D.B.R. facilities for fire resistance studies

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TECHNICAL NOTE

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SUBJECT D.B.R. Facilities for Fire Resistance Studies

The furnace laboratory which houses the fire resistance test facilities is a major part of the Fire Research Building. The building is a part of the Building Research Centre of the Division of Building Research and is located on the Montreal Road property of the National Research Council, on the east side of Ottawa. It was completed in March 1958.

The fire resistance test facilities consist of two furnaces, complete with auxiliary equipment, together with the associated facilities for construction, handling, conditioning and disposal of large test specimens. The design of the special facilities contained in the laboratory was carried out concurrently with the design and construction of the building itself, by a separate firm of consultants, Messrs. Ewbank and Partners (Canada) Ltd., working in co-operation with the architects and engineers for the building. The Building contract provided for the overhead crane rails and the furnace pits and certain concealed piping. The large overhead building crane, the chimney, the fuel supply, the furnaces (with controls, flues and induced draft equipment) large panel loading frames and the hydraulic equipment were provided in separate contracts. This work was completed and the furnaces were put under test in September 1958. The outdoor work yard with its materials handling facilities was constructed by Plant Engineering Services, N.R.C., and was completed in November 1958.

Furnace Type and Size

The kinds of furnaces to be provided and their size were the main determinants of the laboratory dimensions. Existing facilities in other countries were studied carefully over several years, and the Canadian needs for research and testing both current and future were taken into consideration.

It was decided to provide a wall panel furnace and a floor panel furnace leaving out for the present, at least, further consideration of a column furnace and a beam furnace.

The minimum acceptable size of wall furnace was set by the desire to be able to test to the current U.S. and British standards, and a nominal panel (furnace) size of 12 by 12 ft. was selected. (Panels constructed in frames or fitted with framing members may be 14 by 14 ft in size.) This dimension in turn largely determined the height of the laboratory since it was desired to use an offset, forked jig hanging from the crane to lift the panels into the furnace loading frame. This lifting jig must clear the top of the furnace loading frame. The maximum clear distance under the crane hook was therefore set at 28 ft clear of the floor, and this in turn set the building height at 40 ft. The height of the main door was set at 24 ft.

The floor furnace size was, after like consideration, set at 12 by 15 ft nominal. It was considered that a floor furnace of this length might be adapted for many beam tests. Provision was made in the planning for an extension to 25 ft. in future. With the panel width decided, it was possible from information on floor furnaces elsewhere to estimate the probable furnace width, making due allowance for furnace wall thickness, burners and piping. To this was added the minimum clearances considered necessary for traffic past the furnace, leading to a requirement for building width of 40 ft, centre to centre of columns.

Floor panels are constructed, handled and tested in retaining frames which may extend at least 18 in. beyond the panel on all sides. This provided a probable minimum frame size of 15 by 18 ft which in turn indicated a desirable main door width of 17 ft 6 in. The floor panel plus frame provided the maximum load to be lifted, and determined the crane capacity of 30 tons.

Furnace Laboratory

The laboratory consists of a single large room 120 ft long, 40 ft wide and 40 ft high. It can be extended another 40 ft in length within the present building, if necessary, in the future by expanding into an area at present set aside for model studies. The structure consists of large rigid frames spaced 20 ft on centres on a span of 40 ft. These frames also carry the girders and rails for the 30-ton overhead crane which can run the full length of the laboratory and provides 28-ft clearance from the floor to the maximum elevation of the hook. The interior finish for the laboratory walls is provided by glazed tile which facilitate cleaning down when necessary.

Storage of Specimens

Space for the storage of specimens while curing and drying has been provided at one end of the laboratory. One bay (20 by 40 ft) is used for this purpose, with wall specimens stored vertically in one half of the bay (20 by 20 ft) and floor specimens stored horizontally on top of a mezzanine in the other half. While storage accommodation is limited, at least four wall and three floor specimens can be accommodated at one time. It is proposed to enclose this storage area with some form of light movable construction which will make it possible to maintain special conditions for controlled drying while still permitting the use of the overhead crane for handling specimens. Provision has been made under the mezzanine for air heating and handling equipment.

Because of low outdoor temperatures in winter, the laboratory atmosphere will normally be between 10 per cent and 35 per cent relative humidity for as long as 6 months. Summer humidities which may rise naturally to 85 per cent (at 85°F) can be reduced to an acceptable value for drying by raising the temperature about 20°F. It is proposed to employ the natural dryness of winter air, and reduction of humidity by heating in summer to provide suitable humidities for drying within the enclosure, when necessary.

Construction Area Within the Laboratory

The floor area provided within the building for construction is limited. An area approximately 30 by 40 ft has been provided adjacent to the large side door and between the furnaces and the storage area. A maximum of two floor panels (requiring 20 by 20 ft of floor each) or a much larger number of wall specimens (requiring 6 by 20 ft each) might be constructed there at one time. This same area must also be used at times for bringing heavy materials from outside within reach of the crane and in the handling of panels and loading and lifting gear.

Outdoor Work Yard

An outdoor area of 120 by 120 ft adjacent to the large door on the south side of the furnace laboratory has been fully developed as a construction and storage area. It has been levelled, equipped with a grid system of standard gauge trackage and paved. The track begins within the furnace laboratory, centred on the large 18 by 24 ft door, and runs to the far side of the yard. There are three tracks crossing at right angles, providing 16 unit storage areas each 20 by 25 ft.

Steel cars made by welding suitable frames to salvaged street car trucks have been provided to handle individual loads up to 30 tons. Turntables were considered expensive as well as impractical under severe winter snow and ice conditions. Loads are carried on steel frames set on the cars. For switching, the load-carrying frames are raised on four hydraulic jacks while the car is replaced by a second car run in at right angles. A 5000-lb. car puller with a system of pulley blocks has been provided for moving cars.

A simple rectangular frame of 32 ft span, 21 ft high, has been erected over one of the track intersections. It has been equipped with an overhead 5-ton electric hoist and a 24-ton chain hoist and can be used for transferring loads from one car to another as well as for unloading large loads delivered by motor transport without the need to run them into the laboratory under the 30-ton crane.

The work yard will provide for construction of panels outdoors in summer and for the handling and storage of many pieces of heavy gear, including extra panels and other furnace closure devices as well as materials used in panel construction. The cross track immediately adjacent to the building terminates at a retaining wall, over which materials to be discarded can be dumped, to be removed later at convenient intervals by suitable loading and hauling equipment.

Control Room

A control room 25 ft long by 13 ft wide set back from the south wall of the laboratory has been provided and various instruments including the temperature program controller for the furnaces are installed on a panel in this room. Trenches have been laid in the control room floor and in addition a number of 3 in. fibre ducts leading to the two furnaces have been installed beneath the furnace laboratory floor so that all wiring, capillary tubing, thermocouple leads, etc., are under the finished floor.

Supply Air

Equipment has been installed to provide from 3000 to 6000 cfm maximum of filtered and heated supply air as required. This system will replenish the air taken from the laboratory for combustion.

Observation Gallery

An enclosed observation gallery at the first floor level overlooks the furnace laboratory. This gallery is at the east end of the furnace laboratory and is located in the front wing of the building.

Furnaces and Loading Systems

Current standard test procedures call for both wall and floor panels to be exposed to a standard fire condition while loaded, if panels simulate load-bearing construction, or restrained, if considered non-load-bearing. The main equipment involved which has thus far been referred to as a furnace actually consists of a furnace proper and a loading device. These two components are now to be discussed separately.

Wall Furnace

The wall furnace consists essentially of a movable burner assembly open at the front, with the burners located in the rear wall of the unit. The combustion chamber is completed when the front face of the burner assembly is fixed to the specimen under test. In this position the top of the furnace is immediately under the flue used for removing the combustion gases.

The size of the specimen exposed to the combustion chamber is 12 by 12 ft, although the loading frame itself will accommodate a specimen 14 by 14 ft. The heat in the combustion chamber is supplied by 100 burners having a capacity of 50 cubic ft of gas per hour at a pressure of 25 lb. per sq in. The fuel used is propane having a gross heating value of approximately 2500 Btu per cu ft, thus the maximum total heat input is approximately 12,500,000 Btu per hour.

Floor Furnace

The floor furnace in contrast to the wall furnace is a fixed installation. The burners are installed in the two long sides and the two flues are permanently connected to the common flue used for conducting the flue gases from the building. The combustion chamber is completed when the specimen is laid on top of the furnace.

The furnace at present will allow a floor specimen to have an area of 12 by 15 ft exposed to heat. When using this furnace for the testing of beams it will be possible to extend a beam past the furnace wall and load this portion of the beam as well.

Heat is supplied by means of 30 burners, (15 on each side), each burner having a capacity of 220 cu ft of gas per hour at 25 lb per sq in. pressure. As in the case of the wall furnace, propane will be the fuel so that the gross heat input is approximately 16,500,000 Btu per hour.

Fuel System

Liquid propane is stored in a 1,750 gallon tank located outside the building. When operating the furnaces the liquid is passed through 3 vaporizers, each capable of vaporizing 70 gallons of propane per hour at 25 psi. The gas is then piped underground in a 4-in. pipe to the building. Inside the building the propane then passes through a diaphragm motor control valve which closes if there is a failure of the control air. In addition there is a 3-way solenoid valve which, in the event of fan failure, vents the air from the diaphragm motor valve causing it to close. There is also a pilot flame bypass valve in the line before the motor control valve and two shut-off lever-handle gas cocks immediately after this valve which direct the flow either to the floor or the wall furnace. The wall furnace has ten banks of burners with ten burners in each bank while the floor furnace has five banks of 3 burners each on each side. Each group of 3 burners is fitted with a solenoid actuated shut-off valve and pressure gauge.

Combustion Control

The combustion control for both of the furnaces is furnished by a potentiometric temperature program controller which follows the time temperature curve designated in the current U.S. Standard, ASTM E119-57, Standard Methods of Fire Tests of Building Construction and Materials.

The temperature fixed by the curve is the average temperature obtained from readings of nine thermocouples connected in parallel and symmetrically distributed around the test specimen. The lighting up of the burners and the initial period of furnace operation is accomplished with the furnace control on manual setting. Each burner has a pilot burner as an integral part and it is necessary to ignite a number of these pilot burners individually to start the combustion process. When satisfactory combustion conditions are definitely established the controller is then transferred to automatic control. The fuel input is normally at a maximum at the beginning of the operation and gradually diminishes in accordance with the demands created by the furnace. When the fuel requirements approach the minimum firing rate of the burners, the controller actuates a pressure switch which is arranged to cut out a preselected number of burners.

Draft Control

Draft control equipment has been installed which maintains a furnace draft of 0.1 in. water gauge. A pneumatic draft controller, equipped with a 2-way selector switch, positions the induced draft fan outlet damper to maintain a substantially constant furnace draft of 0.1 in. water gauge when one furnace is in operation.

Chimney Temperature Control Equipment

The flue gases are ultimately exhausted through a radial brick chimney located outside the building after having passed through the induced draft fan. The temperature of the flue gas (max. 2300°F) to the induced draft fan is lowered by entraining air (air-gas ratio 4 to 1) through cowls into the ducts leading to the fan. A pneumatic temperature indicating controller adjusts the tempering air supply so that the flue gas air mixture temperature at the induced draft fan is maintained at 550°F.

Wall Loading System

The main components of this loading system are a strong structural steel frame and a number of hydraulic jacks fitted into the frame. There are eight jacks located in the top member and in each of the side members while the bottom member has 6 jacks and 2 fixed supports. The capacity of the jacks is 30 tons each, thus a maximum vertical load (12-ft span) of 10 tons per ft can be applied. The jacks have a 6-in. stroke and when they are in their retracted position the opening between the jackpads is slightly more than 14 by 14 ft. Wall specimens are built on reinforced concrete sills (1 ft high by 14 ft long). Thus the maximum size of a wall panel which will fit in the opening is 13 by 14 ft. When necessary, in order to accommodate smaller panels and to provide a good bearing surface for the jacks, spacers are used between the edges of the panel and the jacks.

When testing a load-bearing wall, the upper jacks apply the load while the side jacks are used to help steady the specimen. In the case of a non-load-bearing wall the side jacks are used for restraining the specimen. In all cases the two fixed supports in the lower frame member support the specimen when it is first placed in the frame while the clamp in the upper member holds it in position until the loading jacks are in place.

Floor Loading System

When testing floors, a system utilizing hydraulic jacks loads the specimen which rests in a frame that both supports and if necessary restrains the specimen. There are 30 jacks, each having a capacity of 30 tons so that on an area of 180 sq ft (12 by 15 ft specimen) the maximum loading is 500 lb per sq ft. The load is taken out through a structural steel frame to which the jacks are fixed. During a test this loading frame is fastened to the frame supporting the specimen. Prior to a test the specimen is constructed in the latter frame which also facilitates the movement of the specimen from one location to another.

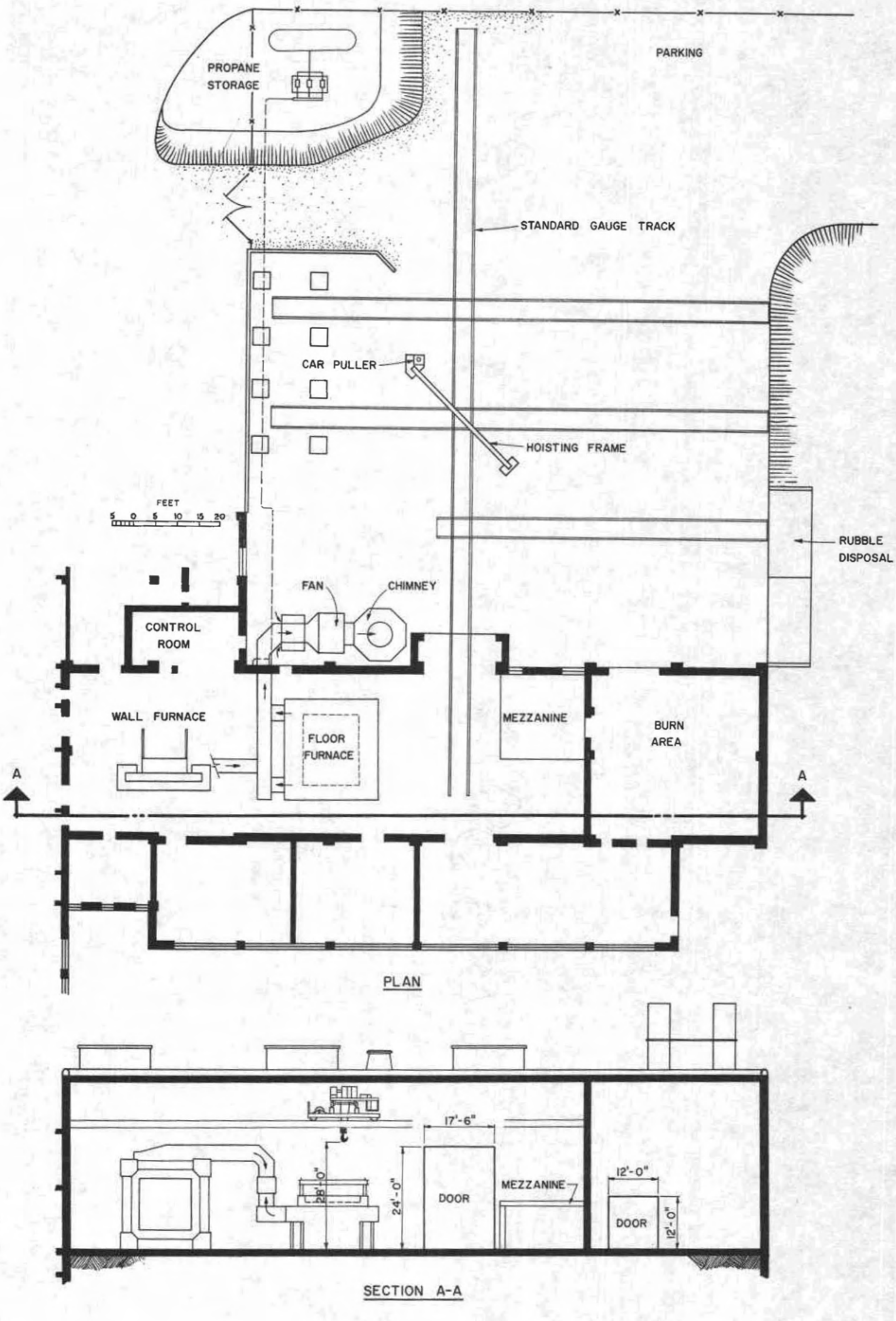
Comments

The burners, which induct the full air supply required for combustion, produce a non-luminous flame. It is debatable whether a non-luminous or a luminous flame provides the more desirable fire test conditions. A decision was made to provide the former since it permits more positive combustion and control, though this may not be the best simulation of a building fire.

The floor furnace was not provided with a means of access other than by lifting the panel from the top. This is a potential weakness which may yet have to be rectified. A large vertical slot in the west end of the furnace, to be filled with removable fire brick, could provide access and in addition would have been useful when testing beams which are longer than the furnace.

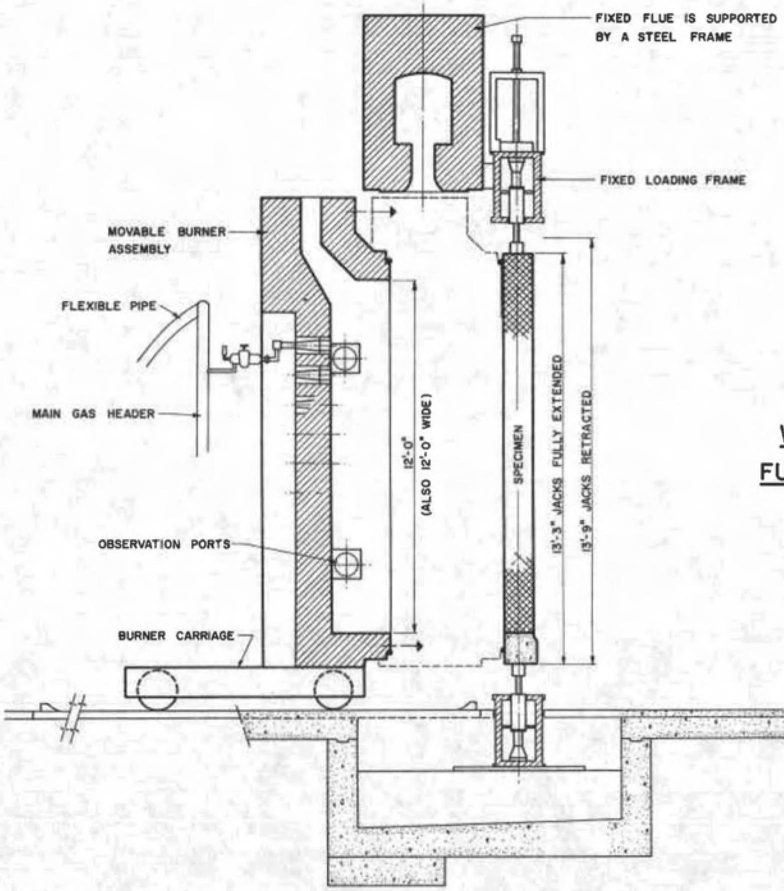
It is now evident that a long catwalk running the length of the north wall of the furnace laboratory, fixed to the steel frames, about 15 feet above the floor would have been most useful. This would have provided a means of supporting wall panels to prevent overturning when they are set close to and parallel to the North wall. The furnace frames themselves do offer this same possibility, but a catwalk might have been more convenient in this regard, while providing in addition a working platform at a useful level for other purposes.

Many minor improvements in addition to those noted will no doubt become evident with extended use of the facilities. Experience with the furnaces thus far has not indicated the need for any major changes to the basic design.



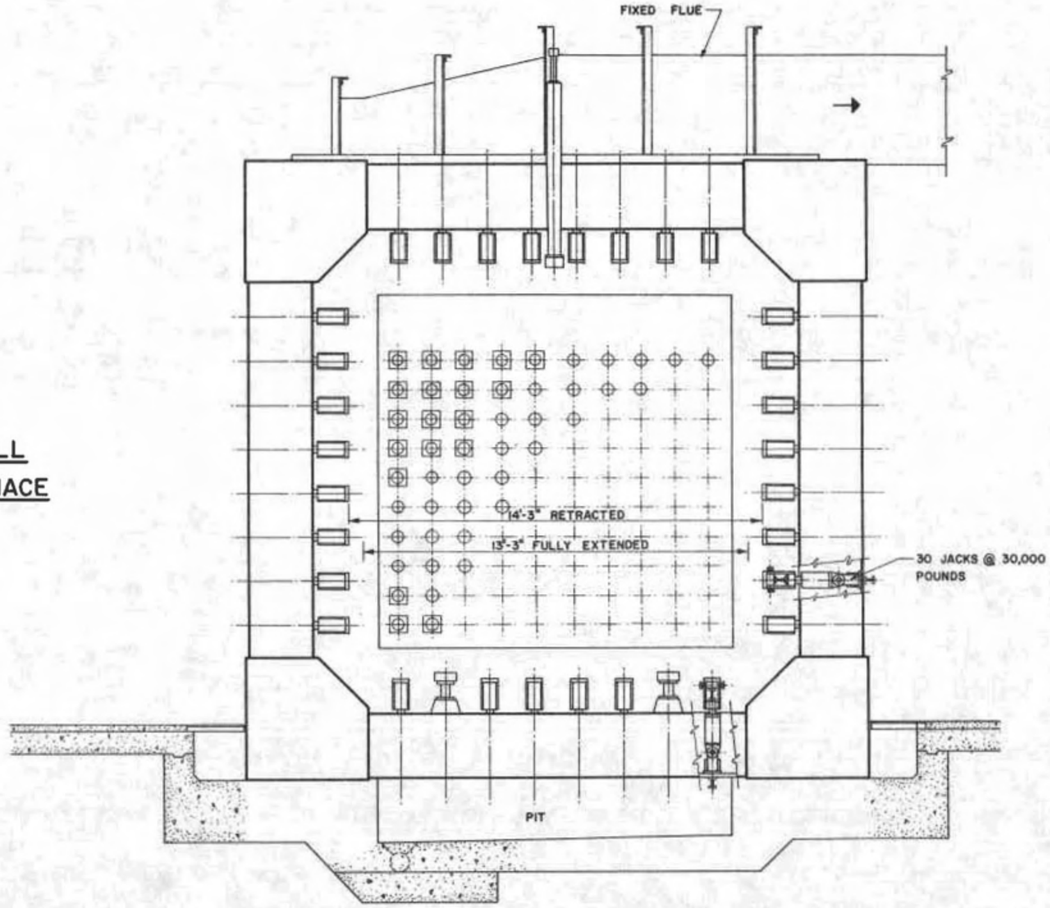
PLAN OF LABORATORY & OUTSIDE WORK AREA

FIRE BUILDING, N.R.C.

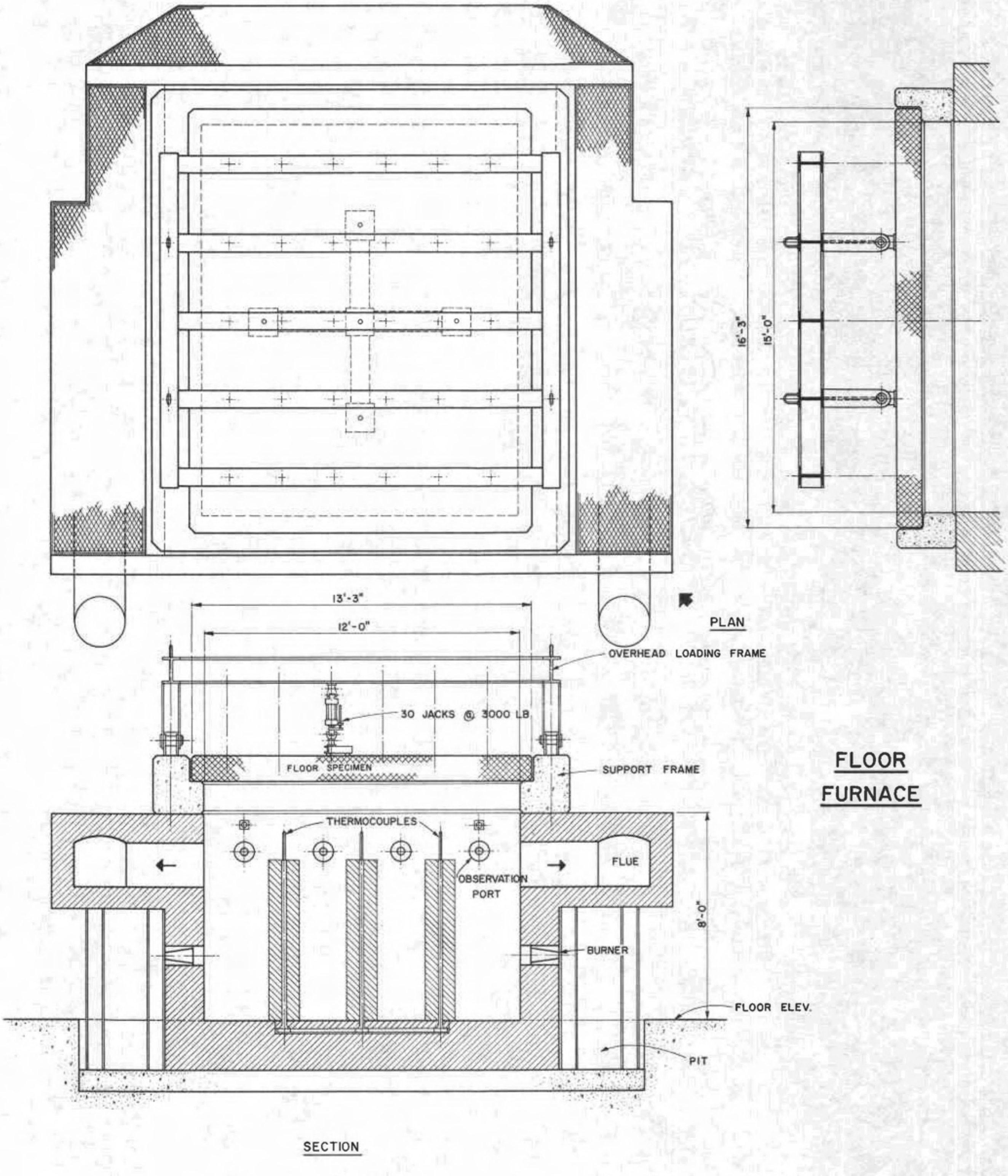


SECTION

WALL FURNACE



FRONT ELEVATION WITH TEST SPECIMEN REMOVED



FLOOR FURNACE