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Protecting Electrical Distribution
Plant & Support Structures
from Vibrations Caused
by Construction & Operation Activity

REVISION SHEET

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1.0 Introduction

This document provides the protection requirements for Hydro Ottawa Plant from vibrations caused by construction and operational activity including Acute Shock. The standard construction sources of Acute Shock discussed in this document include Rubblization, Blasting, Compaction, and Pile Driving. The standard operational sources of vibration discussed in this document include large machines and heavy vehicles.

Hydro Ottawa has distribution equipment that can handle higher particle velocities but also has instruments in its electrical substations that are sensitive to lower particle velocities.

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Ontario Building Code, Section 4.1.9, “Live Loads due to Earthquakes”, 1997

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US Department of the Air Force, ETL 01-9, “RUBBLIZING CONCRETE PAVEMENTS”, <http://www.afcesa.af.mil/userdocuments/publications/ETL/ETL%2001-9.pdf>

NRC Traffic Vibrations in Buildings Update 39

Evaluation and protection of high voltage electrical equipment against severe shock and vibrations by Kong Dohwan, Ph.D, State University of New York at Buffalo, 2010

3.0 Scope

This document details the steps that need to be taken in order to protect the Hydro Ottawa electrical distribution plant and substations from planned Acute Shocks and operational vibrations. Steps for the protection of electrical cables and support structures during Acute Shock and the testing of ducts after Acute Shock are also detailed.

4.0 Definitions

“Acute Shock” is any form of shock or vibration that might affect Hydro Ottawa Underground Plant. In this document it refers to Rubblization, Blasting, Compaction and Pile Driving.

“Blasting” is any mining operation including boring.

“Compaction” is any vibration generating operation, which will result in a potential increase of the density of soils or controlled backfill materials. The means to increase the density may be static or dynamic. This specification only pertains to compactors that have a plate size greater than 1220mm [48”].

“Contractor” is the party responsible for introducing the Acute Shock as part of their construction process.

“Engineer” is anyone who is licensed by the Professional Engineer’s of Ontario or possesses a Certificate of Authority.

“Facilities” All plant (buildings, building contents and underground structures) owned and operated by Hydro Ottawa.

“Independent Blasting Consultant” shall be a Registered Professional Engineer and a holder of a Certificate of Authorization (C of A), specializing in blasting.

“Multi-Head Breaker” is a Rubblization machine similar to a Resonant Frequency Breaker, but is composed of two rows of multiple drop hammers.

“Pile” is any vertical or slightly slanted structural member introduced or constructed in the soil in order to transmit loads and forces from the superstructure to the subsoil; the structural member can also be used as a component of a retaining wall system.

“Pile Driving” is the placement of Piles carried out by gravity hammer, vibratory hammer, auguring, pressing, screwing or any combinations of the above methods.

“Resonant Frequency Breaker” is a Rubblization machine that utilizes high frequency, low amplitude impacts with a typical shoe force of 8900N [2000 lbs] to break the concrete. This force is delivered through a shoe or hammer approximately 150 to 300 mm [6” to 12”] in width.

“Rubblization” is a process in which existing concrete pavement is broken into small pieces and the steel/concrete bond is broken. The Rubblization process is accomplished using either a Resonant Frequency Breaker or a Multi-Head Breaker. Typically, road authorities use Rubblization during rehabilitation of their roads.

“Surface Blasting” is any blasting for which the blast area lies at the surface of the ground.

“Tunnel Blasting” defines operations involving the piercing of below ground (generally horizontal) opening in rock.

“Underground Plant” is any electrical distribution assets that are subsurface.

5.0 General Requirements

Responsibility for any damages will be those of the party performing the Acute Shock. Under Section 113.0.1 of the Ontario *Electricity Act* states: “No person shall damage or cause any damage to any work or matter to be used in the generation, transmission, distribution, retail or use of electricity in Ontario”. The Contractor shall comply with the Ontario Provincial Standard Specification OPSS 120 General Specification for the Use of Explosives.

The Contractor Shall be held responsible for protecting Hydro Plant when excavating under OHS sections 228 and 229. Prior to any Acute Shock operation in the vicinity of the electrical distribution system, the hazard to Hydro Ottawa’s plant shall be evaluated to ensure the uninterrupted operation and long-term safety of its Facilities. Responsibility for the design of the Acute Shock and any resultant damage is born entirely by the party causing the Acute Shock. A

recognized Independent Blasting Consultant shall be retained at the contractor's expense to evaluate and validate the risks for as outline within this procedure.

Responsibility for the design of the Acute Shock and any resultant damage shall be born entirely by the blasting contractor. A recognized Independent Blasting Consultant shall be retained at the contractor's expense to evaluate and validate the risks of the Acute Shock.

5.1 Pre-Survey of Existing Facilities

Prior to performing an Acute Shock event, the Hydro Ottawa Design Supervisor shall be notified of the event. A Hydro Ottawa Cable Locator will be sent to the site to indicate the location of Underground Plant or alternatively the Design Supervisor can provide the Contractor with drawings showing the location of Hydro Ottawa Underground Plant.

If Hydro Ottawa's Underground Plant is deep enough as determined by the Independent Blasting Consultant to avoid damage from Acute Shock, work may proceed while Hydro Ottawa remains in contact with the Engineer during the re-build and complete final field inspection for damage at the completion of the work.

If the Acute Shock event is to be undertaken within 30m of a Hydro Ottawa substation, Hydro Ottawa may at its discretion, hire an Independent Blasting Consultant to evaluate the risk of potential damage to its facility. The cost of this evaluation will be charged to the party planning to do the work.

The process for damage inspection is defined in Section 10 "Post Event Inspection".

Once notified that an Acute Shock event will proceed, the Design Supervisor shall initiate a pre-inspection of all plant within 10m (Blasting) or 5m (Rubblization, Pile Driving or Compaction) of the proposed Acute Shock event.

Verifying pre-Acute Shock conditions of Hydro Ottawa Underground Plant for ducts within 10m (Blasting) or 5m (Rubblization, Pile Driving or Compaction) of the Acute Shock event will have a brush and mandrel passed through to verify existing conditions if empty/capped. All manholes and stations basements within 10m (Blasting) or 5m (Rubblization, Pile Driving or Compaction) of an Acute Shock event shall be verified with a visual inspection and pictures to prove existing conditions.

Substations contain sensitive and complex electrical equipment such as disconnect switches and high power transformers. Each of these components has vulnerable parts. Due to the complexity of this equipment pre-shock testing of this equipment is not practical. As stated in section 5.0 Hydro Ottawa, at its discretion, may require constant vibration monitoring. If there is a significant increase in vibrations or a malfunction of the electrical equipment due to vibrations all work must stop and remedial action will be required as stated in section 9. All costs associated with the pre-inspection are to be paid for by the Contractor.

5.2 Support During Excavation

If plant needs to be exposed for any reason it shall be dug by hand excavation methods or alternatively by Hydro-Vac method. If there is excavation occurring beneath Hydro Ottawa duct banks, it shall be supported in the same manner as shown in UDS0013. If backfill material that was originally over the Underground Plant is to be removed, it shall be replaced as stated in Hydro Ottawa's Specification GCS0005, Section 6.1.6 Backfilling.

5.3 Summary of Restrictions: Table 5-1

	Hydro Ottawa Underground Plant	Hydro Ottawa Substation
Rubblization	<ul style="list-style-type: none"> • Details shall be provided to Hydro Ottawa if within 5m of a plant • The maximum vibration at a plant is 150mm/s • The energy intensity on the rubblization machine shall be reduced if within 500mm of underground structures • Rubblization over top of an underground plant is not permitted 	<ul style="list-style-type: none"> • The maximum particle velocity at the substation is 30mm/s if within 30m of a substation
Blasting	<ul style="list-style-type: none"> • A pre-inspection by Hydro Ottawa of all underground structures within 10m of the proposed blasting is required if work is within 10m of plant • A report from an explosives consultant must be provided if the blasting is within 3m of a plant 	<ul style="list-style-type: none"> • Hydro Ottawa may hire an Independent Blasting Consultant at Contractor's expense if the blasting is within 30m of a substation • A report from an explosives consultant must be provided if the blasting is within 30m of a substation
Pile Driving and Compaction	<ul style="list-style-type: none"> • Investigation required if work is within 5m of a plant • Any vibration over 150mm/s at a plant is considered damaging • Piling is not permitted within 1500mm of an Underground Plant or Facility 	<ul style="list-style-type: none"> • Investigation required if work is within 30m of a substation • If within 30m, any vibration over 30mm/s at a substation is considered damaging

6.0 Rubblization

Rubblization is used on road surfaces with a concrete base in order to eliminate joints or cracks in the concrete that might appear in the asphalt overlay. The Rubblization process is accomplished using either a Resonant Frequency Breaker or a Multi-Head Breaker. The process breaks the existing concrete into smaller pieces while also breaking any steel concrete bond. The broken concrete is then used as a base for new pavement.

Contractors looking to perform Rubblization within 5m of Hydro Ottawa Underground Plant shall provide Hydro Ottawa with the following:

- Name of the owner of the project, general contractor, and design Engineer;

- Dates of Rubblization activities;
- Copy of construction drawing sketch drawn to scale indicating;
 - Proposed Rubblization route;
 - Location of Hydro Ottawa plant (Provided by Hydro Ottawa Underground Design Supervisor if required).

Details of proposed Rubblization route including Hydro Ottawa Underground Plant (location of Hydro Ottawa Underground Plant to be provided by Hydro Ottawa upon request):

- Shoe size, shoe force and frequency of equipment being used.

6.1 Electrical Distribution Underground Plant Isolation During Rubblization

Once electrical distribution Underground Plant is located, full depth surface saw cuts are to be made around the underground structure to isolate it from the concrete being Rubblized. Arrangements shall be made to have a Hydro Ottawa Underground Inspector present while the saw cuts are being made near electrical distribution Underground Plant.

The contractor shall ensure that Hydro Ottawa plant shall experience less than 150mm/s at the plant during the Rubblization event. If work is being done within 30m of a Hydro Ottawa substation the particle velocity at the station is to be less than 30mm/s. The energy intensity of the Rubblization machine shall be reduced when within 500mm to electrical underground structures in order to reduce the chances of damaging the Underground Plant. Rubblization machines are not to be operated directly over the Underground Plant.

The section of concrete above the Underground Plant shall be broken using an alternate method to Rubblization. The section of concrete can be removed and replaced with a suitable aggregate that matches the composition of the Rubblized concrete. The composition of the aggregate shall be decided by the Engineer responsible for the construction of the road surface.

Should the concrete over the electrical distribution Underground Plant require breaking, it shall be broken using either a handheld jackhammer or a hydraulic jack or another method that is less intense than Rubblization.

6.2 Testing After Rubblization

Testing of the duct structures shall be performed within 30 days following the instructions listed in Section 10 “Post Event Testing”.

7.0 Blasting

If Hydro Ottawa electrical distribution Underground Plant is within 10m of blasting, Hydro Ottawa shall be notified and Hydro Ottawa will conduct a pre-inspection of all Underground Plant within 10m of the proposed blasting. Hydro Ottawa shall be contacted a minimum of 5 business days before Blasting commences.

If Blasting is to take place within 30m of a Hydro Ottawa substation, Hydro Ottawa may at its discretion, hire a recognized Independent Blasting Consultant at the Contractor's expense to evaluate and validate the risk. Hydro Ottawa is to be notified 30 days in advance of the work.

7.1 Use of Explosions Consultant

A party wishing to blast will need to provide a report from an explosives consultant if:

- Charge weights exceed values in Table 7-1;
- The blasting is less than 3m from electrical distribution Underground Plant;
- Any Tunnel Blasting or boring operation within 30m of a Hydro substation.

The Blasting Consultant to be hired is required to be an Engineer. A certified report (if required by the above statement) prepared by the Engineer shall be forwarded to the Underground Design Department at Hydro Ottawa. The report shall state that Hydro Ottawa Underground Plant will be safe from the Blasting to be performed; otherwise it shall state alternate methods that will not damage Hydro Ottawa Underground Plant. If there is no way to safely protect the plant then the applicant may have to pay to relocate the electrical distribution Underground Plant.

Blasting Contractors will need to provide notification of the following details to Hydro Ottawa when Surface Blasting:

- Name of the owner of the project, general Contractor, and design Engineer;
- Name of Blasting Contractor and person in charge of the blast;
- Date of Blasting;
- Copy of construction drawing sketch drawn to scale indicating;
 - Details of proposed drilling pattern and loading pattern for explosives;
 - Distance of drilled holes to Hydro Ottawa Facilities (location to be provided by Hydro Ottawa Underground Supervisor if required);
- Total explosive weight to be detonated per delay;
- Type of explosive to be used;
- Predicted vibration levels expected at any Hydro Ottawa underground structures within 10m and controls used to confirm levels.

Tunnel Blasting applicants will need to provide all details required for Surface Blasting as well as the following details:

- Location plans and profile views with construction drawing or sketch, drawn to scale.

Explosives shall be of a type that will not propagate between holes nor desensitize due to compression pressures. No explosives shall be left in the drill hole overnight.

Horizontal stand-off distances for Surface Blasting and direct stand-off distances for Tunnel Blasting of less than 3m are not permitted. If the applicant insists that Blasting is necessary, the required Independent Blasting Consultants report shall evaluate and validate the proposal. Otherwise alternative methods to Blasting shall be used.

Table 1 shall be used to guide explosive charge weights (Based upon a Peak Particle Velocity (PPV) of 150mm/sec). If the table is not used then the contractor shall use equipment to monitor how much vibration is present at the Hydro Ottawa facility.

Monitoring of Blasting vibrations with a portable seismograph capable of producing a report within 10m of Hydro Ottawa Facilities is mandatory to confirm that predicted vibration levels are respected if Table 7-1 is not used.

Stand Off Distance From Electrical Plant (m)	Maximum Allowable Explosive Charge Weight Per Delay (kg)
3.0	0.8
4.0	1.4
5.0	2.1
6.0	3.1
7.0	4.2
8.0	5.5
9.0	6.9
10.0	8.6
12.0	12.3
14.0	16.8
16.0	21.1
18.0	30.9
20.0	34.2
22.0	41.4
24.0	49.3
26.0	57.9
28.0	67.1
30.0	77.0

Table 7-1: Maximum Allowable Stand-Off Charge Weights

7.2 Post Blasting

Within 30 day, Hydro Ottawa shall inspect its plant to identify any damages that may have occurred. This will follow the procedures set out in Section 9 “Post Event Inspection”.

8.0 Pile Driving and Compaction

8.1 Piling and Compaction Operations

This section shall apply for any compactor greater than 1200mm [48”]. Prior to any Pile Driving or Compaction operations within 5m of electrical distribution Underground Plant or 30m of a Hydro Ottawa Substation, the potential for damage shall be evaluated. Any Pile Driving or Compaction producing a peak particle velocity at Hydro Ottawa Underground Plant of greater than 150mm/s shall be considered damaging. If work is to be undertaken within 30 m of a Hydro Ottawa Substation any activity producing a peak particle velocity greater than 30 mm/s shall be considered damaging.

If in the opinion of Hydro Ottawa (opinion of Hydro Ottawa to be provided at time of plan circulation), Pile Driving or Compaction will cause damage, then the following alternatives or contingencies will need to be used:

- A review of the particular situation by an independent consulting Engineer including a risk analysis and a prevention program;
- Change in the construction methods;
- Replacement or relocation of the electrical distribution Underground Plant.

Contractors wishing to Pile Drive or use Compaction will need to provide the following:

- Name of project owner, general Contractor and relevant sub-trades;
- Name of design Engineer and a copy of plans issued for construction with detailed drawings identifying all affected Underground Plant (to be provided by Hydro Ottawa should it be required);
- The type of Piles and equipment used; including the methods of control to prevent the deviation of the Piles;

If the Pile Driving or Compaction actions are deemed hazardous to it Facilities by Hydro Ottawa, then an Engineer will need to be hired by the Contractor to validate the actions. The following situation shall be deemed hazardous and require the opinion of an independent Engineer specialized in vibration control, analysis and soil movement:

- a) Soil types fitting the description of Type 4 soil (see appendix A) as defined in Article 226 of the Occupational Health and Safety Act and Regulations for Construction Projects.

For all the Pile Driving and Compaction situations mentioned before this statement, monitoring of vibrations, with seismographs deployed near the Hydro Ottawa Facilities affected, is mandatory unless a report written by an Engineer has been issued stating that vibration levels at Hydro Ottawa Underground Plant will be less than 150mm/s or 30mm/s at a substation. The seismographs shall be portable with the capability of producing a report. This will confirm that the vibration intensity generated by the Pile Driving or Compaction work is as projected. Furthermore, reports of recorded intensities shall be provided on a regular basis as determined by Hydro Ottawa or at the request of Hydro Ottawa.

The peak particle velocity measured on the Underground Plant, or at the closest point of a Hydro Ottawa underground structure with respect to the work, shall not exceed 150 mm/s. Furthermore, the maximum displacement for the vertical and/or horizontal component corresponding to the above stated vibration intensity shall not exceed 150 mm at any given length of the Underground Plant in question.

For all operations, if the PPV and/or the displacement limit are surpassed, all operations must stop notwithstanding any delays or costs incurred by the Contractor or owner of the proposed work. Hydro Ottawa will require that the cause of these higher vibrations or displacement be investigated. The operations shall resume only when the cause and remedy are established and with the approval of Hydro Ottawa's Design Department.

Should any subsequent recordings indicate vibration intensities or displacements above the prescribed limits, all operations shall immediately stop. Hydro Ottawa shall require that the work be carried out according to methods it judges to be acceptable to maintain the integrity of the Underground Plant or related structure notwithstanding any delays or costs incurred by the Contractor responsible for the proposed work.

No Piling operations shall be permitted within a standoff distance of 1500mm from the Underground Plant or other Hydro Ottawa facility unless approved by Hydro Ottawa. Auguring of the soil up to the base of the Underground Plant may be required in order to avoid deviation of the Piles within a distance of 1500mm from the Underground Plant.

8.2 Post Piling or Compaction Operations

On completion of the daily operations and 30 days after the end of operations, Hydro Ottawa shall conduct an inspection for damages according to section 9 "Post Event Inspection". The resulting damages will be repaired at the expense of the Contractor responsible for the proposed work.

9.0 Traffic Vibrations

Heavy trucks and buses rarely create perceptible ground-borne vibration unless vehicles are operating very close to buildings, sensitive structures, or where there are irregularities, such as potholes or expansion joints, in the roadway. The pneumatic tires and suspensions systems of normal automobiles, trucks and buses are sufficient to minimize most ground-borne vibration forces. If it is determined due to the close proximity to a substation that the traffic vibration may impact the stability of the Hydro Ottawa equipment in the building, Hydro Ottawa may require that measures to protect the building from any vibration damage be implemented. In order to determine existing conditions, pre-construction testing of the existing ground vibration in the area is to be undertaken and recorded. Vibrations level are to be monitored during construction and for a 30 day period after construction to determine the vibration level once traffic patterns have been established. If vibration levels have increased significantly, screening or damping of the vibrations using in-ground barriers may be required. The in-ground barrier may consist of a trench filled with a material different from the surrounding soil to break up the vibration waves. It is the responsibility of the party creating the potential vibration damage to provide a solution acceptable to Hydro Ottawa and cover the cost of monitoring and any remedial work required.

10.0 Post Event Inspection

After the Acute Shock event has been performed within 10m (Blasting) or 5m (Rubblization, Pile Driving or Compaction) of Underground Plant, where possible, empty/capped ducts shall be tested by passing through a mandrel and brush of suitable diameter. This testing shall be conducted in the exact same manner as described in Hydro Ottawa's specification GCS0005, Section 6. A visual inspection of manholes and stations shall be conducted as well to note any differences after the Acute Shock when compared with the pre-event inspection that was conducted. If vibration recording equipment has been installed in a substation, the Blasting Consultant is to evaluate the information obtained from the recording equipment and submit a report to Hydro Ottawa to determine if any remedial action is required.

Pictures shall be taken of the manholes and stations to ensure that a record is kept of the post event condition.

After initial inspection, further detailed forensic testing may be required of the Underground Plant as determined by Hydro Ottawa if damage to the duct structure is discovered.

All costs associated with the post event inspection are to be paid for by the Contractor.

Appendix A – Soil Types

(From the Ontario Occupational Health & Safety Act and Regulations for Construction Projects)

(1) For the purposes of this Part, soil shall be classified as Type 1, 2, 3, or 4 in accordance with the descriptions set out in this section.

(2) Type 1 Soil

- a) is hard, very dense and only able to be penetrated with difficulty by a small sharp object;
- b) has a low natural moisture content and a high degree of internal strength;
- c) has no signs of water seepage; and
- d) can be excavated only by mechanical equipment.

(3) Type 2 Soil

- a) is very stiff, dense and can be penetrated with moderate difficulty by a small sharp object;
- b) has a low to medium natural moisture content and a medium degree of internal strength; and
- c) has a damp appearance after it is excavated.

(4) Type 3 Soil

- a) is stiff to firm and compact to loose in consistency or is previously excavated soil;
- b) exhibits signs of surface cracking;
- c) exhibits signs of water seepage;
- d) if it is dry, may run easily into a well-defined conical Pile; and
- e) has a low degree of internal strength.

(5) Type 4 Soil

- a) is soft to very soft and very loose in consistency, very sensitive and upon disturbance is significantly reduced in natural strength;
- b) runs easily or flows, unless it is completely supported before excavating procedures;
- c) has almost no internal strength;
- d) is wet or muddy; and
- e) exerts substantial fluid pressure on its supporting system.