GUIDELINES FOR THE DISTRIBUTION OF NATURAL GAS IN MULTI-FAMILY BUILDINGS

Fifth EDITION

April 2009

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INTRODUCTION

This document has been prepared by the Fuels Safety Division, Technical Standards and Safety Authority (TSSA) in conjunction with the Office of the Fire Marshal of the Ministry of the Solicitor General and Correctional Services; the Housing Development and Buildings Branch of the Ministry of Municipal Affairs and Housing; and Ontario's major gas utility companies to provide guidelines for the design, installation, operation and maintenance of gas company plant, housepiping lines and appliances in buildings designed for multi-storey, multi-family residential occupancies exceeding four storeys In height.

These guidelines are intended to establish essential requirements and minimum standards. The exercise of competent engineering judgment is a necessary requirement to be employed concurrently with the use of these guidelines. In addition, utility piping construction and maintenance procedures may have more stringent requirements for certain practices and shall be adhered to.

This document is intended for use in conjunction with the Ontario Gaseous Fuels Regulation as adopted by O. Reg. 212/01 as amended for piping and equipment downstream of the meter. For piping upstream of the meter, this document is intended for use in conjunction with the CSA Z662-07 Oil and Gas Pipeline Systems Standard as adopted by O. Reg. 210/01.

Due to the unique nature of some of these installations, it is anticipated that questions will arise concerning unusual structures of gas equipment installations and the applicability of these Guidelines with respect to those structure. In such cases, the question should be submitted for resolution to the natural has utility representative responsible for service to the structure.

This document will be reviewed on a periodic basis by the parties involved to ensure it continues to represent up-to-date knowledge and information to ensure safe design, installation and operating practices consistent with the obligation to effectively serve the public.

1.0 BUILDING

1.1 Scope

1.1.1 This section is intended to assist the engineer/ architect and the utility in completing a safe and professional installation.

1.1.2 This section shall apply to buildings primarily designed for multi-family residential occupancies exceeding four storeys in height. These guidelines do not apply to single-family detached dwellings.

1.1.3 The design, installation and maintenance of natural gas systems shall conform to the requirements specified in the following codes:
i) Ontario Building Code;
ii) Ontario Fire Code;
iii) Ontario Gaseous Fuels;
iv) Oil and Gas Pipeline Systems Standard; and
v) Other codes as applicable.

1.2 General

1.2.1 It is the responsibility of the building owner or his/her agent to ensure that the review and approvals required under sub-section 1.3 are completed before the installation of the piping system starts in both new or existing buildings.

1.2.2 The utility shall be satisfied that the review required under sub-section 1.3 has been conducted before the start of piping system installation.

1.3 Structural Analysis

1.3.1 Three types of structure have been widely used for high rise residential buildings:
i. reinforced concrete slab and wall construction;
ii. reinforced concrete flat slab construction; and
iii. precast concrete slab or steel joist floors supported on masonry walls.

The type of structure being reviewed shall be identified in accordance with Appendix A and documented by a professional structural engineer. See Appendix C for a sample of Structural Certification.

The first two types of structure, if cast-in-place (CIP) and designed and built to Ontario Building Code requirements commencing in 1986, are identified to be resistant to progressive collapse. The third listed type of construction requires a review as described in Appendix A and the incorporation of special structural details to develop resistance to progressive collapse.

1.3.2 Gas shall not be distributed to in-suite gas appliances in individual suites in a building Identified to be prone to progressive collapse. Guidelines for assessing gas deflagration loadings and for assessing the potential for progressive collapse may be found in Appendix A.

2.0 GAS HOUSEPIPING AND UTILIZATION

2.1 Scope

2.1.1 This section specifies requirements in addition to those contained in the Ontario Gaseous Fuels to be followed for the design and installation of natural gas piping, tubing and appliances in all multi-unit residential buildings, This section applies to gas piping, tubing and equipment installed downstream of the outlet of the utility meter set assembly.

2.2 Piping and Tubing Installation

2.2.1 The owner or his/her agent shall be satisfied with the architect/engineer design methods) of sleeving and sealing gas piping/tubing penetrating walls, floors and roof.

2.2.2 Where practical, gas piping or tubing running vertically from one floor to another, or from one suite to another shall be aligned continuously, one above the other.

2.2.3 All piping or tubing joints shall be made at locations accessible for Initial inspection.

2.2.4 Gas piping penetrating any type of construction material shall be steel sleeved or double wrapped, and sealed by a firestop system having a FT rating not less than the fire protection rating required for closures in the fire separation.

NOTE: The FT rating is to be determined by the fire test method in CAN4Sl1S-M "Standard Method of Fire Test of Firestop Systems".

2.2.5 Sealing must be also applied between the sleeve and the fire separation where the sleeve is installed by core drilling.

2.2.6 Grouts, sealants or sleeves shall be non-corrosive to the piping or tubing and shall be specified or approved by the architect / engineer.

2.3 Pressure Testing

2.3.1 Pressure testing shall be performed in accordance with the Ontario Gaseous Fuels Regulation, as adopted by O. Reg. 212/01.

2.3.2 The utility shall assess the validity of such a test before natural gas is introduced into the system.

2.3.3 A successful pressure test shall show no pressure drop below the initial test pressure or the installer shall reconcile the experienced pressure drop.

2.3.4 Upon completion of a successful pressure test, a confirmation tag stating the information required by the Ontario Gaseous Fuels Regulation, as adopted by O. Reg. 212/01 shall be attached to the piping system in a visible location.

2.4 Emergency Valves and Shut-Off Valves

2.4.1 Where a master meter serves more than one building, an emergency valve shall be provided to isolate the gas supply to each building. The emergency valve shall be located above ground in a readily accessible location, before the gas piping enters the building, and dearly identified for the fire department.

2.4.2 Where more than one individual dwelling unit is supplied with natural gas from a master meter, each unit shall be provided with a lockable shut-off valve which is:
i. installed externally adjacent to the dwelling unit;
ii. clearly identified as to its purpose; and
III. can be accessed from a common area.

2.4.3 A shut-off valve shall be installed on each pipe branch serving an entire floor or at the base of a riser serving a single suite on each floor if the requirements stated in 2.4.2 (i), (Ii), and (iii) cannot be achieved. Signs must be provided per the requirements of 4.2.1.5.

2.4.4 Where a vertical main with floor meter closets is utilized, meter set valves may provide the function required in 2.4.2. Signs must be provided per the requirements of 4.2.1.5.

2.5 Regulators

2.5.1 Each regulator requiring venting to the outdoors must have a separate vent line. Under no circumstances are vent lines to be manifolded.

2.6 Connections to Movable Appliances

2.6.1 An appliance that may be moved by the occupants of a dwelling shall be connected to the natural gas piping system by means of an approved quick disconnect device installed as part of the natural gas piping system if a shutoff valve is not an Integral part of the device then a readily accessible manual shut-off valve shall be installed upstream of, and as close as practical to the quick-disconnect device.

2.6.2 The valve referred to in 2.6.1, shall be equipped with built in stops to limit the rotation of the handle to one-quarter turn when fully opening or fully closing the valve.

2.6.3 The quick-disconnect device shall comply with CGA Certification Requirements CR94-001 and shall exhibit the following features: it shall shut off the flow of gas when the quick-disconnect is not fully engaged and when it is exposed to a temperature in excess of 93°C (thermal shut-off).

2.6.4 A certified flexible hose/connector shall be used to connect an appliance to the quick-disconnect device in accordance with the Ontario Gaseous Fuels Regulation. The flexible hose/connector shall be of such a length so that it provides an easy access to the quick-disconnect and allows free movement of the appliance for cleaning purposes, repair, etc.

3.0 GAS PIPELINE SYSTEMS

3.1 Scope

3.1.1 This section specifies requirements to be followed for the design and installation of gas utility piping in or on multi-unit buildings; it applies only to gas piping systems upstream of the outlet of the utility meter set assembly.

3.1.2 The design and Installation of these piping systems shall conform to the requirements specified in the CSA Z662-07 Oil and Gas Pipeline Systems standard as adopted by O. Reg. 210/01.

3.2 General

3.2.1 A typical steel distribution system will consist of:

i. an outdoor regulator station reducing main line pressure to a lower operating pressure;
ii. sections of vertical and/or horizontal distribution piping inside or outside of a building; and
iii. individual custody meters located in meter cabinets or closets inside of a building.

Refer to Figures 3.1 to 3.4 for a typical installation.

Various other piping and metering configurations are possible. The engineer/architect and the utility are encouraged to provide the -best-fit- to the circumstances encountered.

3.2.2 The utility engineering department shall approve plans/drawings of the piping network upstream of the utility meter.

3.2.3 The utility engineering department shall approve changes to a design or where the installation or design requirements deviate from the original plan.

3.3 Pipe Material

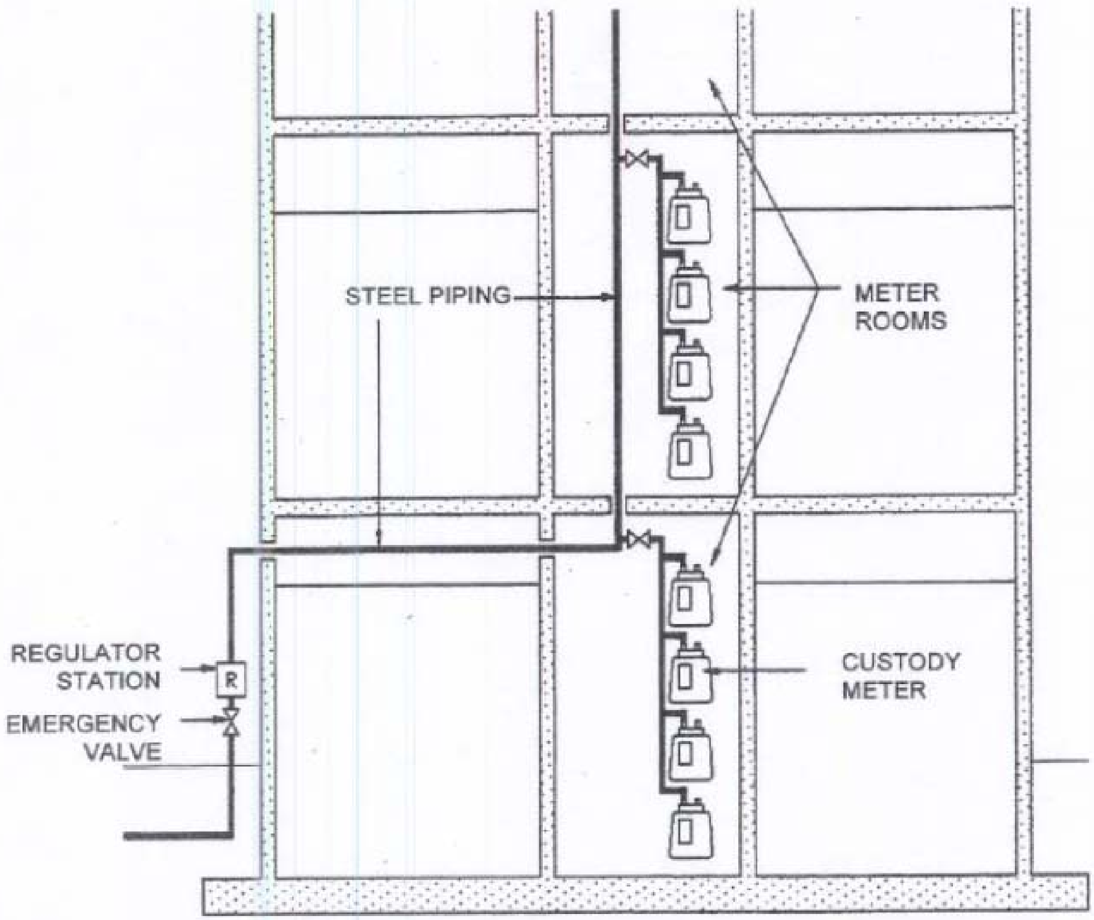
3.3.1 Steel line pipe shall conform to the applicable requirements of CSA Z662-07 Oil and Gas Pipeline Systems Standard.

3.3.2 Low frequency electric resistance welded line pipe is prohibited.

NOTE: "low frequency electric resistance welded line pipe" means a pipe having a welded seam for which the formed edges were heated by electric resistance technique using a frequency less than 1000 hertz to the coalescence temperature and then joined by mechanical pressure without the addition of extraneous metal.

FIGURE 3.1

TYPICAL INSTALLATION OF AN INDOOR STEEL DISTRIBUTION SYSTEM

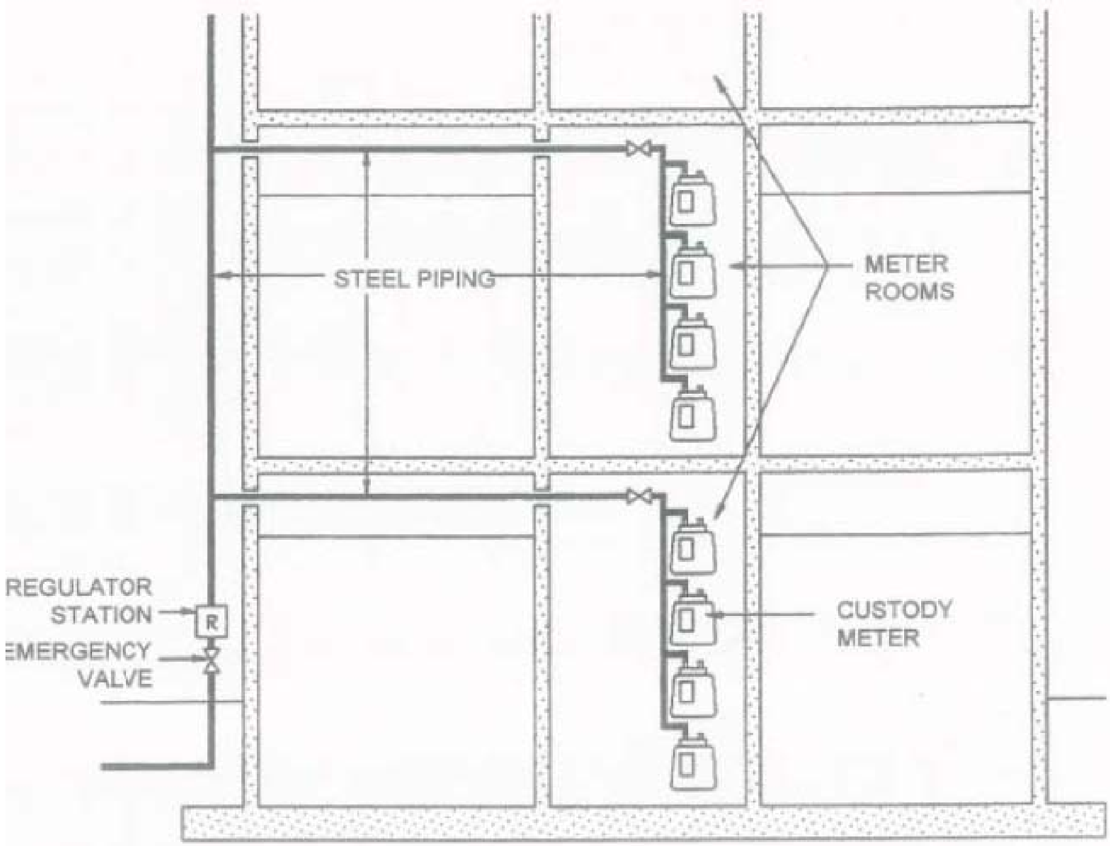


NOTES:

1. ALL INTERNAL WALL AND FLOOR PENETRATIONS ARE TO BE SEALED FOR FIRE SEPARATION.
2. THIS FIGURE DOES NOT REFLECT ALL DETAILS - REFER TO TEXT.

FIGURE 3.2

TYPICAL INSTALLATION OF AN OUTDOOR STEEL DISTRIBUTION SYSTEM



NOTES:
1. ALL INTERNAL WALL AND FLOOR PENETRATIONS ARE TO BE SEALED FOR FIRE SEPARATION.
2. THIS FIGURE DOES NOT REFLECT ALL DETAILS - REFER TO TEXT.

FIGURE 3.3B

OPTIONAL VENTILATION FOR STACKED METER CLOSETS

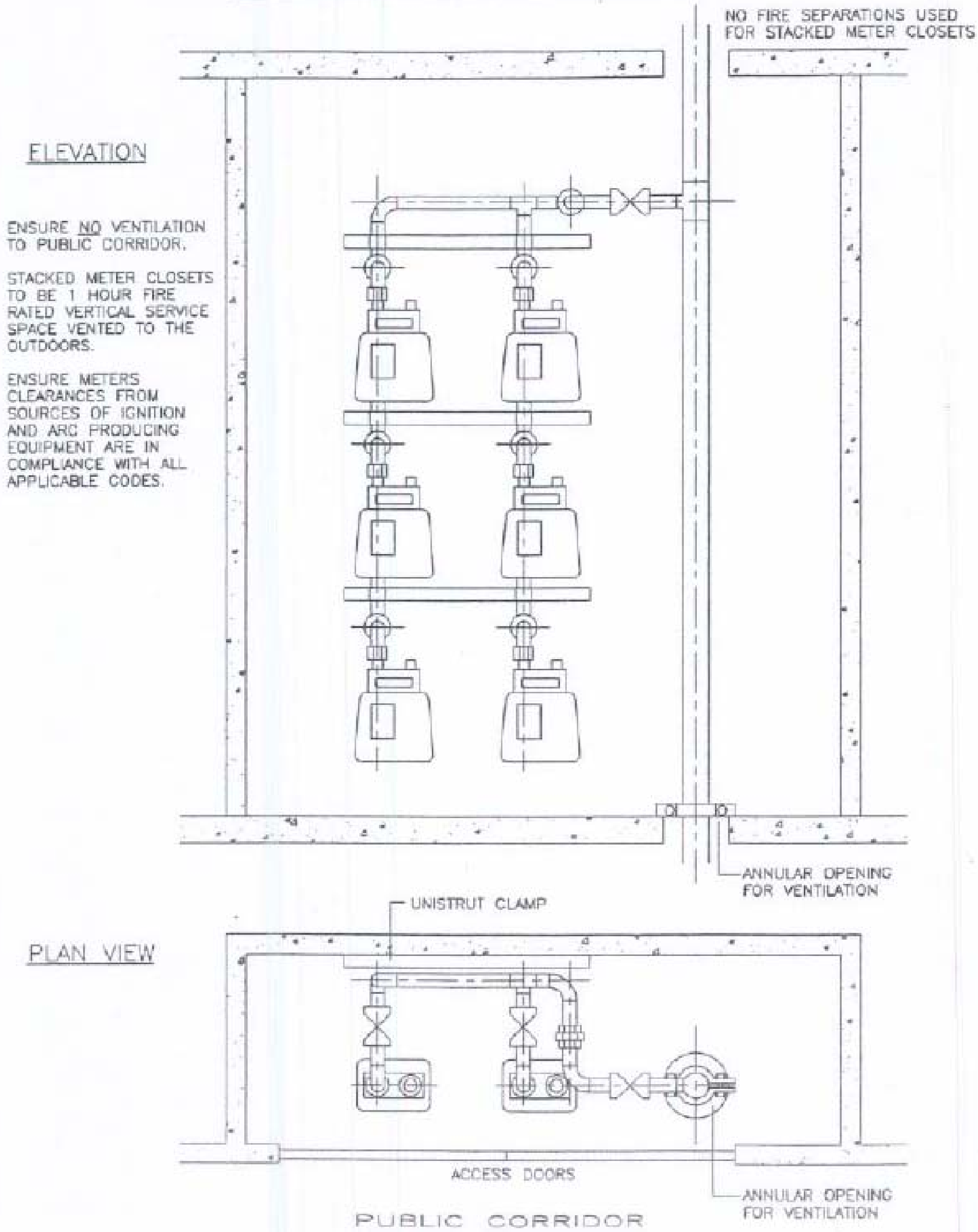
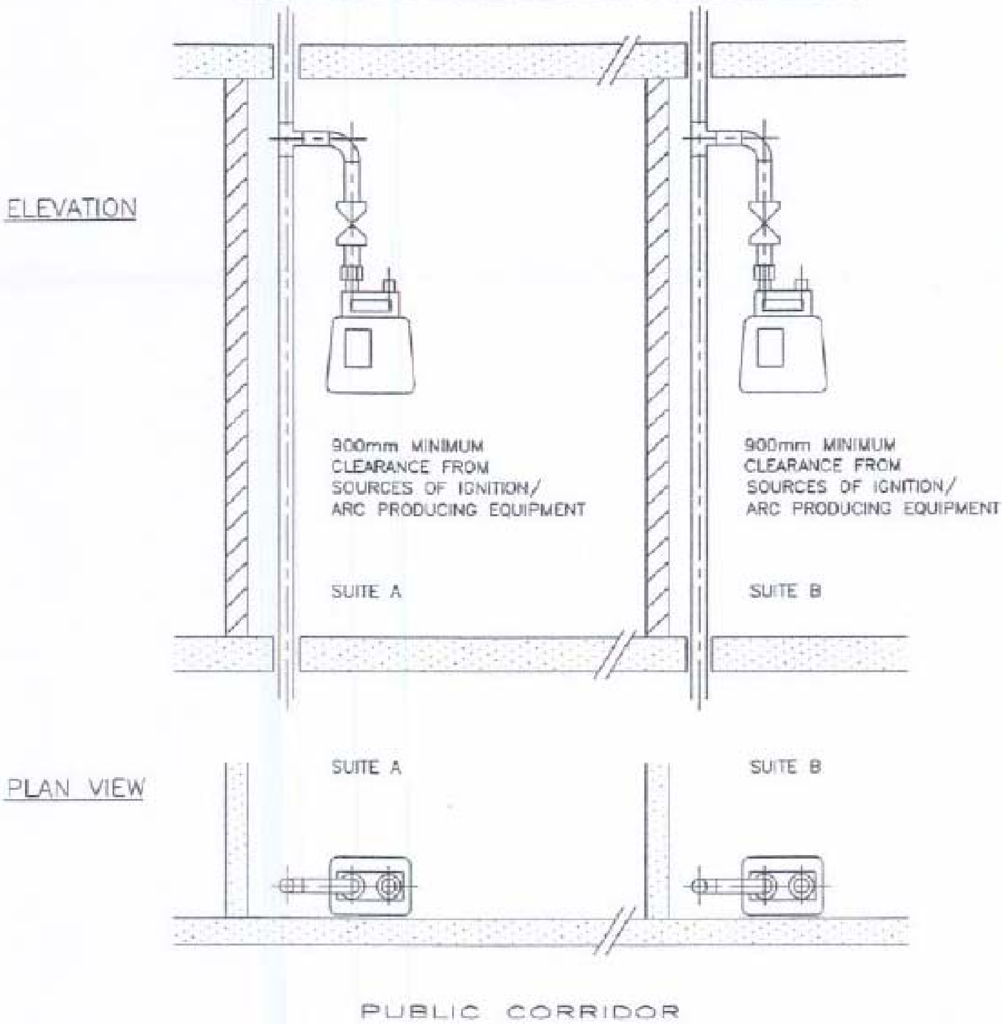


FIGURE 3.4

INDIVIDUAL IN-SUITE METERING



NOTE:

WHERE METERS ARE LOCATED WITH OTHER EQUIPMENT, ENSURE THAT CLEARANCES FROM SOURCES OF IGNITION/ARC PRODUCING EQUIPMENT COMPLY WITH APPLICABLE CODES.

THIS FIGURE DOES NOT REFLECT ALL DETAILS. REFER TO TEXT.

3.4 Pressure

3.4.1 The maximum operating pressure shall not be higher than 140 kPa (20 psig) in the piping upstream of a meter and 14 kPa (2 psig) within individual residential suites.

3.5 Piping Design

3.5.1 All gas piping upstream of the meter shall be sized and specified by the gas utility engineering department. The design shall take into account the protection of gas piping, regulator(s) and meters, from combustible sources, corrosive chemicals and physical hazards.

3.5.2 Any portion of the distribution piping installed on the exterior or on the roof of a building shall be installed as required by the utility standards. Provision shall be made where necessary for expansion and contraction of the piping due to temperature fluctuations.

3.5.3 Piping smaller than 73.0 mm in diameter (NPS 2 1/2) shall have threaded or welded connections. Piping having a diameter of 73.0 mm or larger shall be welded.

3.5.4 Piping within a building shall be installed in accessible locations or in ducts or chases ventilated to the outside, and shall be installed in such a manner that it can be leak tested in its final position prior to being concealed. False ceiling spaces as defined by the Ontario Gaseous Fuels Regulation as adopted by O. Reg. 212/01, and spaces concealed by drywall board but monitored by way of auto test inserts, shall be deemed to be accessible.

3.5.5 Piping or tubing shall not be installed:
i. in a stairwell, unless it is totally enclosed by a chase consisting of material having the same fire resistance rating as required for the stairwell;
ii. in a chimney, flue, elevator shaft, dumbwaiter or chute;
iii. In a heating or ventilating plenum, duct or shaft; or
iv. In contact with cinders, ashes or other corrosive materials.

3.5.6 Piping or tubing may be Installed In a false ceiling space including one used as a return air plenum of a central warm air or air conditioning system.

3.5.7 Piping or tubing shall not be concealed in a location where a corrosive chemical(s) is used.

3.6 Piping Protection

3.6.1 Protection shall be provided where piping is exposed to vehicular traffic.

3.7 Emergency Valve and Shut off Valves

3.7.1 The minimum requirement for manual emergency valve and shut-off valves shall be as follows:
i. emergency valve: above ground in a readily accessible location, before the gas piping enters the building, clearly identified for the fire department;
ii. meter shut-off valve: upstream of individual regulator-meter assembly or upstream of the individual meter if there is no regulator; on each shut-off valve, markings shall be provided indicating the floor and suite served;
iii. meter bank shut-off valve: upstream of any meter bank.
iv. signage shall be provided on doors if valves described in (ii) and (iii) are located in cabinets.

3.8 Service Regulators

3.8.1 Service Regulator(s) installed outdoors or indoors shall be located in an accessible area. All service regulators installed inside a building that require venting must be vented to the outside with due consideration for required clearances from dryer vents or air intakes including any building openings as required by the Ontario Gaseous Fuels Regulation as adopted by O. Reg. 212/01.

3.8.2 Each service regulator requiring venting must have a separate vent line. Under no circumstances are vent lines to be manifolded.

3.8.3 Service regulators that do not require external venting may be installed inside of a building. These regulators must be equipped with an over pressure cutoff device.

3.9 Meters

3.9.1 Meters shall be installed with due consideration for possible damage, vandalism and tenant/occupant safety. Possible meter locations include central meter closets or meter cabinets. Such closets and cabinets shall be constructed in accordance with all applicable codes. Refer to Figures 3.3 and 3.4 for drawings of typical meter locations.

3.9.2 If meters are located in a meter closet or meter cabinet accessible from public corridors, the closet or cabinet shall be vented outdoors. The minimum ventilation area shall be equivalent to the area of an opening of 1 inch in diameter.

NOTE: In cases where it may not be practical to vent each meter closet individually to the outdoors, an alternative solution would be to have each meter closet vent into the meter closet on the floor above. This could be accomplished by not firestopping the gas pipe riser. The uppermost meter closet would then be vented to the outdoors. The meter closets would have to be located vertically one above the other and together the closets would have to be treated as a vertical service space and separated from the remainder of the building accordingly. Refer to figures 3.3(a), 3.3(b) and 3.4.

3.9.3 Meter closets or meter cabinets shall be used only to house meters, regulators and gas appliances. They shall not be used as storage areas.

3.9.4 Meters are to be installed per standard gas utility customer service procedures.

3.10 Pipe Installation

3.10.1 The utility shall be satisfied with the architect/engineer design methods) of sleeving and sealing gas piping penetrating walls, floors and roof. The architect or engineer shall specify or approve the firestop system material to be used.

3.10.2 Gas piping from one floor to another, or from one suite to another, shall be aligned continuously, one above the other where practical, and all joints shall be made at accessible locations for initial inspection.

3.10.3 Gas piping penetrating any type of construction material shall be steel sleeved or double wrapped, and where the construction material is part of a fire separation, be sealed by a firestop system having a FT rating not less than the fire protection rating required for closures in the fire separation.

NOTE: The FT rating is to be determined by the fire test method in CAN4Sl15-M Standard Method of Fire Test of Firestop Systems.

3.10.4 Sealing must be also applied between the sleeve and the fire separation where the sleeve is installed by core drilling.

3.10.5 Grouts, sealants or sleeves shall be non-corrosive to the piping.

3.10.6 For below ground penetrations, the pipe shall be sealed at the entry and exit of the foundation wall with non-corrosive material to prevent entry of gas and water around the pipe.

3.11 Piping Support

3.11.1 Support for piping inside a building shall be provided by pipe clamps, which are designed for this purpose.

3.12 Welding

3.12.1 All welding procedures shall be approved by the utility.

3.12.2 All welders shall be qualified in accordance with the requirements of CSAZ662-07 Oil and Gas Pipeline Systems standard as adopted by O. Reg. *210/01* and shall be holders of a valid identification card issued under the Boilers and Pressure Vessels Regulation.

3.12.3 Welded fittings or joints shall not be installed in a non-accessible location such as between the top and bottom of floor slabs or in existing finished walls unless provisions are made to have them accessible for the initial inspection.

3.12.4 All welds shall be visually inspected. Further, mandatory radiographic Inspection shall be performed in accordance with clause 7.10.8.2.1 of the CSA Z662-07 Oil and Gas Pipelines Systems standards as adopted by Q. Reg. *210/01* for all grades of pipe.

3.13 Pressure Testing

3.13.1 Pressure testing shall be performed in accordance with the CSA Z662-07 Oil and Gas Pipeline Systems standard except that the test pressure shall not be less than 340 kPa (50 psig) for a period of 24 hours with air or inert gas.

3.13.2 The test pressure shall be recorded on a 24 hour chart. The utility shall assess the validity of such a test before natural gas is introduced into the system.

3.13.3 A successful pressure test shall show no pressure drop below the Initial test pressure or the utility shall reconcile the experienced pressure drop.

3.13.4 Upon completion of a successful pressure test, a confirmation tag signed by a pipeline inspector at the employ of the utility shall be attached to the piping system in a visible location.

3.14 Purging

3.14.1 Purging of piping shall be performed in accordance with the utility procedures.

3.15 Piping Identification

3.15.1 Piping shall be either painted, or banded, with at least one coat of yellow paint or tape. Banding shall be at 6 m (20 ft) Intervals, at any change In direction, and both sides of a wall, floor, or partition, pierced by the piping.

3.15.2 All piping shall be identified where the gas supply enters a building, at a point adjacent to both sides of a wall, floor or partition pierced by the piping and at intervals of not more than 2 m (6 ft) along its entire length as follows:
a) in any portion of a system containing less than 14 kPa (2 psig) pressure, with yellow tape or a yellow tag bearing the words· natural gas· in bold black letters of not less than 6.25 mm (1/4") in height; and

b) in any portion of a system containing 14 kPa (2 psig) pressure or higher, with yellow tape or a yellow tag bearing the maximum pressure of the line and similar wording as in (a) above.

3.15.3 All piping installed outside a building shall be painted a colour acceptable to the building owner and identified as carrying natural gas.

3.16 Corrosion Control

3.16.1 All outdoor buried piping must be electrically isolated from above ground piping at a location where the piping comes above the ground. When piping enters a building below the ground, the piping must be electrically isolated as close as practical to the outside wall where the pipe enters the building.

3.16.2 It is recommended that a pipe be double wrapped or that a plastic sleeve be installed through exterior walls for added protection of the gas piping. The hole must be caulked on each face of the wall with a compound non-corrosive to steel and it must form a water/gas tight seal.

3.16.3 At all points where the indoor gas piping comes In contact with the building or with support brackets, the pipe shall be double wrapped with tape approved by the utility for corrosion protection. No metallic contact between the gas piping and building materials shall be allowed.

3.16.4 Indoor piping shall be electrically isolated at each meter.

4.0 OPERATING AND MAINTENANCE PROCEDURES

4.1 Architects and Engineers

4.1.1 The architect or engineer responsible for a building project shall inform the building owner in writing of the building owner's obligations under these guidelines.

4.2 Building Owners

4.2.1 Information

4.2.1.1 For buildings required to have a fire safety plan under the Ontario Fire Code, the building owner shall Incorporate in the plan, measures that are appropriate to the introduction of natural gas into the building; this would include instructions for action when a sustained smell of natural gas is detected.

4.2.1.2 The utility shall be responsible to provide sufficient information for the fire safety plan with respect to the utility's natural gas installation to allow the owner to identify key valves to shut off the flow of gas to the building and to storeys within the building.

4.2.1.3 The building owner shall post the following information in a visible location at the entrance of the building, preferably adjacent to the fire annunciation panel if provided, and shall provide in the fire safety plan for the building:
i) notification that there is gas distribution piping throughout the building; and,
ii) identification of the location of the emergency valve and meter bank shutoff valves referred to in sub-section 3.7.

4.2.1.4 Where meter set valves, meter bank valves or other shut-off valves are located In closets or enclosures outside of the suites, signage shall be provided by the building owner on doors or access panels before or at the time when it is necessary to turn the gas on.

4.2.1.5 Where a suite shut-off valve is located on a floor other than the floor on which the suite is located, the building owner shall provide signs at the elevator door on the suite floor and at each exit from the suite floor, which identify the floor on which the shut-off valve for the suite is located.

4.2.2 Emergency Valve

4.2.2.1 It shall be the building owner's responsibility to ensure that the emergency valves located downstream of the gas utility meter set are inspected and partially operated at least once per calendar year, with a maximum Interval of 18 months, between such inspections and operations.

4.2.3 Access

4.2.3.1 Where the piping, meters or regulation equipment are on the roof, access shall be provided by the owner.

4.2.3.2 Provisions shall be made by the building owner for accessibility to piping or tubing by way of platforms, catwalks, steps and railings.

4.2.4 As-Built Drawings

4.2.4.1 As-built drawings showing all permanent repairs of the gas system and location of all appliances and the gas piping/tubing system downstream of the meter shall be kept by the building owner.

4.3 GAS UTILTY COMPANIES

4.3.1 Repair of Defective Utility Pipes

4.3.1.1 Defects such a gouges, grooves and dents shall be removed by cutting out cylindrical pieces of the pipe containing the defects and replacing them with pipe that meets the design criteria.

4.3.1.2 Temporary repairs are permitted. A record of all permanent repairs shall be maintained by the utility for a period of five years.

4.3.2 Corrosion Control

4.3.2.1 The utility shall take electric potential readings once a year to verify the absence of stray current on all outdoor buried utility piping.

4.3.2.2 A corrosion inspection of all visible piping and components upstream of the outlet of the meter shall be completed a minimum of once every three years. A record must be kept of each inspection until the next inspection is completed.

4.3.2.3 When corrosion is found on indoor piping, the utility shall decide if and when the corroded pipe must be replaced. Corrective action shall be taken to prevent more corrosion from occurring.

4.3.3 Leak Survey

4.3.3.1 A leak survey by the utility shall be completed inside the building once after the fist year following installation and then completed once every three years. This shall include an inspection of all piping and components upstream of the outlet of the meter. A record must be kept of each inspection until the next inspection is completed.

4.3.4 Emergency Valve

4.3.4.1 Emergency valves upstream of the gas metering shall be inspected and partially operated at least once per calendar year, with a maximum interval of 18 months between such inspections and operations.

4.3.5 Locate Service

4.3.5.1 The utility shall provide a free and readily available locating service of all piping upstream of the gas metering.

4.3.6 Access

4.3.6.1 Where the utility gas piping, meters or regulators are located in or on a building, a Maintenance Access Agreement or lock-up procedure must be obtained from the building owner to gain admittance to the premises to perform the required maintenance work on a 24 hour basis.

4.3.7 As-Built Drawings

4.3.7.1 "As-built" drawings of the indoor gas system upstream of the meter shall be kept by the utility.

4.3.7.2 The utility shall maintain "as-built" drawings showing:
i) the location of the external emergency valve;
II) the routing of the gas distribution system upstream of the meter; and,
iii) where applicable the location of the meter bank and riser shut-off valves.

APPENDIX A

GAS DEFLAGRATION AND PROGRESSIVE COLLAPSE IN HIGHRISE RESIDENTIAL BUILDINGS WITH PARTICULAR EMPHASIS ON PRECAST CONCRETE AND STEEL JOIST FLOOR SYSTEMS ON LOAD BEARING MASONRY WALLS

GAS DEFLAGRATION AND PROGRESSIVE COLLAPSE IN HIGH RISE RESIDENTIAL BUILDINGS WITH PARTICULAR EMPHASIS ON PRECAST CONCRETE AND STEEL JOIST FLOOR SYSTEMS ON LOAD BEARING MASONRY WALLS

INTRODUCTION

This section is intended to introduce the structural requirements of the Guidelines and to ensure that structural engineers are aware of the need, under the Guidelines, to investigate the adequacy of the structure of a residential building to resist progressive collapse.

The single most significant structural requirement of the Guidelines is the stipulation that a building with in-suite natural gas supply must be resistant to progressive collapse following a gas deflagration. Since the Guidelines apply only to residential buildings that are more than four storeys in building height, wood frame construction is eliminated from consideration. Under the Ontario Building Code, residential buildings higher than four storeys must be of noncombustible construction.

The National Building Code of Canada (NBCC) introduced a new clause in 1970 requiring that building structures be resistant to progressive collapse. In 1980, this clause was deleted in favour of adding "structural integrity" to the design requirements. An appendix of the NBCC directs the reader to a Commentary of the Code, which explains the particular quality ascribed to structural integrity namely, resistance to progressive collapse. Since the Ontario Building Code was and continues to be modeled on the NBCC, resistance to progressive collapse has been and still is a requirement. Unfortunately, the term "structural integrity" may not be interpreted to include *resistance to progressive collapse* by some structural engineers. This may have led to the construction of some types of building structure, which do not possess adequate resistance to progressive collapse.

The Canadian Standards Association standards for the design of masonry, reinforced concrete, steel and wood structures all address the issue of structural integrity in some manner. **Reference 1** contains an exemplary commentary on resistance to progressive collapse. However, while these documents and the NBCC Commentary mention the possibility of problems Inherent in combining construction materials, no specific guidance is given. Combinations of materials of particular Interest in multistorey residential buildings are pre-cast concrete floor slabs supported on masonry walls, and thin cast-in-place concrete floor slabs on steel joists supported on masonry walls.

Most of the multi-family residential buildings higher than four storeys constructed in Ontario are of one of the following types:

- reinforced concrete (one-way spanning) slab and (shear) wall construction;
- reinforced concrete (two-way spanning) flat slab construction (with or without drop panels), or
- pre-cast concrete slab floors or cast-in-place concrete slab floors on steel joists, supported on masonry walls.

Some structural systems have inherent resistance to progressive collapse while others are prone to such collapse unless specific remedial action is taken. One-way concrete slab and wall systems that have been designed as monolithic continuous structures, properly reinforced for all induced moments resulting from continuity, and provided with minimum reinforcement in each direction in accordance with the 1984 or 1994 editions of the CSA Standard CAN3-A23.3, *Design of Concrete Structures for Buildings,* are considered to be resistant to progressive collapse and are deemed to satisfy the requirements of the Guidelines.

In the case of flat slab systems, experience has shown that if a flat slab collapses onto the floor below due to shear failure around the column, there is a significant risk of a similar failure in the lower slab, thus initiating a progressive collapse. In order to prevent such an occurrence, the 1984 and 1994 editions of the CSA Standard CAN3-A23.3 require that minimum bottom reinforcement must be provided in the slab to pass through the column supports in each orthogonal direction to provide catenary support for the slab in the event of shear failure. Therefore, only flat slab systems designed and constructed to these editions of the CSA Standard are considered to satisfy the requirements of the Guidelines.

Before addressing mixed structural systems, which employ masonry bearing walls, it is appropriate to review Appendix A of the Guidelines, which addresses and discusses structural aspects in detail. Progressive collapse and the structural test for resistance to progressive collapse are defined. The fundamental differences between the effects of rapid chemical high explosive and a relatively slow gas deflagration are reviewed from a structural standpoint. A method is given for the estimation of peak pressure following venting of unburned gas through failed window glass from a suite filled with an air-gas mixture of optimum proportions. The high pressure developed may cause apprehension among structural engineers. However, the intent is not to design every structural component to resist deflagration pressures --an impractical and onerous undertaking. Instead, local failure should be allowed to occur, but progressive collapse will be forestalled by ensuring the presence of "alternative paths" by which gravity loads and stability forces may continue their course.

Appendix A then concentrates on outlining failure-resisting mechanisms that can be developed in masonry construction to maintain support of both walls and severely damaged floor systems. The Appendix is illustrated in sufficient detail to enable a structural engineer to better understand the principle of alternate paths, to design a masonry bearing building to provide resistance to progressive collapse following a gas deflagration, and possibly to develop his/her own mechanisms for the provision of resistance to progressive collapse.

GAS DEFLAGRATION AND PROGRESSIVE COLLAPSE IN HIGH RISE RESIDENTIAL BUILDINGSWITH PARTICULAR EMPHASIS ON PRECAST CONCRETE AND STEEL JOIST FLOOR SYSTEMS ON LOAD BEARING MASONRY WALLS GUIDELINES

1. GUIDELINES

1.1 Progressive Collapse

Progressive collapse is the propagation, by a chain reaction mechanism, of a local structural failure into the failure of a substantial portion of the building, totally disproportionate in magnitude to the initial failure.

COMMENTARY

The 1968 failure of one comer of a 23-storey residential building in London, England, alarmed structural engineers around the world. Although the root cause was inadequacy in the structural detailing, the fact that it was triggered by a gas deflagration focuses attention and magnifies concern on the construction presently under consideration. However progressive collapse will be seen in perspective in North America when it is recalled that most spectacular failures have tended to occur under construction and have not involved the types of structure being considered when built to current codes; witness the 12 storey steel framed Union Carbide office building, Toronto. 1958; the 16-storey cast-in place reinforced concrete apartment building, Boston, 1970, and the 16-storey post-tensioned concrete lift-slab building in Bridgeport, Connecticut, 1987.

The failed London building was not unique but one of perhaps hundreds of similar buildings with in suite gas service. The fear of catastrophe unleashed a series of inquiries, research and repair on an unprecedented scale.

2. Structural Test for Progressive Collapse

2.1 A structure may be deemed resistant to progressive collapse if, by accepted engineering principles *it* can be shown that, following a postulated abnormal event, neither the failure of members likely to be affected by the event nor the debris there from will induce further sequential structural failure.

Some jurisdictions have defined resistance to progressive collapse to be the ability of a structure to accommodate, with only local failure, the notional removal of any single structural member. Aside from the possibility of further damage that uncontrolled debris from the failed member may cause. it appears prudent to consider whether the abnormal event, i.e. a gas deflagration, can be relied upon to fail only a single member. Reference to Figure 1 suggests the potential failure of one or more structural members. It is suggested in Reference 4 that only a single member need be considered since failure of this will relieve the gas deflagration pressure. Study of gas pressure venting through failing window glass leads one to doubt the validity of the argument from Reference 4. The interior pressure continues to rise significantly following glass failure and is a function of the mass of the panes of glass. Obviously, heavy floor slabs will be much less efficient vents.

3. Principles of Resisting Progressive Collapse

3.1 The objective is to conceive design and construct building structures in such a manner that should they be subject to accidental abnormal loading at some time during their useful life, a local structural failure will not give rise to progressive collapse. The characteristics that confer this quality on a building are termed "structural integrity".

For a perceived event, such as a gas deflagration, it is possible to approximate an internal pressure against which the surrounding structural members will continue to function. The British defined this to be 5 psi or 34 kN/m2, whereupon many British engineers designed structures to resist this ultimate load. The relative spaciousness and spans of North American apartments render this approach impractical. Furthermore, the British (Reference 4) acknowledge that the likelihood of resisting this pressure in floor uplift is remote.

3.2 Alternate paths for the flow of loads around damaged members should be incorporated into the structure if the elements cannot resist the maximum deflagration pressures. An alternate path is a structural detour by which loads continue their route to the foundations, flowing around the direct route temporarily disrupted by damaged members. Implicit in this concept is the requirement that debris will be controlled. It is also accepted that deflections may be so great as to render parts of the building unserviceable, but the progressive chain of failure will be arrested.

Although the term "explosion" is used loosely to describe the rapid combustion of gas, strictly speaking explosion applies to chemical explosives such as TNT in which the necessary oxygen is part of the explosive. Gas cannot bum until it has been mixed with air to provide the required oxygen; this dilutes the gas/oxygen mixture with nitrogen and disperses it into a large volume. The gas/air mixture does not explode but bums rapidly, that is, it "deflagrates". While the pressure pulse of a gas deflagration may last several hundred milliseconds that of TNT may be only one millisecond. A gas deflagration is usually slow enough to allow time for the gases produced to be discharged through a vent opening in an exterior wall, partially unburnt.

While load bearing walls several storeys below the roof may be capable of resisting gas deflagration pressures, the prudent course in Ontario is to develop alternate paths to enable the loads to bypass a local damaged area. With modest structural cost, walls can be constructed so that they will function also as beams, utilizing strut and tie mechanisms within the wall beams to develop shear resistance; with the provision of tie reinforcement within walls, arch and strut mechanisms can function to resist considerable gravity load from above; floors can be suspended from walls above but in certain circumstances, floors also can act as catenary suspension systems. With application and ingenuity, structural engineers may develop further the mechanisms il1ustrated in Figures 2 and 3.

4. Structural Systems

4.1 Three types of structure hate been widely used for high rise residential buildings:

- reinforced concrete slab and I wall construction;
- reinforced concrete flat slab construction;
- precast concrete slab or steel joist floors supported on masonry walls.

The first two types of structure, if cast-in-place (CIP) and designed and built to current Ontario Building Code requirements, are deemed to be resistant to progressive collapse. The third listed type of construction requires the incorporation of special structural details to develop resistance to progressive collapse.

In these Guidelines, it is feasible to review the effects of gas deflagration only on commonly used types of construction. Other types of construction will require specific evaluation using loading data given in the -Basic Parameters".

The types of cast-in-place reinforced concrete mentioned, having adequately detailed and anchored reinforcement meeting the requirements of CSA Standard CAN3-A23.3M84, Design of Concrete Structures for Buildings, are deemed to be resistant to progressive collapse. Of particular importance in flat slab construction is the structural integrity reinforcement introduced as a requirement of CAN3-A23.3-M84. This standard has been a reference document of OBC since 1986.

4.2 The remaining section of these Guidelines sets forth loadings deemed appropriate in evaluation of the resistance of a structure to the effects of gas deflagration and presents structural mechanisms that may be developed in masonry wall buildings having precast concrete or steel joist floors.

The purpose of the commentary on this section is to illustrate strategies that may be adopted to resist progressive collapse and by so doing, enhance understanding of the guidelines. It is not intended to provide standard designs. The engineer of record for a building design must devise and design the progressive collapse resisting system as part of the structural design of the building.

5. Basic Parameters

5.1 Structures deemed capable of resisting a gas deflagration without progressive collapse must accommodate damage to several members In the proximity of the deflagration if that is indeed a likely occurrence.

Although gas deflagration peak pressures last for only fractions of seconds. Their duration is much longer than the pressure pulses nom high explosives. Consequently, their effect on walls and floors is much different. The natural period of vibration of long span floors may be of the same order as the duration of peak pressure and that: of walls is likely to be less. *As* a result, floors and walls react initially as if static pressure of7 times. or if the British 34kN1m2 is used, 18 times normal design load were applied.

5.2 The peak pressure Is taken at 15kPa (2.2 psig) in a suite with a window (venting) area of 15% .of the floor area. This pressure may be adjusted to reflect both the proportion of window area and the unit mass of the window glass, in accordance with the "Notes on Deflagration Pressure" in Appendix B.

It is not possible simply to vent a deflagration and "get rid of the pressure". Even after window glass has fractured, for the glass to be displaced in a very short time requires force, i.e. pressure, to accelerate the mass. Consequently, pressure rise within a confined space continues until the remaining large volume of unburned air/gas mixture has been expelled. From even a simple understanding of the nature of the combustion, it can be appreciated that the maximum internal pressure cannot possibly be less than that required for window glass failure. In reality, the constraints of available window area versus suite floor area may mean that the pressure will be twice this basic pressure. To add further to the pressure, glass failure is extremely variable. To provide an acceptably low failure rate under exterior wind load means that the internal pressure to ensure glass failure may be significantly greater than the glass design pressure.

Steel stud and gypsum board partitions may fail under the pressures generated.

Basic Parameters (Cont'd.)

5.3

It is recommended that ductile reinforced "strong elements" required to withstand the deflagration to prevent progressive collapse should be designed to resist the appropriate lateral pressure increased by a factor of 1.5. A greater margin of safety should be provided for members, which would fail in a brittle mode.

For members (strong elements) that must withstand gas deflagration pressure and continue to function structurally in order to support load-bearing elements above, some increase in load factor is warranted. For members reinforced so that after peak load, deflagration will continue without significant loss of load carrying capacity, (that is members that will fail in a ductile mode), a load factor of 1.5 on deflagration pressure is thought to be adequate, provided that the member is evaluated in its deformation shape. (Note that axial load from above will enhance the lateral resistance of an undeformed wall element but that secondary bending caused by deformation ultimately will reduce this lateral resistance).

Traditionally, unreinforced masonry has been designed to resist flexure from lateral load on an elastic stress basis, the limiting condition usually being some notional tensile stress. In actual fact, masonry walls under significant axial load can sustain lateral load considerably in excess of that which initiates open tensile cracking. A 3-hinge, 2-bar mechanism forms as maximum lateral load is approached. This mechanism may be referred to as arching, but it is arching out of plane, not in plane as discussed in Section 3.2 and shown in Figures 2 and 3. The mechanism has been used in the assessment of masonry arch bridges and medieval buildings and has been codified in Britain. A detailed analytical treatment is given in Reference 2. While analysis of this mechanism is simple, the possible precipitation of rapid failure at maximum load suggests a more cautious approach to safety. This type of failure is referred to as "brittle" as opposed to "ductile".

In Appendix B, the influence of air/gas mixture turbulence on deflagration is discussed. A turbulence factor, B, is introduced which may vary between L5 and 5.0. Since it is this factor which is difficult to assess, a value of 2.5 rather than 1.5 is suggested for the determination of the pressure for which brittle strong elements should be designed, in addition to the load factor of 1.5 on lateral load.

Basic Parameters (Cont'd.)

5.4 In assessing the adequacy of alternate path structural systems, the factored load against which the ultimate strength of a member may be rated is:

1.0 dead + 0.5 live + 0.2 wind

The Jive load may be reduced from 0.5 to 0.4 at the second floor below the roof and 0.3 at all other floors.

The extraordinary situation of an in-suite gas deflagration warrants the use of minimum load factors when evaluating the ultimate strength of structural members.

6. Prototype Design

6.1 In wall bearing buildings, the walls must be capable of fulfilling their intended purpose, which is to support floors and to stabilize the structure, despite local damage to the walls from gas deflagration.

In the simplest and most commonly used structural configuration, the party walls between suites are made the primary load bearing elements, Figure 2. Usually, these walls provide adequate lateral stability in their own plane.

6.2 Provided there is sufficient gravity load from above, unreinforced walls may be capable of resisting gas deflagration lateral pressure, **Reference 2**. Where walls are ruptured or otherwise rendered Incapable of supporting gravity load, appropriately constructed walls may bridge over the damaged area by acting as storey height beams or tied arches. In addition to the required tension reinforcement to facilitate this form of structural action, It is necessary to ensure that segments of walls, termed -strong elements", remain functional to provide support for the beams or tied arches. These strong elements should be' capable of resisting lateral pressure from gas deflagration, prior to the application of increased gravity load from the wall beams or tied arches above.

Perpendicular to the plane of these cross-walls, in the customary direction of the corridor, there is much less masonry available. Corridor walls are now frequently of steel stud and wallboard and the exterior walls may be largely fenestration. The customary absence of openings in the cross-walls suggests that the most practical way of supporting floor slabs or joists is to span them between the cross-walls.

6.3 The strong elements should be fully grouted and reinforced in each cell, designed to resist both abnormal event lateral pressure and gravity load.

Elevations of two types of cross-walls are shown in Figures 3 and 4, the difference between them being the arrangement of strong elements. Figure 3 illustrates a plane wall of uniform thickness within a storey, without return walls at corridor or exterior. The strong elements, which are not apparent in the finished wall, have been located some distance in from the extreme ends of the wall to minimize flexural and tie reinforcement in the wall. The running bond in the wan must be continued through the strong e1ement to transmit vertical shear. However. it is felt that, provided horizontal shear reinforcement is not required to resist wind or seismic forces, nominal masonry reinforcement may be terminated at the strong element/wall interfaces. This may prevent an excessive area of wall contributing its lateral load to the strong element.

Prototype Design (Cont'd.)

6.4 The lateral load which a strong element is designed to resist should be consistent with the failure mode of the adjacent masonry construction; if a construction separation is formed between strong element and adjacent masonry, only the lateral pressure impinging on the strong element needs to be resisted. If the strong element is integral with the adjacent wall, a two-way mechanism of failure, which contributes additional lateral load to the strong element, should be considered.

The wall in Figure 4 has strong returns at the corridor and the exterior, capable of resisting significant lateral load perpendicular to the plane of the cross-wall. If horizontal shear reinforcement is required for wind or seismic forces, the returns could be made to resist the out-of-plane load contributed by the integrated wall.

Probably the simplest guide to design of arching in walls is Reference 3, since it is specifically the problem under discussion, which is addressed therein. Shallower beams of only one storey height are covered on p. 4-25 of Reference I, using the -strut-and-tie" concept. Note from the figure on pA-25 that the nodal zone may be critical and may require multi-element tension ties spread over the nodal zone, the dimensions of which are dictated by stress limits. For this reason, a single tie at the very bottom of a beam may be inadequate. Openings in wall beams can impair this structural action, depending on location. Reference 2, p. 490, also discusses arching in walls as beams, but beam shear would not appear to be critical in the wall-beams conceived herein. No requirement for special testing is foreseen in order to implement these mechanisms.

6.5 Above an ineffective area of wall, the wall and floors below the arch above should be suspended from vertical hanger reinforcement grouted into the walls. This reinforcement may be proportioned on the basis of its ultimate tensile strength and spaced no more than 2400 mm apart.

Continuous bond beams are anticipated above and below either floor system. The bond beam below is required to provide bearing support for either slabs or joists. The bond beam above is required to receive floor suspension dowels and further accommodate the arch tie or strut tie reinforcement.

6.6 A floor solution is recommended which maintains the floor slabs in position, suspended from the wall above, bridging over the locally damaged wall below.

At exterior or flank walls, vertical grouted reinforcement should be spaced at 1200 mm maximum. Positive hangers from the ends of the precast slabs should be anchored up into these grouted cells.

Suspension of floor from wall structure above (Figures 5 and 6) is deemed preferable to catenary suspension over two long spans. The catenary approach would cause further disruption, introduce high tensile forces which must be compatible with the sag, cannot be used at the exterior support, and is of dubious value at the first interior supports.

Prototype Design (Cont'd.)

6.7 To control debris in the vent that maximum deflagration pressure develops and ruptures the floor structures above and below a suite, catenary systems should be developed in the floor systems to suspend the debris from the walls or the bond beams at the wall/floor intersections.

Development of catenary action in precast prestressed concrete (PC) slabs requires tensile continuity between slabs over supports. Short lengths of9.53 mm dia. pre-stressing strand, extending 750 mm into each grouted joint, are recommended.

To provide reliable catenary resistance to high uplift pressures, precast prestressed concrete floor slabs should incorporate two small (9.53mm diameter) strands located near the top surface. These strands need be prestressed only to a nominal tension, as required by the manufacturing process.

Development of steel joist top chord catenary capacity depends on the joist type. Top chords composite with the concrete slab may be developed through adequately bonded reinforcing bars. In non-composite joists, direct connection of top chords may be necessary; alternatively, extra welded wire mesh may be provided but consideration should be given to the attachment of joist to concrete deck.

To mobilize maximum steel joist resistance to uplift prior to failure and catenary action, the bottom chord should be laterally braced, either by bridging or by an appropriately proportioned ceiling.

6.8 At roof level, tie-down anchorage should be provided to resist uplift.

REFERENCES

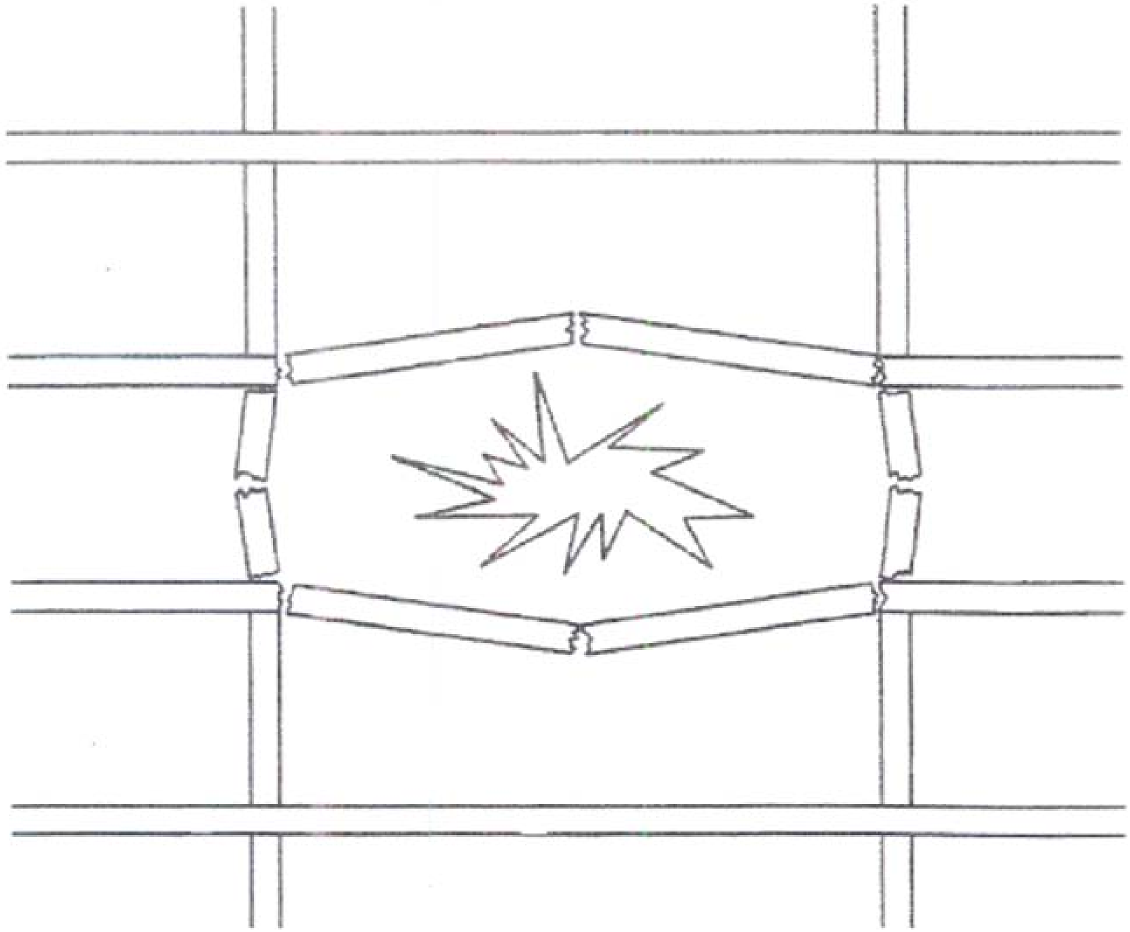
1. Concrete Design Handbook, Canadian Portland Cement Association, Ottawa, 1995.

2. Drysdale, R.G., Hamid, A.A., Baker, L. R., Masonrv Structures Behaviour and Desian, Prentice-Hall Inc., Englewood Cliffs, N.J., 1994.

3. Fintel, M., Annamalai, G., "Philosophy of Structural integrity of multistorey loadbearing concrete masonry structures", Concrete International: Desio" and Construction, V.l, No.5, May 1979, pp.27-35, American Concrete Institute.

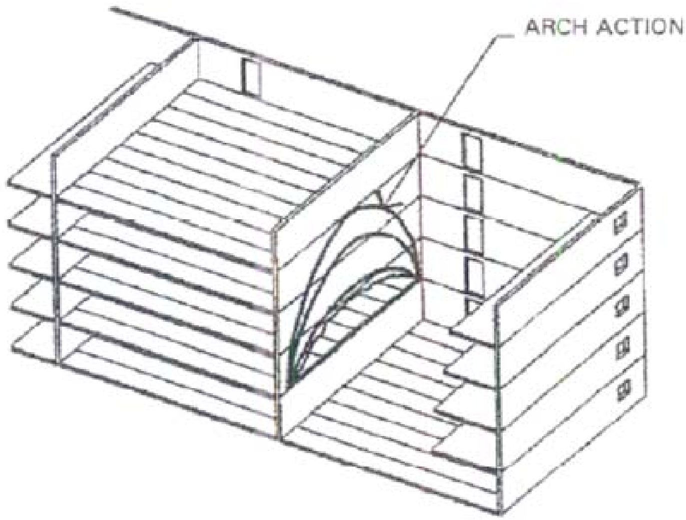
4. Roberts; J.J., Tovey, A.K., Cranston, w.e., Beeby, A.W., Concrete Masonrv Desianer's Handbook, Eyre & Spottiswood Publication Ltd., Leatherhead, England, 1983.

Note: References 1, 2 & 3 are readily available. Other references from the Portland Cement Association, the National Bureau of Standards, the British Building Research Establishment and British Gas, mostly dating from the 1970's, have not been listed since they are not widely available and are not essential to an understanding of these Guidelines.

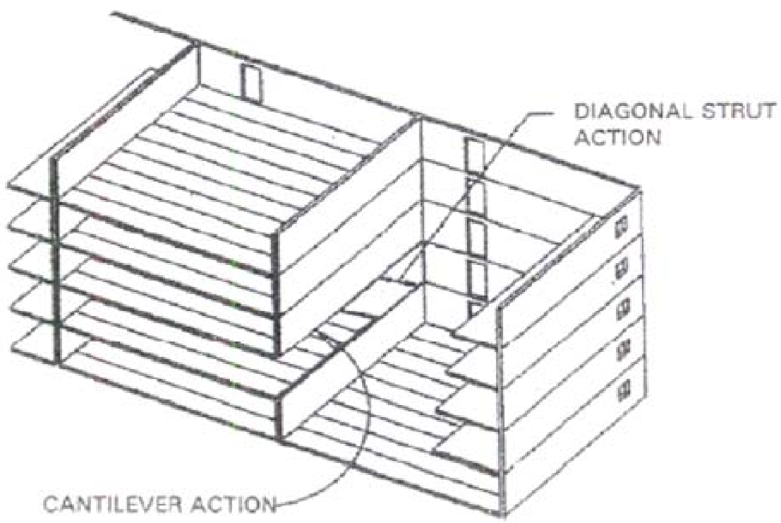


STRUCTURAL MEMBERS AFFECTED BY GAS DEFLAGRATION WITHIN SUITE

FIGURE 1



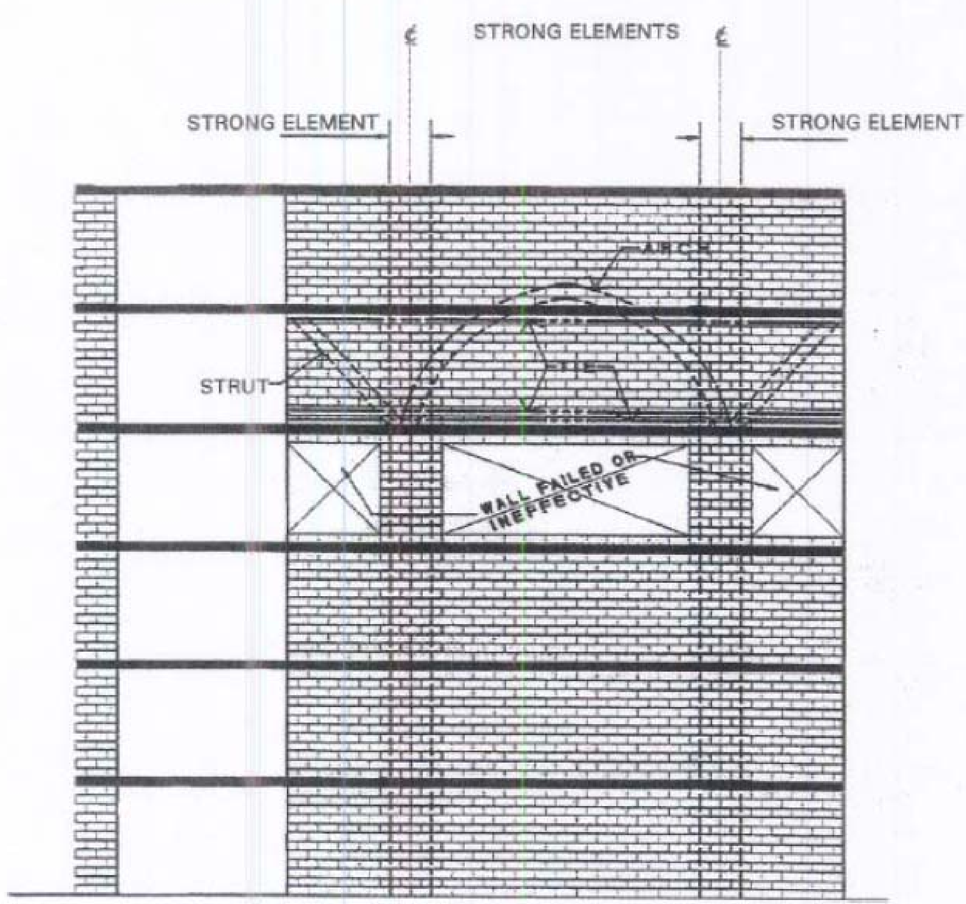
CENTRE PORTION OF WALL INEFFECTIVE



EDGE OF WALL INEFFECTIVE

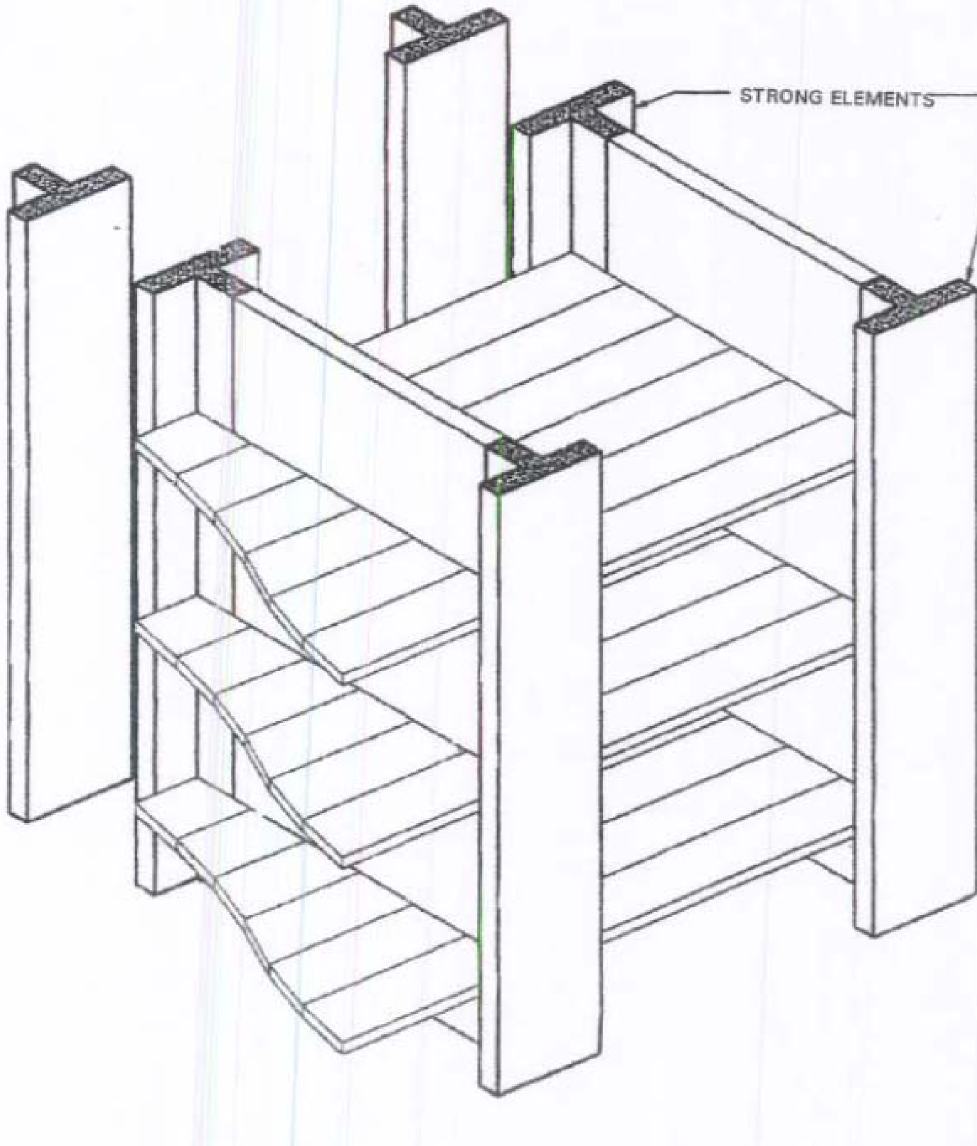
ALTERNATE PATHS

FIGURE 2



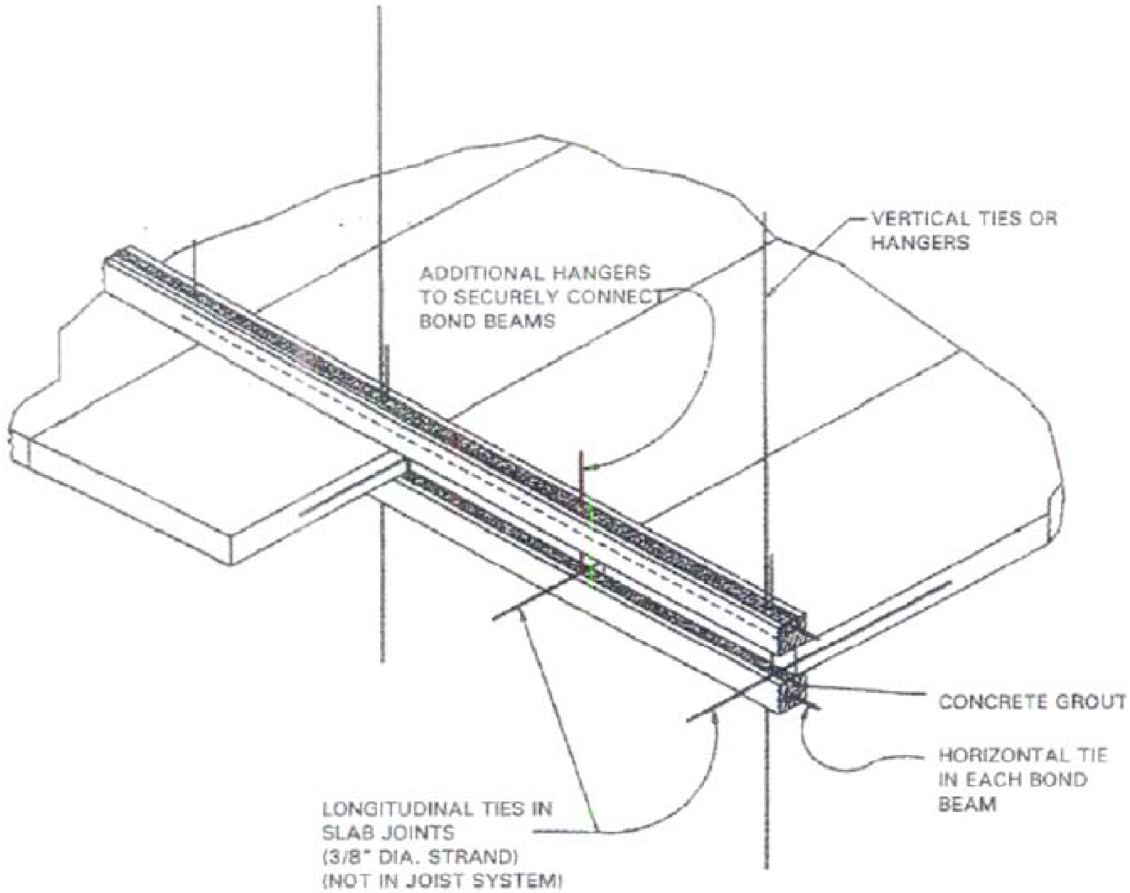
ARCHING ACTION BETWEEN STRONG ELEMENTS WITHIN WALL

FIGURE 3



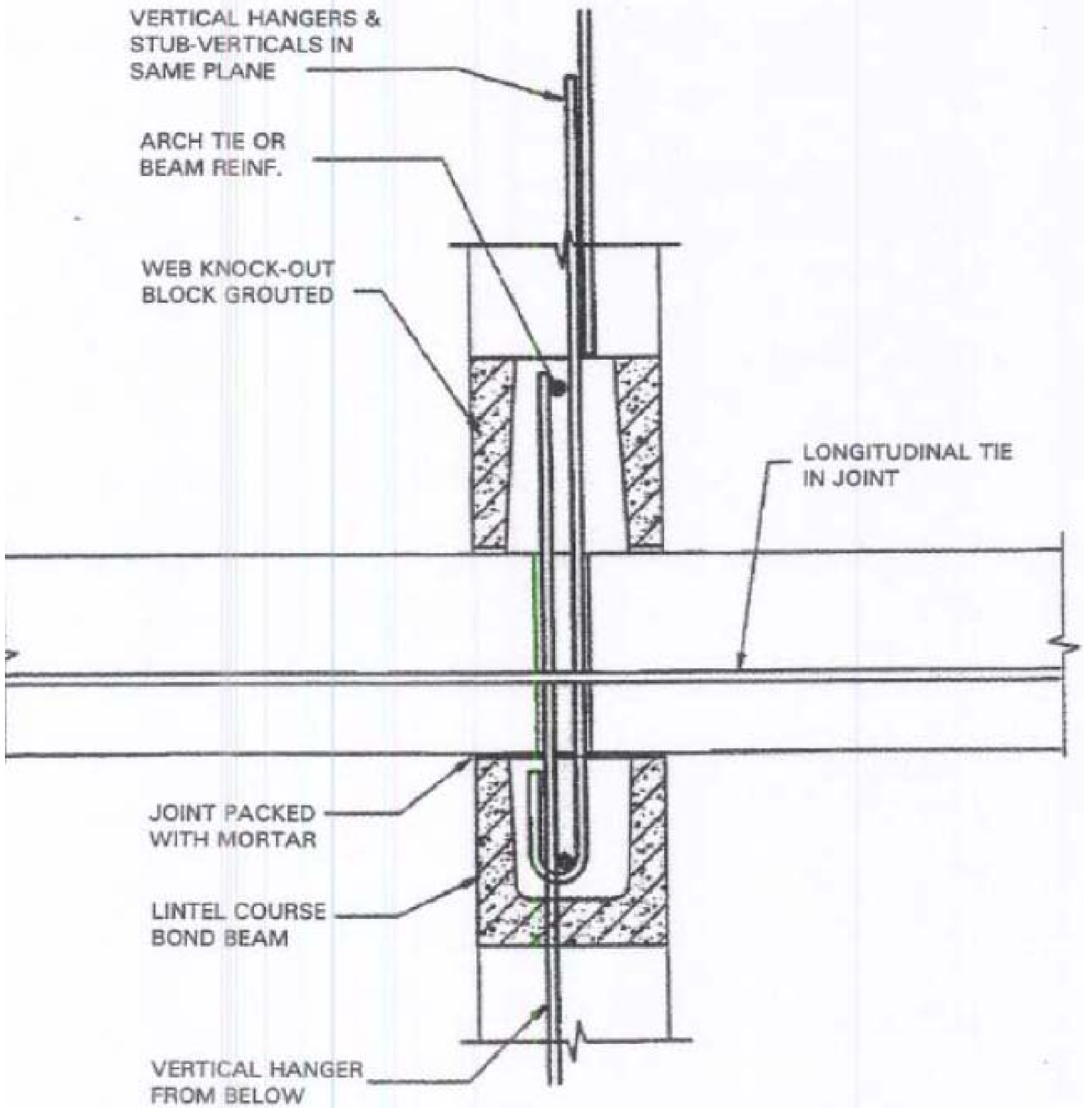
RETURN WALLS USED AS STRONG ELEMENTS

FIGURE 4



ESSENTIALS OF P.C. SLAB
CONNECTIONS AT INTERIOR WALL
(SEE FIGS. 5A & 5B FOR P.C. SLAB & STEEL JOIST IN DETAIL)

FIGURE 5



P.C. SLAB SECTION

FIGURE 5A

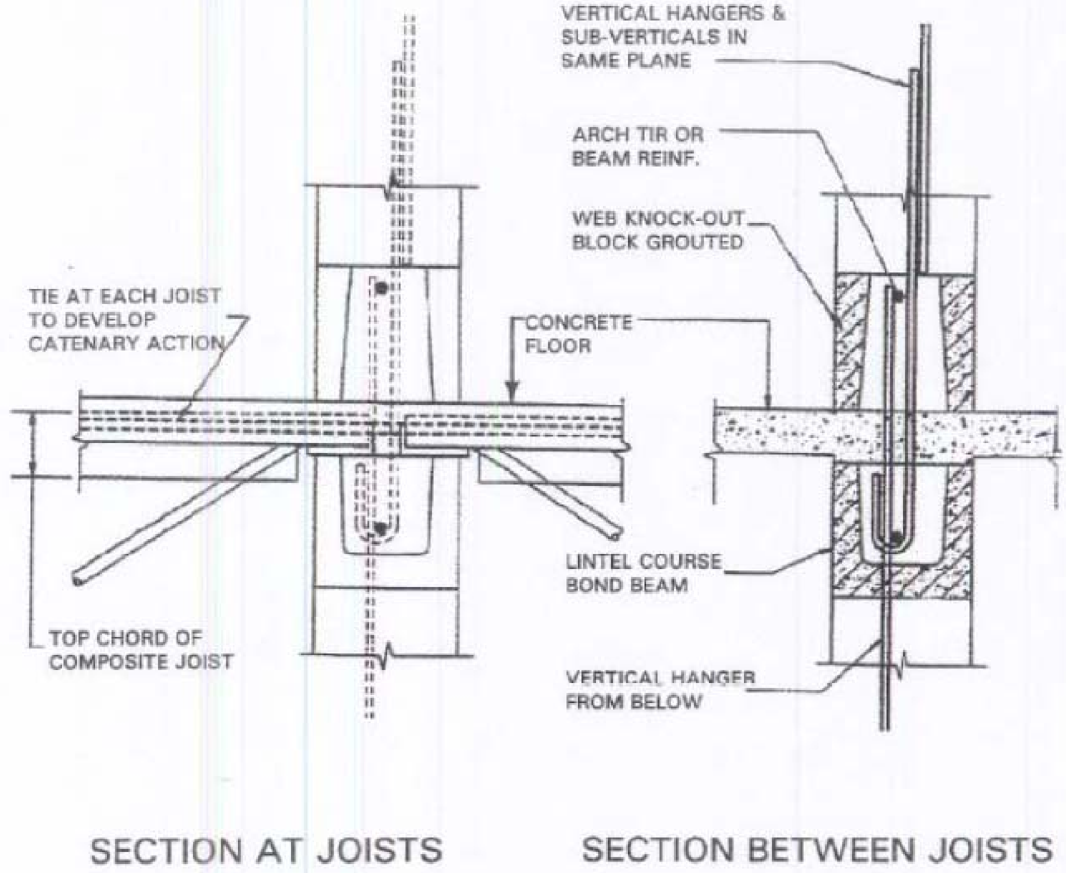
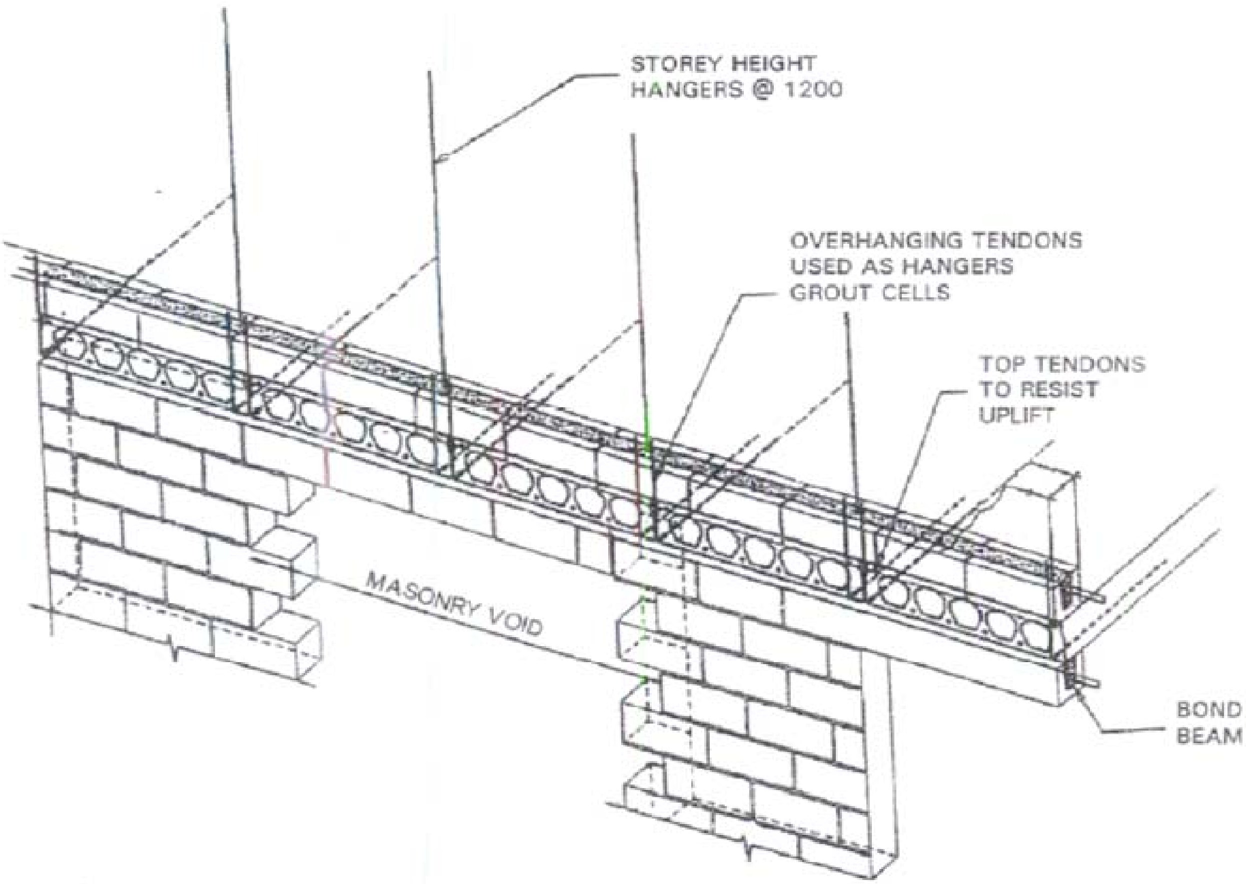


FIGURE 5B

NOTE: AT EXTERIOR WALL, EXTEND JOIST BEARING BEYOND CENTRELINE OF LINTEL BOND BEAM AND TURN TIE BARS UP INTO WALL TO DEVELOP ANCHORAGE



EXTERIOR WALL DETAIL

FIGURE 6

APPENDIX B

NOTES ON DEFLAGRATION PRESSURES AND PREDICTION OF PEAK GAS PRESSURE

NOTES ON DEFLAGRATION PRESSURES AND PREDICTION OF PEAK GAS PRESSURE

1. Empirical formulae

Several empirical formulas for the maximum or peak pressure generated by deflagration of an optimum air/gas mixture have been developed. The following formula, proposed by Cubbage and Marshall, is known to provide good correlation with experimental data of deflagrations in enclosures containing relief panels positively held to the enclosure **Reference 1:**

$$Pm = Pv + 23(S/\text{-}K\ W / V^{1}/^{3})$$

where,

Pm = maximum overpressure (mbar)
Pv = overpressure required to break vent (mbar) St =
burning velocity of gas-air mixture (m/s)
K = vent coefficient
W = weight of vent cladding (kg/m^L)
V = volume of enclosure (m^3)

Note: 10 mbar = 1 kN/m^2

The above formula, which was derived assuming a concentration of gas such that the maximum pressure is developed, is limited in application to situations when the following conditions apply:

i) Ratio of maximum to minimum dimensions of the enclosure is less than 3:1.
ii) Pv <= 490 mbar)
iii) 1 <= K <= 4
iv) 2.4 <=; W <= 24 kg/m^2
v) KW < 73 kg/m^2

2. Discussion of parameters affecting predicted maximum pressure

Overpressure required to break vent (P_y)

The value of Pv determines the duration of the confined deflagration phase, I.e. the interval between ignition and breakage of the vent. The shorter the confined phase, the smaller the pressure rise after removal of the vent will be. Therefore, in order to limit the maximum pressure generated by a deflagration, it is desirable that Pv be as low as possible.

Burning velocity (S_t)

For mixtures of natural gas and air, the maximum burning velocity in conditions of laminar flow is So = 0.45 *m/s.* In real situations, however, the typical condition is that of a turbulent flow. In such cases, the turbulent burning velocity can be computed as follows:

$$S_t = B\ S_o$$

where B = turbulence factor, which ranges from 1.5 to 5.0 in situations where turbulence is not present in an enclosure prior to ignition.

The choice of the appropriate B is rather subjective. A factor of 5.0 would be applicable to deflagrations propagating turbulently through large openings Into other sections of the enclosure or where obstacles are distributed throughout the entire volume of the enclosure. A factor of 1.5 is recommended for room size enclosures where the obstacles are all at one level (e.g. furniture). Assuming this is the condition typically found in an apartment, we have:

St = 1.5 X 0.45 = 0.675 *m/s*

Vent coefficient (K)

This coefficient, which takes into account the area of vent relative to the size of the enclosure, is defined as follows:

i. K = As / Av, if the relief panel is located on the face of the enclosure which has the largest cross-sectional area

ii. K = VV3 / Av , for other- cases

where As = largest cross sectional area of enclosure Av
= area of vent
V = volume of enclosure

For multiple vents in an enclosure, an equivalent vent coefficient, Ke_q, may be computed as follows:

1/K" = 1/K, + 1/K, + ...

where Kl. K_2, ...•. are the vent coefficients corresponding to the various vents.

Weight of the vent (w)

The parameter W reflects the inertia of the vent cover and accounts for the pressure required to move the vent cover a sufficient distance away to allow the establishment of a full flow of gas out of the enclosure after it has fractured. The heavier the vent, the larger the maximum pressure that would develop in the enclosure.

3. Peak gas pressure calculation in representative apartment suite

The following representative data was considered:

Floor area of enc10sure = 61.1 m^2

Window area provided = A_v = 15.2 m^2

Internal volume of enclosure = V = 61.1 x 2.44 = 149 m^3

Burning velocity of natural gas mixture = S_t = 0.675 m/s

Venting pressure = Pv = 45 mbar

Window thickness = 3 mm (Computed using Standard CAN/CGSB-12.20-M89, for double glazed sealed window panes with 1.0 x 1.5 m dimensions and designed to resist a specified wind pressure of 1.20 kN/m^2)

Weight of window = (2 x 0.003) x 2950 = 17.7 kg/m^2

i) Pressure for actual window area (25% of floor area)

K = V'I3/ Av = $149^{2/3}$ / 115.2 = 1.85

Pm = 45 + 23 x (0.675^2 X 1.85 X 17.7) $1149^{1/3}$ =

= 45 + 65 = 110 mbar = 11.0 kPa = 1.6 psi

II) Pressure for area of window = 10% of floor area

A. = 0.10 x 61.1 = 6.11 m^2

K = 1492/3/6.11 = 4.61

Pm = 45 + 23 X (0.675^2 X 4.61 X 17.7) $1149^{1/3}$ = =

45 + 161 = 206 mbar = 20.6 kN/m^2 = 3.0 psi

iii) Pressure for area of wil11dow = 15% of floor area

Av = 0.15 x 61.1 = 9.16m^2

K = $149^{2/3}$ /9.16 = 3.07

Pm = 45 + 23 X (0.675^2 X 3.07 X 17.7) /$149^{1/3}$= = 45 + 107 = 152 mbar = 15.2

kNjm^2 = 2.2 psi

REFERENCE

1. Harris, R,J, The Investigation and Control of Gas Explosions in Buildings and Heating Plant, E. & F.N.Span, London, in association with British Gas Corporation, 1983 .

APPENDIX C

EXPLANATORY NOTE FOR ARCHITECTS, ENGINEERS, AND CONTRACTORS REGARDING THE GUIDELINES FOR THE DISTRIBUTION OF NATURAL GAS IN MULTI-FAMILY BUILDINGS

GUIDELINES HIGHLIGHTS

Structural progressive collapse concerns apply to multi-family buildings with natural gas provided in-suite, exceeding four storeys (4) in height (p.1);

It is the responsibility of the building owner or his/her agent to ensure that the review and approvals required under sub-section 1.3 Structural Analysis are completed before the installation of the piping system starts in both new or existing buildings (clause 1.2.1);

The utility shall be satisfied that the review required under sub-section 1.3 Structural Analysis has been conducted before the start of piping system installation (clause 1.2.2);

Gas shall not be distributed to in-suite gas appliances in individual suites in a building identified to be prone to progressive collapse. Guidelines for assessing gas deflagration loadings and for assessing the potential for progressive collapse may be found in Appendix A (clause 1.3.2);

Section 2.0 Gas House piping and Utilization specifies requirements in addition to those contained in the Ontario Gas Utilization Code (clause 2.1.1);

Section 3.0 Gas Pipeline Systems applies only to gas piping systems upstream of the outlet of the utility meter set assembly; these piping systems shall conform to the requirements specified in the CSA Z662-07 Oil and Gas Pipeline Systems standard as adopted by the Director's Order of Amendment to the Oil and Gas Pipeline Systems Code Adoption Document.

There is greater emphasis on the part of building owners to provide information regarding the location of key gas system valves and to provide sign age which permits rapid location of suite shut-off valves in the event of an emergency (subsection 4.2);

Appendix A provides information in structural engineers' terms regarding how to identify existing building structural types which might be prone to progressive collapse if converted to gas, and guidelines on how to modify reinforcement in new buildings which would render them resistant to progressive collapse.

RECOMMENDATIONS FOR CONTENT OF STRUCTURAL CERTIFICATION LETTERS

EXISTING BUILDINGS UNDERGOING RETROFIT CONVERSION

Provide building address, the year the building drawings were approved for construction, number of storeys and the number of suites;

- State that the following document issued by the TSSA has been reviewed:

  Guidelines for the Distribution of Natural Gas in Multi-Family Buildings Third Edition dated April 2009 including Appendix A;

State which type of structure the building represents per sub-section 4.1, Structural Systems, of Appendix A, and whether or not it is a structure which has been deemed to be resistant to progressive collapse.

IMPORTANT NOTE:

A case has already been encountered where what appeared to be a straightforward structure of the first type described in Appendix A, Clause 4.1 (reinforced concrete one way spanning slab and shear wall construction), had important features missing from the drawings. If these features were missing in the actual building, one would not have a structure, which is resistant to progressive collapse under the guidelines of Appendix A. Structural consultants are urged to be intimately familiar with the buildings, which they are reviewing, particularly in the case of retrofit conversion projects.

NEW BUILDINGS NOT YET CONSTRUCTED

In the case of structures deemed to be resistant to progressive collapse, a letter is still required and the above recommendations for existing structure information apply;

It is recommended that the first sheet or drawing in the structural series of drawings for a new building contain a statement, which confirms that the structure meets the Guidelines;

In cases where the new construction involves a type of structure deemed to be prone to progressive collapse (i.e. the third type of structure described in the Guidelines), Appendix A of the Guidelines provides guidance on how to modify concrete reinforcement to render a structure resistant to progressive collapse. Following such a modification, a letter will be required from the structural engineer certifying that the structural design has been modified and complies with Appendix A of the Guidelines. The recommendations for existing structure information, and a statement of confirmation on the structural drawings would then apply.

SAMPLE STRUCTURAL CERTIFICATION LETTER AS PROPOSED BY LOCAL GAS UTILITIES FOR EXISTING BUILDINGS EXCEEDING FOUR STOREYS

(Style of letter to be written to the local Gas Utility by the professional Structural Engineer on letterhead relative to an existing building.)

Regional Utility Representative
Office of Appropriate Utility Sales

Re: *Existing Multi-Family Building, XYZ Building Street*
Address
City, ON

I, (Name of Engineer), Registered Professional Engineer in the Province of Ontario, structural engineer appointed by the owner to investigate compliance of the Building with the requirements of the TSSA Guidelines for the Distribution of Natural Gas in Multi Family Buildings Third Edition, dated April 30, 2009 (the "Guidelines"), confirm that I understand the intent of subsection 1.3 of these Guidelines. Where, I confirm that I am familiar with Appendix A of the Guidelines and have reviewed the design of the Building in accordance with the criteria set out therein.

I have examined copies of the original structural drawings for this building which were approved for construction by the *City of* XXX on *date* and which bear the Professional Engineers of Ontario seal of *Name of Engineer* and such other documents available to me to assist in my understanding of the building's design. Where important information on the drawings was incomplete, physical investigation was undertaken to confirm, to my satisfaction, that appropriate information was provided for construction.

The building under review is *(X)* storeys and consists of *(XX)* units. My examination of the building was undertaken specifically to determine compliance with the specific requirements of the Guidelines with respect to progressive collapse.

The building structure is: *(Enter one of the following)*

reinforced concrete walls supporting continuous one-way spanning floor slabs in which the minimum areas of reinforcement in each direction, the detailing intended to accommodate continuity moments and the original design live load stated on the drawings comply with the current Ontario Building Code and accordingly resistant to progressive collapse under the Guidelines.

Or

reinforced concrete columns and walls supporting reinforced concrete two-way spanning flat slabs, *(with/without)* drop panels, which incorporate structural integrity reinforcement complying with the requirements of CSA Standard CAN3-A23.3-M84, "Design of Concrete Structures for Buildings" and accordingly resistant to progressive collapse under the Guidelines.

Or

Describe the type o/construction if it does not conform to one of the two types identified above and give specific reasons why the construction may be considered to be resistant to progressive collapse.

I acknowledge that *(Name of Gas Utility)* as relying upon this opinion, to its detriment, with respect to its requirements for compliance with the Guidelines and agrees to identify and hold harmless *(Name of Gas Utility)* from all losses, claims, damages and actions arising, in any way whatsoever, from *(Name of Gas Utility)* reliance upon this opinion.

Signature

Engineer's Name **Engineer's Stamp**

SAMPLE STRUCTURAL CERTIFICATION LETTER AS PROPOSED BY LOCAL GAS UTILITIES FOR NEW BUILDINGS EXCEEDING FOUR STOREYS

(Style of letter to be written to local Gas Utility by the professional Structural Engineer on letterhead relative to an existing building)

Regional Utility Representative
Sales Office of Appropriate Utility

Re: *Existing Multi-Family Building, XYZ Building*
Street Address
City, ON

I, (Name of Engineer), Registered Professional Engineer in the Province of Ontario, structural engineer of record for the design of the Building have reviewed the TSSA Guidelines for the Distribution of Natural Gas in Multi Family Buildings - Fifth Edition, dated April 30, 2009 (the "Guidelines"), and confirm that I understand the intent of sub-section 1.3 of these Guidelines. Further, I confirm that I am familiar with Appendix A of the Guidelines and have reviewed the design of the Building in accordance with the criteria set out therein.

The building will be *(X)* storeys and consist of *(XX)* units.

The type of structure to be constructed is: *(Enter one of the following)*

reinforced concrete continuous one-way spanning floor slabs supported on reinforced concrete walls, complying with the current Ontario Building Code and accordingly resistant to progressive collapse under the Guidelines.

Or

reinforced concrete two way spanning flat slabs *(with/without)* drop panels, supported on columns and walls of reinforced concrete, incorporating structural integrity reinforcement as required by the current Ontario Building Code, and accordingly, resistant to progressive collapse under the Guidelines.

Or

pre-cast concrete slab floors or cast-in-place concrete slab on steel joists supported on masonry walls. Incorporated into the floors and walls are special structural details designed to provide resistance to progressive collapse in accordance with the structural details set out in Appendix A.

Or

(Describe the type of construction if it does not conform to one of the three types identified above and give specific reasons why the construction may be considered to be resistant to progressive collapse.)

Either: I conform that the field review of construction will be carried out under my direction.

Or: The building owner has engaged *(Name of Engineer)* to undertake the field review of construction, as required by the current Ontario Building Codes.

I acknowledge that *(Name of Gas Utility)* as relying upon this opinion, to its detriment, with respect to its requirements for compliance with the Guidelines and agrees to indemnify and hold harmless *(Name of Gas Utility)* from all losses, claims, damages and actions arising, in any way whatsoever, from *(Name of Gas Utility)* reliance upon this opinion.

Signature

Engineer's Name

Engineer's Stamp

l/fsesb/oa/guidelines.fifth draft, April 30, 2009.doc