

SIMPLE SOLUTIONS

FOR DUSTY ENVIRONMENTS
AT METAL/NONMETAL MINES



REDUCING DUST EXPOSURES
WHILE IMPROVING ERGONOMICS

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Foreword

This booklet, *Simple Solutions for Dusty Environments at Metal/Nonmetal Mines*, is designed to provide examples of the types of solutions that you can use to reduce exposure to dust at surface mines and facilities. Practical controls are presented that not only lower dust exposures but also reduce the risks for both musculoskeletal disorders (MSDs) and traumatic injuries (e.g., slips, trips, and falls). Beyond the obvious health benefits, it can be easier to justify engineering controls and interventions when greater impact can be achieved.

While traumatic injuries occur suddenly, both MSDs and respirable diseases tend to be the result of cumulative overexposures. Exposures both at home and at the workplace can combine and manifest themselves in the later years of your career, depending on your exposure rates and cumulative stress.

This booklet provides information based on experience gained within the National Institute for Occupational Safety and Health (NIOSH) and highlights solutions that are relatively low in cost and easy to implement. Dust control solutions that are practical to maintain have the greatest potential for sustained use and ultimately improved mine worker health and safety. The information provided is only a primer on dust control and injury prevention at metal/nonmetal mining operations. For more comprehensive coverage of these topics, please consult the “Additional Resources” section at the end of this booklet.

Common Contributors to Dust Exposure

While any situation that releases dust into the air that workers breathe causes exposure, researchers have gained a body of experience (see “Additional Resources” section at the end of this booklet) that points to several common contributors, as described below. While this document focuses on respirable dusts, engineering controls which are able to reduce these smaller dusts should also work effectively on larger dusts (inhalable and thoracic). Throughout this document it can be assumed that “dust” refers to any size range but with an understanding that the most damaging health effects are caused by respirable dusts. Taking action to reduce emissions from these dust sources can reduce the potential for chronic health impacts from respirable dust exposures.

- **Inadequate Housekeeping** can take on many forms and has an impact anywhere that accumulated material is then released into the air.
 - Buildup of material on interior structures (beams, walls, ceilings of indoor enclosures) as well as the inside of interior structures (equipment cabinets and shelves, etc.)
 - Accumulation of spilled material at conveyors, transfer points, etc.
 - Excessive material on floors brought in from mobile equipment
- **Lack of Effective Local Exhaust Ventilation** can allow dust to spread throughout the plant.
 - Local exhaust ventilation systems that are not operational, missing, blocked, or with holes in ductwork compromising performance
 - Insufficient draw (negative pressure) to carry away dust
 - Poorly designed or oriented hoods or inlets too far away from the source
- **Lack of Total Structure Ventilation** may increase dust concentrations in indoor spaces leading to elevated exposures.
 - Fans that are turned off or otherwise not operational
 - Fans mounted too low in the building
 - Outside air inlets located near dust sources, allowing dusty air to enter the structure
- **Lack of Effective Enclosure Filtration** can lead to dust exposures for workers who spend much of their shift within enclosed cabs, booths, and control rooms.
 - Use of ineffective HVAC (heating, ventilation, and air-conditioning) systems; residential AC units without adequate filtration
 - Use of over-restrictive filters that can reduce airflow and clog too quickly
 - Lack of cab pressure monitors that provide real-time feedback on a booth’s seal and system performance
- **Poor Worker Practices** can lead to unnecessary dust exposures as workers allow their work habits and behaviors to expose them to respirable dusts.
 - Clapping hands to “clean off” gloves
 - Allowing one’s face to be too close to dust emissions (while bag tying and sealing, hosing down, etc.)
 - Handling of dusty equipment, bags, boxes, screens, etc.

Note: Multiple respirable dust sources can be present simultaneously. This list is not all-inclusive but rather serves as a starting point in a complete dust assessment.

Musculoskeletal Disorder/Traumatic Injury Risk Factors

A musculoskeletal disorder (MSD) risk factor is an action or condition that has been found to contribute to a musculoskeletal injury. MSDs may be characterized by discomfort, pain, and limitations in mobility and dexterity that may affect a person's ability to work. Five fundamental risk factors are described below, including examples.

- **Forceful Work** is any task or activity where the body must exert high levels of effort.
 - Lifting or carrying heavy objects
 - Forcefully pulling, pushing, or prying
 - Forceful gripping
- **Poor Posture** occurs when workers use any position other than a neutral posture, which makes them less capable of generating force and may cause pinching of nerves. Poor posture is sometimes also generally referred to as “awkward” posture.
 - Bending over to reach objects below knuckle height
 - Twisting the upper body or head
 - Working with elbows above the shoulders
 - Extended reaches in front of or behind the body
 - Kneeling or squatting
 - Static posture—even good posture can be harmful when sustained for a prolonged period
- **Repetitive Work** occurs when workers repeatedly use the same muscles and tissues to perform a task or activity, irritating tendons, increasing pressure on the nerves, and keeping the body from healing properly.
 - Pinching bags to seal them
 - Manually tightening bolts
 - Using mobile equipment controls such as joysticks
 - Using manual grease guns
 - Extended computer work at stations without concern for ergonomics
- **Vibration Exposure** comes in two forms: hand-arm and whole-body. Vibration exposure can decrease blood flow, damage nerves, contribute to muscle fatigue, and cause low back pain.
 - Driving a haul truck or other mobile equipment on uneven terrain
 - Operating a crusher
 - Using a jackhammer
- **Slip, Trip, and Fall Hazards** are the second leading cause of injury at surface mines.
 - Contaminants on walking surfaces (grease and oils, excessive spillage, etc.)
 - Unstable working surfaces
 - Inadequate barriers

Note: Multiple MSD risk factors may be present simultaneously. The risk of injury increases as the number of risk factors present increases.

Ladder Climbing

When a worker ascends or descends a ladder in a dusty environment, dust can be liberated from the ladder as the worker grabs or steps on the rungs. This dust can then fall directly into the worker's breathing zone and increase his or her dust exposure. Dusty ladders can also pose a slipping and falling risk as settled dust decreases the available friction on rungs and railings.

Risk Factors: Dust: inadequate housekeeping; MSD/traumatic injury: slip, trip, and fall hazards



Photo by NIOSH

Problem: Dust is released into the air from the ladder as a worker grabs or steps onto each rung during ascent or descent.



Solution: When possible, use angled stairways (in blue, right) as opposed to vertical ladders (top photo). When floor space is limited, consider alternating tread stairs (yellow, left), which offer a much smaller footprint while still providing some of the ergonomic and safety advantages of traditional stairs. An unpublished case study suggests that both types of ladders reduce the chances of dust being released into the worker's breathing zone.



Additional Improvements: Good housekeeping is vital to reducing workers' respirable dust exposures. Walking surfaces and handrails should be hosed down to reduce dust accumulation. **Use caution on these wetted surfaces until they have dried.**

Manual Palletizing

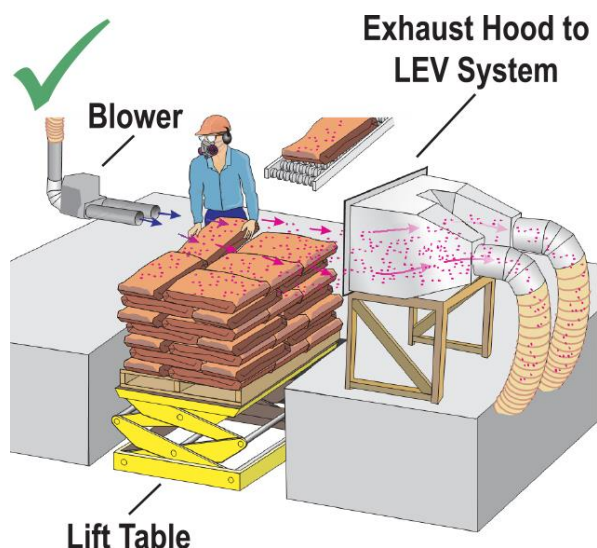
During the bag filling process, the exterior surfaces of bags can become contaminated with dust. This dust can then be released into the air as the bag is handled by workers manually performing palletizing tasks. Lifting and lowering bags frequently can also cause fatigue and lead to injury. Injury risks are increased when the locations of the pallets are not ideal or the weight of the bags is excessive. Additionally, the dust that settles on the walking surface in the palletizing area can often make the floor slippery, increasing the potential for a slip or fall.

Risk Factors: Dust: lack of effective local exhaust ventilation; MSD/traumatic injury: poor posture; slip, trip, and fall hazards



Photo by NIOSH

Problem: Manually palletizing bags often requires awkward postures. Initially the bags must be placed on top of an empty pallet below waist height while as the pallet fills, workers may reach with their hands above the shoulders to place bags on top of the pallet. Soiled bags and bag leakage combined with minimal ventilation also expose workers to respirable dust. Additionally, dust can contaminate worker clothing and create a secondary source of exposure.



Solution: Semi-automated systems include workers and an automated system to perform the bag stacking process. The lift table illustrated in yellow allows the bags to remain at approximately knuckle height for the worker to stack them, which is the most ergonomic loading height. A push-pull ventilation system entrains dust released during the stacking process into a local exhaust ventilation system, keeping it from entering the worker's breathing zone.



Additional Improvements: Consider using fully automated bagging solutions such as form-fill-seal systems that (1) isolate the bag filling to an area away from the worker and (2) eliminate bag handling entirely due to fully automated bag forming, filling, sealing, and conveyance. For more information on form-fill-seal systems, see the following resource:

<https://www.cdc.gov/niosh/mining/UserFiles/works/pdfs/2019-124.pdf#page=272>

Screen Changeout

Screens are used at mineral processing operations to size material, which almost always generates large amounts of dust into the work environment, especially during maintenance and changing of screens. Screens must be maintained and replaced as needed, and careful attention to this work will reduce the dust hazard to workers. The screen frames are heavy, large, and difficult to handle. Also, the used screens must be carefully removed and new screens must be stored and installed.

Risk Factors: Exposure to dust: poor worker practices; inadequate housekeeping; MSD/traumatic injury: poor posture; forceful work



Problem: Screen cleanings and changes involve exposure to high amounts of dusts. Traditional screen decks are large and heavy and require repeated unclipping and reclipping; therefore, if these tasks are not performed properly, they can be a source of dust exposure as well as causing workers to exert high force, overreach, and work in awkward positions.



Solution: Newer, multi-panel screen decks are handled more easily by individual workers. These newer decks eliminate the need to perform the clipping process, and screen mesh reduces the worker's exposure to dusts. While respiratory protection is typically implemented only as a last resort when engineering controls cannot be used, dust release during screen maintenance can be hazardous and difficult to control. Therefore, respiratory protection should be used when performing this task.



Additional Improvements: Store new screens where they will be protected from collecting surface dust deposits that can further expose workers when they install the screens. Consider using a separate work stand outfitted with a local exhaust ventilation system for screen deck maintenance. Overhead hoists and lifting devices can reduce strain on workers when installing larger screens.

Work Boot Cleanliness

Dirty work boots can be a source of background dust exposure to workers and occurs when a worker walks through wet product, overburden, or mud and the material adheres to the work boots. Once a worker's boots are soiled with product, it is then tracked everywhere they go until it either falls off or the boots are cleaned. Muddy work boots have also been identified by mine workers as a risk factor for slips and falls during mobile equipment ingress and egress.

Risk Factors: Dust: inadequate housekeeping; poor worker practices; MSD/traumatic injury: slip, trip, and fall hazards



Photo by NIOSH

Problem: Soiled work boots can track dirt into the cabs of mobile equipment. This leads to the accumulation of dust on the cab floors, which can lead to dust exposure while operating equipment.



Photo by NIOSH

Solution: Provide designated walkways and boot brushes at mobile equipment parking areas to help workers remove contaminants from their boots prior to getting on equipment. Boot brushes should always be located outdoors to avoid exposure to re-aerosolized dust.



Additional Improvements: Designated walkways should be provided and maintained to be free from contaminants. Grated metal walkways can be used to help remove accumulations from boots and prevent pooling of liquid contaminants.

Hose Handling

Handling hoses for washdown or cleanup activities can present a respirable dust hazard, as the hose jacket itself can collect dust which is then released as workers slide their hands over it. Long hoses that are typically required at mine sites not only acquire more settled dust but put undue strain on the worker's back due to their weight.

Risk Factors: Dust: poor worker practices; inadequate housekeeping; MSD/traumatic injury: poor posture; slip, trip and fall hazards



Photo by NIOSH

Problem: The large surface area of hose jackets can collect substantial amounts of respirable dust and must be directly handled by workers when performing washdown operations. Workers often handle the hose close to their breathing zone, making the problem that much worse.



Photo by NIOSH

Solution: Before the hose is unreeled, the coiled or rolled hose should be sprayed off to knock down and wet any residual dust. Holding the hose at an ergonomic position (about knuckle height) will also keep any dust released further away from the worker's breathing zone.



Additional Improvements: Consider using a small horizontal roof or cover over the hose reel to reduce the amount of dust that can accumulate on the hose. To reduce muscle strain, consider using additional hoses closer to the washdown areas as opposed to fewer hoses that must be dragged throughout the plant.

Floor Cleaning

Effective housekeeping is vital to ensuring a safe work environment. Because of the traffic that takes place over plant floors, effective housekeeping must include the removal of loose material (a future dust source) from the floors. Not only does routine cleaning and housekeeping remove accumulations of dust that can be released and inhaled, it also removes other contaminants (such as oil, grease, etc.) on walking and working surfaces that increase the potential of slips, trips, or falls.

Risk Factors: Dust: inadequate housekeeping; MSD/traumatic injury: slip, trip, and fall hazards



Photo by NIOSH

Problem: Although hosing down working areas is an effective means of removing dust accumulation, it should be performed at the end of work shifts so that pooled walkways and wet surfaces have more time to dry before the next shift is started. Hoses can pose tripping hazards during use and when not properly stored.



Photo by NIOSH

Solution: Hosing should begin by using a nozzle with a wide fan pattern, as shown, to initially wet the material and progress towards more narrow streams to push material either towards drains or out of the building. Using a concentrated narrow stream can cause accumulated dust to become airborne before it has become wetted.



Photo by NIOSH

Solution: For within-shift cleaning, rideable floor sweepers can be used to clean dust-laden floors without introducing excess water than can lead to pooling of liquids and increased slip risks.



Additional Improvements: If water sprays are used to hose down areas with accumulated dust, ensure that adequate drainage is in place to route the water away from walking areas.

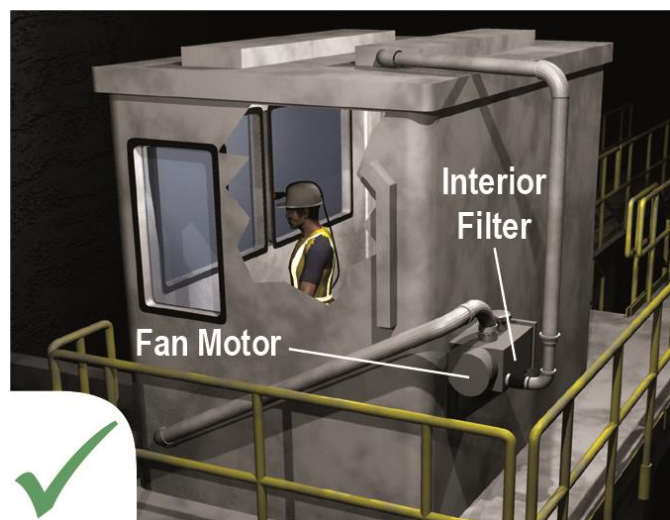
Filter Accessibility

Enclosure filtration systems, whether on mobile or stationary equipment, have the potential to greatly reduce the dust levels inside the enclosure where workers spend much of their time performing their duties. However, these systems are only as good as the initial design, and they require routine maintenance to maintain their effectiveness. Careful attention must be given to the design and location of these systems to ensure easy maintenance that does not pose a dust or ergonomic hazard in itself.

Risk Factors: Dust: ineffective enclosure filtration; MSD/traumatic injury: poor posture; slip, trip, and fall hazards



Problem: The plenums for the ventilation system are located on top of the structure, requiring a ladder (a fall hazard) and potentially exposing the worker to deposited dust.



Solution: The illustrated filter system is located at waist height in an easily accessible location on the side of the booth. Only a simple tool is needed to open the filter housing.

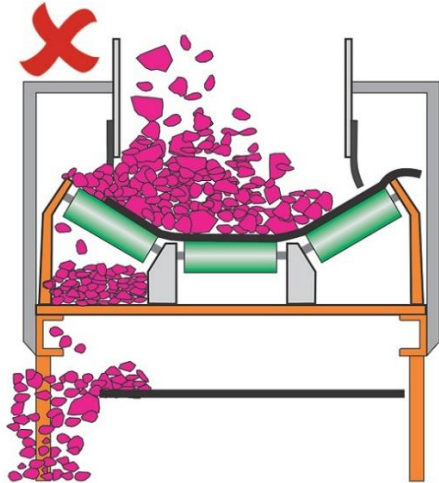


Additional Improvements: Consider using MERV 16 filters instead of HEPA filters. For mining applications with very high dust levels, MERV 16 filters load less quickly, keeping airflow quantities high while still having relatively high dust trapping capability. For more information, download this infographic: <https://www.cdc.gov/niosh/mining/works/coversheet2109.html>.

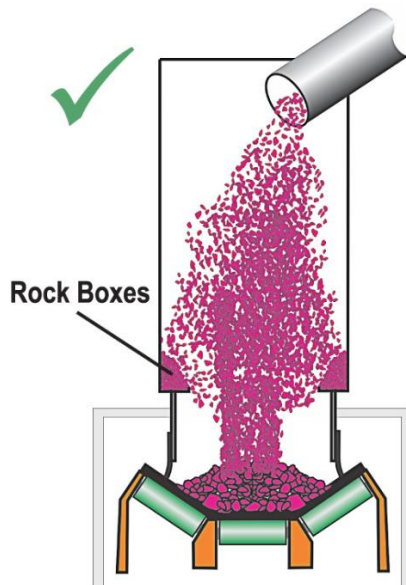
Belt Conveyors

Material spillage along and especially from belt conveyors at transfer points is caused by inadequate material control. Not only can this spillage result in increased dust exposures, but manually cleaning spillage can expose miners to risk factors for shoulder and back MSDs.

Risk Factors: Dust: inadequate housekeeping; MSD/traumatic injury: forceful work; slip, trip, and fall hazards



Problem: Poor material loading onto a conveyor belt leads to spillage and ultimately causes belt damage. Spillage into walkways can increase dust exposure, poses a slip and fall risk for nearby workers, and eventually must be shoveled away, which can cause back strain and exposure to dust.



Solution: Rock boxes can be used to soften the drop and redirect the flow of falling material into the center of the belt.



Additional Improvements: To effectively control spillage at transfer points, ensure the following requirements: (1) the material is fed to the center of the belt, (2) the vertical fall distance of the material is minimized, (3) the transfer material is well contained, and (4) the transfer distance is reduced to the extent practicable.

Enclosed Control Rooms

Many operations, during processes ranging from primary crushing to loadout, can generate substantial amounts of dust. Along with the exposure to dust, workers may also be exposed to high noise levels and whole-body vibration, particularly inside enclosed control rooms.

Risk Factors: Dust: ineffective enclosure filtration; MSD/traumatic injury: vibration exposure



Photo by NIOSH

Problem: Window air conditioners, commonly installed in control rooms or operator booths, do not provide adequate air filtration. These units are typically installed in a rough opening (not sealed) and do not have enough airflow (in cubic feet per minute) or filtration efficiency (dedicated filter media) to reduce respirable dust concentrations. Further, control rooms and booths must be sealed and pressurized to prevent wind-carried dust from penetrating, and they must have a dedicated high-efficiency air filtration and pressurization system installed. Often, control booths are directly mounted to decking or structures that vibrate along with the crushing operation activities which produces substantially more dust inside the booth from the vibration.



Photo by NIOSH

Solution: Providing a separate, positively pressurized control room for workers can provide substantial reductions in dust exposures. Moreover, when isolated from the surrounding equipment, the worker's exposure to noise and whole-body vibration can also be reduced.



Additional Improvements: Consider asking your booth or HVAC system supplier to verify the performance of the operator booth. Ask the fundamental question: How well does it protect the occupants from dust, and how is that protection measured?

Bulk Bagging

Bulk bagging with flexible intermediate bulk containers (FIBCs) is commonly used at many industrial mineral operations as they prepare truck shipments to customers. FIBC filling tasks put workers very near the loading/transfer point of material. Both dust and ergonomic considerations can be optimized when a full job analysis is completed on bagging operations, including bulk bagging practices by workers.

Risk Factors: Dust: poor worker practices; MSD/traumatic injury: poor posture



Photo by NIOSH

Problem: Tying bag collars can expose workers to dust as air is pushed out of the collar area, in particular if the collar is in the worker's breathing zone. Note how in the photo the collar of the bag is directly in the worker's breathing zone, as indicated by the red arrow.



Photo by NIOSH

Solution: Bag collars should be tied as much as possible away from the breathing zone of the worker. The bag collar should be angled away from the face and the head should be kept back and away from the bag. Note how the collar in the bag is a few feet away from the worker's breathing zone, as indicated by the green arrow.



Additional Improvements: Minimize the fall distance of material to bulk bags when possible to reduce dust emissions. Use ergonomic work platforms that raise or lower the bag to the worker's comfortable working height and keep the worker's breathing zone away from the filling area to the extent possible. Install a local exhaust ventilation system to capture dust around the material transfer point.

Broken Bag Disposal

Occasionally bags filled with product break and must be discarded. This can be a significant dust source to workers in and around the bag loading and stacking area and can require additional manual handling (lifting, carrying) of bags. Bags that break as a result of falling off conveyors can also require lifting from the ground while bending and twisting the back, which increases injury risk. The method in which these broken bags are disposed of and the careful handling of broken bags by workers will ensure that hazards are minimized.

Risk factors: Dust: poor worker practices, lack of effective local exhaust ventilation; MSD/traumatic injury: poor posture



Photo by NIOSH

Problem: Broken bags discarded into a dumpster can cause material accumulation on the dumpster as well as the floor and serve as a dust source inside the plant. Dust can be released in the work environment and can contaminate multiple workers. Transporting bags to a dumpster is often performed manually and increases the risk of musculoskeletal disorders.



Photo by NIOSH

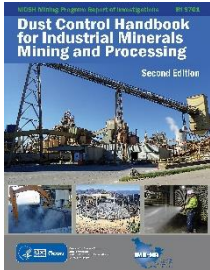
Solution: Broken bags should be handled carefully and, when possible taken to a ventilated product recovery station or outside the plant.



Additional Improvements: Address bag defects, venting issues, rough handling, etc., and correct the circumstances that lead to broken bags. After the salvageable product has been recycled, the empty bag with its residue should be placed in a dumpster located underneath a ventilation hood. Ensure that workers are trained in proper disposal techniques and that supervisors track the number of broken bags so that their occurrence can be reduced. Consider the installation of an optimal design, which is an automated system that does not require workers to handle the bags.

Additional Resources

The NIOSH Mining Program has a number of resources available relevant to reducing and eliminating dust exposure, musculoskeletal disorders, and slip, trip, and fall hazards in mine operations.



Dust Control Handbook for Industrial Minerals Mining and Processing

This handbook provides detailed information on control technologies to address all stages of the minerals handling process, including drilling, crushing, screening, conveyance, bagging, loadout, and transport. The handbook aims to empower minerals industry personnel to apply state-of-the-art dust control technology to help reduce or eliminate mine and mill worker exposure to hazardous dust concentrations.

Download: <https://www.cdc.gov/niosh/mining/works/coversheet2094.html>



ErgoMine

This ergonomics audit tool is designed specifically for mining. It includes audits for bagging, haul truck, and maintenance and repair operations at surface mining and processing facilities. Based on the user's responses to the audit questions, ErgoMine provides recommendations when there is an opportunity for ergonomics improvement. ErgoMine can be downloaded for free on Android devices from the Google Play Store.

Download: <https://www.cdc.gov/niosh/mining/works/coversheet1906.html>



Simple Solutions for Surface Mine Workers

This booklet provides examples of the types of solutions and task design ideas that can be used to reduce exposure to risk factors for musculoskeletal disorders and slips, trips, and falls. Simple Solutions for Surface Mine Workers can be downloaded from the NIOSH Mining website. A printed version can also be requested by emailing mining@cdc.gov.

Download: <https://www.cdc.gov/niosh/mining/works/coversheet2036.html>



Slip, Trip, and Fall Prevention for Mining

This webpage contains extensive background information and mining-related resources to prevent slips, trips, and falls.

Visit: <https://www.cdc.gov/niosh/mining/content/STFprevention.html>



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