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Canadian Centre for Occupational Health and Safety

Diesel Exhaust

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What is diesel exhaust?

Diesel exhaust is produced by the combustion (burning) of diesel fuel. The exhaust is a complex mixture of gases, vapours, aerosols, and particulate substances. The exact nature of the exhaust depends on a number of factors including the type of engine, how well serviced/maintained the engine is, type of fuel, speed and load on the engine, and emission control systems.

Diesel exhaust may contain:

- Carbon (soot)
- Carbon monoxide
- Carbon dioxide
- Oxygen
- Water vapour
- Nitrogen
- Oxides of nitrogen (e.g., nitrogen oxide, nitrogen dioxide)
- Oxides of sulphur (e.g., sulphur dioxide)
- Alcohols
- Aldehydes
- Ketones
- Hydrocarbons
- Polycyclic aromatic hydrocarbons (PAHs)
- Diesel particulate matter (DPM)

What are the main health concerns?

Short term exposure to diesel exhaust can cause coughing, and irritation of the eyes, nose, throat, and respiratory tract. Breathing in diesel exhaust can cause lung irritation and/or an allergic reaction causing asthma (wheezing and difficult breathing), or making pre-existing asthma worse. MAKING PEOPLE SICK ER AT THE HOSPITAL

Very high levels can lead to asphyxiation from carbon monoxide poisoning.

Long term exposure may lead to serious health effects. The International Agency for Research on Cancer (IARC), which is part of the World Health Organization (WHO), classified diesel engine exhaust as carcinogenic to humans (Group 1), determining that exposure to diesel exhaust emissions increases the risk for lung cancer and possibly bladder cancer.

PEOPLE working DAYLY ACROSS from DIESEL POWER PLANT
DOWNWIND FROM PREVAILING S W WIND

Who is at risk of exposure to diesel exhaust?

The most common way individuals are exposed is by breathing air that contains the diesel particulate matter. The fine and ultra fine particles are respirable, which means that the particles can avoid many of the human respiratory system defense mechanisms and enter deeply into the lung.

People may be at risk:

- In areas where diesel powered vehicles are used such as forklift trucks, railway locomotive, buses, trucks, construction vehicles, farm vehicles.
- Where diesel exhaust can accumulate, such as warehouses, car/bus depots, ferries/ships, garages, vehicle testing sites, fire stations, mines, or where diesel generators or winch motors are used.
- In occupations that work in areas where exhaust levels are high or can accumulate, such as police and traffic officers, custom officer/border control booths, ticket/toll booth operators, drivers of diesel vehicles (buses, subway/railway, truck, taxi, forklift, etc.), airline ground crew, farm workers, vehicle maintenance workers, dock/cargo ship workers, miners.

How do I know if exposure to diesel exhaust is an issue?

Conduct a risk assessment to determine the health risks from exposure, and to identify the necessary steps needed to control these risks. See the OSH Answers for more information on how to do a risk assessment (http://www.ccohs.ca/oshanswers/hsprograms/risk_assessment.html).

Questions to investigate include:

- How likely is exposure?
- How long is exposure?
- Who/how many are affected?
- Have health concerns been reported?
- Can engines be turned off or idling avoided? Can engines be operated outdoors only?
- Are the engines in good repair?
- How exhaust is currently ventilated or removed from the location?
- Is there visible smoke from the engine?
- Is soot accumulating in the workplace?
- What controls are currently in place?
- How can exposure be reduced or eliminated?

This checklist is not complete. Be sure to investigate all relevant issues for your workplace or situation.

How can exposure to diesel exhaust be controlled?

Various measures can help lower exposure to diesel exhaust. Workplaces may investigate the measures that work best in their situation. Control measures may include:

- Eliminate by replacing diesel powered engines with electric or other types of power sources (remember to manage any risks introduced by alternative power sources).
- Use alternate fuels where possible.
- Use low-emission engines.
- Use exhaust treatment systems such as filters, catalysts and/or converters, and a corresponding maintenance program.
- Run engines outdoors (instead of indoors).
- Maintain engines to help with their efficiency.
- Maintain the body of the vehicle to make sure that exhaust is not leaking into the cab or passenger area.
- Modify the layout of the work area to separate the area where people must work and areas where exhaust is generated, such as isolate the generator in a separate, ventilated space, or isolate the worker in a sealed, air conditioned cabin (air filtered) where possible.

- Ventilate appropriately, such as providing positive pressure ventilation, exhaust extraction devices, inlet and exhaust general (dilution) ventilation, and/or local exhaust (such as tail pipe hose exhaust).
- Keep openings for border, ticket, toll, or food booths as small as possible and closed as much as possible when there is exposure to exhaust. If booths are in a place where exhaust accumulates, ventilate the booth with fresh air appropriately.
- Use administrative controls such as:
  - Education and training to workers about the exposure to diesel exhaust and proper use of control measures.
  - Turning off engines whenever possible.
  - Regularly maintaining engines.
  - Reduce the hours of work exposed to exhaust through job rotation and scheduling.
- Use of personal protective equipment, such as respirators.

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Wickipedia Diesel Exhaust

To rapidly reduce particulate matter from heavy-duty diesel engines in California, the California Air Resources Board created the Carl Moyer Program to provide funding for upgrading engines ahead of emissions regulations. In 2008 the California Air Resources Board also implemented the 2008 California Statewide Truck and Bus Rule which requires all heavy-duty diesel trucks and buses, with a few exceptions, that operate in California to either retrofit or replace engines in order to reduce diesel particulate matter. The US Mine Safety and Health Administration (MSHA) issued a health standard in January 2001 designed to reduce diesel exhaust exposure in underground metal and nonmetal mines; on September 7, 2005, MSHA published a notice in the Federal Register proposing to postpone the effective date from January 2006 until January 2011.

Health concerns

General concerns

Emissions from diesel vehicles have been reported to be significantly more harmful than those from petrol vehicles.[38] Diesel combustion exhaust is a source of atmospheric soot and fine particles, which is a component of the air pollution implicated in human cancer,[39][40] heart and lung damage,[41] and mental functioning.[42] Moreover, diesel exhaust contains contaminants listed as carcinogenic for humans by the IARC (part of the World Health Organization of the United Nations), as present in their List of IARC Group 1 carcinogens.[7] Diesel exhaust pollution is thought to account for around one quarter of the pollution in the air in previous decades, and a high share of sickness caused by automotive pollution.[43]

Occupational health effects

Exposure to diesel exhaust and **diesel particulate matter** (DPM) is an occupational hazard to truckers, railroad workers and occupants of residential homes in vicinity of a rail yard, and miners using diesel-powered equipment in underground mines. Adverse health effects have also been observed in the general population at ambient atmospheric particle concentrations well below the concentrations in occupational settings.

Two diesel particulate matter monitors

In March 2012, U.S. government scientists showed that underground miners exposed to high levels of diesel fumes have a threefold increased risk for contracting lung cancer compared with those exposed to low levels. The $11.5 million Diesel Exhaust in Miners Study (DEMS) followed 12,315 miners, controlling for key carcinogens such as cigarette smoke, radon, and asbestos. This allowed scientists to isolate the effects of diesel fumes.[44][45]

For over 10 years, concerns have been raised in the USA regarding children's exposure to DPM as they ride diesel-powered school buses to and from school.[46] In 2013, the Environmental Protection Agency (EPA) established the Clean School Bus USA initiative in an effort to unite private and public organizations in curbing student exposures.[47]

Concerns regarding particulates

Diesel particulate matter (DPM), sometimes also called **diesel exhaust particles** (DEP), is the particulate component of diesel exhaust, which includes diesel soot and aerosols such as ash particulates, metallic abrasion particles, sulfates, and silicates. When released into the atmosphere, DPM can take the form of individual particles or chain aggregates, with most in the invisible sub-micrometre range of 100 nanometers, also known as ultrafine particles (UFP) or PM0.1.

Heavy truck, with visible particulate soot

The main particulate fraction of diesel exhaust consists of fine particles. Because of their small size, inhaled particles may easily penetrate deep into the lungs.[1] The polycyclic aromatic hydrocarbons (PAHs) in the exhaust stimulate nerves in the lungs, causing reflex coughing, wheezing and shortness of breath.[48] The rough surfaces of these particles makes it easy for them to bind with other toxins in the environment, thus increasing the hazards of particle inhalation.[10][11]

A study of particulate matter (PM) emissions from transit buses running on ULSD and a mixture of biodiesel and conventional diesel (B20) was reported by Omidvarborna and coworkers, where they conclude PM emissions appeared lower in cases of mixed diesel/biodiesel use, where they were dependent on the engine model, cold and hot idle modes, and fuel type, and that heavy metals in PM emitted during hot idling were greater than those from cold idling; reasons for PM reduction in biodiesel emissions were suggested to result from the oxygenated structure of biodiesel fuel, as well as arising from changes in technology (including the use of a catalytic converter in this test system).[49] Other studies concluded that while in certain specific cases (i.e. low loads, more saturated feedstocks, ...), NOx emissions can be lower than with diesel fuel, in most cases NOx emissions are higher, and the NOx emissions even go up as more biofuel is mixed in. Pure biodiesel (B100) even ends up having 10-30% more NOx emissions compared to regular diesel fuel.[50]

Specific effects

Exposures have been linked with acute short-term symptoms such as headache, dizziness, light-headedness, nausea, coughing, difficult or labored breathing, tightness of chest, and irritation of the eyes and nose and throat.[51] Long-term exposures can lead to chronic, more serious health problems such as cardiovascular disease, cardiopulmonary disease, and lung cancer.[39][40][52] Elemental carbon attributable to traffic was significantly associated with wheezing at age 1 and persistent wheezing at age 3 in the Cincinnati Childhood Allergy and Air Pollution Study birth cohort study.[53]

The NERC-HPA funded Traffic Pollution and Health in London project at King's College London is currently seeking to refine understanding of the health effects of traffic pollution.[54] Ambient traffic-related air pollution was associated with decreased cognitive function in older men.[42]

Mortality from diesel soot exposure in 2001 was at least 14,400 out of the German population of 82 million, according to the official report 2352 of the *Umweltbundesamt Berlin* (Federal Environmental Agency of Germany).

The study of nanoparticles and nanotoxicology is in its infancy, and health effects from nanoparticles produced by all types of diesel engines are still being uncovered. It is clear, that diesel health detriments of fine particle emissions are severe and pervasive. Although one study found no significant evidence that short-term exposure to diesel exhaust results in adverse extrapulmonary effects, effects that are correlated with an increase in cardiovascular disease,[55] a 2011 study in *The Lancet* concluded that traffic exposure is the single most serious preventable trigger of heart attack in the general public, as the cause of 7.4% of all attacks.[41] It is impossible to tell how much of this effect is due to the stress of being in traffic and how much is due to exposure to exhaust.

Since the study of the detrimental health effects of nanoparticles (nanotoxicology) is still in its infancy, and the nature and extent of negative health impacts from diesel exhaust continues to be discovered. There is little controversy, however, that the public health impact of diesels is higher than that of petrol-fuelled vehicles despite the wide uncertainties.[56]

Variation with engine conditions

The types and quantities of nanoparticles can vary according to operating temperatures and pressures, presence of an open flame, fundamental fuel type and fuel mixture, and even atmospheric mixtures. As such, the resulting types of nanoparticles from different engine technologies and even different fuels are not necessarily comparable. One study has shown that 95% of the volatile component of diesel nanoparticles is unburned lubricating oil.[57] Long-term effects still need to be further clarified, as well as the effects on susceptible groups of people with cardiopulmonary diseases.

Diesel engines can produce black soot (or more specifically diesel particulate matter) from their exhaust. The black smoke consists of carbon compounds that have not burned because of local low temperatures where the fuel is not fully atomized. These local low temperatures occur at the cylinder walls, and at the surface of large droplets of fuel. At these areas where it is relatively cold, the mixture is rich (contrary to the overall mixture which is lean). The rich mixture has less air to burn and some of the fuel turns into a carbon deposit. Modern car engines use a diesel particulate filter (DPF) to capture carbon particles and then intermittently burn them using extra fuel injected directly into the filter. This prevents carbon buildup at the expense of wasting a small quantity of fuel.

The full load limit of a diesel engine in normal service is defined by the "black smoke limit", beyond which point the fuel cannot be completely burned. As the "black smoke limit" is still considerably lean of stoichiometric, it is possible to obtain more power by exceeding it, but the resultant inefficient combustion means that the extra power comes at the price of reduced combustion efficiency, high fuel consumption and dense clouds of smoke. This is only done in high performance applications where these disadvantages are of little concern.

When starting from cold, the engine's combustion efficiency is reduced because the cold engine block draws heat out of the cylinder in the compression stroke. The result is that fuel is not burned fully, resulting in blue and white smoke and lower power outputs until the engine has warmed. This is especially the case with indirect injection engines, which are less thermally efficient. With electronic injection, the timing and length of the injection sequence can be altered to compensate for this. Older engines with mechanical injection can have mechanical and hydraulic governor control to alter the timing, and multi-phase electrically controlled glow plugs, that stay on for a period after start-up to ensure clean combustion; the plugs are automatically switched to a lower power to prevent their burning out.

Ecological effects

Experiments in 2013 showed that diesel exhaust impaired bees' ability to detect the scent of oilseed rape flowers.[58]

Remedies

General

With emissions standards tightening, diesel engines are having to become more efficient and have fewer pollutants in their exhaust. For instance, light duty truck must now have NOx emissions less than 0.07 g/mile, and in the U.S., by 2010, NOx emissions must be less than 0.03 g/mile. Moreover, in recent years the United States, Europe, and Japan have extended emissions control regulations from covering on-road vehicles to include farm vehicles and locomotives, marine vessels, and stationary generator applications.[59] Changing to a different fuel (i.e. dimethyl ether, and other bioethers as diethyl ether[60]) tends to be a very effective means to reduce pollutants such as NOx and CO. When running on dimethyl ether (DME) for instance, particulate matter emissions are near-nonexistent, and the use of diesel particulate filters could even be omitted.[61] Also, given that DME can be made from animal, food, and agricultural waste, it can even be carbon-neutral (unlike regular diesel). Mixing in bioether (or other fuels such as hydrogen)[62][63] into conventional diesel also tends to have a beneficial effect on the pollutants that are emitted. In addition to changing the fuel, US engineers have also come up with two other principles and distinct systems to all on-market products that meet the U.S. 2010 emissions criteria, selective non-catalytic reduction (SNCR), and exhaust gas recirculation (EGR). Both are in the exhaust system of diesel engines, and are further designed to promote efficiency.

Selective catalytic reduction

Selective catalytic reduction (SCR) injects a reductant such as ammonia or urea — the latter aqueous, where it is known as diesel exhaust fluid, DEF) — into the exhaust of a diesel engine to convert nitrogen oxides (NO_x) into gaseous nitrogen and water. SNCR systems have been prototyped that reduce 90% of the NO_x in the exhaust system, with commercialized systems being somewhat lower. SCR systems do not necessarily need particulate matter (PM) filters; when SNCR and PM filters are combined, some engines have been shown to be 3-5% more fuel efficient. A disadvantage of the SCR system, in addition to added upfront development cost (which can be offset by compliance and improved performance), is the need to refill the reductant, the periodicity of which varies with the miles driven, load factors, and the hours used.[64] The SNCR system is not as efficient at higher revolutions per minute (rpm). SCR is being optimized to have higher efficiency with broader temperatures, to be more durable, and to meet other commercial needs.[59]

Exhaust gas recirculation

Exhaust gas recirculation (EGR), on diesel engines, can be used to achieve a richer fuel to air mixture and a lower peak combustion temperature. Both effects reduce NO_x emissions, but can negatively impact efficiency and the production of soot particles. The richer mix is achieved by displacing some of the intake air, but is still lean compared to petrol engines, which approach the stoichiometric ideal. The lower peak temperature is achieved by a heat exchanger that removes heat before re-entering the engine, and works due to the exhaust gases' higher specific heat capacity than air. With the greater soot production, EGR is often combined with a particulate matter (PM) filter in the exhaust.[65] In turbocharged engines, EGR needs a controlled pressure differential across the exhaust manifold and intake manifold, which can be met by such engineering as use of a variable geometry turbocharger, which has inlet guide vanes on the turbine to build exhaust backpressure in the exhaust manifold directing exhaust gas to the intake manifold.[66] It also requires additional external piping and valving, and so requires additional maintenance.[66]

Combined systems

John Deere, the farm equipment manufacturer is implementing such a combined SCR-EGR design, in a 9-liter "inline 6" diesel engine that involves both system types, a PM filter and additional oxidation catalyst technologies.[67] The combined system incorporates two turbochargers, the first on the exhaust manifold, with variable geometry and containing the EGR system; and a second a fixed geometry turbocharger. Recirculated exhaust gas and the compressed air from the turbochargers have separate coolers, and air merges before entering the intake manifold, and all subsystems are controlled by a central engine control unit that optimizes minimization of pollutants released in the exhaust gas.[67]

Other remedies

A new technology being tested in 2016 has been created by Air Ink which collects carbon particles using a "Kaalink" cylindrical device that is retrofitted into a vehicle's exhaust system, after processing to remove heavy metals and carcinogens, the company plans to use the carbon to make ink.[68]

See also

Scientists Find Link between Air Pollution and Intellectual Disabilities in Children

Nov 23, 2018 by News Staff / Source

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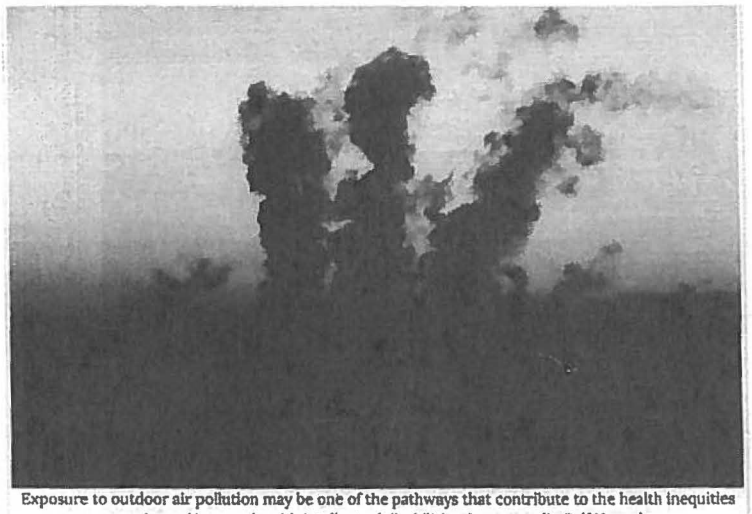
Levels of exposure to outdoor air pollution among children with intellectual disabilities are significantly higher than those of children without intellectual disabilities, according to a study carried out by Lancaster University researchers.



Exposure to outdoor air pollution may be one of the pathways that contribute to the health inequities experienced by people with intellectual disabilities. Image credit: Ralf Vetterle.

"Exposure to outdoor air pollution is a well-established risk factor for a range of adverse health conditions," said study senior author Professor Eric Emerson of the Lancaster University's Division of Health Research and colleagues.

"No previous study has quantified the extent to which children with intellectual disability may be exposed to outdoor air pollution."

Professor Emerson and co-authors analyzed data from the UK's Millennium Cohort Study, a nationally representative sample of over 18,000 UK children born 2000-2002.

Averaging across ages, children with intellectual disabilities were 33% more likely to live in areas with high levels of diesel particulate matter, 30% more likely to live in areas with high levels of nitrogen dioxide, 30% more likely to live in areas with high levels of carbon monoxide, and 17% more likely to live in areas with high levels of sulfur dioxide.

"Intellectual disability is more common among children living in more socio-economically deprived areas, which tend to have higher levels of air pollution," the study authors said.

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"However, exposure to outdoor air pollution may impede cognitive development, thereby increasing the risk of intellectual disability."

"We know that people with intellectual disabilities in the UK have poorer health and die earlier than they should," Professor Emerson said.

"This research adds another piece to the jigsaw of understanding why that is the case and what needs to be done about it."

The findings appear in the *Journal of Intellectual Disability Research*.

E. Emerson *et al.* Risk of exposure to air pollution among British children with and without intellectual disabilities. *Journal of Intellectual Disability Research*, published online November 20, 2018; doi: 10.1111/jir.12561

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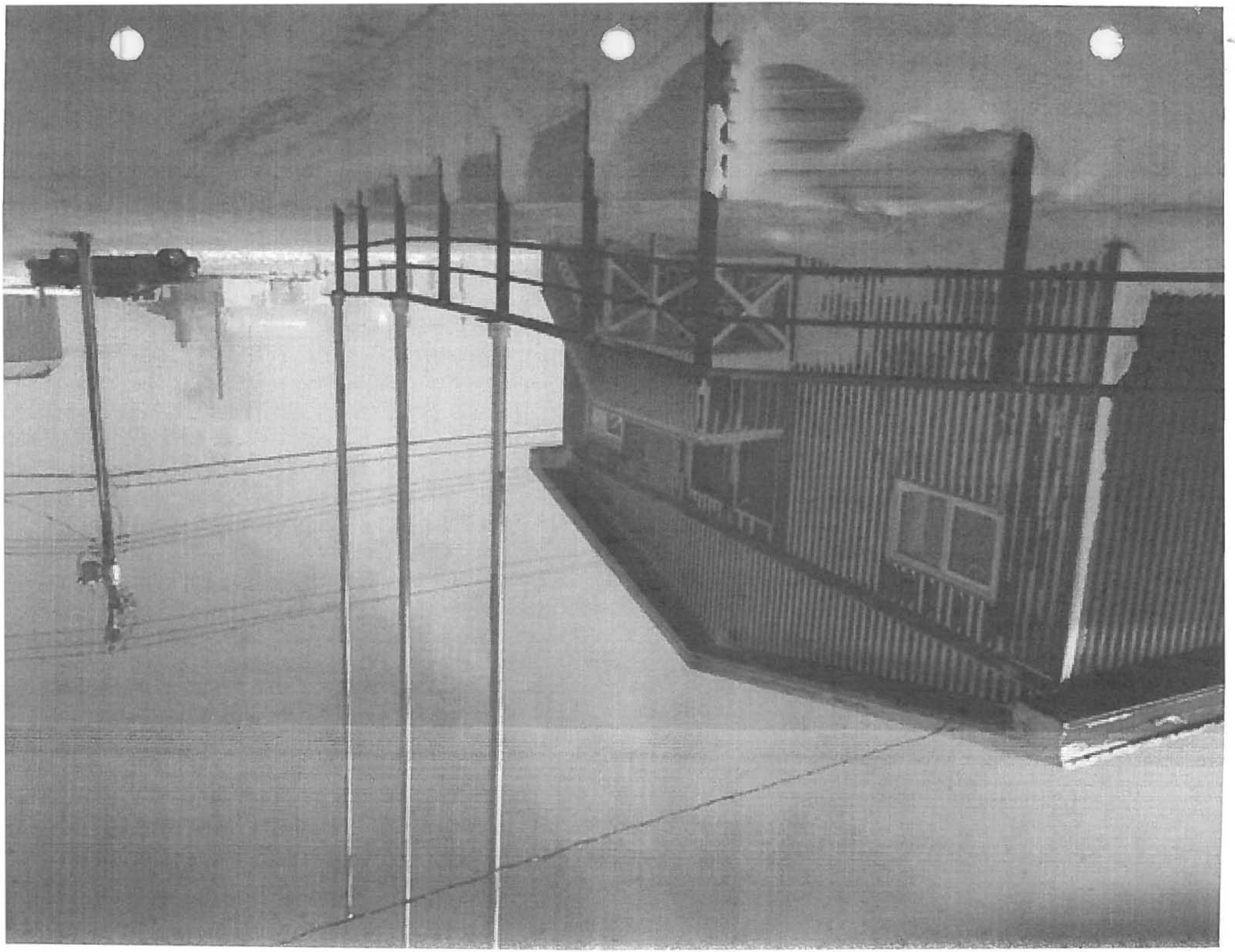

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