Heavy Machinery Mechanic

Occupational Analysis Report

January 2012

Commission
de la construction
du Québec

The purpose of this report is to describe as accurately as possible the heavy machinery mechanic trade as currently practiced in Québec's construction industry. It is a record of discussions held by a group of workers who met for the occasion after industry partners recommended them to the Commission de la construction du Québec for their expertise in the trade.

The occupational analysis is a first step in the definition of the competencies required for practicing the trade. This report becomes one of the reference and decision-making tools used by the Commission for teaching and learning purposes.

The present report does not bind the Commission in any way. It has no legal effect and is meant as a reflection of discussions held on the date of the analysis workshop.

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The masculine gender is used generically in this document to facilitate reading.

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APPROVAL

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INTRODUCTION

In early 2009, the CCQ's Direction de la formation professionnelle launched a large-scale operation to review the occupational analyses[1] of all construction industry trades.

The CCQ undertook this operation for many reasons, particularly the following:

- the project to reform the construction workforce apprenticeship and management system, and the eventual design of qualitative apprenticeship booklets requiring a detailed description of each trade;
- the fact that most construction occupational analyses[2] had been conducted between 1987 and 1991 and had not been reviewed since;
- updates to vocational qualification examination question banks;
- implementation of Chapter 7 of the Agreement on Internal Trade (AIT) and of the Québec-France Understanding on the Mutual Recognition of Professional Qualifications.

These factors demonstrate the necessity of updating the occupational analyses in order to obtain a current and complete profile of the various trades in Quebec.

The occupational analysis of the heavy machinery mechanic trade belongs to this context[3]. Its purpose is to describe this trade as currently practiced by journeymen in the construction industry. The present report was written in order to collate and organize the information gathered during the occupational analysis workshop held in Laval on February 21 and 22, 2011.

This analysis aims to draw a portrait of the trade (tasks and operations) and its working conditions, and to identify the skills and behaviours required. The report of the occupational analysis workshop is an accurate reflection of the consensus reached by a group of workers in the heavy machinery mechanic trade. A special effort was made to include in this report all the data collected during the workshop and to ensure that the data accurately depict the realities of the trade analysed.

1. The terms "profession" and "trade" are considered synonymous.
2. Called "work situation analyses" at the time.
3. This occupational analysis was conducted according to the Cadre de référence et instrumentation pour l'analyse d'une profession produced in 2007 by the ministère de l'Éducation, du Loisir et du Sport (Direction générale de la formation professionnelle et technique) and the Commission des partenaires du marché du travail, ministère de l'Emploi et de la Solidarité sociale.

1. GENERAL CHARACTERISTICS OF THE TRADE

1.1 DEFINITION OF THE TRADE

According to the Regulation respecting the vocational training of workforce in the construction industry (Schedule A, section 6), the term “heavy machinery mechanic” means:

> […] Anyone who does the maintenance and repair of cranes, power shovels, graders, spreaders, rollers, tractors, off-the-road trucks and also any other construction equipment or machinery that is motorized, stationary or mobile, used for landscaping, handling or excavation.
>
> The following works, however, are not considered as part of the trade: the repair of compressed air motors and pneumatic tools such as hammers, drills, chisels and reamers; tire installation and repair, installation of belts, windshield wipers and headlights, greasing and body work.

The participants agree with the definition’s first paragraph, which describes the practice of their trade well. However, they find the second paragraph less representative of the realities of thee trade. In particular, they mention that heavy machinery mechanics have to repair pneumatic tools, install tires, belts, windshield wipers and headlights, and do greasing work. They may have to do body work, but only to make the machinery functional, for example on remote construction sites, and not for aesthetic purposes.

1.2 JOB TITLES

On construction sites, the title “mécano” is often used, as well as “mechanic” and “mechanic-welder.” In some environments, there is confusion between mechanics and welders, because mechanics have to do simple welding work.

The title “heavy machinery mechanic,” used in the Regulation respecting the vocational training of workforce in the construction industry, will be used in the present report.

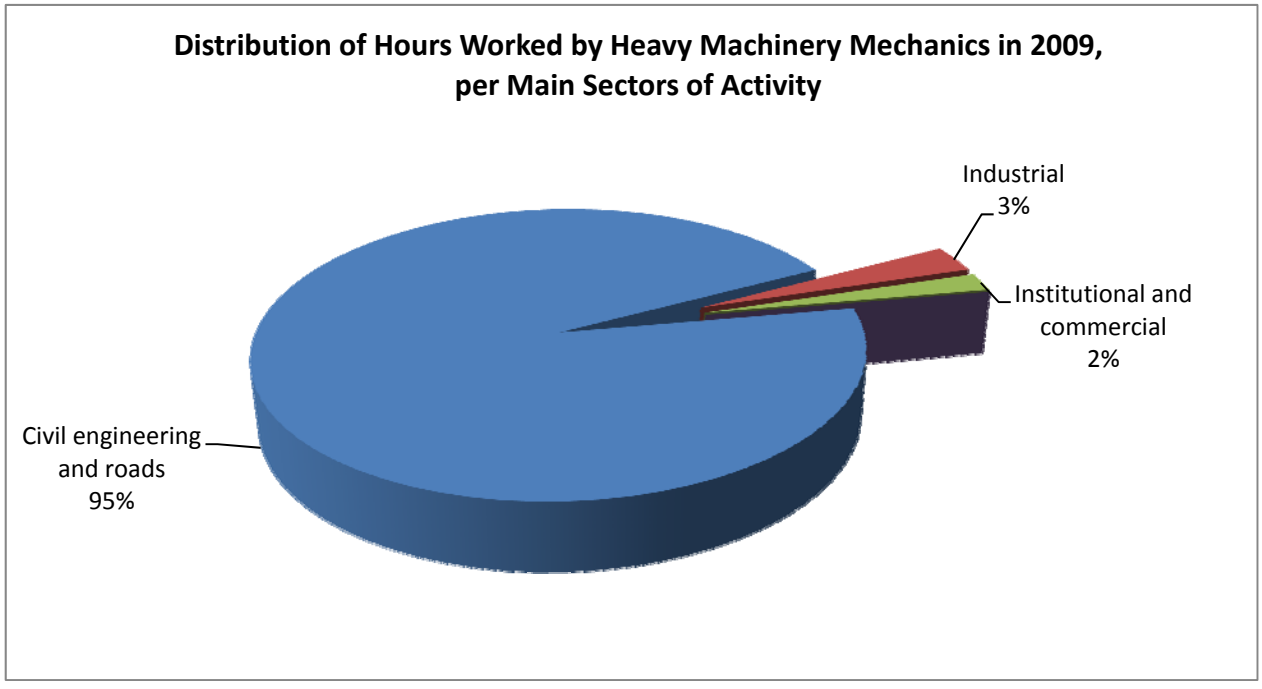
1.3 SECTORS OF ACTIVITY

Heavy machinery mechanics are active, to different degrees, mainly in three construction industry sectors:

- the civil engineering and roads sector;
- the industrial sector;
- the institutional and commercial sector.

The diagram below illustrates the allocation of heavy machinery mechanics' work time in Quebec for 2009[4].

Table 1.1 Workload Allocation



Following the presentation of the above diagram, the participants commented on the sectors in which they practice their trade. They all consider that the above diagram is representative of their work time. As can be noted, the civil engineering and roads sector accounts for almost all the hours worked by heavy machinery mechanics.

4. Commission de la construction du Québec, *Carrières construction*, 2010-2011 edition.

1.4 FIELD OF PRACTICE

The trade's field of practice is the construction industry. The Act respecting labour relations, vocational training, and workforce management in the construction industry (R.S.Q., c. R-20) defines construction as follows:

> […] the foundation, erection, maintenance, renewal, repair, alteration and demolition work on buildings and civil engineering works carried out on the job site itself and vicinity including the previous preparatory work on the ground;
>
> In addition, the word "construction" includes the installation, repair and maintenance of machinery and equipment, work carried out in part on the job site itself and in part in the shop, moving of buildings, transportation of employees, dredging, turfing, cutting and pruning of trees and shrubs and laying out of golf courses, but solely in the cases determined by regulation.

1.5 LEGISLATION AND REGULATIONS

Heavy machinery mechanics in the construction industry are subject to:

- the Act respecting labour relations, vocational training and workforce management in the construction industry (R.S.Q., c. R-20);
- the Regulation respecting the vocational training of workforce in the construction industry (R-20, r.6.2;
- the four sector-based collective agreements of the construction industry;
- the Act Respecting Occupational Health and Safety (R.S.Q., c. S-2.1);
- the Safety Code for the construction industry (R.Q. c. S-2.1, r.6);
- municipal bylaws, if applicable;
- the Highway Safety Code;
- regulations respecting the handling and transportation of hazardous materials.

Moreover, the participants mentioned that some companies add internal rules, particularly regarding safety. Those rules often require heavy machinery mechanics to take specific training and regularly attend meetings.

1.6 WORKING CONDITIONS[5]

The following information provides an overview of the conditions and context of the work of heavy machinery mechanics, as commented by the participants in the occupational analysis workshop. To obtain up-to-date and complete information that has legal effect, it is necessary to refer to the four collective agreements of the construction industry sectors.

Salary

The average annual salary of a journeyman having worked at least 500 hours was $77,486 in 2009. In addition, the proportion of mechanics who declared at least 500 hours was 61%.

In February 2009, the hourly wage of a journeyman heavy machinery mechanic was as follows:

- Industrial, institutional and commercial: $32.12
- Civil engineering and roads: $32.60
- Light residential: $29.99
- Heavy residential: $32.16

Vacations and time off

Mandatory annual holidays of four weeks – two weeks in summer and two in winter at periods predetermined in collective agreements – are the general rule in the construction industry. To avoid penalizing employers and employees experiencing special constraints, the industry's four collective agreements allow certain possibilities for changing the vacation periods prescribed by the general rule.

To these vacation periods are added eight not worked statutory holidays, as well as a lump sum for sick leaves not otherwise paid.

5. The general data on working conditions are taken from the 2010-2013 sector-based collective agreements of the four construction industry sectors, and from the following document, published by the Commission de la construction du Québec: *Carrières construction*, 2010-2011 edition.

Pension plan

Construction industry workers participate in a pension plan. They retain their eligibility for this pension plan throughout their career in construction, even if they change employer, trade or sector.

Insurance

The group insurance plan (medications, illness, disability, death) is fully paid by employers. Workers (and their families, as the case may be) are eligible for it so long as they remain active in the construction industry and work the required number of hours, whether or not they change employer.

Physical requirements

The work requires being in good physical condition and able to lift and move loads of up to 30 to 40 kg. Good endurance is also necessary, because work days are sometimes very long and heavy machinery mechanics often have to complete their work after that of other trades. In fact, repairs and maintenance are generally done when the operator has finished working, unless breakdowns require immediate repairs.

Given that much of the work is done outdoors, a heavy machinery mechanic has to face various weather challenges and health hazards, from chilblains in winter and heatstroke in summer. So he must be in good health.

Moreover, because the work is often done in stressful positions, or even in enclosed spaces, a heavy machinery mechanic has to be supple and flexible. He also needs to have good dexterity.

Work schedules

A 40-hour work week from Monday to Friday is the general rule in all construction industry sectors. The daily limit is 8 hours a day, except in the light residential sector, where it can be 10 hours within a 40-hour week.

To avoid penalizing employers and employees experiencing special constraints, the industry's four collective agreements allow many possibilities for changing the schedule prescribed by the general rule: compressed schedule, schedule shift, etc. These special schedules confer flexibility to the work schedules in effect in the construction industry.

The participants mentioned that their schedules vary according to the type of work and the construction site's location. Because they work most of the time on construction sites of the civil engineering and roads sector or on remote construction sites, and that the collective agreements provide for several arrangements regarding such sites, the work week of heavy machinery mechanics usually numbers 45 to 50 hours, Monday to Friday, with a limit of 9 to 10 hours a day.

In addition, the participants mentioned that in remote areas, overtime is frequent and work weeks may be longer (60 to 70 hours). Most of the participants have had extended stays in such areas, for periods varying according to the construction site. The availability of heavy machinery mechanics to work in remote areas is almost considered an obligation, since at times those areas offer the only work opportunities.

Finally, given that the machinery must be stopped for heavy machinery mechanics to do their work, evening and nighttime schedules are frequent, to avoid hindering and delaying the work of other trades.

1.7 JOB MARKET ENTRY CONDITIONS[6]

To obtain the competency certificate-apprentice in the trade (CCA), candidates must present to the CCQ the original version of an academic transcript or apprenticeship transcript attesting that they have passed the course of study for the DEP in construction machinery mechanics, as well as a guarantee of employment from an employer registered with the CCQ for at least 150 hours within a period of not more than three consecutive months.

6. Other conditions than those listed above may apply. For a complete list of conditions for entering the trade, see the Act respecting labour relations, vocational training and workforce management in the construction industry (R.S.Q., c. R-20). You can also consult the CCQ's website: http://www.ccq.org/E_CertificatsCompetence/E02_Apprenti.aspx?sc_lang=en&profil=GrandPublic.

Although the construction industry favours graduates for access to the trade, labour shortages may at times make it necessary for the CCQ to admit heavy machinery mechanics without a diploma. Thus, candidates without a diploma are eligible to obtain a competency certificate-apprentice only during a labour shortage and must:

- supply proof that they have the academic prerequisites for the program leading to a vocational studies diploma (DEP) in the trade referred to in the application or pledge, by signing a consent letter, to take the necessary training to obtain a DEP;

- present a guarantee of employment produced during a labour-pool opening by an employer registered with the CCQ, for at least 150 hours over a period of at most three consecutive months.

The apprentice heavy machinery mechanic must have completed three apprenticeship periods of 2,000 hours each, for a total of 6,000 hours in his trade, in order to be eligible for the provincial qualification examination that leads to obtaining the competency certificate-journeyman for the trade. Credits are paid into the apprenticeship record book of an apprentice heavy machinery mechanic who has obtained his diploma.

Of the 11 heavy machinery mechanics attending the meeting, 7 obtained their DEP in construction machinery mechanics.

Moreover, certain qualities are sought by employers hiring new heavy machinery mechanics. The following list presents the main qualities, in the order they were mentioned and not in order of importance:

- experience in the type of work required;
- reliability;
- punctuality;
- availability;
- resourcefulness;
- versatility.

It was also mentioned that in some companies, a class 3 driver's licence (straight truck) is considered an asset for heavy machinery mechanics. However, in companies where that licence is necessary, heavy machinery mechanics may well obtain it after being hired; so it is not an essential selection criterion.

In addition, regarding newcomers to the trade, the participants pointed out that they have little time for supervising apprentices working with them. They fear that the coaching tradition will fade away if not paid more attention to. They hope to be able to contribute more to the training of apprentices, particularly nowadays, because they observe a major succession problem.

1.8 PLACE OF WOMEN IN THE TRADE

Section 126.0.1 of the Act respecting labour relations, vocational training and workforce management in the construction industry pertains to women's access to the construction industry: "The Commission, after consultation with the Commission des droits de la personne et des droits de la jeunesse, shall develop measures to favour the access of women to and their maintenance and greater representation on the labour market in the construction industry."

According to the CCQ[7], no woman was practicing the trade of heavy machinery mechanic in the construction industry in 2009 (out of 434 mechanics).

The participants think that the only obstacle to integrating women in the trade is the physical strength required for performing most of the tasks. Other than physical strength, the participants do not see other factors preventing women from practicing the trade.

1.9 CAREER PROSPECTS

Heavy machinery mechanics have various career prospects. After a number of years of experience (varying according to the context and individuals), they can become team leaders, foremen or superintendents, or even contractors. They may also leave the trade while remaining in the same field, for example by becoming trainers or teachers.

7. Commission de la construction du Québec, *Carrières construction*, 2010-2011 edition.

1.10 DEVELOPMENT OF THE TRADE

The main change is the arrival of computerization in the trade, particularly in troubleshooting. In fact, the participants note that computerization has created two “categories” of heavy machinery mechanics – those specializing in computer use in the trade and thus focus on diagnosing, repairing electronic systems, etc., and those who do not use computers much and focus on mechanical work.

The participants mentioned that in many cases, the person diagnosing electronic problems and even repairs electronic systems is a technician or mechanic who is employed by the manufacturer of the machinery or systems, and who therefore does not necessarily hold a construction industry competency card.

Moreover, it is pointed out that with the new Bill C-21, a heavy machinery mechanic and his company could be accused of a criminal violation if they do not meet the responsibilities described in the law. This adds stress and responsibility for the mechanic, because he could be liable for hazardous situations of which he was aware.

1.11 IMPACT OF ENVIRONMENTAL STANDARDS ON THE PRACTICE OF THE TRADE

According to the participants, their work has been modified by the introduction of certain environmental standards – in particular, by the elimination of used oils and fluids and their containers during maintenance and repair work. The rules for handling and storing certain products have also changed and must henceforth be applied with a lot of attention.

2. WORK DESCRIPTION

2.1 TASKS AND OPERATIONS

List of tasks

The following list presents the main tasks performed by heavy machinery mechanics. The order in which the tasks are presented does not necessarily reflect their importance in the trade.

Task 1	Apply a preventive maintenance program
Task 2	Repair or replace engines and fuel systems
Task 3	Repair or replace charging and starter systems
Task 4	Repair, install, modify or replace electrical and electronic systems
Task 5	Repair or replace clutches and transmissions
Task 6	Repair or replace chassis, running gears as well as steering and suspension systems
Task 7	Repair or replace braking systems
Task 8	Repair or replace hydraulic systems
Task 9	Repair or replace cabs and their equipment
Task 10	Repair or replace accessories[8]

8. Accessories such as buckets, forks, winches, boom extensions, blades, hammer, clamshell, scissors, mechanical broom, electromagnet, snow removal equipment, vibrating plate, etc.

Types of machines and equipment

Heavy machinery mechanics perform their tasks on various types of heavy machines and equipment, such as:

- bulldozer;
- off-the-road truck;
- loader-backhoe;
- front loader;
- power compactor;
- compressor;
- concrete spreader;
- asphalt spreader;
- lowbed;
- driller (except for the pneumatic driller);
- cold milling machine;
- generator;
- crane;
- grader;
- paver;
- shovel;
- sprayer;
- trailer;
- etc.

Table of tasks and operations

During the workshop, a table of tasks and operations performed by heavy machinery mechanics was submitted to the participants. After discussion, modifications were made to the table. The final version is presented in the following pages.

Table 2.1 Tasks and Operations

TASKS	OPERATIONS					
1. **APPLY A PREVENTIVE MAINTENANCE PROGRAM**	1.1 Read manufacturer and company instructions and specifications	1.2 Read exception reports	1.3 Conduct a visual inspection	1.4 Perform an operational test	1.5 Take samples of all fluids	1.6 Replace oils and filters
	1.7 Clean steel filters	1.8 Check and re-establish fluid levels	1.9 Check, adjust or replace drive belts	1.10 Bleed the fuel tank and air tanks	1.11 Perform a final operational test	1.12 Check the sealing of lines
	1.13 Check the condition of the exhaust system	1.14 Replace wearing parts, cables and chains	1.15 Grease the equipment	1.16 Complete the equipment maintenance record		
2. **REPAIR OR REPLACE ENGINES AND FUEL SYSTEMS**	2.1 Check an engine and fuel system	2.2 Remove an engine	2.3 Replace or repair air intake and exhaust system components	2.4 Repair, replace or adjust a fuel injection system	2.5 Replace a turbocompressor	2.6 Tune up an engine
	2.7 Repair or adjust an ignition system	2.8 Repair a carburation system	2.9 Adjust clearances, alignments and tightening torques	2.10 Repair a lubrication system	2.11 Repair a cooling system	2.12 Replace a timing chain or distributor gear
	2.13 Replace and synchronize a camshaft and its bearings	2.14 De-ice or replace cylinders	2.15 Check or replace piston rings and pins as well as pistons	2.16 Replace a fuel tank and its piping system	2.17 Reinstall an engine	2.18 Perform an operational test
3. **REPAIR OR REPLACE CHARGING AND STARTER SYSTEMS**	3.1 Check a charging system and a starter system	3.2 Check or replace batteries	3.3 Repair or replace a starter and other system components	3.4 Repair or replace an alternator, control box or generator	3.5 Replace a charging system	3.6 Replace preheating systems
	3.7 Perform an operational test					

TASKS	OPERATIONS					
4. **REPAIR, INSTALL, MODIFY OR REPLACE ELECTRICAL AND ELECTRONIC SYSTEMS**	4.1 Check an electrical and electronic system and its accessories	4.2 Repair, install, modify or replace warning equipment	4.3 Repair, install, modify or replace lighting equipment	4.4 Repair, install, modify or replace electrical or electronic equipment	4.5 Repair, install, modify or replace dashboard indicators	4.6 Perform an operational test
5. **REPAIR OR REPLACE CLUTCHES AND TRANSMISSIONS**	5.1 Check a manual, automatic or hydrostatic transmission	5.2 Repair or replace a transfer box or a manual or automatic transmission	5.3 Adjust a manual transmission clutch	5.4 Replace the torque converter of an automatic transmission	5.5 Replace automatic or hydrostatic transmission filters	5.6 Bleed the hydrostatic system
	5.7 Correct the angle and balancing of a manual or automatic transmission's front and rear drive shafts	5.8 Adjust the hydrostatic pump pressure	5.9 Adjust the linkage or replace solenoids	5.10 Perform an operational test		
6. **REPAIR OR REPLACE CHASSIS, RUNNING GEARS AS WELL AS STEERING AND SUSPENSION SYSTEMS**	6.1 Check a chassis, a running gear and steering and suspension systems	6.2 Install reinforcing plates	6.3 Straighten an arched or crooked chassis	6.4 Repair or replace a differential	6.5 Replace and adjust final drive system components	6.6 Replace tracks and tires
	6.7 Align the wheels	6.8 Adjust steering gearbox clearances	6.9 Replace a power steering pump and belts	6.10 Repair or replace a track drive system's grease cylinder	6.11 Repair or replace a suspension system	6.12 Perform an operational test
7. **REPAIR OR REPLACE BRAKING SYSTEMS**	7.1 Check a braking system	7.2 Repair and adjust drum brakes	7.3 Repair conventional or multiple disc brakes	7.4 Adjust an engine brake	7.5 Adjust or replace manual brake cables	7.6 Repair or replace a flexible and a rigid piping system
	7.7 Repair or replace a master cylinder	7.8 Replace a power brake unit	7.9 Repair or replace an air chamber (booster)	7.10 Perform an operational test		

TASKS	OPERATIONS					
8. **REPAIR OR REPLACE HYDRAULIC SYSTEMS**	8.1 Check hydraulic systems	8.2 Replace hydraulic system components	8.3 Replace filters and O rings	8.4 Check a hydraulic system's flow	8.5 Adjust pump pressure, valves and hydraulic linkages	8.6 Perform an operational test
9. **REPAIR OR REPLACE CABS AND THEIR EQUIPMENT**	9.1 Check cabs and their equipment	9.2 Repair, adjust, replace or install cab components (doors, hoods, caps, hinges, etc.)	9.3 Modify, install, repair or replace protective structures, step plates, ladders, etc.	9.4 Modify, install, repair or replace heating and air conditioning systems	9.5 Install or replace safety equipment (safety belts, fire extinguisher, etc.)	9.6 Perform an operational test
10. **REPAIR OR REPLACE ACCESSORIES**	10.1 Check accessories	10.2 Repair accessories	10.3 Install accessories	10.4 Uninstall accessories	10.5 Perform an operational test	

2.2 OPERATIONS, SUB-OPERATIONS AND CLARIFICATIONS

In the following pages are presented the sub-operations related to most of the operations[9], as well as a few clarifications made by the participants.

Table 2.2 Sub-Operations and Operation Clarifications

TASK 1 APPLY A PREVENTIVE MAINTENANCE PROGRAM

Preventive maintenance is done on all systems and components involved in tasks 2 to 10, i.e.:

- engines and fuel systems;
- charging and starter systems;
- electrical and electronic systems;
- clutches and transmissions;
- chassis, running gears as well as steering and suspension systems;
- braking systems;
- hydraulic systems;
- cabs and their equipment;
- accessories.

Operations	Sub-Operations	Clarifications
1.1 Read manufacturer and company instructions and specifications	1.1.1 Read safety and environmental instructions 1.1.2 Check intervals between maintenance jobs 1.1.3 Check oil and grease types	
1.2 Read exception reports	1.2.1 Check dates and times on reports	
1.3 Conduct a visual inspection	1.3.1 Wash the equipment 1.3.2 Conduct an inspection tour 1.3.3 Detect leaks and wear 1.3.4 Apply environmental standards	
1.4 Perform an operational test	1.4.1 Heat the unit in operation	
1.5 Take samples of all fluids	1.5.1 Take necessary precautions to avoid contamination 1.5.2 Identify sample bottles (engine oil, transmission, antifreeze, etc.)	

9. The sequence of operations may vary according to company organization.

TASK 1 APPLY A PREVENTIVE MAINTENANCE PROGRAM		
Operations	**Sub-Operations**	**Clarifications**
1.6 Replace oils and filters	1.6.1 Remove waste oils and worn filters 1.6.2 Choose appropriate oils and filters 1.6.3 Eliminate waste oils and worn filters	
1.7 Clean steel filters	1.7.1 Ensure that filters are in good condition 1.7.2 Replace filters, if necessary 1.7.3 Replace gaskets, if necessary 1.7.4 Clean filters with a solvent or air blast	
1.8 Check and re-establish fluid levels	1.8.1 Start up the equipment 1.8.2 Ensure that fluids are at an adequate level	
1.9 Check, adjust or replace drive belts[10]	1.9.1 Check the condition of belts, and change them if applicable 1.9.2 Check the tensioner 1.9.3 Adjust the tension 1.9.4 Check belt alignment	
1.10 Bleed the fuel tank and air tanks	1.10.1 Recover discharged fluids 1.10.2 Check the presence of sediments 1.10.3 Detect eventual problems	Examples of problems are exterior contamination, poor air dryer operation, etc.
1.11 Perform a final operational test	1.11.1 Start up the unit 1.11.2 Check for leaks at filters and the drain plug	
1.12 Check the sealing of lines	1.12.1 Check for leaks of: – oil – fuel – antifreeze – air	

10. The CCQ's Direction de l'application des conventions collectives has issued a notice to the effect that belt installation is not part of this trade.

TASK 1 APPLY A PREVENTIVE MAINTENANCE PROGRAM		
Operations	**Sub-Operations**	**Clarifications**
1.13 Check the condition of the exhaust system	1.13.1 Check system sealing 1.13.2 Check the presence of worn or damaged parts 1.13.3 Check the condition of fasteners (e.g.: supports)	
1.14 Replace wearing parts, cables and chains		
1.15 Grease the equipment[11]	1.15.1 Apply grease 1.15.2 Check the condition of greasing parts and fittings	
1.16 Complete the equipment maintenance record	1.16.1 Ensure data accuracy, such as: – date – number of hours / kilometres – machine model and serial number – etc. 1.16.2 Note the risks of defects	

TASK 2 REPAIR OR REPLACE ENGINES AND FUEL SYSTEMS		
Operations	**Sub-Operations**	**Clarifications**
2.1 Check an engine and fuel system	2.1.1 Visually inspect 2.1.2 Start the engine 2.1.3 Check fluid levels 2.1.4 Detect abnormal noises 2.1.5 Detect leaks of fluids, air, etc. 2.1.6 Check the exhaust (colour, odour) 2.1.7 Check for damaged parts	

11. The CCQ's Direction de l'application des conventions collectives has issued a notice to the effect that greasing of equipment is not part of this trade.

TASK 2 REPAIR OR REPLACE ENGINES AND FUEL SYSTEMS		
Operations	**Sub-Operations**	**Clarifications**
2.2 Remove an engine	2.2.1 Secure the installation 2.2.2 Disconnect the battery 2.2.3 Remove the hood 2.2.4 Flush the antifreeze 2.2.5 Disconnect electrical connectors, fuel lines, the exhaust, cables and collars 2.2.6 Stabilize the transmission and accessories 2.2.7 Unbolt the engine 2.2.8 Remove the engine	
2.3 Replace or repair air intake and exhaust system components	2.3.1 Remove the air filtration system (air box) 2.3.2 Unbolt the air intake system and remove it 2.3.3 Remove the exhaust system 2.3.4 Remove the air supercharging system	
2.4 Repair, replace or adjust a fuel injection system		The system's main components are the lines, injectors, primary pump, secondary pump, filter and tank.
2.5 Replace a turbocompressor	2.5.1 Remove the intake and exhaust piping system 2.5.2 Disconnect the turbocompressor's lubrication and oil return pipes 2.5.3 Remove the turbocompressor 2.5.4 Install a new turbocompressor	A turbocompressor is reconditioned by a specialized workshop.

TASK 2 REPAIR OR REPLACE ENGINES AND FUEL SYSTEMS		
Operations	**Sub-Operations**	**Clarifications**
2.6 Tune up an engine	Gasoline engine 2.6.1 Replace the cap distributor, rotor, spark plugs, wiring, condenser, points 2.6.2 Adjust the distributor, carburetor, valves 2.6.3 Adjust the injectors and belt tension 2.6.4 Change the timing belt and tensioner 2.6.5 Clean or replace oil strainers and filters Diesel engine 2.6.6 Adjust the valves 2.6.7 Adjust the injectors and, if applicable, the engine brake 2.6.8 Check the injectors 2.6.9 Change filters and oils 2.6.10 Check and adjust the belts	Heavy machinery mechanics mainly work on diesel engines (90%), because all heavy machines have them. Given that heavy machinery mechanics are generally the only mechanics present on site, they are often asked to repair other types of machinery and equipment than heavy machines. They may therefore work on gasoline engines (e.g.: light trucks, generators, waterpumps, chainsaws, etc.), but to a lesser extent (10%).
2.7 Repair or adjust an ignition system	2.7.1 Replace the distributor cap, rotor, spark plugs, wiring 2.7.2 Check and adjust the timing	For gasoline engines.
2.8 Repair a carburation system	2.8.1 Disassemble the carburetor 2.8.2 Change gaskets 2.8.3 Clean the system 2.8.4 Adjust the system	For gasoline engines.
2.9 Adjust clearances, alignments and tightening torques	2.9.1 Put the engine to top dead centre 2.9.2 From the rocker, adjust the exhaust and intake valves and the injectors 2.9.3 Check and adjust pinion alignment and clearance 2.9.4 Check and adjust the tightening torque	
2.10 Repair a lubrication system	2.10.1 Check and adjust the oil pump and strainer 2.10.2 Check the pressure sensor 2.10.3 Check and replace gaskets	

TASK 2 REPAIR OR REPLACE ENGINES AND FUEL SYSTEMS		
Operations	**Sub-Operations**	**Clarifications**
2.11 Repair a cooling system	2.11.1 Check and change fan belts 2.11.2 Check fan operation 2.11.3 Check the antifreeze fluid level and density 2.11.4 Check for external leaks 2.11.5 Check the radiator cap's condition 2.11.6 Check the water pump's condition 2.11.7 Check for dust that can block the radiator 2.11.8 Check the thermostat 2.11.9 Check the fan coupling 2.11.10 Detect any anomaly 2.11.11 Make necessary repairs or replacements	
2.12 Replace a timing chain or distributor gear	2.12.1 Put the engine to top dead centre 2.12.2 Remove the cap 2.12.3 Check the condition of gears 2.12.4 Replace or adjust parts, if necessary	
2.13 Replace and synchronize a camshaft and its bearings		With very rare exceptions, this operation is not performed on construction sites.
2.14 De-ice or replace cylinders	2.14.1 Pass abrasive beads or stones 2.14.2 Remove cylinders (flush the antifreeze fluid) 2.14.3 Press the cylinder and check the protrusion	With very rare exceptions, this operation is not performed on construction sites.
2.15 Check or replace piston rings and pins as well as pistons	2.15.1 Remove pistons 2.15.2 Clean piston grooves 2.15.3 Check piston sizes 2.15.4 Install piston rings 2.15.5 Check the measurements of piston ring nozzles 2.15.6 Check and replace circlips in piston pin boxes	With very rare exceptions, this operation is not performed on construction sites.

TASK 2 REPAIR OR REPLACE ENGINES AND FUEL SYSTEMS		
Operations	**Sub-Operations**	**Clarifications**
2.16 Replace a fuel tank and its piping system	2.16.1 Flush the tank 2.16.2 Disassemble the lines 2.16.3 Disassemble the tank 2.16.4 Clean the tank's location 2.16.5 Install a new tank and lines 2.16.6 Check for leaks 2.16.7 Bleed the system	
2.17 Reinstall an engine	2.17.1 Position the engine 2.17.2 Install lines for the antifreeze fluid, gasoline and electric wires 2.17.3 Install the radiator 2.17.4 Bolt auxiliary components (transmission, pumps, etc.) 2.17.5 Install accessories (mufflers, belts, air filter, etc.) 2.17.6 Install the battery	
2.18 Perform an operational test	2.18.1 Start the engine 2.18.2 Check fluid levels 2.18.3 Check for leaks, noises and smoke during and after operation 2.18.4 Check the oil pressure and the temperature	Operational tests are generally performed in cooperation with the machine operator. However, in the latter's absence, a heavy machinery mechanic must be able to operate the machine minimally to make a diagnosis and perform an operational test after repairs. But he does not need to be able to operate the machine for production purposes as would an operator.

TASK 3 REPAIR OR REPLACE CHARGING AND STARTER SYSTEMS		
Operations	**Sub-Operations**	**Clarifications**
3.1 Check a charging system and a starter system	3.1.1 Turn the unit on 3.1.2 Take readings (amperes, volts) 3.1.3 Detect anomalies on: – the battery – the starter – the alternator – the charging system – the preheating system – etc.	Checking the battery involves: – checking the electrolyte's level and density; – visually inspecting connectors; – checking voltage; – performing a CCA (Cold Cranking Amps) test. Checking the charging system involves: – visually inspecting the wiring; – checking continuity, resistances, diodes and connections. Checking the preheating system involves checking the continuity, resistance and signal.
3.2 Check or replace batteries	3.2.1 Remove the battery 3.2.2 Install a new battery	
3.3 Repair or replace a starter and other system components	3.3.1 Disconnect the power supply 3.3.2 Remove components 3.3.3 Install new components 3.3.4 Reconnect the power supply	
3.4 Repair or replace an alternator, control box or generator	3.4.1 Disconnect the power supply 3.4.2 Remove components 3.4.3 Install new components 3.4.4 Reconnect the power supply	
3.5 Replace a charging system	3.5.1 Cut power 3.5.2 Replace components (alternator, generator, etc.) 3.5.3 Turn the power back on	
3.6 Replace preheating systems	3.6.1 Cut power 3.6.2 Replace components 3.6.3 Turn the power back on	
3.7 Perform an operational test	3.7.1 Turn the power back on 3.7.2 Perform a starting test 3.7.3 Test the charging system 3.7.4 Detect any anomaly	See clarifications for operation 2.18.

TASK 4 REPAIR, INSTALL, MODIFY OR REPLACE ELECTRICAL AND ELECTRONIC SYSTEMS		
Operations	**Sub-Operations**	**Clarifications**
4.1 Check an electrical and electronic system and its accessories	4.1.1 Check the electric voltage, current and power 4.1.2 Check circuit continuity 4.1.3 Find the defective component's circuit 4.1.4 Consult the electrical plan, as necessary 4.1.5 Interpret the manufacturer's error codes	
4.2 Repair, install, modify or replace warning equipment	4.2.1 Disconnect the power supply 4.2.2 Repair, install, modify or replace components 4.2.3 Reconnect the power supply	
4.3 Repair, install, modify or replace lighting equipment	4.3.1 Disconnect the power supply 4.3.2 Repair, install, modify or replace components 4.3.3 Reconnect the power supply	
4.4 Repair, install, modify or replace electrical or electronic equipment	4.4.1 Disconnect the power supply 4.4.2 Repair, install, modify or replace components 4.4.3 Reconnect the power supply	
4.5 Repair, install, modify or replace dashboard indicators	4.5.1 Disconnect the power supply 4.5.2 Repair, install, modify or replace components 4.5.3 Reconnect the power supply 4.5.4 Parameterize, if applicable	
4.6 Perform an operational test		See clarifications for operation 2.18.

TASK 5 REPAIR OR REPLACE CLUTCHES AND TRANSMISSIONS		
Operations	**Sub-Operations**	**Clarifications**
5.1 Check a manual, automatic or hydrostatic transmission	5.1.1 Check the oil level 5.1.2 Perform an operational test 5.1.3 Check gaskets 5.1.4 Check the magnetic plug 5.1.5 Check sensors and replace them if necessary 5.1.6 Detect oil leaks or odours	
5.2 Repair or replace a transfer box or a manual or automatic transmission	5.2.1 Flush the oil 5.2.2 Disconnect wires and pipes 5.2.3 Remove the transmission 5.2.4 Repair or replace the transfer box or transmission 5.2.5 Replace the transmission shaft, if applicable 5.2.6 Put oil back in	
5.3 Adjust a manual transmission clutch	5.3.1 Remove the protective shield 5.3.2 Press on the clutch 5.3.3 Place the adjusting mechanism in front of the door 5.3.4 Have the pedal fully depressed 5.3.5 Adjust the clutch 5.3.6 Adjust the clutch brake	
5.4 Replace the torque converter of an automatic transmission	5.4.1 Flush the oil 5.4.2 Disassemble the fittings 5.4.3 Remove the torque shaft 5.4.4 Shift the transmission down 5.4.5 Change the converter 5.4.6 Reinstall the transmission 5.4.7 Adjust the oil level	
5.5 Replace automatic or hydrostatic transmission filters		
5.6 Bleed the hydrostatic system		

TASK 5	REPAIR OR REPLACE CLUTCHES AND TRANSMISSIONS				
Operations		**Sub-Operations**		**Clarifications**
5.7	Correct the angle and balancing of a manual or automatic transmission's front and rear drive shafts	5.7.1 5.7.2 5.7.3 5.7.4	Check the universal joint Check the balancing Check the torque shaft Make necessary corrections	
5.8	Adjust the hydrostatic pump pressure			This operation applies to hydrostatic transmissions.
5.9	Adjust the linkage or replace solenoids			
5.10	Perform an operational test			See clarifications for operation 2.18.

TASK 6	REPAIR OR REPLACE CHASSIS, RUNNING GEARS AS WELL AS STEERING AND SUSPENSION SYSTEMS				
Operations		**Sub-Operations**		**Clarifications**
6.1	Check a chassis, a running gear, and a steering and suspension system	6.1.1 6.1.2 6.1.3 6.1.4 6.1.5 6.1.6	Clean components Visually inspect Check the wear of components Check tolerances Perform a road test Observe stress points	
6.2	Install reinforcing plates	6.2.1 6.2.2 6.2.3	Check manufacturer standards Weld the reinforcing plates Paint	
6.3	Straighten an arched or crooked chassis	6.3.1 6.3.2 6.3.3 6.3.4 6.3.5	Check manufacturer standards Remove accessories fastened to the chassis Straighten Check that standards are met Reinstall the accessories	These are rather temporary chassis repairs that may be necessary on large or remote construction sites.

TASK 6	REPAIR OR REPLACE CHASSIS, RUNNING GEARS AS WELL AS STEERING AND SUSPENSION SYSTEMS			
Operations		**Sub-Operations**		**Clarifications**
6.4	Repair or replace a differential	6.4.1 6.4.2 6.4.3 6.4.4 6.4.5 6.4.6 6.4.7 6.4.8	Install wheel blocks Flush the oil Remove the axles Remove the operating shaft Remove the differential Clean and inspect Make repairs or install a new differential Check the adjustment	
6.5	Replace and adjust final drive system components	6.5.1 6.5.2 6.5.3 6.5.4 6.5.5 6.5.6	Flush the oil Remove the axles Remove the final drive system Clean and inspect Install the new final drive system Adjust the synchronization	
6.6	Replace tracks and tires[12]	Tires 6.6.1 6.6.2 6.6.3 6.6.4 6.6.5 6.6.6 Tracks 6.6.7 6.6.8 6.6.9 6.6.10 6.6.11 6.6.12	 Block the vehicle Loosen the bolts Raise the vehicle Remove the bolts Remove the wheel and change the tire Put the bolts back and tighten them Slacken the track Uncouple the track Remove the track Replace damaged components Reinstall the track Adjust track tension	

12. The CCQ's Direction de l'application des conventions collectives has issued a notice to the effect that tire installation and repair are not part of this trade.

TASK 6	REPAIR OR REPLACE CHASSIS, RUNNING GEARS AS WELL AS STEERING AND SUSPENSION SYSTEMS		
Operations		**Sub-Operations**	**Clarifications**
6.7	Align the wheels	6.7.1 Check and adjust: – the wear of parts – front and rear wheel alignment – the caster angle – the camber angle	
6.8	Adjust steering gearbox clearances	6.8.1 Check and adjust excess flow valves 6.8.2 Check and adjust clearances according to manufacturer standards	
6.9	Replace a power steering pump and belts	6.9.1 Flush the oil 6.9.2 Remove pipes and lines 6.9.3 Loosen the pump and remove the belt 6.9.4 Remove the pump 6.9.5 Reinstall a new pump and new belts 6.9.6 Fill up and flush the system	
6.10	Repair or replace a track drive system's grease cylinder	6.10.1 Slacken the track 6.10.2 Uncouple the track 6.10.3 Remove grease pressure 6.10.4 Remove the grease cylinder 6.10.5 Repair damaged components as necessary 6.10.6 Install the new or repaired cylinder 6.10.7 Refill with grease and adjust track tension	
6.11	Repair or replace a suspension system	6.11.1 Disassemble the lines 6.11.2 Purge the nitrogen as necessary 6.11.3 Raise the vehicle 6.11.4 Disassemble a defective suspension part 6.11.5 Install a new part 6.11.6 Adjust the cylinder's height and pressure	
6.12	Perform an operational test		See clarifications for operation 2.18.

TASK 7 REPAIR OR REPLACE BRAKING SYSTEMS		
Operations	**Sub-Operations**	**Clarifications**
7.1 Check a braking system	7.1.1 Test the braking system 7.1.2 Detect failures such as leaks, abnormal wear, suspicious noise, etc.	
7.2 Repair and adjust drum brakes	7.2.1 Check and, if applicable, replace: – drums and shoes – air chambers, worn camshafts and their clearances – brake slack adjusters – wheel oil rings 7.2.2 Adjust the brakes	
7.3 Repair conventional or multiple disc brakes	7.3.1 Check the condition of discs 7.3.2 Check the condition of calipers 7.3.3 Recondition the calipers, if applicable 7.3.4 Check the wear of brake pads 7.3.5 Replace defective or worn components	
7.4 Adjust an engine brake		
7.5 Adjust or replace manual brake cables	7.5.1 Check the condition of cables (wear, rust, damage) 7.5.2 Check the condition of the mechanisms and steering gear 7.5.3 Replace as necessary and adjust	
7.6 Repair or replace a flexible and a rigid piping system	7.6.1 Check the condition of the piping system (wear, rust, perforation, cracks) 7.6.2 Check fasteners 7.6.3 Ensure that pipes and fittings are the correct type 7.6.4 Repair or replace a component 7.6.5 For brake systems using oil-based fluids, bleed the system and adjust the master cylinder fluid level	

TASK 7 REPAIR OR REPLACE BRAKING SYSTEMS		
Operations	**Sub-Operations**	**Clarifications**
7.7 Repair or replace a master cylinder	7.7.1 Flush the master cylinder 7.7.2 Repair or replace the master cylinder 7.7.3 Put the master cylinder back 7.7.4 Make the first adjustments 7.7.5 Fill with oil 7.7.6 Bleed and retrofit 7.7.7 Bleed the system and adjust the master cylinder fluid level	
7.8 Replace a power brake unit	7.8.1 Flush the brake booster, check the unit's condition and operation 7.8.2 Replace the unit as necessary 7.8.3 Bleed the system and adjust the master cylinder fluid level	
7.9 Repair or replace an air chamber (booster)	7.9.1 Check for leaks 7.9.2 Check the emergency spring 7.9.3 Check the air chamber's size 7.9.4 Repair or change the air chamber (booster)	
7.10 Perform an operational test		See clarifications for operation 2.18.

TASK 8 REPAIR OR REPLACE HYDRAULIC SYSTEMS		
Operations	**Sub-Operations**	**Clarifications**
8.1 Check hydraulic systems	8.1.1 Check the hydraulic oil level 8.1.2 Start the engine[13] 8.1.3 Check the engine speed 8.1.4 Check the condition of pipes 8.1.5 Check vibrations 8.1.6 Check the cylinders 8.1.7 Check the valves 8.1.8 Check the pump 8.1.9 Detect leaks, wear, breakages, suspicious noises	

13. The sequence of sub-operations 8.1.1 and 8.1.2 may be reversed according to system manufacturer recommendations.

TASK 8 REPAIR OR REPLACE HYDRAULIC SYSTEMS		
Operations	**Sub-Operations**	**Clarifications**
8.2 Replace hydraulic system components	8.2.1 Depressurize and flush the hydraulic tank 8.2.2 Change the hydraulic pump 8.2.3 Change the pipes 8.2.4 Change the cylinders 8.2.5 Change the hydraulic engine 8.2.6 Change the valves 8.2.7 Adjust the oil level 8.2.8 Bleed the system and adjust the hydraulic tank fluid level	
8.3 Replace filters and O rings	8.3.1 Remove the tank pressure 8.3.2 Change filters and joints 8.3.3 Check and clean the oil strainer 8.3.4 Adjust the oil level	
8.4 Check a hydraulic system's flow	8.4.1 Start the engine and bring it to its operating condition 8.4.2 Install a flowmeter 8.4.3 Test	
8.5 Adjust pump pressure, valves and hydraulic linkages	8.5.1 Check with manufacturer standards 8.5.2 Make adjustments	
8.6 Perform an operational test	8.6.1 Check the system in every position 8.6.2 Check the oil temperature 8.6.3 Detect any anomaly (leaks, smoke, etc.)	See clarifications for operation 2.18.

TASK 9 REPAIR OR REPLACE CABS AND THEIR EQUIPMENT		
Operations	**Sub-Operations**	**Clarifications**
9.1 Check cabs and their equipment	9.1.1 Visually inspect 9.1.2 Check safety equipment 9.1.3 Check filtration systems	
9.2 Repair, adjust, replace or install cab components (doors, hoods, caps, hinges, etc.)	9.2.1 Check the dashboard 9.2.2 Add or replace windshield wipers 9.2.3 Repair, adjust, install or replace internal components (seat, steering wheel, etc.) 9.2.4 Make temporary body repairs 9.2.5 Make modifications	
9.3 Modify, install, repair or replace protective structures, step plates, ladders, etc.		
9.4 Modify, install, repair or replace heating and air conditioning systems		Repairs to the air conditioning system are generally done by specialized companies.
9.5 Install or replace safety equipment (safety belts, fire extinguisher, kits, etc.)		In cabs are found first-aid kits and “environmental” kits containing absorbent pads, retaining beads, etc., in case of oil spills or spills of other products damaging to the environment.
9.6 Perform an operational test		See clarifications for operation 2.18.

TASK 10 REPAIR OR REPLACE ACCESSORIES

The repaired or replaced accessories are: bucket, fork, winch, boom extension, blades, hammer, clamshell, scissors, mechanical broom, electromagnet, snow removal equipment, vibrating plate, etc.

Operations	Sub-Operations	Clarifications
10.1 Check accessories		
10.2 Repair accessories		Repairs not already described in tasks 2 to 8 mainly involve minor welding work.
10.3 Install accessories		
10.4 Uninstall accessories		
10.5 Perform an operational test		See clarifications for operation 2.18.

2.3 ACHIEVEMENT CONDITIONS

Data on achievement conditions were collected for the heavy machinery mechanic trade as a whole. The data pertain to aspects such as work areas, work instructions, health and safety hazards, reference documents, and material resources used.

Table 2.3 Achievement Conditions

ACHIEVEMENT CONDITIONS
Work areas[14] Heavy machinery mechanics mainly work outdoors, in open pits, in tunnels, on barges, etc. When they work indoors, it is in temporary construction site garages. They may have to work from heights, in confined or closed spaces.
Collaboration and supervision Heavy machinery mechanics almost always work alone, i.e., during about 90% of their work time. But this number may vary slightly according to the company and type of work to be done. If they need information or assistance, heavy machinery mechanics can always communicate with their supervisor or colleagues. The workers, particularly the most experienced ones, have a lot of autonomy. Their supervisor assigns tasks to them; then they work autonomously.
Instructions Instructions are mainly verbal and given by the foreman. They may pertain to tasks to be performed, but also health and safety precautions related to the work to be done.
Stress factors The main stress factors are related to tight work deadlines and employers' production requirements, which the participants say are greater and greater.

14. Non-exhaustive list.

ACHIEVEMENT CONDITIONS
References The main references used by heavy machinery mechanics are manufacturer manuals for the various machines they have to repair, electrical or electronic plans, technical manuals, parts catalogues, etc.
Raw materials, tools and equipment In Annex 1 of the present report is a list of material resources used by heavy machinery mechanics in the practice of their trade.
Health and safety hazards According to the participants, the main health and safety hazards to which heavy machinery mechanics are exposed are the following: – heavy moving parts (injuries, crushing, cuts); – projection of foreign bodies, filings, etc. (eye injuries); – noisy machines (hearing problems); – hot oil or parts (burns); – intense cold and heat (chilblains and heatstroke); – stressful positions (backache); – uneven or slippery ground (falls); – working from heights (falls); – dangerous products (burns, intoxication). Moreover, in Annex 2 of the present report is a more detailed list of the main hazards related to the tasks and operations of the heavy machinery mechanic trade, as well as applicable preventive measures.

2.4 PERFORMANCE CRITERIA

Performance criteria were gathered for each task. They are used for assessing whether the tasks were performed satisfactorily. The criteria pertain to aspects such as the quantity and quality of work done, the observance of a work procedure, the attitudes adopted, etc.

To draw the list of criteria for each task, the participants worked in teams of two or three. Their results were then collected and presented in full session. Thus, certain criteria may at times be as relevant to other tasks as to those for which they have been retained.

Table 2.4 Performance Criteria

TASK 1 APPLY A PREVENTIVE MAINTENANCE PROGRAM
Performance Criteria
– Correct choice of lubricants – Accurate identification of samples – Careful reading of defect reports – Accurate and clear maintenance reports – Work cleanliness – Following manufacturer recommendations – Observance of health and safety rules – Observance of environmental protection rules – Productive work technique – Complete verification of all components – Vigilance regarding potential problems – Carefully checking the quality of work
TASK 2 REPAIR OR REPLACE ENGINES AND FUEL SYSTEMS
Performance Criteria
– Secure fastening and precise connection of components such as pipes, supports, collars, etc. – Work cleanliness – Observance of manufacturer procedures and standards (tightening torque, size of parts, etc.) – Observance of health and safety rules – Observance of environmental protection rules – Using the appropriate tools – Efficient work method – Meticulous reassembly of all components – Carefully checking the quality of work – Accurate and clear reports

TASK 3 REPAIR OR REPLACE CHARGING AND STARTER SYSTEMS

Performance Criteria

- Correct application of systems' operating principles
- Locking the system appropriately, if applicable
- Efficient execution of temporary corrective maintenance, if applicable
- Fastening components securely and at the correct locations
- Accurate identification of wires and connections during repairs
- Correct interpretation of electrical plans
- Systematic work method during the diagnosis
- Observance of standards for electrical systems (wire colours, gauges, etc.)
- Observance of health and safety rules
- Observance of environmental protection rules
- Appropriate use of tools and instruments (e.g.: multimeter)
- Using appropriate test accessories
- Correctly checking sensors
- Carefully checking the quality of work
- Accurate and clear reports

TASK 4 REPAIR, INSTALL, MODIFY OR REPLACE ELECTRICAL AND ELECTRONIC SYSTEMS

Performance Criteria

- Correct application of systems' operating principles
- Locking the system appropriately, if applicable
- Efficient execution of temporary corrective maintenance, if applicable
- Fastening components securely and at the correct locations
- Accurate identification of wires and connections during repairs
- Correct interpretation of electrical plans
- Systematic work method during the diagnosis
- Observance of standards for electrical systems (wire colours, gauges, etc.)
- Observance of health and safety rules
- Observance of environmental protection rules
- Appropriate use of tools and instruments (e.g.: multimeter)
- Using appropriate test accessories
- Correctly checking sensors
- Carefully checking the quality of work
- Accurate and clear reports

TASK 5 REPAIR OR REPLACE CLUTCHES AND TRANSMISSIONS

Performance Criteria

- Adequate alignment of the transmission shaft
- Correct choice of oils
- Fastening bolts securely
- Adequately positioning electric wires, sensors and pipes
- Work cleanliness
- Efficient work method
- Observance of manufacturer standards
- Observance of tightening standards
- Observance of health and safety rules
- Observance of environmental protection rules
- Observance of tolerances
- Carefully checking the quality of work
- Accurate and clear reports

TASK 6 REPAIR OR REPLACE CHASSIS, RUNNING GEARS AS WELL AS STEERING AND SUSPENSION SYSTEMS

Performance Criteria

- Appropriate choice of oils according to their use
- Securely fastening parts to the chassis
- Carefully washing parts before assembly
- Cleanliness of fragile and precision parts (e.g.: bearings)
- Efficient work method
- Observance of health and safety rules
- Observance of environmental protection rules
- Adequately stabilizing the vehicle
- Carefully checking tolerances
- Carefully checking the quality of work
- Accurate and clear reports

TASK 7 REPAIR OR REPLACE BRAKING SYSTEMS

Performance Criteria

- Safe operation test
- Correct troubleshooting
- Cleanliness and orderly storage of parts
- Following manufacturer recommendations
- Observance of health and safety rules
- Observance of environmental protection rules
- Productive work technique
- Using the appropriate tools
- Observance of tolerances
- Carefully checking the quality of work
- Accurate and clear reports

TASK 8 REPAIR OR REPLACE HYDRAULIC SYSTEMS

Performance Criteria

- Correct choice of oils
- Complete test of all functions
- Appropriate decisions for changing or repairing parts
- Meticulous disassembly of parts
- Cleaning parts appropriately
- Securely fastening parts
- Efficient work method
- Following manufacturer recommendations
- Observance of health and safety rules
- Observance of environmental protection rules
- Carefully checking the quality of work
- Accurate and clear reports

TASK 9 REPAIR OR REPLACE CABS AND THEIR EQUIPMENT

Performance Criteria

- Choosing the appropriate bolts
- Choosing the appropriate tools
- During welding, appropriate protection of windows and other fragile components
- Adequately finishing parts to prevent rust (e.g.: paint)
- Securely fastening pipes and wires
- Correct operation of repaired or replaced components
- Efficient work method
- Work cleanliness
- Following manufacturer recommendations
- Observance of health and safety rules
- Observance of environmental protection rules
- The operator's satisfaction with the work done
- Securely fastened dashboard
- Careful inspection of all components
- Carefully checking the quality of work
- Accurate and clear reports

TASK 10 REPAIR OR REPLACE ACCESSORIES

Performance Criteria

- Correct application of systems' operating principles
- Choosing the appropriate tools
- Correct choice of oils
- Appropriate decisions for changing or repairing parts
- Meticulous disassembly of parts
- Complete test of all functions
- Efficient execution of temporary corrective maintenance, if applicable
- Fastening components securely and at the correct locations
- Correct operation of repaired or replaced components
- Correct interpretation of plans
- Efficient work method
- Work cleanliness
- Observance of manufacturer standards and recommendations
- Observance of health and safety rules
- Observance of environmental protection rules
- Observance of tolerances
- The operator's satisfaction with the work done
- Appropriate use of tools and instruments
- Careful inspection of all components
- Vigilance regarding potential problems
- Carefully checking the quality of work
- Accurate and clear reports

2.5 FUNCTIONS

Functions correspond to a set of related tasks. This set may be defined by the work's results or by a sequence of steps.

For the heavy machinery mechanic trade, two functions appear to stand out:

- a function related to **maintenance**, with the following task:
  - Apply a preventive maintenance program;
- a function related to **repair** or **replacement**, grouping the following tasks:
  - Repair or replace engines and fuel systems;
  - Repair or replace charging and starter systems;
  - Repair, install, modify or replace electrical and electronic systems and accessories;
  - Repair or replace clutches and transmissions;
  - Repair or replace chassis, running gears as well as steering and suspension systems;
  - Repair or replace braking systems;
  - Repair or replace hydraulic systems;
  - Repair or replace cabs and their equipment;
  - Repair, install or uninstall accessories.

3. QUANTITATIVE DATA ON TASKS

3.1 OCCURRENCE

Occurrence data concern the percentage of heavy machinery mechanics[15] who perform a task in the same work environment. The data presented in the tables below are the average results of the workshop participants. However, they account for the use of time not only of the workshop participants, but also of all heavy machinery mechanics working in the companies represented.

Table 3.1 Task Occurrence

	Task	Occurrence
1	Apply a preventive maintenance program	83%
2	Repair or replace engines and fuel systems	66.3%
3	Repair or replace charging and starter systems	94.6%
4	Repair, install, modify or replace electrical and electronic systems	90%
5	Repair or replace clutches and transmissions	72.7%
6	Repair or replace chassis, running gears as well as steering and suspension systems	80%
7	Repair or replace braking systems	94.6%
8	Repair or replace hydraulic systems	83.7%
9	Repair or replace cabs and their equipment	96.4%
10	Repair or replace accessories	96.4%

15. Including apprentices.

3.2 WORK TIME

Work time, also expressed in percentages, represents the average time allocated to each task by the consulted participants since the beginning of their careers.

Table 3.2 Work Time Allocated to Each Task

Task		Work Time
1	Apply a preventive maintenance program	18.7%
2	Repair or replace engines and fuel systems	7.9%
3	Repair or replace charging and starter systems	10.8%
4	Repair, install, modify or replace electrical and electronic systems	8.7%
5	Repair or replace clutches and transmissions	4.4%
6	Repair or replace chassis, running gears as well as steering and suspension systems	9.7%
7	Repair or replace braking systems	10.3%
8	Repair or replace hydraulic systems	13.6%
9	Repair or replace cabs and their equipment	5.9%
10	Repair or replace accessories	10%
		100.00%

Upon examination of the work time allocation, it was noticed that there are no great differences between the percentages of time allocated to each task. Indeed, task 1, “Apply a preventive maintenance program,” with 18.73%, comes first, and task 9, “Repair or replace cabs and their equipment,” with 5.91%, comes tenth. The difference between the task that requires the most time and the one that requires the least is thus only 12.82%.

After task 1 comes task 8, “Repair or replace hydraulic systems,” with 13.63%, and tasks 3, 7 and 10, with 10.82%, 10.27% and 10.00%, respectively. The 5 other tasks have percentages varying between 9.73% (task 6) and 5.91% (task 9).

Moreover, an examination of individual results reveals that everyone consulted performs all 10 tasks.

3.3 IMPORTANCE AND DIFFICULTY OF TASKS

The **importance** of a task is estimated according to the more or less harmful consequences of performing a task poorly or not at all. The importance is assessed according to the following scale:

1. Not important at all: Poor execution of the task has no consequences on the quality of the result, the costs, health and safety, etc.
2. Not very important: Poor execution of the task could lead to minimal costs, a result of lesser quality, minor injury or accident hazards, etc.
3. Important: Poor execution of the task could lead to an unsatisfactory result, substantial additional costs, injuries, accidents, etc.
4. Very important: Poor execution of the task could lead to an unacceptable result and have very substantial consequences in terms of costs, safety, etc.

A task’s **difficulty** is assessed according to the following scale:

1. Very easy: The task involves little risk of error; it requires no notable physical or mental effort. Performing the task is less difficult than average.
2. Easy: The task involves a few risks of error; it requires minimal physical or mental effort.
3. Difficult: The task involves many risks of error; it requires a good physical or mental effort. Performing the task is more difficult than average.
4. Very difficult: The task involves a high risk of error; it requires substantial physical or mental effort. The task is among the most difficult in the trade.

The data presented in the table below are the average results for the workshop participants.

Table 3.3 Importance and Difficulty of Tasks

	Task	Importance	Difficulty
1	Apply a preventive maintenance program	3.55	2.00
2	Repair or replace engines and fuel systems	3.73	3.00
3	Repair or replace charging and starter systems	3.36	2.09
4	Repair, install, modify or replace electrical and electronic systems	3.36	2.45
5	Repair or replace clutches and transmissions	3.66	2.64
6	Repair or replace chassis, running gears as well as steering and suspension systems	3.73	2.55
7	Repair or replace braking systems	3.91	2.55
8	Repair or replace hydraulic systems	3.64	3.00
9	Repair or replace cabs and their equipment	3.18	2.00
10	Repair or replace accessories	3.55	2.27

4. KNOWLEDGE, SKILLS AND ATTITUDES

The occupational analysis enabled us to specify some of the knowledge, skills and attitudes necessary for performing the tasks. Those qualities are transferable, i.e., applicable to a variety of tasks and situations.

The following pages present the knowledge, skills and attitudes that, according to the participants, are considered essential for performing the tasks of the heavy machinery mechanic trade.

4.1 KNOWLEDGE

Communication

Although heavy machinery mechanics mainly work autonomously, they have to communicate with various persons when performing their tasks. For example, they are in contact with their supervisors and other heavy machinery mechanics. They also have to communicate with the operators of machines they have to maintain and repair. Good relations with operators facilitate their work, particularly at the moment of diagnosis.

In addition, given that heavy machinery mechanics have to conduct searches on various manufacturers' websites, they frequently consult information available only in English. Manufacturer manuals are also often written only in English.

Finally, heavy machinery mechanics have to write brief handwritten accounts of their work and time on machines and equipment. Those few lines of text enable the company and others to follow up on repairs done on each machine or piece of equipment.

Electronics and electricity

Heavy machinery mechanics have to know basic electrical principles (Ohm's law, parallel and series circuits, etc.). They also must be able to read electrical and electronic plans and to interpret their specific symbols. They also must know how to use various measuring instruments (e.g.: multimeter).

Computer skills

Of the 11 meeting participants, 9 stated that they regularly use computers in their work, mainly to consult parts catalogues and technical manuals, do Internet searches, order parts, diagnose problems (2 persons), etc. But they specify that the tools used, apart from Web browsers and search engines as well as certain common file formats (e.g.: PDF), are specific to the machinery and equipment.

Lifting

A heavy machinery mechanic has to apply necessary rigging techniques for the various loads to be lifted and moved. He must choose lifting equipment according to the load and each machine's capacity. To that end, he must be able to calculate the weight of loads. He must also operate certain lifting devices (e.g.: hoist) or guide the operator of devices with greater capacity.

Mathematics

The application of mathematical knowledge is necessary to heavy machinery mechanics – mainly the four basic operations and the rule of three, in order to calculate, for example, quantities, volumes and weights, and to convert units of one measuring system to another. Some work also requires knowledge of trigonometry and geometry (calculating angles).

Machine operation

A heavy machinery mechanic must be able to perform operational tests on the machines he has to repair. Although those tests are generally performed in cooperation with the machine operator, in the latter's absence the heavy machinery mechanic must be able to operate the machine minimally to make a diagnosis and verify his work after a repair. However, he does not have to operate the machine for production purposes as an operator does.

Pneumatics and hydraulics

Heavy machinery mechanics have to know the operating principles of pneumatic and hydraulic systems. They must also be able to read the plans of those systems and interpret their specific symbols.

Products

Given that heavy machinery mechanics use a variety of products (lubricants, solvents, sealants, etc.), they have to know the products' characteristics, conditions of use and selection criteria.

Knowledge of the Workplace Hazardous Materials Information System (WHMIS) is very important, in order to know what precautions to take for using, transporting and storing those materials.

Occupational health and safety

Heavy machinery mechanics have to know the rules and standards of prevention regarding health and safety, for themselves and other workers on the construction site. In addition to the rules stemming from laws and regulations, they must in some cases know the specific measures to apply on certain construction sites and in certain companies. They then have to take training sessions specific to those sites or companies and to attend regular (daily, in some cases) meetings, so as to stay informed about important measures to be applied.

Welding and oxygen cutting

Although welding work done by heavy machinery mechanics are relatively simple, they need to have a good knowledge of electric-arc and semi-automatic welding processes as well as oxygen cutting, in order to do quality work.

4.2 SKILLS

Skills are types of know-how. They are divided into three categories: cognitive, motor and perceptual.

Cognitive skills

Cognitive skills pertain to intellectual strategies applied in working. The main cognitive skills that heavy machinery mechanics need are the following:

- problem-solving;
- analysis;

- logic;
- concentration;
- decision-making.

Motor skills

Motor skills involve gestures and movements. The main motor skills that heavy machinery mechanics need are the following:

- dexterity;
- fine motor skills (handling very small objects);
- coordination.

Perceptual skills

Perceptual skills are sensory skills enabling a person to perceive by his senses what is happening in his environment. The main perceptual skills that heavy machinery mechanics need are the following:

- visual memory (ability to remember the assembly sequence for parts, components, etc.);
- perception of abnormal odours (e.g.: overheating) and recognition of products;
- spatial perception (interpreting different plan views, evaluating distances, etc.);
- tactile perception (e.g.: fingertip recognition of invisible elements).

4.3 ATTITUDES

Attitudes are ways of acting, reacting and relating with others or with one's environment. They involve personal skills. The main attitudes heavy machinery mechanics need are the following:

- autonomy;
- teamwork ability;
- resourcefulness;

- dexterity;
- ability to listen;
- interest in innovations;
- attention to detail;
- patience;
- versatility;
- punctuality;
- cleanliness;
- sense of observation;
- vigilance.

5. TRAINING SUGGESTIONS

Initial training

The participants made suggestions about various aspects of initial training. They suggest to:

- Review the content of health and safety training on a construction site, so as to make it more representative of the realities of the trade;
- Focus on environmental protection rules;
- Inform beginners about the physical aspect of the trade and about actual working conditions on a construction site;
- Prepare students well by including training periods on construction sites;
- Plan a variety of tasks during the training periods on construction sites and not limit students to labourer work.

Continuous training and professional development

For professional development, the participants suggest to:

- Insist that all heavy machinery mechanics attend training sessions each year;
- Find a way to remedy the problem of training registrations (some analysis workshop participants mention that they have often registered for training that ended up cancelled for lack of registrations);
- Organize training activities during times of year when heavy machinery mechanics are less busy (for example, in January);
- Offer training sessions on subjects such as hydraulics, hydrostatic transmissions, electricity, electronics and diagnoses.

Annexes

Annex 1

TOOLS AND EQUIPMENT

During the workshop, the participants were shown lists of raw materials, tools and equipment from the national occupational analysis of the heavy machinery mechanic trade (Red Seal). In the following pages is the list, for each task, of raw materials, tools and equipment that was validated by the participants.

Table A.1 Tools and Equipment

Liste of tasks listed in the table below:

1. *Apply a preventive maintenance program*
2. *Repair or replace engines and fuel systems*
3. *Repair or replace charging and starter systems*
4. *Repair, install, modify or replace electrical and electronic systems*
5. *Repair or replace clutches and transmissions*
6. *Repair or replace chassis, running gears as well as steering and suspension systems*
7. *Repair or replace braking systems*
8. *Repair or replace hydraulic systems*
9. *Repair or replace cabs and their equipment*
10. *Repair or replace accessories*

*Grey boxes indicate items that **are not** used.*

	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	Task 9	Task 10
BASIC HAND TOOLS										
bar (pry, aligning, heel)										
tool chest										
wire brush										
pin punch										
chisel										
impact wrench										
pipe wrench										
torque wrench										
adjustable wrench										
hex key set, metric and imperial										
ratchet wrench										
utility knife										
scraper										

	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	Task 9	Task 10
torx bit										
convertible 2/3 jaw puller										
H puller										
jumper wire										
wrench set, combination (metric & imperial)										
socket set										
feeler gauge set										
wrench set, flare nut (metric & imperial)										
universal joint										
test light										
file										
hammers: impact, rubber, sledge, air, slide, soft blow										
cutting equipment: side cutter, tube cutter, wire cutter, plier cutters, shears										
micrometer										
digital multimeter										
battery post and clamp cleaner, battery terminal nut										
pick (o-ring, seal)										
vernier caliper										
wire crimper and stripper										
battery terminal puller										
pliers: insulated, snap ring, torque, multipliers										
Punch										
centre punch										
pin punch										
magnetic pick-up tool (telescopic, flex)										
metric and imperial steel rule										
tape measure										
hacksaw and blade										
screwdriver										
SHOP TOOLS										
air line adapter										
grinder: bench, hand, valve										
reamer										
analyzer: gas, infrared, vibration meter										
leak detection equipment										
shop vacuum										

	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	Task 9	Task 10
spacer	■				■			■		
tire bar	■		■	■	■			■	■	
3/4 – 1 inch power bar/torque wrench			■	■					■	■
pry bar										
spark lighter										
jumper wire	■					■	■			■
butane torch					■	■		■		■
cutting and welding torch set										
battery charger					■	■	■	■	■	■
fast charger		■			■	■		■	■	■
cylinder cart and tank										
drift	■	■	■	■	■		■	■		■
tube bender	■	■	■	■	■	■		■		■
chisel: air, electric, hand	■				■					
caliper: outside, inside	■				■	■	■	■		■
compressors: air, mechanical spring, piston ring, pneumatic spring, spring, valve spring	■		■	■	■		■	■	■	■
container										
seal driver	■		■	■	■	■			■	
cooling system pressure tester			■	■	■	■	■	■		■
crack detecting equipment	■		■	■	■	■	■			■
tap and die set	■									
funnel			■	■					■	
bleeding equipment		■	■	■		■				
component heating or cooling equipment	■	■	■	■	■	■	■		■	■
nitrogen charging equipment		■	■	■	■	■	■	■	■	■
welding equipment					■					
retrieval and storage equipment	■		■	■	■	■				■
vice										
flaring tool		■	■	■		■		■	■	
stud extractor	■									
puller: bearing, gear, heavy duty, mechanical	■				■		■		■	■
soldering iron/gun	■					■				■
tire tread depth gauge		■	■	■	■	■		■	■	■
strobe light			■	■	■	■	■	■	■	■
temperature gauge			■	■	■	■	■		■	■
thread file					■			■		

	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	Task 9	Task 10
file										
black light			■	■	■	■	■	■	■	■
tire machine	■	■	■	■	■	■		■	■	■
seal driver	■		■	■	■			■	■	
honing equipment	■		■	■	■	■	■		■	■
diagnostic equipment					■	■	■			■
torque multiplier			■	■	■	■				
computer equipment: terminal, on-board computer, portable diagnostic computer, printer					■	■				■
alignment tool		■						■	■	■
clutch alignment tool			■	■		■	■		■	■
torque angle tool, torque wrench	■		■	■	■		■		■	■
scanning tool	■	■				■	■	■	■	■
steering tool	■	■	■	■	■		■	■	■	■
overhaul tool	■	■	■	■	■	■		■	■	■
crimping tool					■	■				
drill: bench, hand drivers, twist, air	■				■			■		
hot air gun		■			■	■		■		■
grease gun		■	■	■						
vacuum pump		■	■	■		■	■			■
hand pump		■	■	■		■	■		■	■
sander	■		■	■	■			■		■
press: arbor, spring, hydraulic, bushing, shop, mechanical, hand	■		■	■	■		■	■		
extension cord/trouble light										
bearing heater	■		■	■	■			■	■	
graduated vessel	■		■	■			■		■	■
straight edge					■			■		
sandblaster	■	■	■	■	■	■	■	■		■
saw: jigsaw, hacksaw, hole saw	■	■	■	■	■	■	■	■		
recycling unit			■	■					■	
coolant recycling unit			■	■	■	■	■	■		■
fuel recovery and storage system		■			■	■	■	■	■	
tachometer					■	■	■			
battery load/starting system tester		■				■	■	■		■
continuity tester						■	■			
harness tester					■	■	■	■		
module tester			■	■		■	■			■

	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	Task 9	Task 10
valve spring tester										
thermostat tester										
labelling kit										
flushing kit										
suction cup										
SAFETY EQUIPMENT										
CPR accessories (disposable)										
communication device										
ear wash station										
safety cage										
safety hat										
safety boots										
stretcher										
fireproof blanket										
fall arrest equipment										
ladder										
emergency backup lighting										
fall prevention equipment										
fire extinguisher										
gloves										
leather gloves										
splash suit										
leggings										
safety glasses										
goggles										
face shield										
manlift										
first aid station										
ear protection										
respirator										
sprinkler system										
apron										
HOISTING, RIGGING AND HOLDING EQUIPMENT										
spreader bar										
ground strap										
shim/blocking										
axle stand										

	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	Task 9	Task 10
dolly										
forklift										
hydraulic hand jack										
transmission jack										
hydraulic floor jack										
bottle/axle jack										
sling/cable/chain										
vice										
mobile crane										
shop crane										
engine crane										
clevis										
cable hoist										
chain hoist										
shop crane										
tire guard										
hydraulic guard										
clamp										
support stand										
repair stand										
engine repair stand										
CLEANING EQUIPMENT										
hot tank degreaser										
soft brush										
wire brush										
cleaning cloth										
caustic cleaning tank										
brake cleaning equipment										
cleaning gloves										
pressure washer										
glass bead machine										
steam cleaner										
solvent washer										
parts cleaning solvent										
air blowgun										
crocus cloth										

	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	Task 9	Task 10
MEASURING TOOLS, GAUGES AND EQUIPMENT										
ammeter										
vibration analyzer										
measuring rod										
meter stick										
chronometre										
test lead										
torquemeter										
flowmeter										
hydrometer										
borescope										
funnel										
dial gauge										
hydraulic pressure testing gauge/fittings										
air pressure gauge										
pinion angle gauge										
boost gauge										
non-magnetic feeler gauge										
compression gauge										
small hole gauge										
air pressure gauge										
holding gauge										
oil temperature gauge										
belt tension gauge										
manifold gauge										
electric pressure gauge										
mechanical pressure gauge										
transmission gauge set										
timing light										
test light										
pressure gauge										
fuel pressure gauge										
vacuum gauge										
depth micrometer										
inside micrometer										
multimeter										
level										

	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	Task 9	Task 10
plasti-gauge										
pyrometer										
straight edge										
steel ruler										
spectroscope										
stethoscope										
tachometer										
digital multimeter										
thermometer										
timing gauge										

Annex 2

Grid of Occupational Health and Safety Elements

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Table A.2 Description of Hazards in the Heavy Machinery Mechanic Trade

No.	Hazards	Effects on Health and Safety	Means of Prevention
1	**Chemical hazards or dangers** • Welding fumes and other by-products (flux, acid) • Other products (lubricant, adhesives, etc.)	• Effects of welding fumes[16] **Acute:** irritation of eyes and respiratory tracts, pulmonary oedema, asphyxia, metal-fume fever **Chronic:** rhinitis, expectorations, coughs, chest pain, eye pain, headache, bronchitis, pneumoconiosis, skin or mucous membrane lesions, susceptibility to pneumonia, skin irritation, irritative dermatosis (References 1, 2, 3, 4, 5) • Other possible effects depending on the products: consult the material safety data sheets of products used	• Catch fumes at the source and ensure adequate ventilation. • In case of insufficient ventilation, wear a respirator (observe exposure and protection values – choose a respirator according to the regulation guide, sec. 45, Regulation respecting occupational health and safety). • Wear appropriate gloves. • Wear splash-proof goggles when the situation requires it. • Have taken training on safe handling of products (WHMIS). • Consult the material safety data sheet and the label of controlled products used (welding products, lubricants, degreasers, etc.). (Reference 4)

16. The effects of welding fumes depend on multiple factors, notably the composition of welded metals, the welding material, the method used, and the welding parameters. Other effects may be observed depending on the welding material's composition, whether metal or flux.

No.	Hazards	Effects on Health and Safety	Means of Prevention
	• Battery acid	• Chemical burns	• Wear gloves made of adequate material (preferably butyl, rubber, PVC and Viton gloves for protection against battery acid; neoprene or nitrile gloves may also be used). • Wear an apron of the same material as the selected gloves. • Wear a visor or splash-proof goggles as well as appropriate safety boots or shoes. • In case of emergency, have an eye-wash station or an emergency shower (sec. 75 and 76 of the Regulation respecting occupational health and safety).
	• Exhaust fumes, carbon monoxide (CO), nitrogen oxide (NOx)	• **CO:** headache, dizziness, vertigo, respiratory disorders, chest pain, loss of vigilance, of manual dexterity and of visual perception, vomiting, convulsions, fainting, coma, death • **NOx and exhaust fumes:** eye and respiratory tract irritation, coughing, dyspnea, chest pain (Reference 3)	• If an inspection must be made with an engine running in an enclosed area, discharge exhaust fumes outside by means of a conduit placed on the muffler. (See also the following document: http://autoprevention.qc.ca/docs/PP_CO_VentLocale.pdf. Certain aspects must be considered regarding the design of the vacuum system; see the article on carbon monoxide at http://autoprevention.qc.ca/docs/AP_2006-09-complet.pdf.)
2	**Physical hazards or dangers**		
	• Hot surface • Hot fluid	• Local cutaneous burns • Chilblains	• Wear appropriate gloves. • Use tools adequately. • Plan the work. • Choose appropriate tools. • Have taken training. • Wait for the vehicle to cool before starting any mechanical work near hot parts, of before starting work or verifications on hydraulic or cooling fluids and systems.
	• Noise	• Hearing loss	• Choose less-noisy tools. • Wear PPE if the source cannot be controlled.

No.	Hazards	Effects on Health and Safety	Means of Prevention
	• Hot ambient temperature	• Dehydration • Heatstroke	• Adjust the means according to the hazard level. (Reference 8)
	• Very cold ambient temperature	• Hypothermia • Local chilblains	• Wear adequate clothing. • Limit exposure time (take breaks in a heated location if necessary). • Limit the workload to avoid excessive sweating. • Cover metal handles and bars with thermal insulation. • Use machines and tools designed for use without having to remove glove or mittens. • Have backup heating and screens preventing or limiting exposure to wind. • Use handling aids reducing the workload and sweating. (See also Reference 9)
	• Device turned on electrically	• Burns • Electrification • Electrocution	• Make sure the vehicle is turned off. • Disconnect battery cables before working on the vehicle's electrical system. • Have taken required training for turning the electrical system off (sec. 185 of the Regulation respecting occupational health and safety). • During welding operations: – wear dry clothing; – avoid contact with the part to be welded.
	• Visible radiation, ultraviolet and infrared	• Cutaneous burns • Eye irritation • Arc strike (welding or electric glare) • Cataracts • Skin cancer (Reference 4)	• Wear personal protective equipment for welding-cutting: appropriate eye protection, clothing, gloves and boots. • Equip the work area with a spark arrester for protection against UV radiation. (Reference 4)

No.	Hazards	Effects on Health and Safety	Means of Prevention
3	**Ergonomic hazards**		
	• Repetitive movements • Elbows and wrists without support • Grasping objects repetitively • Using tools repetitively (mechanical pressure) • Stressful posture • Load handling	• Muscular fatigue • Musculo-skeletal disorders in upper limbs (tendinitis, epicondylitis, bursitis, etc.) • Backache	• Choose light tools of appropriate anthropometric sizes. • Maintain tools in good condition. • Use adequate handling equipment and have taken required training. (Reference 10)
	• Working in a dark or poorly lit location	• Eyestrain • Headache	• Use adequate backup lighting.
	• Excessive efforts • Working upright • Difficult access to the work space • Stressful posture	• Muscular fatigue • Musculo-skeletal disorders in upper limbs (tendinitis, epicondylitis, bursitis, etc.) • Backache	• If possible, plan the work in an uncluttered area laid out to facilitate the tasks to be performed, with a flat and level floor. • Use lifting equipment to handle heavy parts. • Have access to necessary tools in good condition to do the work required.

No.	Hazards	Effects on Health and Safety	Means of Prevention
4	**Safety hazards or dangers**		
	• Shape of tools and narrow work space for handling • Mechanical pressure	• Cuts • Contusions • Crushing • Hand lesions • Palm calluses	• Have received training and information regarding the tools' safe handling. • Read the manufacturer's instructions. • Store unused tools and lay out used tools correctly. • Maintain tools: sharpening, honing, etc. • Choose adequate tools. • Wear PPE (palms) and closed shoes.
	• Moving parts or vehicle during repairs[17]	• Crushing • Lesions in upper limbs	• Stay away from rotating or moving parts and inside corners. • Do not wear ample clothing or a tie. • Do not wear jewellery, earrings, rings, necklaces, etc. • Make sure the vehicle is immobilized, stop the engine and remove the keys. • Activate the hand brake. • Place wheel blocks if the working plane is inclined. • Consult the manufacturer's manual.
	• Fire	• Severe burns	• See the means of prevention under "Risques chimiques," "Travail en espace clos et sécurité en soudage." (References 4 and 5)
	• Working from heights	• Same-level fall that can cause multiple injuries • Death	• Use a safety harness. • Use ladders and scaffolds safely (sec. 324 and 346 of the Regulation respecting occupational health and safety). • Use a worker lifting device, a self-propelled elevating work platform, a boom-type self-propelled platform, a vehicle-mounted aerial device, a crane and a fork lift with a platform authorized by the vehicle manufacturer.

17. Driving a vehicle is hazardous in itself. Road accidents during work are numerous. For further information on this subject, consult the following articles: "Pour prévenir les accidents de la route reliés au travail" and "Une politique de sécurité routière: un exemple!" – *Objectif Prévention*, Vol. 32, No. 3, p. 12-17.

No.	Hazards	Effects on Health and Safety	Means of Prevention
	• Working in a cluttered location • Working in a location difficult to access or narrow	• Contusions • Fractures • Other injuries caused by materials falling, an object breaking or a limb being jammed	• Wear PPE, particularly a hard hat. • Plan the work and the work area to avoid clutter.
	• Sudden overflow or spill of hot fluids under pressure	• Cutaneous burns • blindness	• Wait for the vehicle to cool before removing caps on hydraulic and cooling fluid tanks. • Use PPE, particularly splash-proof goggles, gloves and aprons.
	• Projection of fused particles and sparks	• Cutaneous burns	• Wear PPE for grinding, cutting, welding, gouging, torch straightening, etc. • Equip the work area with a spark arrester to protect nearby workers. (Reference 4)
	• Equipment or vehicle falling on the worker (11-12) (References 11 and 12)	• Multiple injuries • Death	• Make sure that equipment or attachments are completely immobilized (plan for shims, supports, dead shores, mechanical locks, wood blocks and other blocking accessories – sec. 185 of the Regulation respecting occupational health and safety). • Consult the manufacturer's manual for detailed instructions.
	• Accumulation of energy inside a machine, due to springs, gases or fluids under pressure (hydraulic, pneumatic)	• Contusions • Cuts • Bruises	• Before starting the work, empty components when a machine is equipped with a hydraulic pressure accumulator, a pneumatic cylinder, or any other component that can accumulate pressure.
	• Leaks of fluid under high pressure – hydraulic oil	• Contusions • Cuts	• Use a piece of paper or wood (never probe with the hands, even while wearing gloves, to detect hydraulic system leaks). • Use a visor or splash-proof goggles to protect the eyes.
	• Slippery or irregular floors • Same-level fall	• Fractures • Sprains • Strains	• Keep floors clean and dry. • Clean quickly after an oil spill.

No.	Hazards	Effects on Health and Safety	Means of Prevention
	• Explosion	• Burns • Contusions	• Do not place an open flame or an ignition source near the battery. • Follow the connection and disconnection sequence of battery cables during an overvoltage.
	• Unsafe vehicle	• Accidents	• Equip the vehicle with signs indicating that it is under repair and must not be used. • Keep control of the keys.
5	**Psychosocial hazards or dangers** • Time constraint, urgency • Sustained attention	• Stress • Fatigue • Loss of concentration	• Plan and organize your work. • Benefit from assistance. • Perform certain tasks with another mechanic.

References - Grid of Occupational Health and Safety Elements

This list does not constitute an exhaustive review of the literature, but is mentioned as an indication. Codes of documents from the CSST's Documentation Centre are shown in brackets.

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