PNEUMATIC NAILER INJURIES

A Report on Washington State 1990-1998

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Numerous cases of nail gun injuries have been documented, involving injuries not only to the extremities (such as the hands) but also more-serious injuries to the brain, heart, neck and eyes. Systematic surveillance of work-related nail gun injuries has not been previously reported in the State of Washington or elsewhere. This study conducted retrospective surveillance of injuries related to the use of pneumatic nailers in Washington. Case data were extracted from the Washington State Workers' Compensation database. Based on the findings, the authors outline engineering controls, administrative controls and personal protective equipment that can prevent injuries related to use of these devices.

Nail guns (nailers, pneumatic hammers, pneumatic nailers or air-powered nailers) are relatively new types of tools. With the squeeze of a trigger, they can drive anything from a small finishing nail into a piece of plywood to a three-inch nail into wood and concrete block. These tools, which look like large power drills with a supply of nails and a pneumatic hose attached, can fire up to nine nails per second (Gaylord 50) at velocities as high as 1,400 ft. per second (Hoffman, et al 1644). Thanks to such features, these tools can substantially increase production rates in many jobs, which leads to lower production and manufacturing costs.

However, nail guns impart a large amount of energy to a small projectile. If the nail is not properly aimed, is shot before the operator is ready or penetrates the work piece, then a high-velocity projectile is loose in the workplace. If this nail strikes a worker, s/he may suffer an injury—ranging from a slight scratch to a fractured bone or worse.

Case reports of nail gun injuries have been documented as early as 1966 (Montoli), and such injuries have been discussed in case series and instructional publications. Reported injuries range from damage to the extremities to more-serious injuries to the brain, heart, neck and eyes (Beaver and Cheatham; Eachempati, et al; Bauch, et al; Vosswinkel and Bilfinger; Hoffman, et al; Alberico, et al; Lee and Sternberg). However, no systematic surveillance of these injuries has been reported—in the state of Washington or elsewhere. The objective of this study was to conduct retrospective surveillance of work-related injuries related to the use of pneumatic nailers in Washington.

RESEARCH METHODS

In Washington, employers must obtain WC insurance through the Dept. of Labor and Industries (L&I), unless they are able to self-insure. Hence, two-thirds of workers in the state are covered by the State Fund insurance. The remaining one-third typically work for the largest 400 companies and are covered through their employers. In addition, self-employed workers are not required to have coverage.

The L&I Industrial Insurance System (LINIIS) contains data needed to administer claims, including incident type, nature of injury, source of injury, occupation, employer information, claim status and cost. Details are encoded using codes in ANSI Z16.2, "Methods of Recording Basic Facts Relating to the Nature and Occurrence of Work Injuries"; these codes indicate injury type and source as well as the nature of the injury and body part involved in the case.

An employer's industry is identified using standard industrial classification (SIC) codes and a worker's occupation is identified by standard census occupation codes. The state also uses a risk classifica-

TABLE 1 Cost & Number of Lost-Time Days (1990-1998)

WIC Description (Code)	Cost	# Lost-Time Days	Percentage
Wood Frame Building Construction (0510)	$3,853,378	26,270	61.3
Interior Finish Carpentry (0513)	$388,889	1,571	3.7
Building Construction NOC (0518)	$298,065	1,647	3.8
Carpentry NOC (0516)	$274,941	2,611	6.1
Wood Products Manufacturing (2903)	$251,255	3,467	8.1
Wallboard Installation (0515)	$199,083	713	1.7
Roofing (0507)	$171,728	1,512	3.5
Cabinet/Countertop Manufacturing (2907)	$149,668	1,928	4.5
Other	$645,385	3,122	7.3
Total	**$6,232,392**	**42,841**	

NOC = Not otherwise classified

TABLE 2 Indicated Body Part for Nail Gun Injuries (1990-1998)

Body Part	Frequency	Percentage	Cumulative Percentage
Finger(s)	1,543	42.7	42.7
Hand	844	23.3	66.0
Foot	215	5.9	72.0
Thigh	167	4.6	76.6
Wrist	139	3.8	80.4
Knee	137	3.8	84.2
Toe(s)	104	2.9	87.1
Lower Leg	66	1.8	88.9
Forearm	64	1.8	90.7
Eye(s)	49	1.4	92.0
Leg(s) Unusual	48	1.3	93.4
Other	240	6.6	100.0
Total	**3,616**		

Claimants in WIC 0510 accounted for more than 60 percent of recorded lost-time days. The most-common body part injured was the finger(s) (42.7 percent) and hand (23.3 percent). The foot, thigh, wrist, knee and toe(s) were other commonly identified sites of injury. In 1.4 percent of the injuries, the eye was identified as the injured body part. Nearly all claims involved the claimant being "struck by" an "unusual object," "flying object" or "object not elsewhere classified."

tion, known as the Washington Industrial Classification (WIC), to describe a job. This system uses a combination of industry and occupation to group workers by similar risk of injury for insurance purposes.

Data extracted for this study were assembled by matching records with a specific source of injury to textual data collected on the claim initiation form. Textual responses were then searched for terms indicative of nail gun injuries. To be included in the study, a claim must have met each of the following criteria.

1) Incident occurred between Jan. 1, 1990, and Dec. 31, 1998.

2) Source of injury category used was either a hammer-type power hand tool (which includes hammers, tampers, jackhammers and air nailers) or an unusual metal item (including fasteners such as bolts, nails, nuts, pins, rivets, screws, spikes, staples, clamps and couplings). Non-nail-gun-related incidents were excluded when criterion number 4 was applied to the data.

3) In addition to the primary source, the associated source of injury also had to be listed as either a hammer-type power hand tool or as an unusual metal item.

4) A nail gun was specifically identified in the incident report. A nail gun was assumed to be involved if the report contained any of the following words: "nailgun," "nail gun," "nailer"; or both of the following words: "pneumatic" and "nail."

5) Claims were limited to those under State Fund insurance jurisdiction.

6) Claims were limited to accepted claims, including "compensable," "noncompensable," "fatal," "kept on salary," "loss of earning power" and "total permanent disability" claims.

DATA ANALYSIS

Frequency of claims by year of injury, industry, occupation, risk class (WIC), type and nature of injury, and body part involved were used to describe general characteristics of the reported injuries. Claims rates were determined by dividing the number of identified claims by the number of hours worked. The number of hours worked was extracted from payroll data reported to L&I. This was then converted to "full time equivalent workers" (FTEs) by multiplying the claims rate by a conversion factor which assumes that the average FTE works 2,000 hours per year. Claims rates were reported in unit of claims per 10,000 FTEs/year by multiplying the rate by 10,000.

To identify industry and occupation groups for intervention priority, the prevention index (PI) was calculated. PI is the average of the frequency ranking and claims rate ranking by industry or WIC. Claims rates for categories containing less than 16 cases or 90,000 hours (the equivalent of five FTEs per year) were not included. Trends over time in claims rates were then assessed using Poisson regression and assumed linear trend. Invalid industry codes were not used in this analysis.

RESULTS

In the nine-year period 1990 through 1998, 3,616 accepted State Fund claims were associated with nail gun injuries. Of those, most were non-compensable medical-only claims (2,885), with approximately one-fifth being compensable, involving more than three days away from work. No fatalities involving nail guns were reported during this period.

For the nine years, the total cost was $6,232,392 or $692,548 per year. More than 60 percent of this cost was incurred from claimants in the wood frame building construction class (WIC 0510) (Table 1). The median number of lost-time days was zero for all claimants. Of those with compensable claims, the median number of lost-time days was 11. Claimants in WIC 0510 also accounted for more than 60 percent of recorded lost-time days (Table 1).

The average age of claimants was 29.6 years. About two-thirds were single and almost all were male. In comparison, the average age of claimants not reporting nail gun injuries was 34.6 years; nearly 70 percent were male and 60 percent were single.

The most-common body part injured was the finger(s) (42.7 percent) and hand (23.3 percent). The foot, thigh, wrist, knee and toe(s) were other commonly identified sites of injury (Table 2). In 1.4 percent of the injuries, the eye was identified as the injured body part. Nearly all claims

TABLE 3 WC Claims Rates for Nail Gun Injuries by WIC (1990-1998)

WIC	Description	Frequency	Employee Hours (Ten Thousands)	Rate (/10,000 FTEs-Yr.)	PI	Slope of Rate Over Time
0510	Wood Frame Building Construction	2,002	19,452	205.8	1	0.0645 **
0513	Interior Finish Carpentry	186	5,671	65.6	4	0.0412
0516	Carpentry NOC	138	3,084	89.5	4.5	0.0407
2903	Wood Products Manufacturing	246	11,464	42.9	4.5	0.0414
2908	Factory Built Housing	75	974	154.1	5	0.0267
0105	Fence Erection	48	732	131.2	6	-0.0501
0518	Building Construction NOC	178	8,791	40.5	6	-0.0208
0507	Roofing	88	3,076	57.2	6.5	0.1376 **
2907	Cabinet/Countertop Manufacturing	103	5,949	34.6	7.5	-0.0768 *
7114	Temporary Help—Assembly	35	2,055	34.1	10.5	-0.0152
3404	Aluminum Product Manufacturing	38	13,977	5.4	11.5	-0.0548
1108	Glass Merchants	18	2,310	15.6	12.5	0.0003
6709	Sheltered Workshops	19	5,352	7.1	12.5	-0.0710
2009^	Building and Home Improvement Centers	23	9,444	4.9	13	-0.3062
3510	Plastic Products Manufacturing	16	9,527	3.4	15.75	-0.0423
3402	Machine Shops	17	21,976	1.5	16	0.0728
2104	Fruit and Vegetable Packing	16	17,228	1.9	16.25	0.0097

** = P < 0.05*
*** = P < 0.01*
^ = Estimates based on data from 1993-1998
NOC = not otherwise classified

Of the WICs, building construction was the most-commonly reported among claimants. For industry classifications as defined by SIC codes, general contractors for single-family homes and carpentry work were the most-reported classifications among claims—42.5 percent and 12.4 percent, respectively.

TABLE 4 WC Claims Rates of Nail Gun Injuries by SIC (1990-1998)

SIC	Description	Frequency	Employee Hours (Ten Thousands)	Rate (/10,000 FTEs-Yr.)	PI
15	Building Construction—General Contractors & Operative	1,818	46,670	77.9	1
24	Lumber & Wood Products, Except Furniture	306	32,432	18.9	2.5
17	Construction Special Trade Contractors	805	108,816	14.8	2.5
52	Building Materials, Hardware, Garden Supply & Mobile Home	91	27,169	6.7	4.5
34	Fabricated Metal Products, Except Machinery & Transportation	33	19,593	3.4	7.5
25	Furniture & Fixtures	17	4,730	7.2	8.5
65	Real Estate	46	62,661	1.5	8.5
73	Business Services	76	112,861	1.3	9
47	Transportation Services	21	14,641	2.9	9.5
57	Home Furniture, Furnishings and Equipment Stores	23	27,354	1.7	10
32	Stone, Clay, Glass and Concrete Products	16	8,953	3.6	10.25
16	Heavy Construction Other than Building Construction	18	21,074	1.7	10.5
50	Wholesale Trade—Durable Goods	42	99,769	0.8	11
83	Social Services	25	50,527	1.0	11.5
35	Industrial and Commercial Machinery, and Computer Equipment	16	23,680	1.4	13.25

(93 percent) involved the claimant being "struck by" an "unusual object," "flying object" or "object not elsewhere classified." Another two percent involved the claimant being "struck by falling object." Eighty-five percent of the injuries resulted in a "cut," while eight percent caused a fracture.

The most-common occupation reported by claimants was carpentry (54.3 percent). Other occupations included construction laborers (9.9 percent), non-construction laborers (5.6 percent), construction supervisors (3.3 percent), assemblers (2.7 percent), roofers (2.3 percent), cabinet makers and bench carpenters (1.6 percent), construction trades not elsewhere classified (1.5 percent) and construction helpers (1.1 percent). Nearly eight percent did not report any occupation. Occupations linked with construction accounted for more than 70 percent of the claims.

Of the WICs, building construction was the most-commonly reported among claimants; it included the following categories: wood frame building, construction or alterations (55.4 percent); interior finish carpentry (5.1 percent); building alteration and concrete construction not otherwise classified (4.9 percent); building repair and carpentry (3.8 percent); and roofing construction and repair (2.4 percent). Manufacture of wood products was also commonly reported; this class includes the manufacture of wood boxes, shocks, pallets or bins (2.8 percent); cabinets, countertops or fixtures (2.8 percent); wood trusses (2.1 percent); factory-built homes (1.7 percent); and wood doors, sashes, molding and miscellaneous millwork (1.1 percent) (Table 3).

For industry classifications as defined by SIC codes, general contractors for single-family homes and carpentry work were the most-reported classifications among claims—42.5 percent and 12.4 percent, respectively. In addition, other construction-related industries, such as contractors for non-residential buildings other than industrial buildings; roofing, siding and sheet metal work; and special trade contractors not elsewhere classified, were among the highest-ranked for the number of nail-gun-associated injuries.

Aside from construction, the following industries were among those with a high number of claims: manufacturing of wood pallets/skids, manufacturing of cabinets, manufacture of structural wood

TABLE 5 WC Claims Rate By Year (1990-1998)

Year	Frequency	Employee Hours (Ten Thousands)	Rate (/10,000 FTEs-Yr.)
1990	399	223,185	3.6
1991	298	226,265	2.6
1992	359	233,865	3.1
1993	329	237,383	2.8
1994	358	245,029	2.9
1995	386	252,013	3.1
1996	527	260,495	4.0
1997	470	272,161	3.5
1998	490	282,408	3.5
Total	**3,616**	**2,234,732**	**3.2**

The average nail-gun-related claims rate for the nine years was 3.2 claims/10,000 FTEs. This rate sharply declined between 1990 and 1991. From 1991 to 1996, the rate increased, peaking in 1996. It then decreased slightly, but rates in 1997 and 1998 were greater than reported rates before 1996.

members not elsewhere classified, manufacture of prefabricated wood buildings and components, and retail trade of lumber and other building (Table 4).

The average nail-gun-related claims rate for the nine years was 3.2 claims/10,000 FTEs (Table 5). This rate sharply declined between 1990 and 1991. From 1991 to 1996, the rate increased, peaking in 1996. It then decreased slightly, but rates in 1997 and 1998 were greater than reported rates before 1996. As Figure 1 shows, since 1991, the increasing trend in the claims rate was statistically significant (p=0.0061). Tables 3 and 4 list the claims rates and PI for the top WIC (four digit) and two-digit SIC. Using SIC codes, general contractors for single-family homes had the highest PI (1.0). Using WIC, wood frame building construction or alterations had the highest PI (1.0).

Claims rates were examined for trends over the nine-year study period for each WIC category. This analysis found that not all categories demonstrated an increasing trend of nail gun claims over the study period. Table 3 lists slope parameters for the Poisson regressions for each category. Only wood frame building construction (0510) and roofing (0507) showed statistically significant increasing trends over time (Figure 2). After continual increases of claims rates, factory-built housing (2908) showed a sharp decline in rate and number of claims during 1998.

A statistically significant decrease in claims rate was also noted in the manufacture, modification or repair of cabinet, countertop and fixture category (2907), as was a statistically significant decrease (p=0.028) in the building and home improvement centers category (2009). Estimates of slope for these establishments were based on the last six years. By excluding 1990, a statistically significant increase (p=0.0185) in the claims rate was noted for fruit and vegetable packing (2104) as well.

To further investigate the increase of claims in wood frame building construction, the proportion of all construction claims attributed to nail gun injuries was determined. In 1991, 6,662 claims were accepted by the State Fund from claimants in this industry class. Of these, 2.5 percent were identified as nail gun injuries. By 1998, only 4,665 claims were accepted for this group, but the percentage of injuries identified as being nail-gun-related more than doubled to 5.7 percent; risk ratio=2.25, 95 percent CI: 1.86, 2.72.

DISCUSSION

From 1990 through 1998, 3,616 injuries involving nail guns incurred WC costs of $6,232,392. The most-common injury was a cut, usually resulting from a claimant being struck by a flying or unusual object. Injuries in the wood frame building construction or alterations category accounted for more than half of the claims, some 60 percent of incurred costs and the highest claims rate. In addition, this industry class had the highest PI and its claims rate has been increasing since 1990. Other construction categories, as well as the manufacture or assembly of wood products, have also contributed to the increased number of nail gun injuries.

This surveillance report is the first to describe the increase of work-related nail gun injuries over this nine-year period. While the report documents the increase of injuries, data are not sufficient to determine whether this is related to an increase in the number of nail guns in use; an increase in the number of hours the tool is used; a decrease in tool proficiency; a decline in jobsite safety; or some combination of these factors.

Other study limitations must also be noted. This report relies on the accuracy and completeness of WC data reported to L&I. The case definition for a nail gun injury is sensitive to the coding of WC claims. It may be fair to suggest that the number of nail gun incidents has been underestimated for the following reasons.

1) At least some injuries may be treated at the worksite and are not reported to the WC system.

2) The definition of a nail gun incident may not be sensitive to all nail-gun-related injuries. Certain incidents may not have been identified due to misspellings, coding inconsistencies or lack of keyword in the textual report. Such problems would lead to an underestimation of the number of identified incidents.

3) The number of hours reported by the company was used as a surrogate for the number of hours a worker was exposed to potential incidents. One would expect that most workers are not exposed to potential incidents throughout the entire workday. Hence, it is likely the number of hours worked does not reflect the number of hours exposed. As a result, stated claims rates are an underestimation of actual rates.

4) The proportion of hours workers are exposed to potential nail gun incidents likely varies between industrial classifications. Therefore, the level of underestimation of claims rates, which depends on the proportion of hours actually exposed, may vary between industrial classifications.

Claims with an invalid SIC code were not included in analysis involving this variable. However, 1.6 percent of all nail gun injuries were reported among claims in this category. Further analysis demonstrated that of claims with an invalid SIC code, nearly 70 percent were categorized in the wood frame building construction or alterations WIC. Therefore, claims with an invalid SIC do not likely represent an industry not already reported as one with a high number of nail gun injuries.

PREVENTING INJURIES

Since these tools will likely continue to be used, management can reduce worker exposure by using a combination of engineering controls, administrative controls and personal protective equipment (PPE). These are the basic control strategies considered when attempting to reduce workplace injuries or illnesses.

The priority for implementation starts with engineering controls, followed by administrative controls, then PPE. This hierarchy reflects the fact that it is better to first attempt to control an exposure using a method which requires no human intervention—where the hazard can be engineered out. Likewise, it is generally better to have en employee prevent

FIGURE 1 Number of Claims & Claims Rate of Nail Gun Injuries (1990-1998)

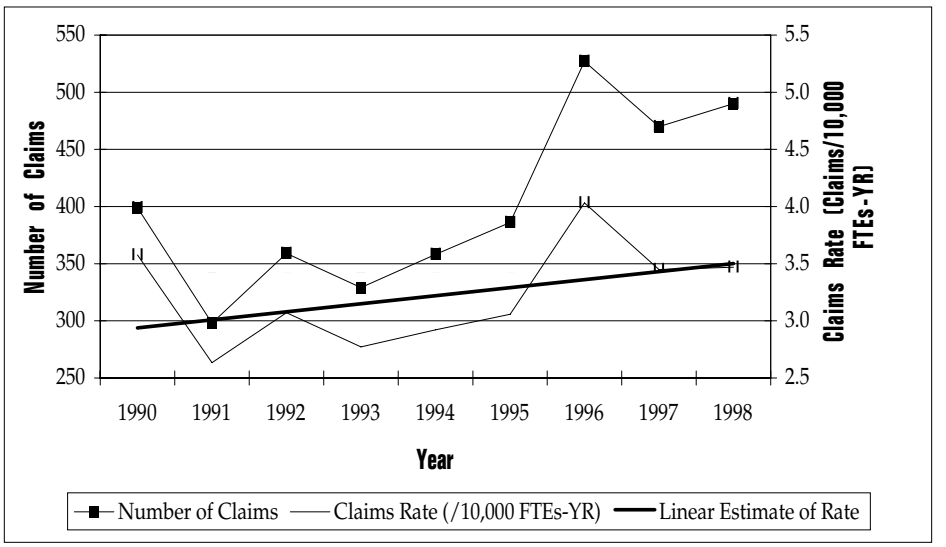
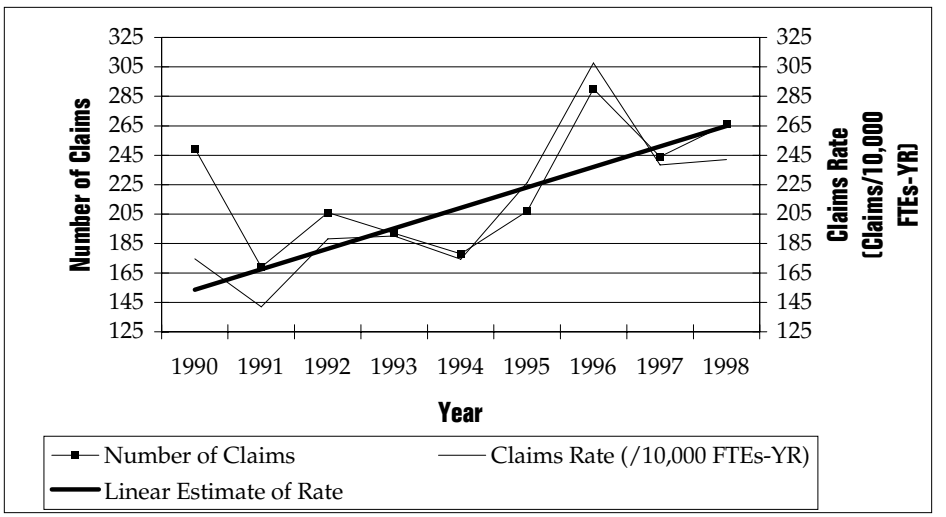


FIGURE 2 Number of Claims & Claims Rate of Nail Gun Injuries for Wood Frame Building Construction (1990-1998)



Data for Figure 2

Year	Claims	Claims Rate
1990	250	175
1991	169	142
1992	206	188
1993	192	190
1994	178	174
1995	207	226
1996	290	308
1997	244	238
1998	266	242

an incident than it is to have him/her rely on PPE to prevent the exposure that will cause injury.

Because of the mobile nature of these tools, a combination of controls may be necessary. The following recommendations, based on various sources, are designed to reduce the number and severity of nail-gun-related injuries (Oregon Dept. of Consumer and Business Services; SENCO Tools; Canadian Centre for Occupational Health and Safety; Eagle Insurance Group; Makita USA Inc.).

Engineering Controls

•Use the sequential trigger (also known as a restrictive trigger or operating in the trigger fire mode). This mechanism allows a nail to be fired only if the trigger has been depressed after the nose guard trigger release has been activated; in addition, it permits only one nail to be fired per trigger activation. As employees gain experience with the tool, the "bump" trigger system can be implemented to reduce the potential risk of musculoskeletal disorders (e.g., trigger finger).

•Manufacturers should work with users and safety professionals to better balance the speed and productivity of using the "bump" mode with the accuracy and potential for fewer acute trauma

Nail guns can substantially increase production rates in many jobs, which leads to lower production and manufacturing costs. However, they also introduce many hazards that must be controlled to prevent injury.

injuries using the sequential mode. In all cases, the possibility of trigger finger must be considered.

•The male end (nipple) of the compression fitting should be the fitting screwed into the tool, and the loose end attached to the air hose should be the female fitting. If reversed, air pressure may remain in the tool after the air hose has been removed, which could allow a nail to be fired even if the hose is not attached.

•Use only clean, dry compressed air at manufacturer-recommended pressure.

•Never use bottled gases or air.

•Secure the hose when working on scaffolding.

Administrative Controls

Training

•Have all users review the owner's manual for operation, maintenance and safety procedures. This could be a good annual safety meeting topic or monthly safety tailgate meeting exercise.

•Have workers demonstrate safe use of the tool. This is crucial for employees with little or no experience with pneumatic nailers.

•When purchasing or renting a tool, ensure that the distributor reviews the basics of safe tool use.

Use & Transportation

•Post warnings about the use of high-power pneumatic tools.

•Do not carry the tool by the hose or with a finger on the trigger.

•Do not hold down the trigger unless intending to fire the tool—especially when walking or climbing a ladder.

•Never point the tool at anyone even if it is empty or disconnected from the air supply.

•Whenever the tool is initially connected to the air supply, aim the tool away from the body and other people. It is possible for the trigger mechanism to stick in the activated position; when this occurs, the gun will fire a nail even though the user has not touched the trigger.

•Never assume the tool is empty.

•Do not fire the tool unless the nose is placed firmly against the work piece.

•Keep the free hand out of the line of fire.

•Never rest the tool against any part of the body.

•Ensure that the tool is appropriate for the job.

•Design the task so that co-workers will be out of the line of fire.

•Disconnect the air hose prior to clearing a jam, repairing the unit, handing it to another worker, leaving the work area or moving the tool to another work area.

•Since sparks can fly from the tool when it is in use, do not operate it near flammable materials such as gasoline, thinner, paint or adhesives. Those materials may ignite and explode, causing serious injury.

Checks & Maintenance

•Inspect and perform any necessary maintenance on the tool and compressor prior to use.

•Check the air supply and pressure prior to connecting the tool.

•Make sure the nose guard safety spring is operational prior to use.

•Before clearing a blockage, disconnect the hose, then depress the trigger to ensure that all air is exhausted from the tool.

Safe Construction Methods

•Nail from top to bottom when nailing wall sheathing in a vertical position.

•Nail from the eaves to the ridge when working on a roof.

•Move forward when nailing horizontal areas.

•Nails may not always be driven in straight or can be deflected, so keep hands and fingers away from areas where errant nails may exit the work piece.

Personal Protective Equipment

•Always wear safety glasses.

•Use hearing protection as necessary according to the job environment.

•Wear steel-toe boots as the work environment dictates. ■

Management can reduce worker exposure to nail-gun hazards by using a combination of engineering controls, administrative controls and personal protective equipment.

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