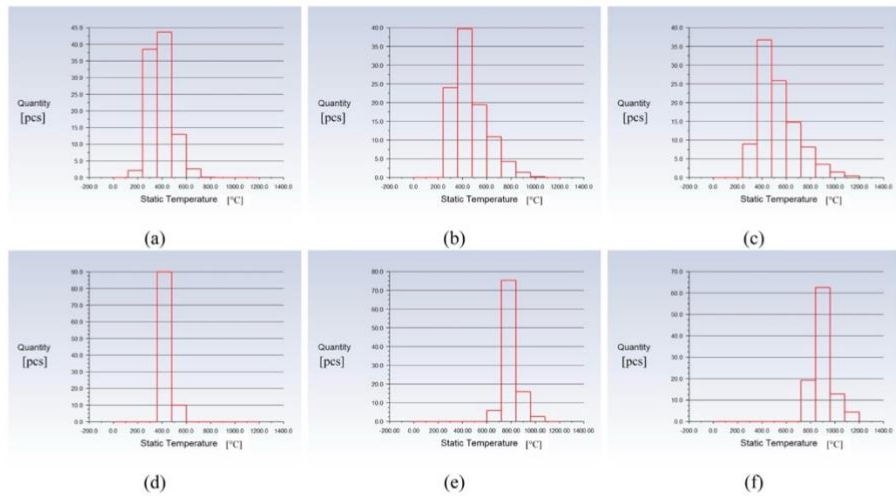
	Model - A three-dimensional model was developed for both the new vertical shaft furnace and the traditional horizontal furnace using Fluent simulation software. Comparison - The preheating efficiency of the two furnaces was compared across varying operational conditions, specifically preheating durations (600 s, 900 s, 1200 s) and initial gas velocities (5 m/s, 7 m/s, 9 m/s). Assumptions - The scrap was simplified into regular, smooth circular tubes. The inlet flue gas temperature was assumed to be constant. Validation - Simulation results were validated against actual production temperatures measured at a steel plant. The result showed a close correlation. Conclusion - The vertical shaft furnace demonstrates significantly superior performance in both scrap temperature achievement and heat absorption efficiency compared to the traditional horizontal furnace under identical gas heat consumption conditions. The vertical design addresses the issue of localized overheating and suboptimal core temperatures common in horizontal furnaces, leading to a more even temperature distribution. Appropriately increasing gas velocity can effectively raise preheating temperature in practical production environments.
Research Question/Problem/ Need	The article aims to address the high energy consumption and low efficiency of the current, predominantly utilized horizontal tunnel furnaces for scrap steel preheating. The need is to design and evaluate a method to improve preheating efficiency and heat utilization to thermally compensate for an increased scrap ratio in converter steelmaking.
Important Figures	 (a) (b)

	Figure 2 shows the two different models used in the simulation. A depicts the new proposed design while B depicts the current design.  Figure 9 provides a visual to show how temperature distribution of scrap at different gas velocities are similar. The graphs show each temperature on the x axis and the amount of metals that were within this static temperature category on the y axis.
VOCAB: (w/definition)	Converter Steelmaking: Process that involves charging materials, primarily molten iron and scrap steel, into a converter to produce steel. Scrap Ratio: The proportion of scrap steel (relative to molten iron) charged into the converter, where using this ratio is a strategy to lower expenses and cut carbon emissions. Shaft Furnace (Three-stage vertical furnace): A vertical furnace system designed for scrap preheating where flue gas from the bottom layer ascends, allowing the middle and upper layers to absorb waste heat in a continuous and multi stage process. Fluent Software: Computational Fluid Dynamics (CFD) software used to develop the three-dimensional models and simulate the heat transfer in the furnaces. Waste Heat Utilization Rate: A measure of the efficiency of the furnace in absorbing waste heat carried by the flue gas to increase the scrap temperature.
Cited references to follow up on	Schubert, C.; BÃ¼schgens, D.; Eickhoff, M.; Echterhof, T.; Pfeifer, H. Development of a Fast Modeling Approach for the Prediction of Scrap Preheating in Continuously Charged Metallurgical Recycling Processes. Metals 2021, 11, 1280. [CrossRef] Zhang, L.; Fang, Q.; Zhou, W.; Wang, J.; Yu, G.; Zhang, H.; Ni, H. Numerical simulation on the melting behaviors of steel scrap in

	a ladle with bottom argon blowing . Chin. J. Eng. 2024, 46, 822–834. [CrossRef]
Follow up Questions	The vertical furnace achieves peak efficiency at a gas velocity of 9 m/s. What are the practical or economic trade offs (like fan energy cost or refractory wear) of operating the furnace at this maximum velocity? The simulation assumed the inlet flue gas temperature is constant. How does this change the model when transitioning the theory into practical tests where the temperature is not constant?
Why I Researched	I researched to find out how heating of metals works. I want to know where high heat stresses will impact the longevity of my product and how I can design it to mitigate this mechanical overload.

Article #8 Notes: Thermal characteristics of fire extinguishing agents in compartment fire suppression

Source Title	Thermal characteristics of fire extinguishing agents in compartment fire suppression
Source citation (APA Format)	Kim, T.-S., Park, T.-H., Park, J.-H., Yang, J.-H., Han, D.-H., Lee, B.-C., & Kwon, J.-S. (2024). Thermal characteristics of fire extinguishing agents in compartment fire suppression. *Science Progress*, *107*(3), 1–16. https://journals.sagepub.com/doi/full/10.1177/00368504241263435
Original URL	https://journals.sagepub.com/doi/full/10.1177/00368504241263435
Source type	Journal Article
Keywords	Fire foam, foam agent, compressed air foam, foam microstructure, radiant heat flux
#Tags	#FireExtinguishingAgents #CAF #TraditionalFoam #CompartmentFire #ThermalCharacteristics #RadiantHeatShielding
Summary of key points + notes (include methodology)	Background: Water is the most common fire-extinguishing agent. However, foam is considered an alternative when water is unavailable or ineffective. Foam works through oxygen suffocation and a cooling effect. Its lower surface tension allows for faster heat absorption. Compressed Air Foam (CAF) systems are widely used and create foam with a higher density and more complete bubble structure than traditional foam systems. They do this by mixing a water-foam solution with compressed air. The bubbles in CAF are surrounded by a thin water film, allowing them to absorb more heat than the same volume of just water. The physical properties of foam, like expansion ratio and bubble size, are crucial for its effectiveness. The study compared the thermal characteristics of internal cooling, burnback resistance, and radiant-heat-shielding across water, traditional foam, and Compressed Air Foam (CAF) during a full-scale compartment fire suppression experiment. Agents Tested: Water, Traditional Foam (synthetic surfactant 3%, expansion ratio 780), and Compressed Air Foam (CAF) (synthetic

<table>
<tr><td></td><td>surfactant 3%, expansion ratio 780, air-to-foam solution ratio 1:9).

Experimental Setup: An area (6 m × 3 m × 3 m) with a gasoline pool fire and wooden/polyurethane foam combustibles were used.

Procedure: Once the internal temperature reached approximately 800℃, each fire suppression method was first applied to the outer wall of the compartment (to evaluate internal cooling and burnback resistance) and then directed into the compartment from the opening (to evaluate radiant heat shielding).

Measurement: Temperature was recorded by thermocouples (TCs) inside and outside the compartment. Radiant heat flux was measured outside the opening.

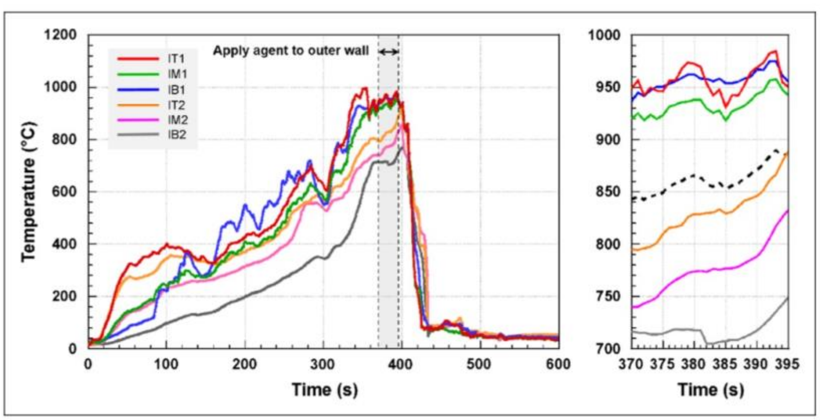
Conclusion: Foam agents, particularly CAF, are superior to water in terms of cooling, burnback resistance, and radiant heat shielding. CAF's denser bubbles and higher heat resistance allow its barrier effect to last significantly longer on hot surfaces. The thermal effect of CAF, even when applied to the outer walls, is valuable for lowering internal room temperature in actual firefighting scenarios.</td></tr>
<tr><td>Research Question/Problem/ Need</td><td>Traditional foam and CAF have different bubble structures and extinguishing mechanisms. This results in different thermal characteristics that affect fire-extinguishing abilities. The existing small-scale research results are often inapplicable to actual fire situations. All of this is to denote the differences in the thermal characteristics (cooling, burnback resistance, and radiant-heat-blocking effect) of water, traditional foam, and CAF during compartment fire suppression.</td></tr>
<tr><td>Important Figures</td><td>

Figure 6</td></tr>
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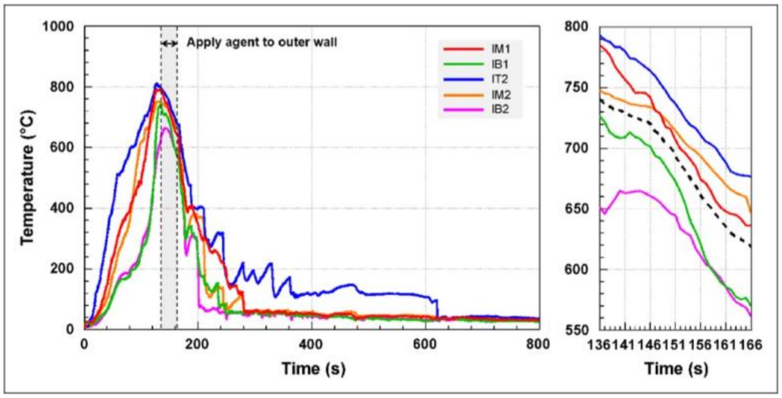

Figure 8

Figure 8 shows the rapid and constant decrease of temperature after the CAF was applied. This strongly contrasts the water in figure 6 which had a limited effect suppressing the fire.

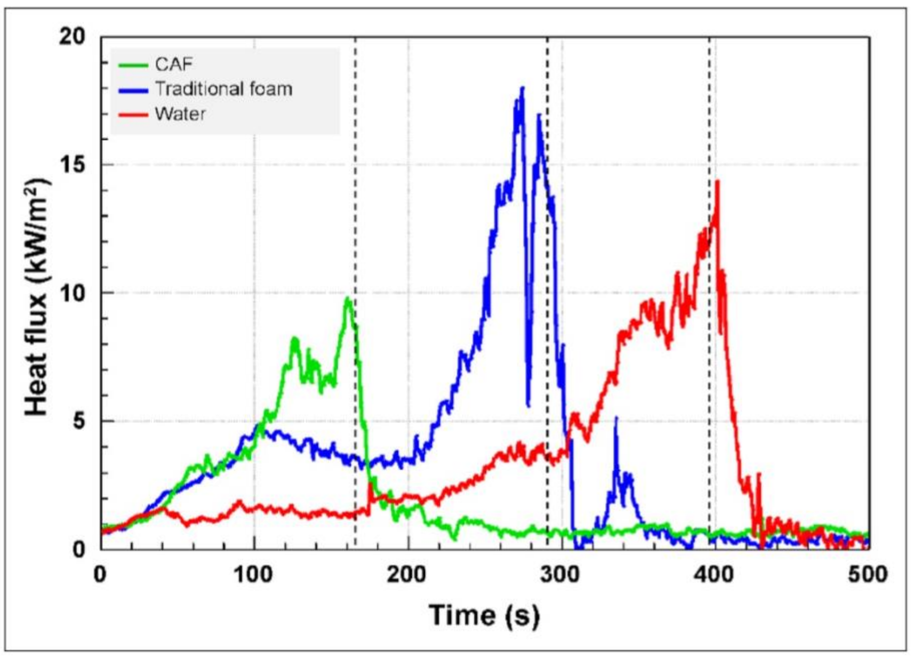

Figure 10 shows the radiant heat flux of each suppression method measured over time. The graph clearly shows that both types of foam were much more effective at providing a radiant heat shield during the early stage of suppression.

VOCAB: (w/definition)

Compressed Air Foam (CAF): A high-density, uniform foam created by actively injecting compressed air bubbles into a water-foam solution in a mixing chamber.

Traditional Foam: Foam created by an air-aspirating discharge device that aspirates and mixes air into the foaming solution, typically resulting in a lower density compared to CAF.

	Burnback Resistance: The ability of an extinguishing agent to resist vaporization and maintain its barrier properties on a hot surface, delaying the re-rise of temperature and potential re-ignition. Radiant Heat Flux: The rate of thermal energy transfer per unit area exposed to a fire, measured to evaluate an agent's heat-shielding effect for firefighters. Internal Cooling: The effect of applying an extinguishing agent to the exterior walls of a compartment to reduce the temperature inside the burning room.
Cited references to follow up on	Fengyuan T, Jun F, Lulu F, et al. Experimental study on mass loss mechanism and cooling effect of compressed air foam on fuel surface at different temperatures. Case Stud Therm Eng 2023; 52: 103747. Lee YK, Kim YS, Kang YS, et al. A study on the evaluation of re extinguishing performance of a synthetic surfactant compressed air foam with scaled model. Korean Soc Hazard Mitig 2017; 17: 269–276. Park TH, Kim TS, Park JH, et al. Experiments on the application of class A and B fires to derive the optimum air ratio of compressed air foam systems. Fire Sci Eng 2023; 37: 38–43.
Follow up Questions	How do the bubble size distribution and expansion ratio affect the radiant-heat-blocking effects of CAF versus traditional foam? Does the total extinguishment time in Table 3 (188 s for water, 186 s for traditional foam, 331 s for CAF) suggest a trade-off between the foam's thermal properties (slower cooling) and its longer-lasting barrier effect? The study used a 1.0% foam-to-water ratio for the Class A foam. How would varying the foam-to-water ratio impact the measured thermal characteristics of CAF and its overall performance?
Why I Researched	I wanted to determine what extinguishing methods would be best for testing. Even though CAF is by far the best option highlighted in the paper, a machine that can produce CAF costs close to $10k. Therefore, I will most likely stick to traditional foam and water, determining which one will be most effective for the application before each test.

Article #9 Notes: Magnetization of Metal Mesh for Fine Dust Capture

Source Title	Magnetization of Metal Mesh for Fine Dust Capture
Source citation (APA Format)	Choi, S. I., Feng, J., Kim, S. B., & Jo, Y. M. (2018). Magnetization of metal mesh for fine dust capture. *Aerosol and Air Quality Research*, *18*(8), 1932–1943. https://doi.org/10.4209/aaqr.2017.11.0491
Original URL	https://aaqr.org/articles/aaqr-17-11-2017aac-0491
Source type	Research Article
Keywords	Magnetic filter; Fine dust; Metal mesh; Pressure drop; Filtration
#Tags	#MagneticFiltration #FineDustCapture #AirQuality #IronCompounds #PermanentMagnets
Summary of key points + notes (include methodology)	Fine dust, particularly PM10 and PM 2.5, can penetrate human lungs and lead to severe health issues. Major fine dust sources include coal-fired power plants, automobiles, and metro-subways. Fine dust can be captured by filtration devices using mechanisms like electrostatic or magnetic forces. Previous magnetic separation studies typically used external power to form a magnetic field, limiting their wide application. This study addresses that by using permanent magnets to form the magnetic field. Iron compounds like FeO, Fe_3O_4, and Fe_2O_3 (maghemite) are favorable for magnetic attraction. Filter Preparation: Test filters were prepared by magnetizing a stainless woven mesh with varying thicknesses of rectangular permanent magnets (1,750 G, 2,500 G, and 3,000 G). A repulsive design (same poles confronting) was used to force the magnetic field into the mesh center. Test Dusts: Three field dusts were tested: fly ash (coal-fired power plant), subway dust (metro subway), and boiler dust (urban

	integrated power plant). Iron content: Subway dust (25.24%), Boiler dust (12.01%), Fly ash (8.66%). Chemical analysis (XRD) identified ferromagnetic and diamagnetic components (like hematite) to predict magnetic capture potential. Filtration Test: A lab-scale setup used dry air to pneumatically convey dust through the filter at 0.5 m/s. Total collection efficiency (ϵ) and grade efficiency ($\epsilon(x)$) were measured by weighing dust and measuring size distribution. Conclusion: The study confirmed that it is possible to have a magnetized metal mesh filter with permanent magnets for fine dust control without needing an external power source. The intensity of the source magnets is directly related to dust capturing efficiency. The structure of the dust (like the presence of highly magnetic iron compounds) was found to be more effective for magnetic capture than the total elemental iron composition. The filters improved fine dust capture with a low pressure resistance.
Research Question/Problem/ Need	Traditional magnetic dust collection methods require external power to form a magnetic field, which limits their widespread application for field dust control processes. The study's aim was to investigate the magnetic capture of fine dust containing iron compounds using a metal mesh magnetized by permanent magnets. The researchers sought to develop a permanent magnet solution for specific situations (coal-fired power plant, metro-subway, urban energy plant) to assess the feasibility of magnetic collection in an open-space system.

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<td>Important Figures</td>
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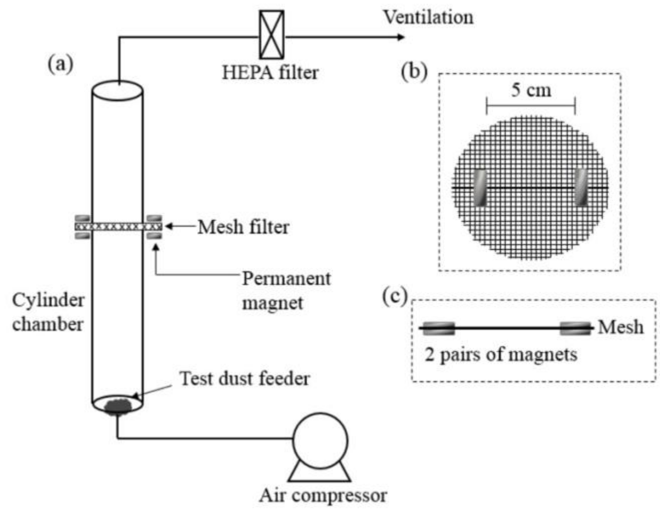

Figure 1 shows the setup for the filter. It is a diagram of the lab-scale test that shows the mesh filter, permeant magnet, along with all other key components. The diagram visualizes the concept of indirect magnetization.

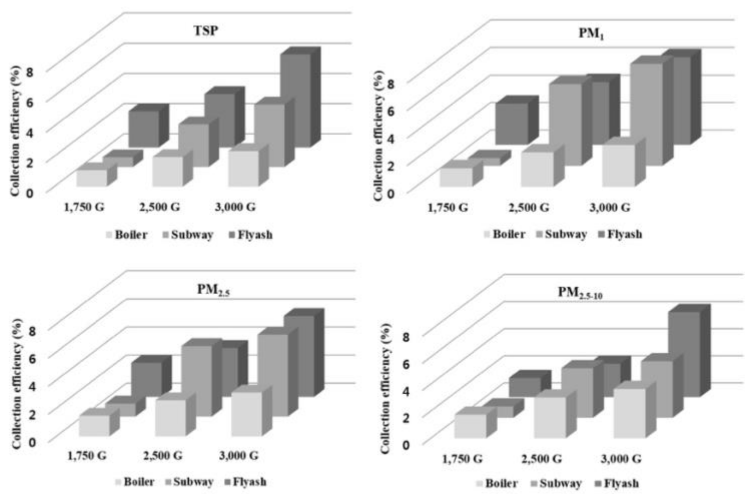

Figure 13 show a summary of all the collected data. It shows the collection efficiency of each type of dust at each magnet field strengths. The figure shows all these values 4 times, because the tests were run on multiple different intensities of source magnets.
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<td>VOCAB: (w/definition)</td>
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PM^1: Particulate matter smaller than 1µm.

TSP (Total Suspended Particulate Matters): The total weight of dust particles suspended in the air.

Maghemite (Fe_2O_3) and Magnetite (Fe_3O_4): Iron oxides classified as ferromagnetic substances that are highly favorable for magnetic attraction.
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	Hematite ($\alpha-Fe_2O_3$): An iron oxide known to be a diamagnetic substance. This means it does not strongly respond to an external magnetic field and is less susceptible to magnetic capture. Repulsive Force: The magnetic configuration used in the study (same poles facing each other) to enforce the magnetic field into the mesh filter's center, where the magnetic intensity would otherwise be very low.
Cited references to follow up on	Huang, S., Zhang, X., Tafu, M., Toshima, T. and Jo, Y. (2015b). Study on subway particle capture by ferromagnetic mesh filter in nonuniform magnetic field. Sep. Purif. Technol. 156: 642–654 Li, Y., Zhao, C., Wu, X., Lu, D. and Han, S. (2007b). Aggregation experiments on fine fly ash particles in uniform magnetic field. Powder Technol. 174: 93–103. Suh, D.H. and Maeng, J.H. (2015). A study on expanding the recycling of coal ash for minimizing environmental impact imposed by the establishment of thermal power plant ash ponds. J. Environ. Impact Assess. 24: 472–486.
Follow up Questions	The maximum collection efficiency for PM_1 was 50% with the 3,000 G magnet. What combination of magnetic intensity, air velocity, and mesh aperture size would be required to achieve a significantly higher efficiency (like 90%) for this particle size?
Why I Researched	Part of my project involves having a magnetized grate to catch all the metal pieces from the burnt wood. The ash would fall below the grate, and the metal would cling to the grate. I wanted to read an article that went into how I could magnetize a grate to catch the metal pieces.

Article #10 Notes: Tyre and road wear particles (TRWP) - A review of generation, properties, emissions, human health risk, ecotoxicity, and fate in the environment

Source Title	Tyre and road wear particles (TRWP) - A review of generation, properties, emissions, human health risk, ecotoxicity, and fate in the environment
Source citation (APA Format)	Baensch-Baltruschat, B., Kocher, B., Stock, F., & Reifferscheid, G. (2020). Tyre and road wear particles (TRWP) - A review of generation, properties, emissions, human health risk, ecotoxicity, and fate in the environment. *Science of the Total Environment*, *733*, 137823. https://doi.org/10.1016/j.scitotenv.2020.137823
Original URL	https://www.sciencedirect.com/science/article/pii/S0048969720313358
Source type	Review Article
Keywords	Tyre wear, Emission factors, Monitoring, Environmental behaviour, Runoff treatment, Degradation
#Tags	#TRWP #Microplastics #TireWear #EnvironmentalFate #Ecotoxicity #AirPollution #RoadRunoff #NonExhaustEmissions
Summary of key points + notes (include methodology)	Tyre wear is believed to be the most dominant source of synthetic polymer-based material released to the environment. It often makes up over 50% of total microplastic (MP) emissions in some countries. Tyre wear particles are generally classified as microplastics due to their polymer structure, solid state, insolubility, and size range (1-1000 μm). Traffic-related non-exhaust emissions (including tyre, road, and brake wear) are broadly discussed as a significant contributor to particulate matter (PM) in ambient air, and their percentage contribution is growing as exhaust emissions decrease. A comprehensive search was conducted in the 'Web of Science' and the online database maintained by the German Federal Institute of Hydrology (BfG). Key words included 'tyre/tire,' 'microplastic,' 'environmental,' 'degradation,' 'ecotoxicological,' 'health,' and 'non-exhaust emissions'.

	The review focused on data related to TRWP, distinguishing them from other MPs, and primarily included literature published since 2000 for monitoring studies. Annual emissions were compiled, based on two main approaches: 1. emission factors (mass generated per vehicle km) and 2. total consumption of tyres (weight loss due to abrasion). The article concluded that huge amounts of TRWP are annually emitted to the environment. These TRWP are predominantly emitted to soils near roads and aquatic compartments. While eco-toxicological effects on aquatic organisms were found, test conditions often did not reflect environmental reality. The risk for human health via inhalation is currently assessed as low, but key knowledge gaps remain. There need to be more studies targeting realistic conditions, environmental monitoring methods, and human health risks via the food chain. Mitigation measures, like installing adequate stormwater treatment and promoting lighter vehicles, are recommended based on the precautionary principle.
Research Question/Problem/ Need	The need addressed is to compile the current and scattered knowledge on tyre and road wear particles (TRWP) concerning their generation, properties, emissions, fate, and impact on environmental and human health. The review serves as an information source to explain key TRWP issues and to identify the significant knowledge gaps that hamper accurate risk assessment and the implementation of effective mitigation measures.

Important Figures

Table 1
Emission factors of tyre wear for different vehicle types (mg/vehicle km).

Vehicle type	Urban roads	Rural roads	Highways	Reference
Light duty vehicles[a]	5			EPA (1995)
Heavy duty vehicle[a]	7.5			
Motorcycle[a]	1.72			Reference year 1995
Passenger car[a]	3.45			CEPMEIP (2020)
Light duty vehicle[a]	4.5			
Heavy duty vehicle[a]	18.56			
Passenger car	53			Gebbe and Hartung (1997)
Van	107			
Bus	344			
Lorry	539			
Truck	1092			
Passenger car[a]	6.1			Rauterberg-Wulff (1998)
Lorry[a]	≤32			
Passenger car	Mean: 100; range: 40–360[c] 74[d]			Luhana et al. (2004)
Passenger car	Mean: 90; range: 53–200			Hillenbrand et al. (2005)
Van/Lorry	Mean: 700; range: 107–1500			
Bus	700 (like van and lorry)			
Truck	Mean: 1200; range: 1000–1500			
Not specified[a]	9			Kupiainen et al. (2005)
Car	50			Gustafsson et al. (2008)
Bus	700			
Motorized 2-wheeler	7			Aatmeeyata et al. (2009)
Not specified[a]	2.2			Sjödin et al. (2010)
Passenger car	33			Anonymous (2012)
Light commercial	51			
Heavy commercial	178			
Not specified[a]	2.4–7			Panko et al. (2013a)
Passenger car[a]	8.8	6.8	5.8	NAEI (2017)
Motorcycle[a]	3.8	2.9	2.5	
Moped[a]	3.8	–	–	
Light duty vehicle[a]	14	11	9.1	
Heavy duty vehicle[a]	47	27	31	
Bus/coach[a]	21	17	14	
Passenger car[b]	132	85	104	DELTARES and TNO (2016)
Motorcycle[b]	60	39	47	
Moped[b]	13	9	10	
Van[b]	159	102	125	
Lorry[b]	850	546	668	
Truck[b]	658	423	517	
Bus[b]	415	267	326	
Light special vehicle[b]	159	102	125	
Heavy special vehicle[b]	850	546	668	

Unit: mg/vehicle km includes the vehicle-specific number of tyres.
[a] Emission factors exclusively for fine airborne particulates (PM10).
[b] Emission factors exclusively for coarse particulates.
[c] Compiled by Luhana et al. (2004) from literature.
[d] Measured by Luhana et al. (2004).

Table 1 shows the highly variable Emission Factors (EFs) for tyre wear for different vehicles under different road conditions. It helps synthesize data found across different sources and highlights the difficulty in determining a precise global EF.

Table 2
Annual emissions of tyre wear for different countries and regions.

Country/Region	Tyre wear emissions in total (referring to tyre tread) [t/a]	Tyre wear emissions per capita [kg/(cap*a)][a]	Calculation method	EF applied	Remarks	Reference
Europe						
EU	1,327,000	2.6	[b]		Total vehicle km derived from data for Germany	Wagner et al. (2018)
DEU	61,000	0.8	[b]	Own data	Derivation of EF is not explained	Baumann and Ismeier (1997)
DEU	111,420	1.4	[b]	[i]		Hillenbrand et al. (2005)
DEU	60,000–111,000	0.7–1.4	[c]			Essel et al. (2014)
DEU	133,000	1.7	[b]	[i]		Wagner et al. (2018)
DEU	75,200 98,400	0.9 1.2	[b]	[j] [k]		Own calculation (Baensch-Baltruschat et al., 2020)
DNK	6514–7660	1.1–1.3	[b]	[l m]	Recalculation of data estimated by Lassen et al. (2015)	Kole et al. (2017)
DNK	4200–6600	0.7–1.1	[d]			Lassen et al. (2015)
DNK	7310	1.3	[d]			Kole et al. (2017)
FRA (entire)	37,646	0.6	[b]	[k]		Unice et al. (2019)
Seine river basin	13,804	0.9	[e]			
ITA	50,000	0.8	n/a			Milani et al. (2004)
NLD	15,452 (total) 7726 (polymer)	0.9 0.5	[b]	[n]		Sherrington et al. (2016)
NLD	17,300 (only tyre wear)	1.0	[b]	[o]		Verschoor et al. (2016)
NLD	15,030 8768 (corrected for amounts trapped in open pore road surface)	0.9 0.5	[b]	[p]		Kole et al. (2017)
NOR	7500 (total) 4500 (polymer)	1.4 0.8	[b]	[l m]		Sundt et al. (2014)
NOR	9600 (total) 5700 (polymer)	1.8 1.1	[f]			Sundt et al. (2014)
SWE	13,000	1.3	[b]	[q]		Magnusson et al. (2016)
GBR	38,000–76,000	0.6–1.2	[d]			EA UK (1999)
GBR	42,000–84,000	0.6–1.3	[d]		Update of data given by EA UK (1999)	Kole et al. (2017)
Countries outside Europe						
AUS	20,000	0.9	n/a			Milani et al. (2004)
BRA	294,011	1.4	[b]	[m r]		Kole et al. (2017)
CHN	756,240	0.5	[b]	[m r]		Kole et al. (2017)
IND	292,674	0.2	[b]	[m r]		Kole et al. (2017)
JPN	239,762	1.9	[g]		Recalculation of data estimated by Yamashita and Yamanaka (2013)	Kole et al. (2017)
USA	1,000,000 1,110,000	3.0 3.4	[b] [d]	[s]		Councell et al. (2004)
USA	1,524,740	4.6			Update of data given by Councell et al. (2004)	Kole et al. (2017)
USA	1,797,480	5.5	[b]	[m r]		Kole et al. (2017)
USA	1,120,000	3.4	[b]	[i]		Wagner et al. (2018)
World total	5,917,518	0.8	[h]		Extrapolation from emissions of DEU, DNK, GBR, ITA, NDL, NOR, SWE, AUS, BRA, CHN, JPN, IND, and USA	Kole et al. (2017)

[a] Own calculation, data source for number of inhabitants: total Europe (EUROSTAT, 2018), others (CIA, 2018).
[b] Estimation based on emission factors and total vehicle km.
[c] Data based on Gebbe et al. (1997) and WDK (Association of German Rubber Manufacturing Industry, reporting year 2005).
[d] Estimation based on consumption of tyres and abrasive loss (weight loss during use).
[e] Derived from data for entire France based on population density and lengths of urban and rural roads in the Seine river basin.
[f] Estimation based on the number of tyres collected for retreading and weight loss during use.
[g] Estimation based on the number of registered vehicles, life expectancy of tyres and loss during life time.
[h] Extrapolated from the emission data for DEU, DNK, GBR, ITA, NLD, NOR, SWE, AUS, BRA, CHN, IND, JPN, and USA, and the world's number of vehicles.
[i] Emissions factors compiled by Hillenbrand et al. (2005).
[j] Emissions factors compiled by Gebbe and Hartung (1997).
[k] Emission factors by DELTARES and TNO (2016).
[l] Luhana et al. (2004).
[m] Anonymous (2012).
[n] DELTARES and TNO (2014).
[o] Klein et al. (2015) (Dutch Pollutant Release and Transfer Register).
[p] Van Duijnhove et al. (2014).
[q] Gustafsson et al. (2008).
[r] Aatmeeyata et al. (2009).
[s] Unified EF: 50 mg/km.

Table 2 provides data on the annual emissions of tyre wear for many different countries and regions. The data is presented (collected from many different sources) in total tonnes per year per capita (kg/(cap·a)).

VOCAB: (w/definition)

Tyre and Road Wear Particles (TRWP): Heterogeneous particles generated by contact between the tyre and road surface during driving, consisting of abraded tyre material and road surface material.

Real-world TRWP: TRWP found in environmental compartments which are heteroaggregates consisting of tyre and road wear particles mixed with fine dust from other traffic-related wear sources like brake wear and road dust resuspension.

Microplastics (MP): Particles classified within the size range of 1-1000 µm and having a (semi)-synthetically produced polymer structure and solid state.

Non-Exhaust Emissions: Traffic-related emissions that do not come from the vehicle exhaust, including tyre, road, and brake wear, as well as road dust resuspension.

Emission Factor (EF): A value used to estimate annual tyre wear emissions, defined as the mass of generated tyre wear or TRWP per vehicle kilometer (mg/vehicle km).

Cited references to follow up on

Amato, F., Cassee, F.R., Denier van der Gon, H.A.C., Gehrig, R., Gustafsson, M., Hafner, W., et al., 2014a. Urban air quality: the challenge of traffic non-exhaust emissions. J. Hazard. Mater. 275, 31–36.

	Cadle, S.H., Williams, R.L., 1978. Gas and particle emissions from automobile tires in laboratory and field studies. Rubber Chem. Technol. 52, 146–158. Gustafsson, M., Blomquist, G., Gudmundsson, A., Dahl, A., Swietlicki, E., Bohyard, M., et al., 2008. Properties and toxicological effects of particles from the interaction between tyres, road pavement and winter traction material. Sci. Total Environ. 393, 226–240.
Follow up Questions	The estimated half-life for tyre rubber particles in soils is 16 months. What key environmental factors (like UV exposure, microbial activity, and temperature) are hypothesized to drive photodegradation and biodegradation of the polymer component (natural and synthetic rubber)? Given that e-mobility will increase traffic volume without reducing tyre wear emissions, what mitigation measure (from the suggested list) is considered the most feasible and effective to reduce the total annual mass of TRWP released to the environment in urban areas?
Why I Researched	I want my project to be movable. I wanted to determine the best way to move around my 100lb product through a construction site. I need my product to be durable and easy to maneuver. I more specifically wanted to look at rubber tire durability on different terrains to determine what type and size of tires to buy for my product. I also researched to look at the other emissions that are present when driving a vehicle. I will use this data to see how much pollution I am preventing by building an alternative method to dispose of the wood.

Article #11 Notes: Design of Manual Handling Carts: A Novel Approach Combining Corrective Forces and Modelling to Prevent Injuries

Source Title	Design of Manual Handling Carts: A Novel Approach Combining Corrective Forces and Modelling to Prevent Injuries
Source citation (APA Format)	Gille, S. (2025). Design of Manual Handling Carts: A Novel Approach Combining Corrective Forces and Modelling to Prevent Injuries. *Safety*, *11*(1), 25. https://doi.org/10.3390/safety11010025
Original URL	https://www.mdpi.com/2313-576X/11/1/25
Source type	Journal Article
Keywords	musculoskeletal disorders resistive forces pushing force model manual handling risk prevention
#Tags	#ManualHandling #Ergonomics #MusculoskeletalDisorders #CartDesign #PushingForce #ResistiveForces #OccupationalSafety
Summary of key points + notes (include methodology)	Work-related musculoskeletal disorders (MSDs) are the most prevalent work-related health issue in the European Union. 9–20% of low back injuries have been linked to pushing and pulling tasks. Current design standards for wheeled equipment traditionally measure maximal loads and moving forces on a smooth, flat, surface. This test method overestimates the maximum load acceptable for operators because the forces are higher when equipment is used in less ideal environments. The increased effort on these real-world surfaces increases the risk of MSDs. The study proposed a new method to correct the pushing force measured on a steel plate to account for real-world floor conditions. 1. Corrective Force Measurement: Corrective forces for a single wheel were defined as the difference between the

	resistive force found on a floor covering and the resistive force found on a steel plate. 2. Experimental Data: Resistive forces were measured for 44 wheel designs with varying diameter, tread, and bearing types across four resilient floor coverings. 3. Corrective Force Abaci: Corrective forces were calculated and compiled into abaci that describe the average corrective force as a function of the wheel's tread, bearing, and the hardness of the floor covering's base foam. 4. Model Development and Validation: A Newtonian mechanics model (Equation 10) was developed to translate single-wheel corrective forces to the total pushing force for a four-wheeled cart moving on a flat, horizontal floor. The model, combined with the abaci, was validated against 731 experimental trials using a four-wheeled cart under various loads and wheel configurations. The model found a mean deviation of only 5.1% between experimental results and model predictions, proving high applicability. The resistive force (and corrective force) increases linearly with the load and is heavily influenced by the hardness of the floor covering's base foam. It was found that the harder the foam, the lower the effort required. Wheels with polyurethane and polyamide treads resulted in low resistive forces but high corrective forces (large difference from steel plate force). Conversely, solid rubber treads required high resistive forces but had lower corrective forces (minimal difference from steel plate force). The findings allow design standards to be changed to account for real conditions. This will help reduce the risk of musculoskeletal disorders.
Research Question/Problem/ Need	How can current test methods for manual handling equipment be changed to accurately predict the pushing force and safe maximal load when the equipment is used on resilient floor coverings, rather than the standard smooth steel plate, to prevent musculoskeletal injuries?

Important Figures

Figure 1 shows the equipment used to measure the resistive forces for a single wheel under controlled, uniform motion. This system eliminated energy losses not related to wheel/floor contact, providing the input data needed to calculate the corrective forces for the model.

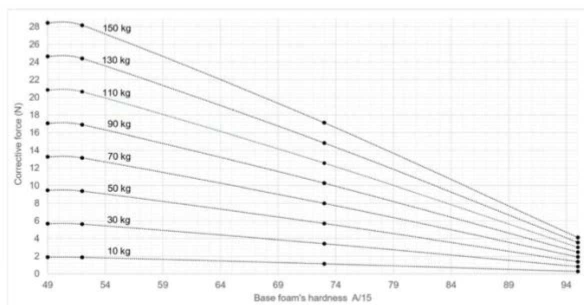


Figure 7. Corrective forces abacus for wheels with injected polyurethane tread and C.B.B.

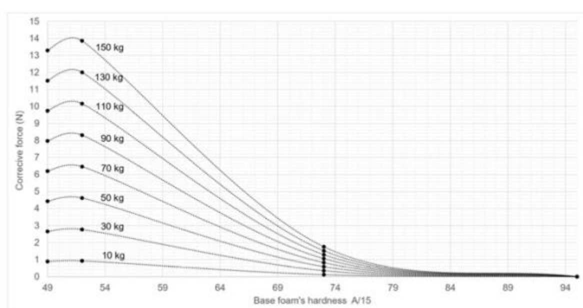


Figure 8. Corrective forces abacus for wheels with elastic tyre tread and C.B.B.

Figures 7 and 8 are the practical output of the research. They show the evolution of the corrective force (y-axis) and base foam hardness (x-axis) for various loads. These abaci allow a designer to select the required correction based on the specific wheel type and floor hardness before plugging it into the push force model.

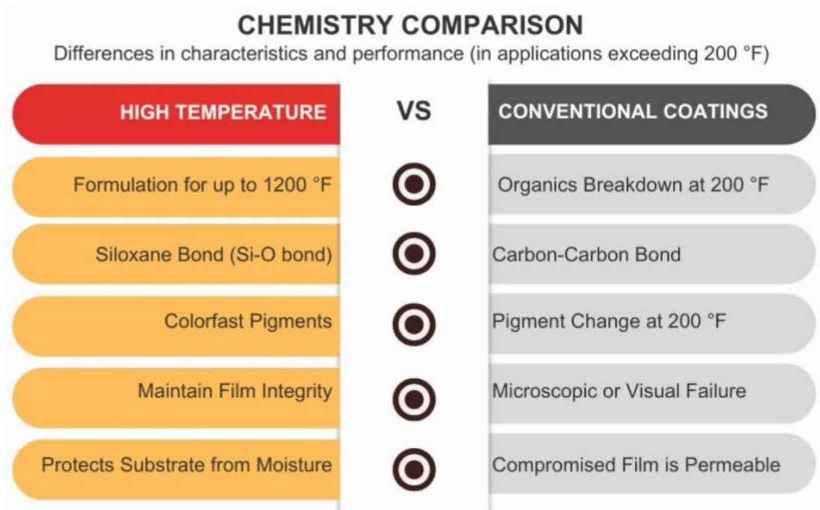
VOCAB: (w/definition)

Musculoskeletal Disorders (MSDs): Work-related health issues affecting the body's movement system (muscles, tendons, ligaments, nerves, discs, etc.).

	Resistive Forces: The minimum forces required to push a wheel to overcome the forces that oppose movement, such as the force linked to the deformation of the wheel and the ground. **Corrective Force:** The force value used to adjust the pushing force measured on a steel plate to account for a specific floor covering. It is the difference between the floor resistive force and the steel resistive force. **Initial Force (Starting Force):** The highest pushing force recorded just as a wheeled piece of equipment starts moving from a static location. **Sustained Force (Driving Force):** The pushing force measured when a wheeled piece of equipment is moving at a constant speed.
Cited references to follow up on	Kingma, I.; Kuijer, P.P.F.M.; Hoozemans, M.J.M.; van Dieen, J.H.; van der Beek, A.J.; Frings-Dresen, M.H.W. Effect of design of two-wheeled containers on mechanical loading. Int. J. Ind. Ergon. 2003, 31, 73–86. [CrossRef] Weston, E.B.; Aurand, A.; Dufour, J.S.; Knapik, G.G.; Marras, W.S. Biomechanically determined hand force limits protecting the low back during occupational pushing and pulling tasks. Ergonomics 2018, 61, 853–865. [CrossRef] [PubMed] Park, S.Y.; Kim, S.H.; Park, D.J. Effect of the Air-Pressure Differences of the Wheelchair Tires on user's Upper Extremity Muscle Activities and Acceleration Changes. Int. J. Eng. Res. Technol. 2020, 9, 3266–3271. [CrossRef]
Follow up Questions	The model assumed the cart moves in a straight line. What modifications to the pushing force model (Equation 10) would be needed to accurately predict the force required during swiveling and turning motions (where resistance is significant)? The study recommends materials like hard monolayer floor coverings to reduce required effort. Does a hard floor material's low resistive force inadvertently increase the risk of slip and fall injuries for the operator? Does this end up trading one type of MSD risk for another?
Why I Researched	I want to add handles so my design can be moved. The handles must allow the user to move the design simply without much effort. I wanted to look at ergonomics so that I don't hurt any users. I want to design my product to encourage safe lifting and prevent injuries.

Article #12 Notes: A Brief Guide to High Temperature Coatings

Source Title	A Brief Guide to High Temperature Coatings
Source citation (APA Format)	Forrest Technical Coatings. (2025). A brief guide to high temperature coatings. Forest Technical Coatings. https://resources.forrestpaint.com/a-brief-guide-to-high-temp-coatings
Original URL	https://resources.forrestpaint.com/a-brief-guide-to-high-temp-coatings
Source type	Overview Article
Keywords	High temperature coatings, Corrosion, Silicone resins, Liquid coatings, Powder coatings
#Tags	#HighTemperatureCoatings #SiliconeCoatings #CorrosionProtection #MaterialSelection #IndustrialCoatings #PowderCoatings #LiquidCoatings
Summary of key points + notes (include methodology)	High temperature coatings are crucial protective barriers for components operating at high temperatures. The coatings, when used properly, are able to safeguard substrates from corrosion. Standard coatings fail as low as 200 degrees F while high temperatures coatings can survive 1200 degrees F for long durations. Core Chemical Mechanism: High temperature coatings rely on silicone resins based on the siloxane bond (Si-O) which is 25% stronger than standard carbon-carbon bonds. Performance Assessment: A **quench test** (rapid cooling of a heated coating in cold water) is used to assess integrity against sudden temperature fluctuations. Liquid Coatings offer more advantages than powder coatings for my purposes (see figure below). Limitations of high temperature coatings is that they lose resistance to impact and sudden temperature fluctuations.

Research Question/Problem/ Need	The primary objective is to provide an overview to help users (manufacturers) address the practical need of selecting the correct high-temperature coating technology for operating temperatures from 200 degrees F to 1200 degrees F to ensure safeguarding substrates from corrosion and failure.
Important Figures	 The chart shows the fundamental chemical distinction between high temperature coatings (strong Siloxane Bond (Si-O bond)) and conventional coatings (weaker Carbon-Carbon Bond).  The figure shows the result of metal after burning with a high temperature coating vs. a conventional temperature coating when both metals were exposed to high temperatures for extended durations.

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The figure shows the advantages of both liquid and powder coatings. For my STEM project, a liquid coating will work best because it requires less equipment and it would require less total coating because the spray would cover more surface area.
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<td>VOCAB: (w/definition)</td>
<td>
Siloxane Bond (Si-O bond): The silicone-oxygen bond that forms the chemical basis of silicone resins used in high-temperature coatings.

Micropitting: Non-visible microscopic damage developed in a coating film after exposure to high temperatures, allowing moisture to penetrate and cause corrosion underneath.

Quench Test: A performance characteristic test where a heated coating is rapidly cooled in cool or cold water to assess its integrity against sudden temperature fluctuations

Colorfast Pigments: Pigments contained in high-temperature coatings that are not affected by heat and maintain their color during extended operation.

Ambient Cure: A recent technological where the coating reaches its full properties and cure without the need for external heat, making it a low-cost, environmentally friendly option.
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<td>Cited references to follow up on</td>
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www.forrestpaint.com
info@forrestpaint.com
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<td>Follow up Questions</td>
<td>
The paper compares liquid vs. powder coatings. What are the Volatile Organic Compound (VOC) emission levels for solvent-based liquid coatings compared to the zero emissions of powder coatings.

How do modern liquid formulations achieve compliance with stricter environmental standards?
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Why I Researched	I want to add spray paint to my final product to give it a nice finish. What should I look for in a spray paint to ensure it will continue to work at high temperatures? How will spray paint affect the tolerancing of my product? Should I disassemble everything and spray paint or just spray the final product?

Article #13 Notes: Measurement, prediction and modeling the impact of vibration as the possibility of protection cultural heritage objects

Source Title	Measurement, prediction and modeling the impact of vibration as the possibility of protection cultural heritage objects
Source citation (APA Format)	Toplak, S., Ivanic, A., Jelusic, P., & Lubej, S. (2014). Measurement, prediction and modeling the impact of vibration as the possibility of protection cultural heritage objects. *International Journal of Physical Sciences*, *9*(22), 495-505. https://academicjournals.org/journal/IJPS/article-full-text-pdf/840377B48840.
Original URL	https://academicjournals.org/journal/IJPS/article-full-text-pdf/840377B48840
Source type	Journal Article
Keywords	Fuzzy logic Ground vibrations Vibrations monitoring Vibrations prognosis Neural networks.
#Tags	#VibrationAnalysis #ANFIS #ConstructionEngineering #FuzzyLogic #TrafficVibration #HeritageConservation
Summary of key points + notes (include methodology)	Construction machinery (like pile drivers and vibratory rollers) and heavy freight traffic produce harmful vibrations that can transmit through soil and damage nearby structures. Sustainable road planning often fails to quantitatively assess these negative impacts during the design phase. The researchers used Instantel Minimate Plus seismographs and geophones to measure ground vibration velocity in three specific scenarios. 1. heavy truck traffic, 2. vibratory roller compaction (using HAMM 3520 and AMMAN AC 110 rollers), 3. sheet piling (driving and pulling). Existing empirical models were applied to predict vibrations:

<table>
<tr><td></td><td>Watts (1990) for traffic, and Achmus et al. (2005) and Phillips et al. (2010) for construction machinery. (Both cited below for follow up).

The prognostic equation by Watts set very strict criteria that were mostly exceeded by actual measurements. This showed high data scattering.

Surface dynamic compaction generated higher vibration velocities than deep dynamic compaction as the distance from the source increased.</td></tr>
<tr><td>Research Question/Problem/ Need</td><td>Experts lack adequate construction and traffic vibrations to support decisions and predict the impacts during the sustainable planning of infrastructure. The researches wanted to find whether they could accurately predict vibration intensity from machinery.</td></tr>
<tr><td>Important Figures</td><td>

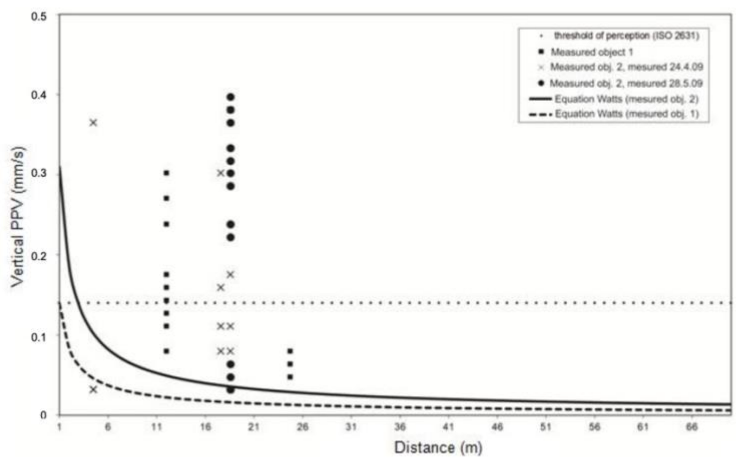

Figure 1. The results of the measured values using the prognostic equation for heavy trucks.

The graph plots Vertical PPV (mm/s) against Distance (m). The curves represent the Watts equation predictions, while the dots represent actual field measurements. It demonstrates that the Watts equation often underestimates the vibration intensity compared to real-world data. This is illustrated through how the dots appear significantly higher than the curves, highlighting the difficulty in predicting traffic vibration using simple formulas.</td></tr>
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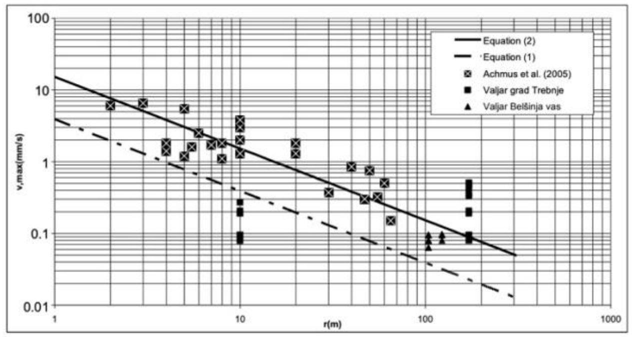

Figure 2. The measured versus predicted values of foundation oscillation velocity.

This graph compares the foundation oscillation velocity v_i against distance r for vibratory rollers. The solid and dashed lines represent equations while the markers represent measured data. The clustering of data points along the prediction lines means that the equations are reliable for predicting roller vibrations.
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<td>VOCAB: (w/definition)</td>
<td>Peak Particle Velocity (PPV): The maximum speed at which a particle of ground moves (vibrates) as a wave passes through it. PPV serves as the standard metric for assessing vibration intensity.

Geophone: A device containing a seismic mass and electromagnetic coils. It is used to measure ground vibration velocity by converting physical movement into electrical impulses.

Classification of Environmental Protection Activities (CEPA): A functional classification used to categorize activities related to environmental protection, including the reduction of noise and vibration.</td>
</tr>
<tr>
<td>Cited references to follow up on</td>
<td>Achmus M, Kaiser J, Wörden FT (2005). Bauwerkserschütterungen durch Tiefbauarbeiten: Grundlagen,
Messergebnisse, Prognosen.
nstitut für Grundbau, Bodenmechanik und Energiewasserbau Universität Hannover, Hannover. 61:1-82

Watts GR (1990). Traffic induced vibrations in buildings. Research Report 246, Transport and Road</td>
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<td>Follow up Questions</td>
<td>On a chaotic construction site, what are the peak acceleration or deceleration forces (sudden stops against a curb or rapid starts) that a product must withstand to prevent mechanical failure, and how do these compare to the controlled accelerations used in the study?

How might the corrective forces described in the study need to be adjusted or scaled up to account for the high resistance surfaces typical of a construction site (such as loose gravel, mud, or unpaved earth).</td>
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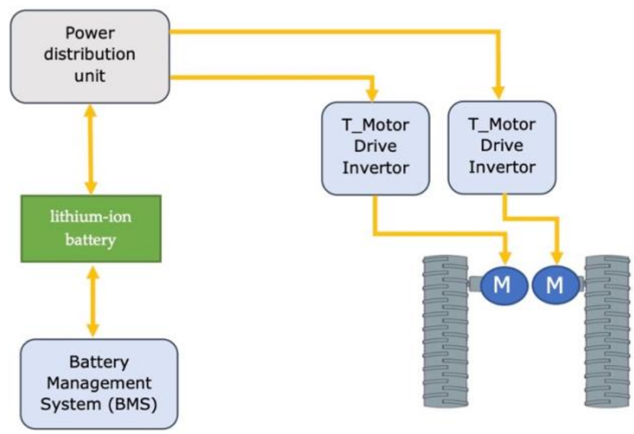
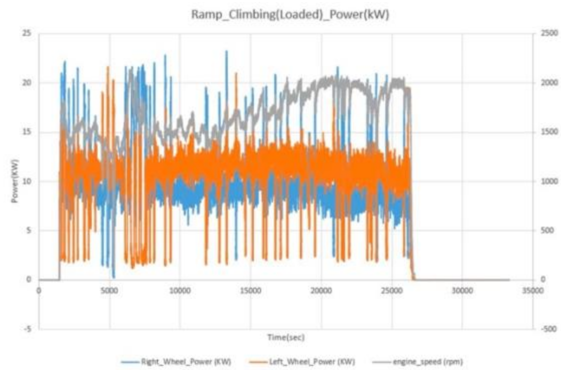
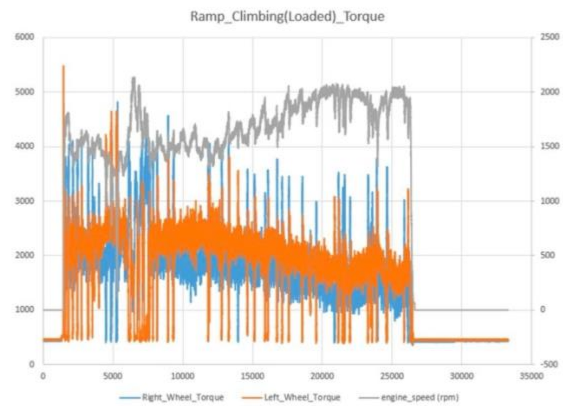
Why I Researched	A product on a construction site needs to be durability. What forces might a product like this most likely experience on a construction site?

Article #14 Notes: Electric Motor Selection Criteria for Traction System in Construction Machines

Source Title	Electric Motor Selection Criteria for Traction System in Construction Machines
Source citation (APA Format)	Karasoy, S., Can, M. B., Öz, F., & Fıçıcı, F. (2024). Electric motor selection criteria for traction system in construction machines. *Orclever Proceedings of Research and Development*, *4*(1), 123–146. https://www.journals.orclever.com/oprd/article/view/471
Original URL	https://www.journals.orclever.com/oprd/article/view/471
Source type	Conference Article
Keywords	Electric Motor Traction System Construction Machines
#Tags	#ConstructionMachinery #PMSM #InductionMotors #BatteryTechnology #Powertrain #SustainableConstruction #MotorSelection
Summary of key points + notes (include methodology)	The construction machinery sector is shifting toward electric traction. The electric powertrain architecture (battery, power electronics, motor, gearbox) replaces the traditional internal combustion engine and hydrostatic systems. Requirements for construction machine motors include high torque at low speeds, high power density, and durability under harsh conditions. The researchers evaluate the characteristics of Brushed DC, Asynchronous (Induction), Permanent Magnet Synchronous (PMSM), and Switched Reluctance motors based on criteria like torque-speed characteristics, efficiency, cost, and maintenance. The study conducted real-world performance tests on a mini backhoe. Brushed DC Motors: Generally not preferred due to low efficiency, large size, and high maintenance needs, despite good low-speed torque. Asynchronous Motors: Reliable, low cost, and low maintenance. Suitable for high-torque industrial applications but may have lower

	power factor at high speeds. PMSM Motors: Offer the highest efficiency, power density, and performance. They provide full torque at low speeds, crucial for construction tasks, but come with higher costs and sensitivity to temperature/demagnetization.
Research Question/Problem/ Need	What are the critical criteria and optimal choices for selecting electric motors for the traction systems of electric construction machinery (specifically mini backhoe loaders)?
Important Figures	 *Figure 1: Basic Electrical Power Traction System Scheme* Illustrates the flow of electricity for an electric powertrain. It establishes a visual basic understanding for the study.

	 *Figure 9: Ramp Climbing Power Test Results (loaded)*  *Figure 10: Ramp Climbing Torque Test Results (loaded)* Figures 9 and 10 show the sustained high power and torque that is required to climb a grade while carrying a load. This test verifies the motor's ability to deliver continuous high torque without overheating or stalling, a critical safety and performance requirement.
VOCAB: (w/definition)	Power Traction System: The subsystem of a construction machine consisting of the battery, power electronics, electric motor, and gearbox that allows for movement and supports the machine's weight. Regenerative Braking: A mode where the electric motor acts as a generator during braking to slow down the machine and charge the battery. PMSM (Permanent Magnet Synchronous Motor): An AC motor using permanent magnets in the rotor, offering high efficiency, high power density, and full torque at low speeds, but at a higher cost. Asynchronous Motor (Induction Motor): An AC motor where the rotor rotates at a speed slightly different (slip) from the stator's magnetic field; known for reliability, low cost, and robustness in harsh environments.
Cited references to follow up on	Karki, A., et al. (2020). "Status of Pure Electric Vehicle Power Train Technology and future prospects," Applied System Innovation. Jack, A. G., et al. (1996). "A comparative study of permanent magnet and

	switched reluctance motors for high-performance fault-tolerant applications," IEEE Transactions on Industry Applications.
Follow up Questions	For the Tracked Mini Wheel Loader, the study mentions a simple gear transmission box. Would a two-speed gearbox provide significant efficiency gains by allowing the motor to operate in a more efficient RPM range during both high-torque digging and high-speed transportation, or does the added complexity outweigh the benefits?
Why I Researched	How can an electric motor be integrated to the design to help it move? How can I use the motor to optimize efficiency and ease of use on the job site. How often would I have to charge it or change a battery?

Article #15 Notes: An adaptive reliability-based maintenance policy for mechanical systems under variable environments

Source Title	An adaptive reliability-based maintenance policy for mechanical systems under variable environments
Source citation (APA Format)	*Duan, C., Deng, T., Song, L., Wang, M., & Sheng, B. (2023). An adaptive reliability-based maintenance policy for mechanical systems under variable environments. Reliability Engineering & System Safety*, *238*, 109396. https://doi.org/10.1016/j.ress.2023.109396
Original URL	https://pdf.sciencedirectassets.com/271430/1-s2.0-S0951832023X00076/1-s2.0-S0951832023003101/main.pdf Note: Sign in required. If you cannot access, ask Ryan.
Source type	Journal Article
Keywords	Environmental effects Wiener process Matrix-based approximation method Conditional reliability Semi-Markov decision process (SMDP)
#Tags	#ReliabilityEngineering #MaintenancePolicy #DegradationModeling #WienerProcess #AdaptiveMaintenance #EnvironmentalEffects #MechanicalSystems
Summary of key points + notes (include methodology)	Mechanical systems operate in variable environments (load, temperature, humidity) which accelerate degradation and failure. Traditional maintenance models often assume static operating conditions or ignore the specific impact of environmental variables on failure rates. The Degradation Model uses a random effect Wiener process to model system degradation, where the drift parameter follows a general distribution to represent environmental randomness. The Failure Model uses a proportional hazards (PH) model with an environment varying covariate to model failure events (hazard rate).

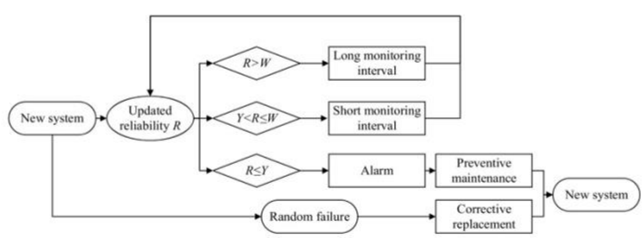
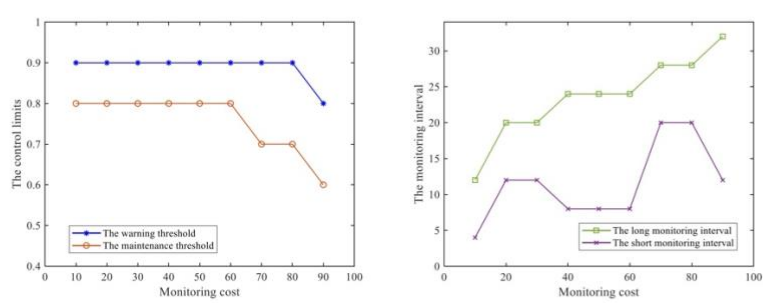
	A Maintenance Policy develops an adaptive reliability-based policy with a switchable control chart. The policy adjusts inspection intervals T_i and reliability thresholds R_{th} dynamically based on the system's current reliability status. The algorithm is optimized using a semi-Markov decision process (SMDP) framework and a computational algorithm to find optimal decision variables that minimize the expected average cost per unit time. Integrating environmental variables into the degradation and failure models provides a more accurate representation of real-world mechanical system behavior. The adaptive maintenance policy significantly outperforms tractional policies in terms of accuracy to the real world.
Research Question/Problem/ Need	Existing maintenance models fail to account for the complex interaction between system degradation, sudden failures, and variable operational environments, leading to either excessive maintenance costs or unexpected failures.
Important Figures	 **Fig. 3.** The flowchart of the reliability-based switchable control chart. Figure 3 details the logic of the adaptive maintenance policy. It shows the decision nodes where the system checks conditional reliability (R) against warning (W) and maintenance (Y) thresholds to switch between long/short monitoring intervals or trigger maintenance.  (a) Control limits. (b) Monitoring intervals. **Fig. 13.** The changes of the monitoring cost in optimal decision variables.

	Figure 13 shows the sensitivity analysis of how changing monitoring costs affects the optimal control limits (W and Y) and monitoring intervals. The figure helps show how economic factors influence the optimal strategy.
VOCAB: (w/definition)	Wiener Process: A mathematical model used to represent random motion or degradation, characterized by independent, normally distributed increments. Semi-Markov Decision Process (SMDP): A mathematical framework for modeling decision-making in situations where outcomes are partly random and partly under the control of a decision-maker, where the time between decisions is random. Conditional Reliability: The probability that a system will continue to function for a specific future interval, given that it is currently functioning and has a known degradation level.
Cited references to follow up on	Miao Q, Xie L, Cui H, Liang W, Pecht M. Remaining useful life prediction of lithium-ion battery with unscented particle filter technique. Microelectron Reliab 2013;53:805–10. Zheng R, Makis V. Optimal condition-based maintenance with general repair and two dependent failure modes. Comput Ind Eng 2020;141:106322.
Follow up Questions	How does the computational cost of the matrix-based approximation method compare to Monte Carlo simulations as the number of environmental states increases significantly? How can this adaptive policy be extended to multi-component systems where environmental factors affect components differently (for example: temperature affects seals more than gears)?
Why I Researched	If I were to add an electric motor to assist with driving the product and a hydraulic system to assist with dumping, how will this affect my manufacturing costs? How much more would I have to charge for my product to add these premiums, and would it interest more (or less due to cost) people in the product? Would it be worth making two different tiers of devices, one with a motor and hydraulic system and one without?

Article #16 Notes: Experimental study of hydraulic equipment operation process

Source Title	Experimental study of hydraulic equipment operation process
Source citation (APA Format)	Rustamov, K., Komilov, S., Kudaybergenov, M., Shermatov, S., & Xudoyqulov, S. (2021). Experimental study of hydraulic equipment operation process. *E3S Web of Conferences, 264*, 02026. https://www.e3s-conferences.org/articles/e3sconf/abs/2021/40/e3sconf_conmechydro2021_02026/e3sconf_conmechydro2021_02026.html
Original URL	https://www.e3s-conferences.org/articles/e3sconf/abs/2021/40/e3sconf_conmechydro2021_02026/e3sconf_conmechydro2021_02026.html
Source type	Conference Article
Keywords	Hydraulic fluid Hydraulic system Quick-change equipment Multipurpose machine Earthworks Energy efficiency
#Tags	#HydraulicSystems #EarthmovingMachinery #EnergyEfficiency #MultipurposeMachines #RoadConstruction #ExperimentalMechanics #PumpPerformance
Summary of key points + notes (include methodology)	The researchers used the theory of machines, hydromechanics, and computational mathematics (Matlab) to model the system. A multipurpose machine (KM-1) based on a TTZ-80.10 tractor was equipped with earthmoving and dozer equipment. Pump power N and displacement Q were calculated based on measured pressure P, rotation speed n, and pump displacement per revolution q. During soil extraction, pump pressure was 10.76 MPa, rotational speed was 29.46~s^{-1}, and effective engine power was 27.7 kW. Maximum energy consumption (28.2 kW, engine efficiency 0.53) occurred when lifting a soil-filled bucket, which was identified as the most energy-intensive operation. The engine power consumption coefficient during harvesting was 0.41. The

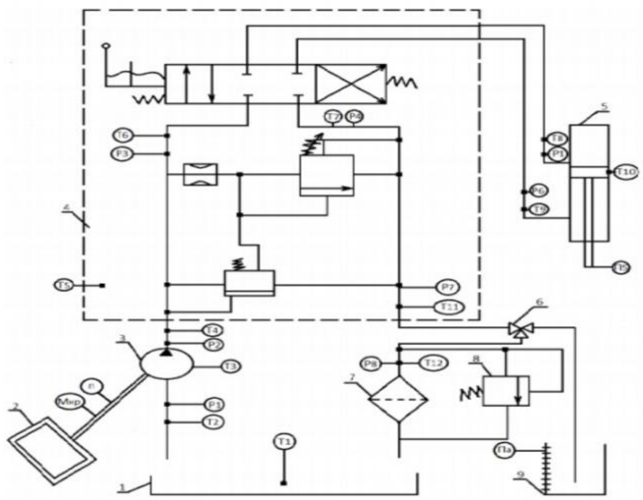
<table>
<tr><td></td><td>minimum power consumption (9.9 kW) occurred during the return cycle.</td></tr>
<tr><td>Research Question/Problem/ Need</td><td>How do resistance forces affect the hydraulic system of a multipurpose earthmoving machine during excavation?</td></tr>
<tr><td>Important Figures</td><td>


Fig. 1. Approximate (principal) hydraulic scheme of the study

This schematic illustrates the entire hydraulic circuit, including the pump, distributor, power cylinder, and various sensors. It is included to visualize the experimental setup and the locations where data was measured to validate the math model.

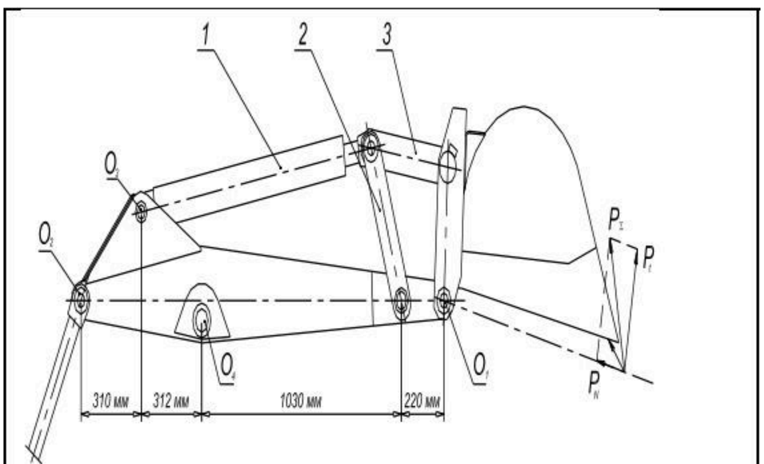


Fig. 5. Structural diagram of the arm and bucket drive

Figure 5 shows the mechanical linkage of the excavator arm, specifically the hydraulic cylinders and linkages. This figure is needed to understand the kinematics of the machine.
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VOCAB: (w/definition)	Multipurpose Machine (KM-1): A universal road-building machine based on the TTZ-80.10 tractor, capable of being fitted with quick-change equipment for various tasks like digging and dozing. Strain Gauge: A sensor used in the experiment to measure the torque of the hydraulic pump drive shaft by detecting mechanical deformation. Gercon Switch (Reed Switch): A magnetically controlled contact sensor used to measure the rotational speed of the engine crankshaft. Pump Displacement Q: The volume of fluid moved by the pump per unit of time, calculated using the pump's performance per revolution q and the rotation speed n.
Cited references to follow up on	Rustamov K.J. Experimental Work of the Hydraulic Equipment of the Multi-Purpose Machine Mm-1. International Journal of Recent Technology and Engineering 8, (4), November 2019. – pp. 12032- 12036 (2019). Wang, Y., Shen, T., Tan, C., Fu, J., and Guo, S. Research status, critical technologies, and development trends of hydraulic pressure pulsation attenuator. Chinese Journal of Mechanical Engineering (English Edition), 34 (1) doi:10.1186/s10033-021-00532-z. (2021).
Follow up Questions	Maximum energy loss occurred during the "lifting a filled bucket" phase. What specific hydraulic circuit modifications (accumulators, regenerative valves, etc.) could be made to recover or minimize energy loss during this high-intensity cycle? How would different hydraulic fluids (different oil temperature, type of oil, and viscosities) impact the volumetric efficiency of the NSh-32M4 pump during the high-temperature field tests?
Why I Researched	How would a hydraulic dump work? How do hydraulics work in general and are they worth adding to my design?

Article #17 Notes: Reliability Importance Measures considering Performance and Costs of Mechanical Hydraulic System for Hydraulic Excavators

Source Title	Reliability Importance Measures considering Performance and Costs of Mechanical Hydraulic System for Hydraulic Excavators
Source citation (APA Format)	Liu, W., Zeng, Q., Wan, L., Liu, J., & Dai, H. (2022). Reliability Importance Measures considering Performance and Costs of Mechanical Hydraulic System for Hydraulic Excavators. *Journal of Sensors, 2022*, Article ID 5748288. https://onlinelibrary.wiley.com/doi/epdf/10.1155/2022/5748288
Original URL	https://onlinelibrary.wiley.com/doi/epdf/10.1155/2022/5748288
Source type	Journal Article
Keywords	Reliability importance measures Mechanical hydraulic system (MHS) Hydraulic excavators (HE) Energy regeneration and recovery system (ERRS) Weibull distribution Preventive maintenance
#Tags	#ReliabilityEngineering #HydraulicSystems #Excavators #MaintenanceStrategy #CostAnalysis #FailureAnalysis
Summary of key points + notes (include methodology)	Construction machinery is a major source of pollution and energy consumption. Energy recovery technologies are increasingly used to improve efficiency. However, they make hydraulic systems more complex calling for intense reliability analysis. Failure data was collected from 973 hydraulic excavators (30 ton models) over 3 years, resulting in 197 failure records for the MHS. The failure data was analyzed using Minitab and the Anderson-Darling (AD) test confirmed that the failure times followed a three-parameter Weibull distribution. A new reliability importance measure, RIM_{PC}, was developed which considers economic factors like maintenance costs and downtime

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losses rather than just reliability parameters or system structure.
A predictive maintenance schedule was proposed which included routine, preventive, restorative, and replacement maintenance based on the reliability decay of components.
The boom was identified as the least reliable component (R(t) = 0.5960 at 3000 hours) and thus the most important. The accumulator was the most reliable component (0.9990 at 3000 hours)
The study ranked components by RIM_{PC} (importance). The components from most important to least important: Boom, Cylinder, Pump, Reversing Valve, Tube, Servo Valve, Accumulator. This ranking differed from traditional measures which ignores cost/performance factors.
Specific maintenance intervals were calculated. The boom, for example, needed restorative maintenance at 3900 hours and a complete replacement at 7000 hours.
The predictive method allows weak links to be identified early in the design stage, allowing extra attention to be put towards the bottlenecks in the products longevity.
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<td>Research Question/Problem/ Need</td>
<td>How can the reliability of complex mechanical hydraulic systems in excavators be effectively assessed and improved by considering not just failure rates, but also system performance losses and maintenance costs?</td>
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<td>Important Figures</td>
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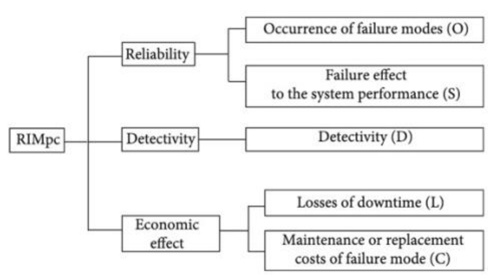

FIGURE 1: Reliability importance measure.
The tree diagram shows the composition of the RIM_{PC} metric. The figure visualizes the core methodology of the paper and explains why the measure is comprehensive.
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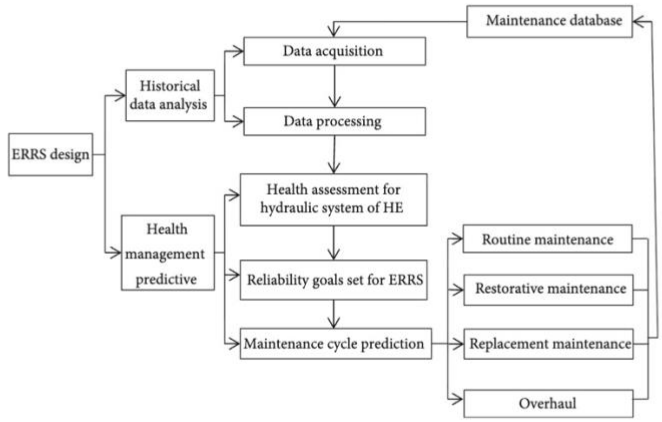
	 Figure 2: Predictive maintenance process of ERRS. The flowchart outlines the steps for implementing the proposed maintenance strategy. It translates the theoretical reliability analysis into a practical workflow that engineers can follow.
VOCAB: (w/definition)	RIM_{PC} (Reliability Importance Measures considering Performance and Costs): A metric proposed that evaluates component importance by combining its reliability probability with a weighting factor based on failure severity, occurrence, detectability, downtime losses, and maintenance costs ERRS (Energy Regeneration and Recovery System): A technology used in hydraulic excavators to capture potential energy. Weibull Distribution: A continuous probability distribution used to model life data and failure times. Restorative Maintenance: A type of maintenance action taken when a component's reliability falls below a set threshold.
Cited references to follow up on	S. Y. Grodzensky, "Reliability models based on modified Wei-bull distributions," Measurement Techniques, vol. 56, no. 7,pp. 768–774, 2013.12 Journal of Sensors G. Levitin and A. Lisnianski, "A new approach to solving prob-lems of multi-state system reliability optimization," Qualityand Reliability Engineering International, vol. 17, no. 2,pp. 93–104, 2001. E. Borgonovo, "Differential importance and comparative stat-ics: an application to inventory management," InternationalJournal of Production Economics, vol. 111, no. 1, pp. 170–179, 2008.
Follow up Questions	The study simplifies the multistate hydraulic system into a binary system (working vs. failed) for analysis. How would the RIM_{PC} results change if a multistate model were used, considering that components like pumps often degrade (for example efficiency loss) before failing completely?

Why I Researched	If I add things like a motor and hydraulics, what type of maintenance am I looking at each year and how much will it likely cost. By how much does a motor and hydraulics increase the price of the product?

Article #18 Notes: What happens if you throw sand into a jet engine?

Source Title	What happens if you throw sand into a jet engine?
Source citation (APA Format)	Veritasium. (2025, November 17). *What happens if you throw sand into a jet engine?* [Video]. YouTube. https://www.youtube.com/watch?v=QtxVdC7pBQM
Original URL	https://www.youtube.com/watch?v=QtxVdC7pBQM
Source type	Review Video
Keywords	Carnot efficiency Erosion Elastic Gamma Gamma Prime
#Tags	#MaterialAnnalysis #HighHeat #Strain #TensileLoad #Gamma #GammaPrime #Elements
Summary of key points + notes (include methodology)	Air is compressed and then fuel is sprayed in. Reaction gives off heat (1500 degrees C). Gas is at 50 atm. It tries to expand, pushing through (and spinning) blades until air goes out back of the engine at 1 atm. The whole engine spins at 12,500 RPM. This gives 20% of the trust (pushing out the back) and takes up 10% of the total air. The other 90% of air gives other 80% of thrust and is just pushed by the big fan moving, never going through the engine. At 35,000 ft (cruising altitude) the air is -55 degrees C while the inside is 1500 (2732 degrees F). This affects the Carnot efficiency. Each blade (at 12,500 RPM) moves through air at 1181 MPH. Each blade wants to move strait but the centrifugal force keeps it moving around. For a 300 gram blade under these conditions, each blade takes on the force of 20 tons. At this temperature, oxygen tries to react with the blades themselves while dust can damage and erode the surfaces inside. All of this has to withstand thousands of flight hours. Department of Materials Science and Metallurgical at Cambridge University. **Steel**: 200 MPa is tensile load for all future metals.

	Tugging on atoms – not breaking or forming. This makes them flex and makes the metal just a little bit longer. At this point, material is elastic and removing the force will put metal back to how it was. Steel failure point: 599.5 degrees C / 1111.1 degrees F Materials can be made up of atoms in a hexagonal structure. But they are not perfect. Pulling on atoms on each side causes dislocations. It causes one plane of atoms to shear past the other one by just one spacing. Creep: metal deforming continuedly under constant load. Takes energy to break atomic bonds as dislocation travels through lattice. As temperature increases and atoms speed up, it takes less stress to dislocate atoms. The metal "gets softer" and the steels strength drops and allows the slow creep to give way to rapid deformation. **Titanium**: Half as dense as steel. It would reduce the centrifugal force substantially. However, titanium fails at 588.4 C or 1091.1 F. Both steel and titanium's strength drop rapidly as temperature increases. **Tungsten**: doesn't melt until 3400 C or 6152 F. However, it is very dense (2.5x steel) and very brittle. Bottom line: you can optimize for melting point, weight, or strength, but the turbine pushes every limit. **Nickel Superalloy**: has added chromium and cobalt – could run hotter and last 10x as long (tens of thousands of hours). However, the real breakthrough came when they added aluminum. At temperatures when steel and aluminum start to break, nickel superalloy actually gets STRONGER. Zoom in on alloy: microstructure is not uniform. Looks like a city grid with blocks with streets between. Each block is so small that a line of 300 would make up the width of a human hair. Both streets and blocks are made up of the same atoms: mostly nickel with a little aluminum. They even have the same crystal structure: atoms sittings at corners and faces of each "cube". However, the streets are random and there is no repeating sequence. This is called the gamma phase. Meanwhile, aluminum always takes up the corners and nickel

always takes up the faces in the blocks. This gives a perfect repeating pattern, called the gamma prime phase. This is crucial when a dislocation tries to shear through the lattice. Doing this in gamma is easy (since it is random it looks the same) while doing this in gamma prime is hard (nickel/aluminum end up sitting in wrong places). Sitting in the wrong places takes energy, so the lattice resists it. If a dislocation hits the blocks, the structure resists it, making it strong.

In gamma prime phase, dislocations have to travel in pairs (to maintain structure) which are called super dislocations. High stress is also needed to get it to shear (high temp = more movement in atoms).

Strength comes at a cost: gamma prime stops dislocations so well that it becomes brittle. A single impact can result in failure.

The challenge is to find the right balance of strength (gamma prime) to trap the dislocations and prevent the creep and enough gamma to keep the metal ductile so it can bend without breaking.

Nickel Superalloy: breaks at 1200 C / 2192 F

What helps make it special: aluminum on surface reacts with oxygen at high heat to form aluminum oxide which is not brittle like steel or titanium.

Superalloys can be tuned to include different elements based on desired properties. Superalloys today can contain 10 different elements.

Chromium: improve resistance to oxidation and corrosion.

Cobalt, titanium, niobium, tantalum, vanadium: help stabilize gamma prime phase.

Molybdenum, iron: strengthen the gamma matrix.

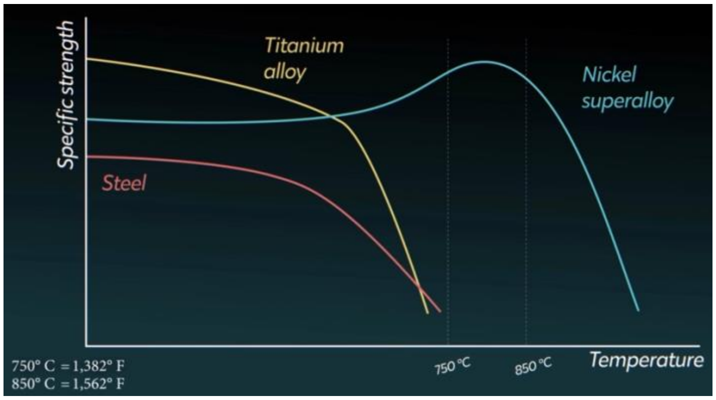
Rhenium: 2^{nd} highest melting point – slows atomic scale rearrangements which enhances the alloys resistance to deformation even at temperatures over 1000 C. However, it is very rare at <1 ppb (part per billion).

Looking at the crystals (see figure below) the edges between crystals can move and the metal can deform (it can stretch). If it has grains, it will creep and fail much easier. This is difficult to solve because normally as a molten alloy cools, tint crystals form throughout the liquid.

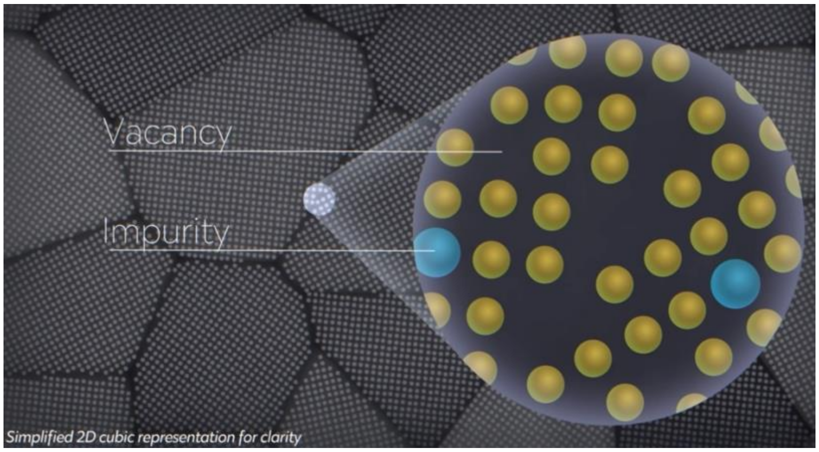
When turbines are made, they are made in furnaces which are induction heated

	(no gas). They are all under vacuum (no oxygen). A blade is made by lowing it out of a hot zone slowly after pouring it into a mold. Just this, however, makes crystals that are in vertical lines which makes it much stronger, but not perfect. If a bend is added to the molding process, only a single columnar crystal will make it. It is referred to as the pigtail at the bottom of the mold to cast it as a single crystal. After being molded, it is heated again (almost to melting point) to allow atoms to spread out evenly. This will form the desired microstructure of the gamma and gamma prime phases. The single crystal is not a uniform front. Instead, it is a solidification front that looks like a forest of tiny tree-like branches called dendrites. These trees are made up of up to 10 different elements and are locked into the same crystal lattice. Between 1960 and 2010, aircraft have become more than 55% fuel efficient. Most of this efficiency comes down to the advances in super nickel alloys. Prices to fly have gotten cheaper because planes can carry more people and their engines last longer. Dirt and dust melt and stick to the turbine blades. It slowly rips off the thermal barrier coating, which losses the temperature reduction meaning the nickel alloy gets hotter and hotter allowing it to start to break over time. Today, engineers are developing better coatings that will be able to better resist molten dust and extend the life of the engine by 30%.
Research Question/Problem/ Need	How are jet engine blades designed to withstand the harsh conditions they face such as high heats, long hours, and high pressures?

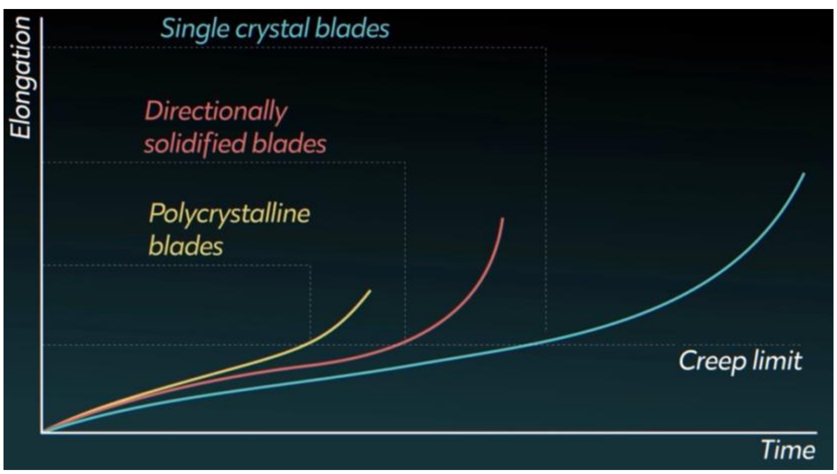
Important Figures

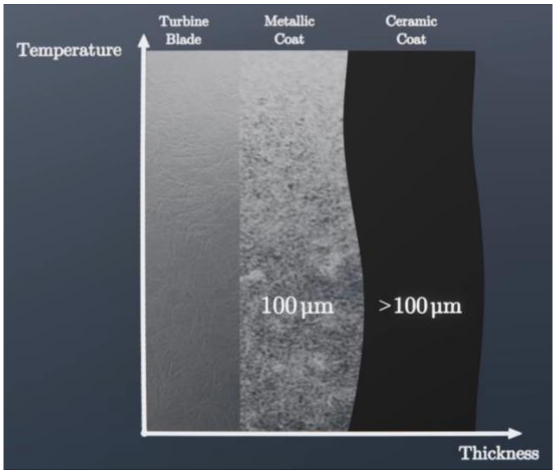


Nickel Superalloy actually gets stronger after steel and titanium drop off. This is because the extra thermal energy lets more dislocations cross lip and get separated which shuts down the motion of dislocations.



Metals are made up of small crystals. The boundaries between the crystals are the weak points.
Crystal (made up of gamma + gamma prime – crystal is a much bigger scale): 3 dimension of atoms lined up in the same orientation. These orientations between crystals are different, leaving room for mismatch layers, open space (vacancy), and broken bonds (impurity).



	Single crystal blades can withstand temperatures and stresses that would destroy basic alloys. They can last up to 9 times longer against creep and thermal fatigue. They are also 3 times more resistant to corrosion.  Every turbine blade is coated with two protective layers. A thin metallic bond coat is used first to resist oxidation (~100 micrometers). A ceramic topcoat is then added (>100 micrometers) and can keep the metal 100-170 degrees cooler.
VOCAB: (w/definition)	Centrifugal force: Force applied to the metal of the engine (or anything) due to the spinning. Strain: Per unit change in length of metals when under tensile load. Carnot efficiency: How much work a heat engine can get from the air expanding. = 1 - (temp cold / temp hot) can improve by raising the temp or raising the altitude you fly at. Edge dislocation: atoms are not perfectly aligned. 2 “lines” of atoms can branch into 3. Plastic deformation: if the shape of the metal changes permanently. Bonds are breaking and reforming.
Cited references to follow up on	Professor Jaafar El-Awady – Department of Mechanical Engineering – John Hopkins University All Citations: https://docs.google.com/document/d/1Nd3KqiBy7v54U9HcMqFFcCnVMPVqreXngbioLAL4tvs/edit?tab=t.0 3D Sim Turbofan via ntrs.nasa.gov - ve42.co/RingofNozzles The physics of deforming metals via solid.dtu.dk - ve42.co/DeformingMetals Steel vs. Titanium via thomasnet.com - ve42.co/TitaniumDensity
Follow up	How can I determine what elements I want to add to my alloy in order to get the results I

Questions	need for a specific project that does not deal with high centrifugal forces?
Why I Researched	What metals will work best for my project? What factors should I look at for casting and manufacturing methods? How does the molecular structure of atoms play a roll?

Article #19 Notes: The effect of liquid metal cooling on thermal gradients in directional solidification of superalloys: Thermal analysis

Source Title	The effect of liquid metal cooling on thermal gradients in directional solidification of superalloys: Thermal analysis
Source citation (APA Format)	Franke, M. M., Hilbinger, R. M., Lohmüller, A., & Singer, R. F. (2013). The effect of liquid metal cooling on thermal gradients in directional solidification of superalloys: Thermal analysis. *Journal of Materials Processing Technology*, *213*(11), 2081-2088. https://www.sciencedirect.com/science/article/abs/pii/S092401361300191X
Original URL	https://www.sciencedirect.com/science/article/abs/pii/S092401361300191X
Source type	Journal Article
Keywords	Liquid metal cooling Thermal gradients Numerical simulation Superalloys
#Tags	#Superalloys #DirectionalSolidification #ThermalGradients #LiquidMetalCooling #InvestmentCasting #NumericalSimulation #Metallurgy #TurbineBlades
Summary of key points + notes (include methodology)	High-performance turbine components are made using directional solidification to create single crystal structures. Reducing the primary dendrite arm spacing is desirable as it reduces segregation, improves homogeneity, and enhances mechanical properties. Researchers used the numerical modeling software ProCAST to compare the conventional High Rate Solidification (HRS) process with the Liquid Metal Cooling (LMC) process. Investigations were performed on cylindrical specimens of varying diameters (2–48 mm) and a large-scale assembly of four turbine blades. LMC significantly improves the operating range of investment casting, allowing withdrawal speeds approximately three times higher than HRS. While LMC and HRS show similar performance for small cylindrical specimens at low speeds, LMC can reduce the primary dendrite arm spacing by 50% for large blade clusters. The numerical data indicates that the design of the baffle has

<table>
<tr><td></td><td>a stronger effect on cooling than the heat dissipation mechanism itself.</td></tr>
<tr><td>Research Question/Problem/ Need</td><td>The study aims to examine how casting geometry, baffle design, mold thickness, and withdrawal speed influence solidification conditions and the resulting microstructure in both LMC and HRS processes. It specifically addresses why experimental findings on LMC performance vary significantly between small laboratory pieces and large industrial components.</td></tr>
<tr><td>Important Figures</td><td>

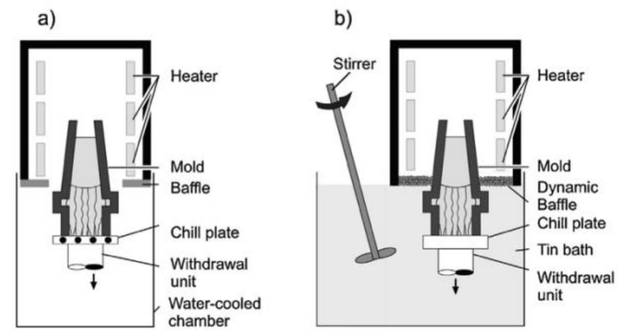
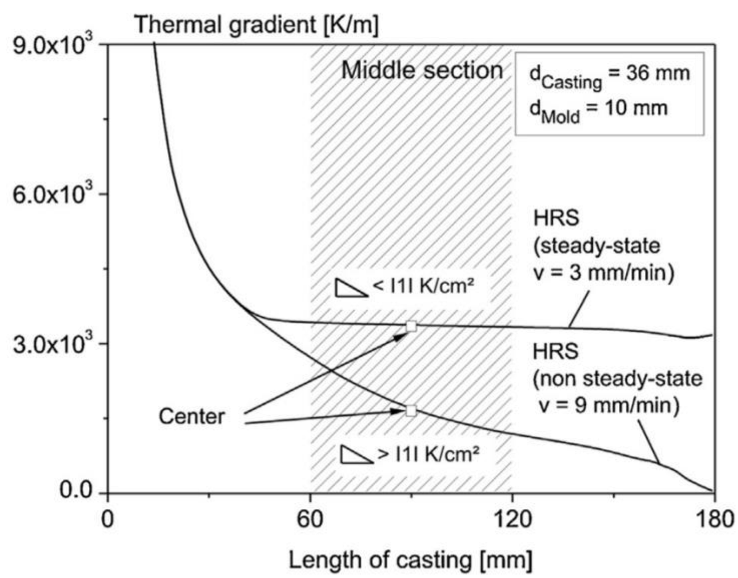


Fig. 1. Schematic of (a) conventional process–High Rate Solidification (HRS) and (b) improved process with higher gradient–Liquid Metal Cooling (LMC).

Figure 1 provides a side-by-side comparison of the conventional radiation-based HRS process (a) and the convective tin-bath LMC process (b).
In addition to giving a visual of the setup, it establishes the fundamental differences in equipment, specifically the different cooling methods. Also, it gives an introduction of a "dynamic baffle" in LMC.



The graph shows how the thermal gradient changes as a 36 mm cylindrical bar is withdrawn.
The graph is used to define "steady-state" conditions, where the solidification front stays in a fixed position. This is the opposite of a "non-steady-state," where the solidification is not fixed. It demonstrates that at high speeds (9mm/min), HRS becomes unstable while LMC remains stable.</td></tr>
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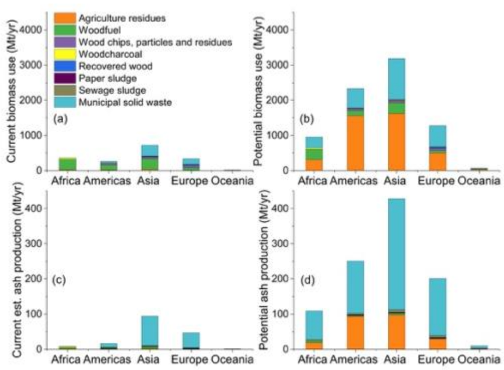
VOCAB: (w/definition)	Liquid Metal Cooling (LMC): An advanced directional solidification process where the mold is lowered into a liquid metal bath (normally tin) to dissipate heat through convection rather than radiation. High Rate Solidification (HRS): The conventional directional solidification technique that relies on radiation with a water-cooled chamber for dissipation. Primary Dendrite Arm Spacing (PDAS): A microstructural characteristic representing the distance between the centers of adjacent primary crystal branches. Traditionally, smaller spacing correlates to better material properties. Baffle: A thermal shield placed between the heating furnace and the cooling zone to minimize radiation interference. Steady-state Conditions: A state during the withdrawal process where the thermal gradient remains unchanging, indicating a fixed solidification front position.
Cited references to follow up on	Alaruri, S., Bianchini, L., Brewington, A., 1998. Effective spectral emissivity measurements of superalloys and YSZ thermal barrier coating at high temperature using a 1.6 m single wavelength pyrometer. Optics and Laser Engineering 30, 77–91. Franke, M.M., Hilbinger, R.M., Heckl, A., Singer, R.F., 2010. Effect of thermo physical properties and processing conditions on primary dendrite arm spacing of nickel-base superalloys – numerical approach. International Foundry Research/Giessereiforschung 62, 14–18.
Follow up Questions	How does the numerical model's accuracy change when considering convection inside the molten metal?
Why I Researched	I simulated 5 different metals and found that the thermal gradient was the same for all for all of them. I want to investigate why I may have gotten these results.

Article #20 Notes: Beneficial management of biomass combustion ashes

Source Title	Beneficial management of biomass combustion ashes
Source citation (APA Format)	Zhai, J., Burke, I. T., & Stewart, D. I. (2021). Beneficial management of biomass combustion ashes. *Renewable and Sustainable Energy Reviews*, *151*, 111555. https://doi.org/10.1016/j.rser.2021.111555
Original URL	https://pdf.sciencedirectassets.com/271969/1-s2.0-S1364032121X00147/1-s2.0-S1364032121008339/main.pdf Note: Sign in required. If you cannot access, ask Ryan.
Source type	Review Article
Keywords	Biomass ash Ash quantity Ash composition Classification Ash management
#Tags	#BiomassEnergy #AshManagement #ResourceRecovery #CircularEconomy #WasteManagement #SustainableEnergy #SoilAmendment #PotassiumRecovery
Summary of key points + notes (include methodology)	The global transition from fossil fuels to renewable energy has increased the use of biomass, which now accounts for 70% of renewable energy supply. Ash properties vary significantly depending on the feedstock meaning tailored management strategies are needed rather than a "one size fits all" disposal approach. Virgin biomass ashes are generally nutrient-rich while waste-derived ashes often contain higher levels of heavy metals and persistent organic pollutants (POPs) like PCDD/Fs. The authors collated data from hundreds of reports to determine mean chemical compositions (major oxides and trace elements) for various biomass ashes. They also assessed the suitability of different ashes for applications like fertilizer, soil

	conditioning, construction materials, and resource recovery based on their chemical profiles and regulatory limits. The ashes were grouped based on different chemical contents' to categorize each ash and explain how to properly use and dispose of it. Wood ashes are dominated by CaO (~30-60%). They are widely used as soil conditioners (liming agents) for acidic soils. Trace metal levels are generally low but occasionally exceed strict forestry limits. In the future, there is a massive capacity to increase energy production from agricultural residues. This which would shift the dominant ash type from wood/waste ash to silica/potassium-rich agricultural ash.
Research Question/Problem/ Need	As bioenergy production expands to meet climate goals, the volume of biomass ash is increasing rapidly. Current management often involves disposal, wasting valuable nutrients and resources. There is a need to understand the distinct chemical properties of different biomass ashes (agricultural vs. forestry vs. waste) to implement safe reuse strategies and avoid environmental contamination.
Important Figures	 Fig. 2. Current biomass utilization level (a) and potential biomass utilization if used to maximum level (b); current estimates of ash production (c) and potential ash production (d) if used to maximum level. The writers visualized the potential growth in bioenergy with the corresponding surge in ash production, highlighting the agricultural residues and other factors.

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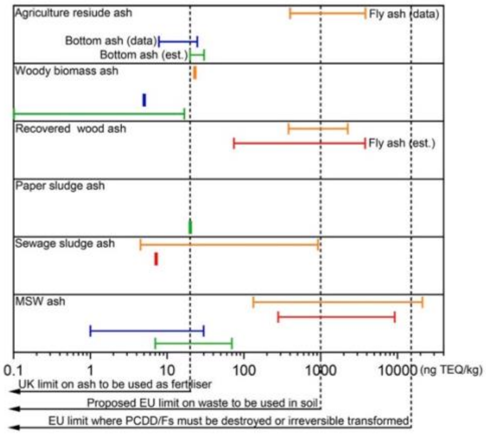

Fig. 3. PCDD/Fs content in biomass ash and current regulations on PCDD/Fs content limits for ash management (blue line and orange lines are reported values of bottom ash and fly ash, respectively [129,147–154]; dark green lines are estimates for bottom ash (MSW and paper sludge) or combined bottom and fly ash (agriculture residue ash and woody biomass ash) [135]; red lines are estimates for fly ash [135]).

Figure 3 assesses the safety of land application. It shows the virgin biomass ashes generally fall below strict limits for fertilizer use while MSW fly ash often exceeds hazardous waste limits, requiring controlled disposal.
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<td>VOCAB: (w/definition)</td>
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Biomass: Organic material from plants (wood, crops) and biogenic wastes (MSW, sewage sludge) used as fuel for energy production.

PCDD/Fs (Polychlorinated dibenzodioxins/dibenzofurans): Toxic persistent organic pollutants (POPs) formed during combustion. They normally form in the presence of chlorine and catalytic metals like copper. Their concentration determines if ash can be applied to land or requires hazardous disposal.

Bottom Ash: The coarse ash fraction that remains in the combustion chamber after incineration; generally contains fewer volatile contaminants than fly ash.
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<td>Cited references to follow up on</td>
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Hjelmar O, Holm J, Crillesen K. Utilisation of MSWI bottom ash as sub-base in road construction: first results from a large-scale test site. J Hazard Mater 2007; 139:471–80

Abdulahi MM. Municipal solid waste incineration bottom ash as road construction material. AU JT 2009;13:121–8.

Lojka M, Bartůnˇek V, Lauermannov´ a A-M, Pavlíkova ´ M, Z´ aleska ´ M, Pavlík Z, et al. Possible use of miscanthus ash as an active mineral admixture in composite materials for construction use. Waste Forum2019.

Federal Highway Administration. User guidelines for waste and byproduct materials in pavement construction. https://www.fhwa.dot.gov/publications/re search/infrastructure/pavements/97148/033.cfm#:~:text=Municipal%20solid %20waste%20(MSW)%20combustor,individual%20ash%20streams%20are% 20produced2016.
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<td>Follow up Questions</td>
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The review mentions that agricultural residues are the largest untapped biomass resource. What are the specific logistical and economic barriers (for example: collection density, transport costs,
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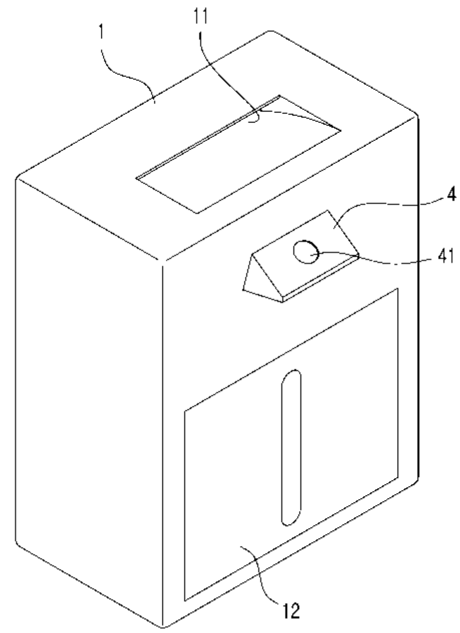
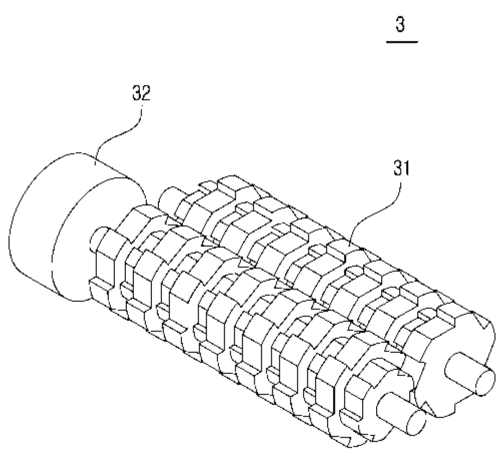
	and seasonal availability) currently preventing the large scale exploitation of this resource compared to wood fuel?
Why I Researched	What should I do with the leftover ash? How has wood ash been used in the past and how can I incorporate it into my project?

Patent #1 Notes: Mask Disposal Processor Using Plasma

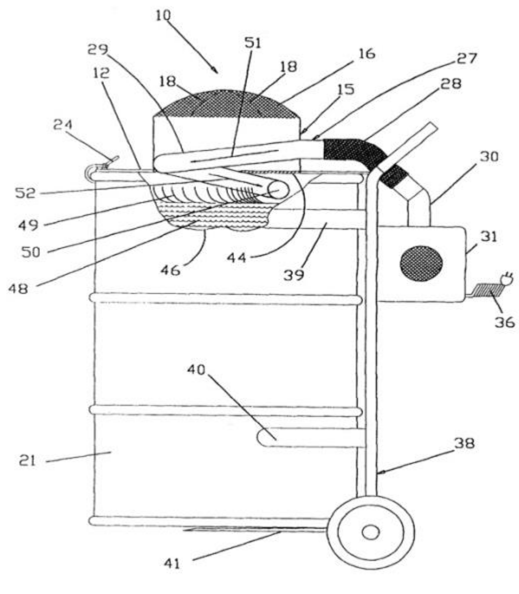
Source Title	Mask Disposal Processor Using Plasma
Source citation (APA Format)	Jeong, J. Y. (2022). *Mask disposal processor using plasma* (*Korean Patent No. KR20220009630A*). Korean Intellectual Property Office. https://patents.google.com/patent/KR20220009630A/en.
Original URL	https://patents.google.com/patent/KR20220009630A/en
Source type	Patent
Keywords	Plasma Disposable Mask Sterilization Shredding/Crushing Medical Waste
#Tags	#PlasmaSterilization #MaskDisposal #WasteManagement #InfectionControl #Biosecurity #MedicalTech #PersonalProtectiveEquipment
Summary of key points + notes (include methodology)	Medical waste, like bandages and syringes, is strictly managed due to infection risks, usually through incineration. Standard medical waste disposal systems using high-pressure steam are often complex and bulky. Disposable masks are currently classified as general waste rather than medical waste, which creates a significant risk of secondary infection. The device consists of a main body, a plasma generation unit, a shredding unit, and a disinfection unit. For sterilization, air is passed through a plasma generator to create "sterilizing air" that fills the device's interior to kill viruses and bacteria on the masks and internal components. Meanwhile, a pair of interlocking cutters rotated by a motor grinds the masks into uniform pieces to ensure thorough exposure to the sterilizing air. After that, a separate disinfection unit sprays sanitizer onto the user's hands after they insert a mask to prevent infection from contact. The use of plasma allows for a simplified, compact structure suitable for both medical facilities and households. Meanwhile, shredding the masks improves sterilization efficiency by increasing the surface area

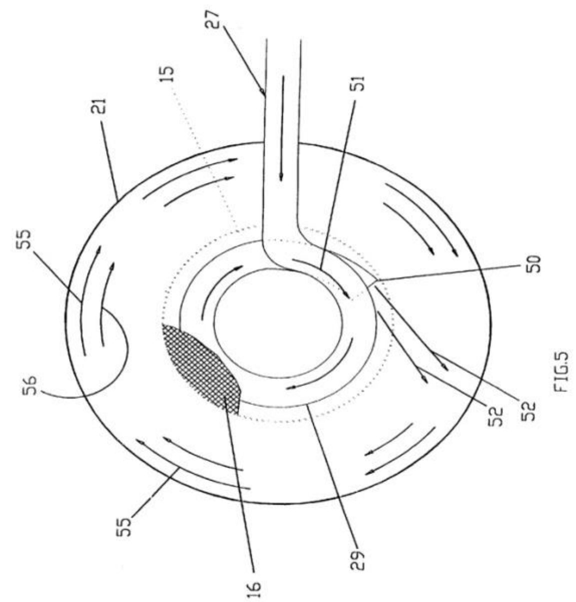
	exposed to the treated air.
Research Question/Problem/ Need	Existing medical waste systems are too large and complex for localized or residential use. A compact, simplified device that can safely sterilize and dispose of masks at the source of waste generation is needed.
Important Figures	 Figure 1 displays the external design of the product, including the mask inlet (11), the collection box (12), and the disinfection button (41).  Figure 3 shows the mechanical assembly of the motor (32) and the pair of interlocking cutters (31). This illustrates the physical process of grinding masks into smaller pieces to enhance sterilization.

VOCAB: (w/definition)	Plasma Generation Unit: The component that converts regular air into sterilizing air to neutralize pathogens. Shredding Unit: An internal mechanism consisting of cutters and a motor used to grind masks into small, uniform pieces. Disinfection Unit: An external spray mechanism used to sanitize the user's hands after waste disposal to prevent contact-based infection.
Cited references to follow up on	JP2003175094A * 2001-12-11 2003-06-24 Ebara Corp Device for sterilizing and treating waste by microwave CN111298148A * 2020-03-05 2020-06-19 北京航天环境工程有限公司 A double-layer steam sterilizer and a movable medical waste emergency disposal system and application
Follow up Questions	How does the energy consumption of a plasma-based unit compare to traditional high-temperature incineration for a similar volume of waste?

Patent #2 Notes: Portable cyclone burner

Source Title	Portable cyclone burner
Source citation (APA Format)	Kaylor, T. R. (2000). *Portable cyclone burner* (*U.S. Patent No. 6,105,515*). U.S. Patent and Trademark Office. https://ppubs.uspto.gov/api/pdf/downloadPdf/6105515?requestToken=eyJzdWIiOiI5ZWViODQzNC1mODIxLTRhM2ItYWJkYi02ZjRiMmE4YmE1Y2QiLCJ2ZXIiOiJlZWU1ZWIzZS1kMDMzLTQ2NDItYWNjYS0wMmZhYmMxMjc1YmYiLCJleHAiOjB9
Original URL	https://ppubs.uspto.gov/api/pdf/downloadPdf/6105515?requestToken=eyJzdWIiOiI5ZWViODQzNC1mODIxLTRhM2ItYWJkYi02ZjRiMmE4YmE1Y2QiLCJ2ZXIiOiJlZWU1ZWIzZS1kMDMzLTQ2NDItYWNjYS0wMmZhYmMxMjc1YmYiLCJleHAiOjB9
Source type	Patent
Keywords	Portable Cyclone, Burner Incinerator Stainless steel 55-gallon drum Blower motor Cyclonic flow Oil spill waste.
#Tags	#PortableBurner #CycloneIncinerator #WasteManagement #FluidDynamics #PatentAnalysis
Summary of key points + notes (include methodology)	Traditional cyclone furnaces are often immobile, require refractory linings, or are designed for fine-grained fuels rather than bulky waste. This invention seeks to provide a lightweight, portable alternative specifically for oily waste like sorbent pads used in spill cleanups. The system uses a standard 55-gallon steel drum modified with a custom stainless steel lid and flue. A blower motor, mounted on a hand truck, forces air through a spiraled tube into the drum. The air enters at a downward angle to create a high-velocity "cyclone" that accelerates combustion. The cyclonic action provides fast, substantially complete combustion

	with minimal pollution, leaving only a few inches of ash. The device is manually portable via a hand truck, allowing for immediate disposal at the site of a spill.
Research Question/Problem/ Need	The patent addresses the need for a manually portable device that can incinerate oil spill waste on-site to avoid the logistics and costs of transporting hazardous oily materials to a central disposal facility.
Important Figures	 FIG.2 Figure 2 details the internal spiral portion (29) of the air line. It demonstrates the critical 270° curve that forces air into a cyclonic pattern (51, 52) within the drum.

	 Figure 5 presents a top-down look at the air routing (55, 56). This helps visualize how the forced air creates the vortex necessary for complete combustion.
VOCAB: (w/definition)	In situ: To process or dispose of materials exactly where they are located rather than moving them. Cyclonic Flow: A circular or spiraling movement of air/gas that enhances the mixing of oxygen and fuel for better combustion. Flue: A duct or pipe that allows exhaust gases to escape from a combustion chamber. Refractory: Heat-resistant material used to line furnaces; notably, this patent avoids the need for heavy refractory linings to remain portable.
Cited references to follow up on	U.S. Pat. No. 3,869,995 (Straitz, III)
Follow up Questions	How would the cyclonic airflow need to be adjusted for the bulkier, varied densities of construction lumber compared to the relatively uniform oil sorbent pads? Can a passive magnetic filter be integrated into the flue (15) or bottom of the drum (21) without disrupting the cyclonic pressure needed for efficient burning?. Since this patent uses a standard steel drum, what is its actual lifespan at 2000°F before the metal structurally fails?

Additional Notes 1: Wood Waste Management (1960-2018)

Source Title	Wood Waste Management (1960-2018)
Source citation (APA Format)	Environmental Protection Agency. (2026, January 12). *Wood: Material-specific data.* https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/wood-material-specific-data
Original URL	https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/wood-material-specific-data
Source type	Figure
Summary of key points + notes (include methodology)	 Last updated on October 23, 2025 The amount of wood waste that has ended up in landfills has increased significantly in past years. In of 2018, 12,150,000 tons of wood waste ended up in landfills. This totals 100,000,000 cubic yards.
Cited references to follow up on	https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/frequent-questions-regarding-epas-facts-and https://catalog.data.gov/dataset/sustainable-materials-management-smm-materials-and-waste-management-in-the-united-states-key-fa12

Potential Other Articles:

https://www.mdpi.com/2073-4360/13/11/1752

Link for patent #2 product:

https://www.elastec.com/products/portable-incinerators/smartash/