The Canadian Brine Limited Brine Field at Windsor, Ontario

by
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ABSTRACT

In the spring of 1957, Canadian Brine Limited, a subsidiary of The Canadian Salt Company Limited, undertook to develop a brine field at Windsor, Ontario, to supply the Detroit plant of Solvay Process Division of Allied Chemical Corporation. The field was to have a capacity of 145 tons per hour of dry salt as brine containing not less than 306 gpl. sodium chloride. One of the major considerations was to bring this project into operation as quickly as possible.

A system of eighteen wells, together with the necessary 2,000 gpm. pumping station, water and brine lines, was laid out and construction commenced in April, 1957. By May, 1958, the brine field was in operation and in the fall of that year it was up to rated capacity.

The well system was developed by hydrofracing, a technique embodying the connection of adjacent wells through the salt bed by fracturing the formation with water at high pressure and dissolving channels through the bed from one well to another. It was the use of this technique that permitted the development of a brine field of this capacity in so short a time.

INTRODUCTION

The Windsor, Ontario, brine field of Canadian Brine Limited, a Subsidiary of The Canadian Salt Company Limited, was developed to supply brine to the Detroit plant of Solvay Process Division of Allied Chemical Corporation. The brine field is located near the western limit of the City of Windsor and about one mile from the Detroit River. It adjoins the Windsor plant of The Canadian Salt Company Limited which fronts on the River directly across from Solvay in Detroit.

The provisions of the contract between the parties called for the supply of brine on a continuous basis at a maximum rate of 145 tons of dry salt per hour as brine containing not less than 306 grams per litre of sodium chloride. It was further provided that the facilities were to be constructed as quickly as possible but, in any case, deliveries of brine up to the ultimate requirements must be made within three years.

Construction of the brine field and auxiliary facilities started in the spring of 1957 and was completed early in 1958. Deliveries of brine to Solvay commenced in May, 1958, and by the fall of that year, the field reached its required capacity. It has been in continuous operation since that time.

DESIGN CONSIDERATIONS

Canadian Brine Limited owns a 194-acre tract of land near The Canadian Salt Company Limited plant and has mineral rights under an adjoining 165 acres of City of Windsor property. Figure 1 shows the layout of the respective properties of Canadian Brine Limited, The Canadian Salt Company Limited and Solvay Process Division.

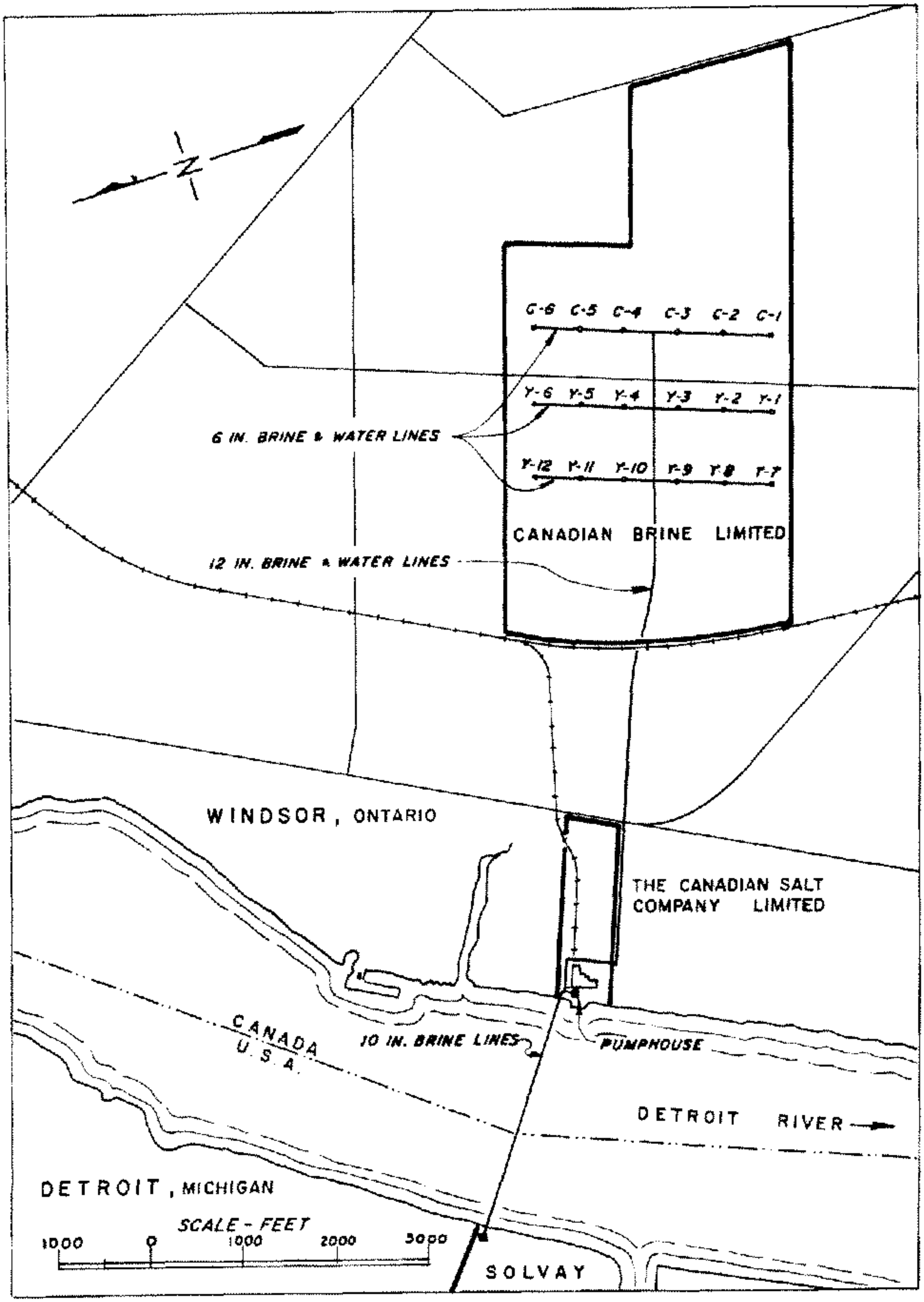

Figure 1. Map of the Canadian Brine Limited property and facilities.

The basic consideration in the design of the brine field itself was the decision to interconnect the wells by hydraulic fracturing or "hydrofracing." Eighteen wells were laid out in three rows of six with 500 feet spacing between the wells and 800 feet between the rows, all as shown in Figure 1. The number of wells and their spacing was decided arbitrarily on the basis of our rather scant experience with hydrofracing one pair of wells at Windsor and some knowledge of work done by others. It was felt that both the 500-foot spacing and the number of wells in relation to the production required represented a conservative approach. Time limitations, however, prevented experimentation.

The pumping station at the Detroit River and the water and brine piping are a fairly standard installation. In the pump house, there are two sets of water pumps, each set capable of 2,000 gpm. at 300 psi. Water is delivered to the field through about 7,800 feet of 12-inch diameter welded steel pipe. Branch water piping to each row of wells is six-inch welded steel as are the return brine-gathering lines from each row of wells. The brine is returned to the pump house through another 12-inch header. A third 12-inch line parallels the other two and acts as a standby. All pipes are wrapped with a bituminous coating and cathodically protected.

Brine from the field is discharged into an open tank at the pump house for de-aeration and is them pumped through two ten-inch extra heavy welded steel pipelines under the Detroit River to the Solvay Plant. These pipelines are also wrapped and cathodically protected.

The total water flow to the field and the brine flow from the field are metered at the pump house and the water into, and the brine out of, each individual well is metered at the well head. All meters are Sparling bronze brine meters.

Drilling, hydrofracing, and the construction of the pumping and pipeline facilities proceeded concurrently. A temporary water supply for the drilling rigs and for hydrofracing was provided from The Canadian Salt Company brine field water system through about 1 1/2 miles of six-inch irrigation pipe laid on top of the ground.

GEOLOGY

Salt at Windsor occurs in the Salina formation of the Upper Silurian Age in the B, D, and F subdivisions. These beds form the east margin of the large salt basin centered in Michigan. They are reasonably flat in the Windsor area, showing a regional dip to the Southwest of about twenty feet to the mile.

The B member is the main upper salt unit and is the bed used for brine production at Windsor. It consists of about 200 feet of salt, containing thin dolomite layers and occurs between approximately 1400 feet and 1600 feet below the surface. Figure 2 shows a generalized geological section of the Windsor area and Figure 3 shows a graphic core of the salt formations in one of the wells plotted on a Radioactivity log of the well. From the top of the Detroit River group to the bottom of the Bois Blanc formation, several heavy flows of water containing hydrogen sulphide are encountered.

WELL DEVELOPMENT

Of the eighteen wells, thirteen were drilled with a rotary drilling rig and five with cable tools. The casing program for both groups, however, was the same. Sixteen-inch surface pipe was set and cemented at the top of the rock, approximately 100 feet. An intermediate string of 12 3/4 inch casing (actually line pipe) was set at approximately 750 feet. The decision to install this intermediate string was based on the possible effects on the hydrofracing, and on the life of the wells, of the lost circulation zones in the porous water-bearing measures in the upper formations. It was felt that shutting off these formations might result in a better cementing job in the production casing and also that encasing the production string in cement might offer protection to the production casing against the corrosive effects of the hydrogen sulphide.

Two of each group of three wells were cased with production strings of 8 5/8 inch J-55 well casing and the remaining well with 7 inch. The larger casing was used to provide room for deep-well pumps in the event that their use might later become necessary. It is now felt, however, that pumps will never be used, since the salt formation appears tight and it is now intended to

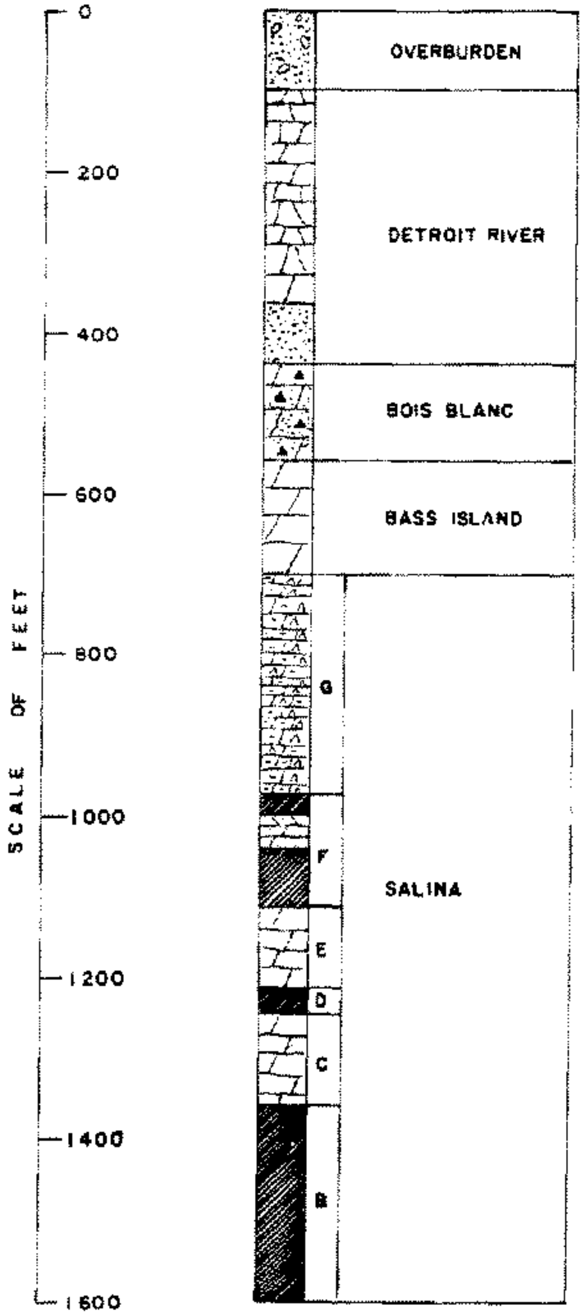

Figure 2. Generalized columnar geological section of the Windsor area formations to 1600 feet.

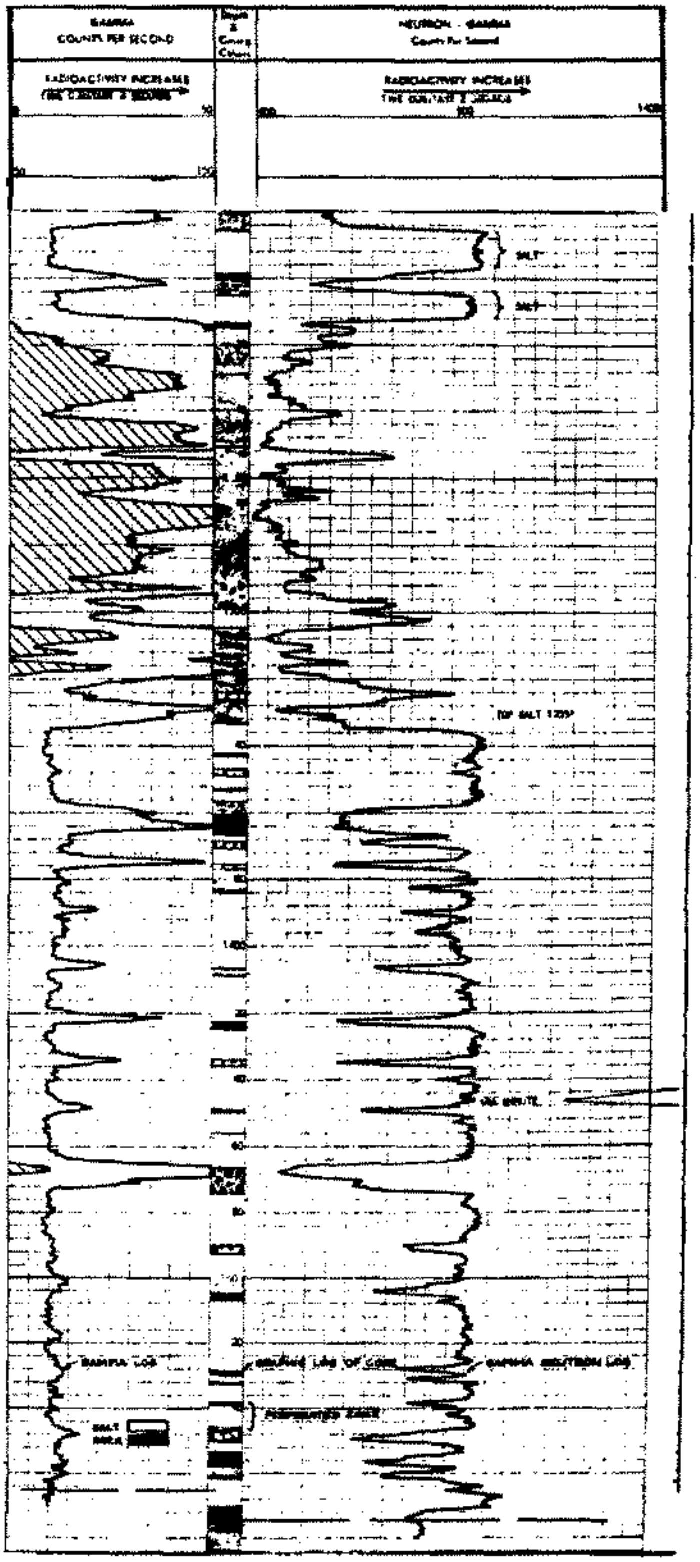

Figure 3. Graphic log of a well core superimposed on the Radioactivity log of the well.

abandon the wells before solution reaches the top of the salt bed. In fourteen of the wells, the production casing was run through the salt bed. The remaining four wells were cased to the top of the hydrofracing zone for reasons discussed later.

The surface and intermediate casings were cemented with a Portland cement-water grout, while the production casings were cemented with a grout made from cement mixed with 25 per cent excess salt over that required to saturate the water added.

As indicated previously, the brine field was developed by means of the hydrofracing technique. The fracturing of formations by the application of hydraulic pressure has been for some time a recognized technique in the petroleum industry for the promotion of better recovery of oil and gas. The application of this technique to the development of brine wells has just come into some degree of prominence in the last few years.

Essentially, the method consists of applying a sufficient water pressure to a relatively thin section of the salt bed in one of two or more wells to induce a fracture in a more or less horizontal plane. Continued pumping causes water to flow into the formation, enlarging the fracture until it reaches a second well. Further pumping eventually dissolves a channel between the two wells.

Since in a bedded deposit which is continuous over the area to be developed, it is logical to expect the fracture to spread along the bedding planes, it is important that the fracturing take place at the same point in the formation in each well to be connected in a given group. Also, since virtually all salt dissolving takes place in the roof of a brine cavity, it is obviously mandatory to fracture at or near the bottom of the salt bed. The fracture is usually initiated by perforating, undercutting or notching the zone to be fractured prior to applying the water pressure.

When the stratum in which the fracture is to be made has been chosen by inspection of the core and Radioactivity log of one well, it can be located in other wells by inspection of the Radioactivity logs of these wells. Figure 4 gives the Gamma Neutron logs of three of our salt wells and shows the similarities between logs which enable the formations to be correlated. The actual hydrofracing zone chosen in the Windsor field was located in an eight-foot bed of salt between two rock stringers near the bottom of the salt bed as shown in Figure 3.

Fourteen of the eighteen wells (Y-1, Y-2, Y-3, Y-4, Y-5, Y-6, Y-7, Y-8, Y-10, Y-11, Y-12, C-2, C-5, and C-6) were cased and cemented through the salt bed and perforated at the hydrofracing zone with three strings of sixteen Halliburton Jumbo Jet charges, the charges on each string set on six inch centres. The remaining four wells were treated differently. In wells Y-9 and C-3, a flow of water injected into well Y-2 had entered these wells prior to their being cased. It was therefore felt that if these wells were cased and cemented through the hydrofracing zone, the cement might flow out into this zone, with the possibility that a subsequent connection of these wells would be interfered with. In addition, the loss of cement into this zone might prevent proper cementing jobs on the wells. Therefore, these wells were completed by plugging back with crushed stone to a point just above the hydrofracing zone. On top of the stone a three foot plug of cement was installed and the casing set on this plug and cemented. The cement plug and stone were then drilled out.

In the later stages of the well-drilling program, the idea was put forward that the perforated casing might act as a restriction to flow into the target wells. An alternative method of completion was therefore tried out on wells C-1 and C-4. This method consisted of drilling through the salt bed, logging to find the hydrofracing zone, plugging back with cement to the top of the hydrofracing zone, setting and cementing the casing at this point, drilling out to the bottom of the hydrofracing zone and then perforating the uncased hydrofracing zone.

No correlation between the methods of well completion and the ease of connecting the wells was apparent in the subsequent hydrofracing operations.

Two high-pressure plunger pumps were purchased for this project: An Oil Well Supply Division Model No. 48P-HD (5" X 8") Triplex Plunger Pump driven through a Model TC-850 Allison torque converter by a General Motors Model 122, 406 Series 110 Twin 6 Diesel Engine, and an Oil Well Supply Division 558-P (4" X 8") Quintuplex Plunger Pump driven through a chain drive by Model NHIS 600 Cummins Twin Diesel engines. The output of the Triplex pump was 360 gpm. at 1200 psi. and of the Quintuplex, 400 gpm. at 1200 psi. Either pump had sufficient capacity to

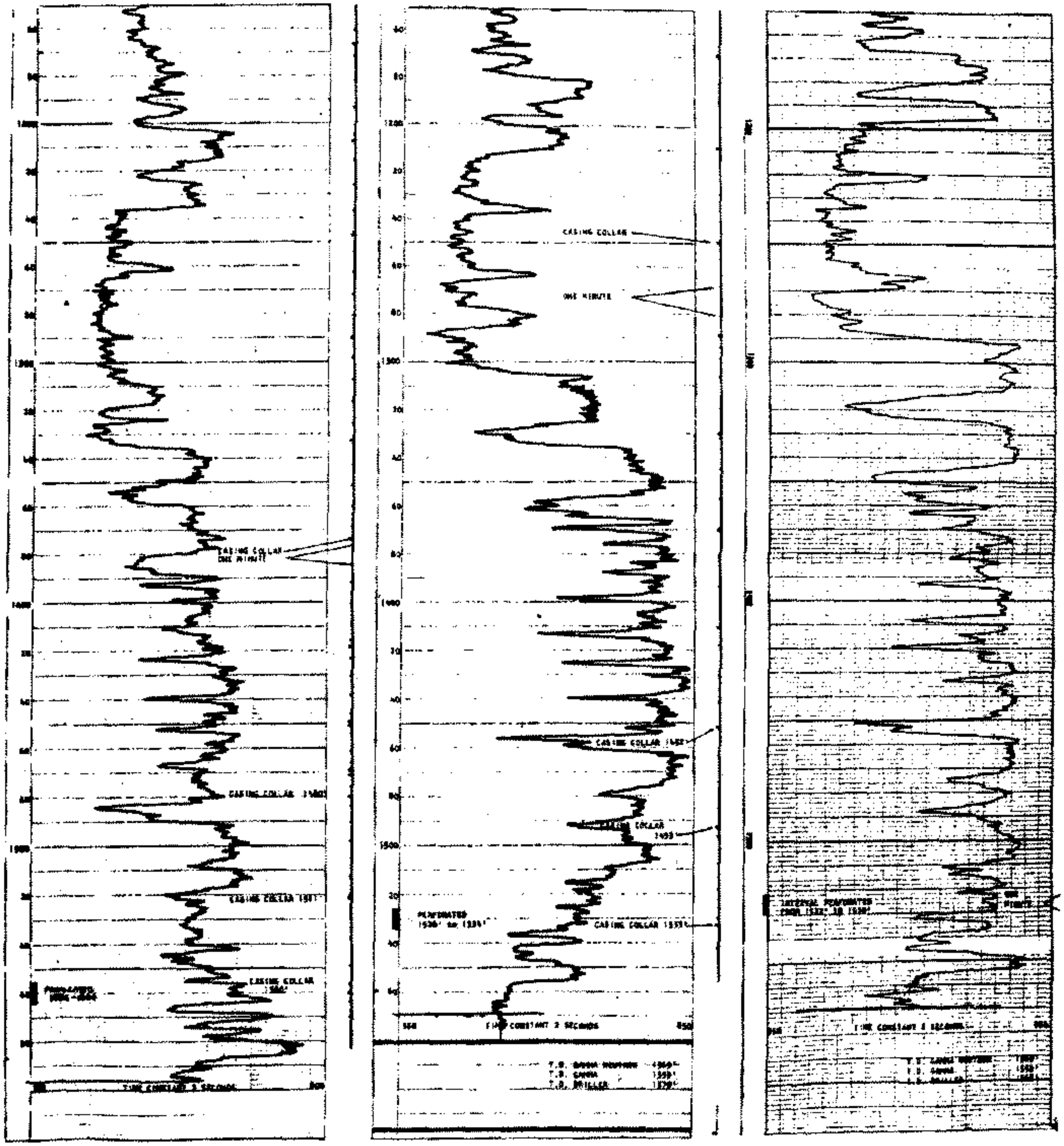

Figure 4. Gamma Neutron logs of Wells Y-6, Y-8, and C-1.

hydrofrac a pair of wells and they were used separately. The mechanical drive on the Quintuplex pump soon proved inadequate for the service and it was necessary to add a Twin Disc torque converter and to replace the mechanical clutches and silent chain compound with Airflex clutches and a roller chain compound.

It was originally planned to connect the eighteen wells in six groups of three and to attempt to keep these groups separate so that one group could be shut down for repairs without interfering with the operation of the remaining groups. The proposed groups were:

1. Y-1, Y-2, Y-3.
2. Y-4, Y-5, Y-6.
3. Y-7, Y-8, Y-9.
4. Y-10, Y-11, Y-12.
5. C-1, C-2, C-3.
6. C-4, C-5, C-6.

It was felt that undesirable connections, even if made, could be eliminated by closing in the recipient well and thereby forcing the water to travel to the desired well. After the desired connection had been washed out to line pressure, it was felt that the undesired high pressure connection would close up and seal off. This theory, however, did not work out in practice. Undesired connections were made and washed out not only between groups of wells in the same row but between rows as well. The final groupings of the connected wells were:

Group 1. Y-1, Y-2, Y-3, Y-5, Y-7, Y-8, Y-9.

Group 2. Y-4, C-1, C-2, C-3, C-4, C-5.

Group 3. C-6, Y-6.

Group 4. Y-10, Y-11, Y-12.

A typical connection made by hydrofracing would proceed along the following lines. Water would be pumped into a perforated well using one of the hydrofracing pumps. The water pressure would immediately rise to about 2500 pounds per square inch, at which pressure the fracture would take place. The pressure would then quickly drop to about 1200 psi. and water would commence to flow into the formation. Within a few hours, a flow of brine would commence from the target well. After further pumping, the flow from the target well would gradually increase until it approximated the flow into the water input well. Continued pumping for anywhere from five to one hundred and fifty hours at from 1200 to 1000 psi. would be necessary to wash out the connection between the wells. The completion of this wash-out period would be signalled by a rapid drop in pressure of the input water to approximately 150 psi., the hydrostatic brine-water differential for this depth. Figures 5, 6, and 7 show typical pressure-time relationships for this operation.

The fracing pressure and the pressure required to wash through the connections are, of course, peculiar to the formation in the Windsor area. Since the wash-through pressure of about 1100 psi. is the pressure required to raise the formation, it is a function of the weight of the over-lying rock and hence of the depth of the formation. The differential pressure between that required for fracturing and for washing-through does not apparently depend on formation depth but rather on other factors, the most significant of which appears to be the method of preparation of the well for fracturing. Petroleum companies, for example, have found that notching permits fracturing at a considerably lower differential pressure over formation pressures than does perforating.

At this point, the writer would like to make a few observations on some specific aspects of the hydrofracing program and subsequent operations of the brine field.

It is generally felt that if the annular space outside the casing is not tightly cemented, there is a distinct danger that the injected water might travel up beside the casing and fracture the formation at a zone of weakness at a higher elevation or even at the top of the salt bed. On two occasions during the hydrofracing program, fractures reached uncased wells. Spinner surveys

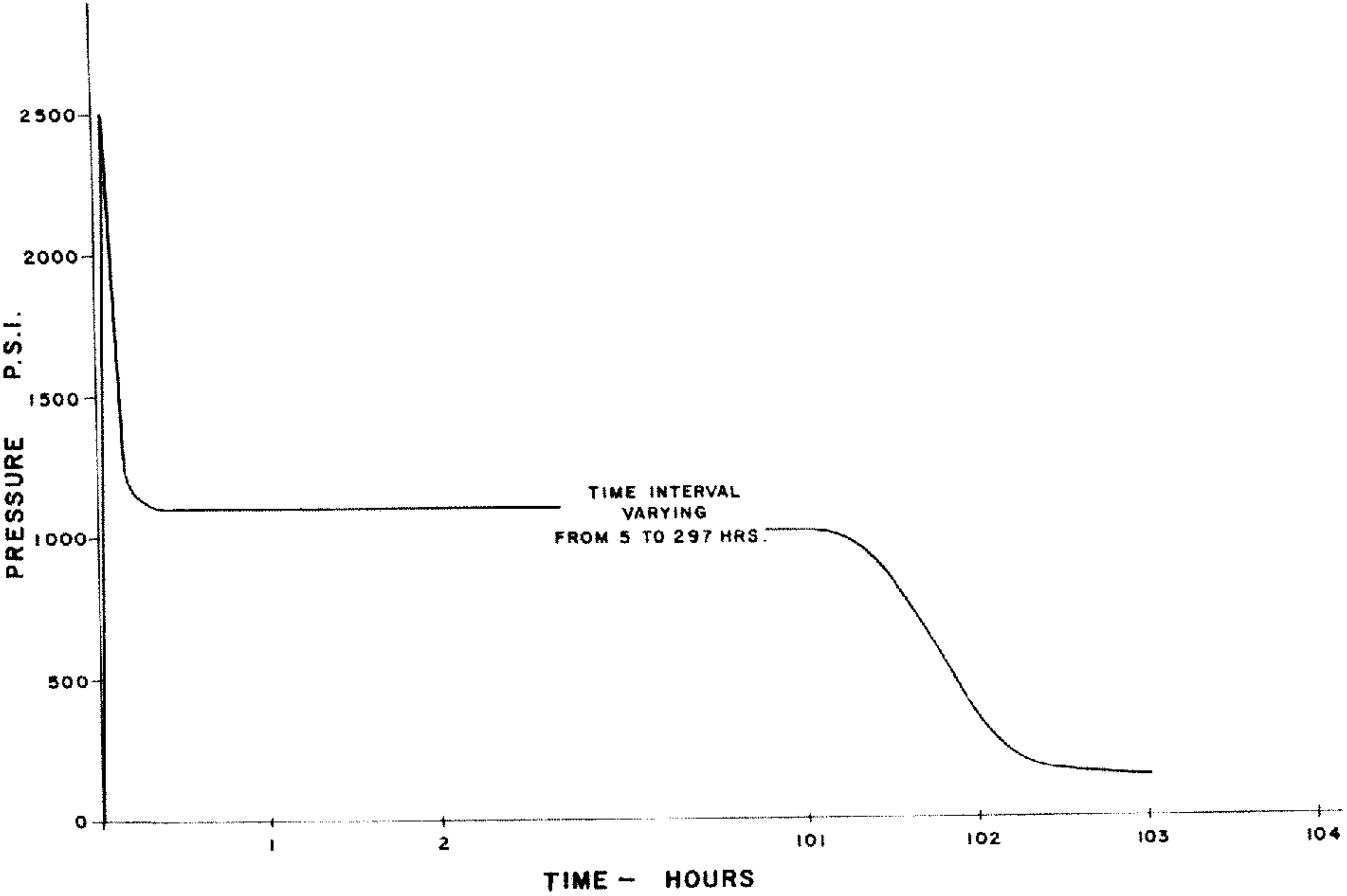

Figure 5. Generalized Pressure-Time relationship for hydrofracing cycle.

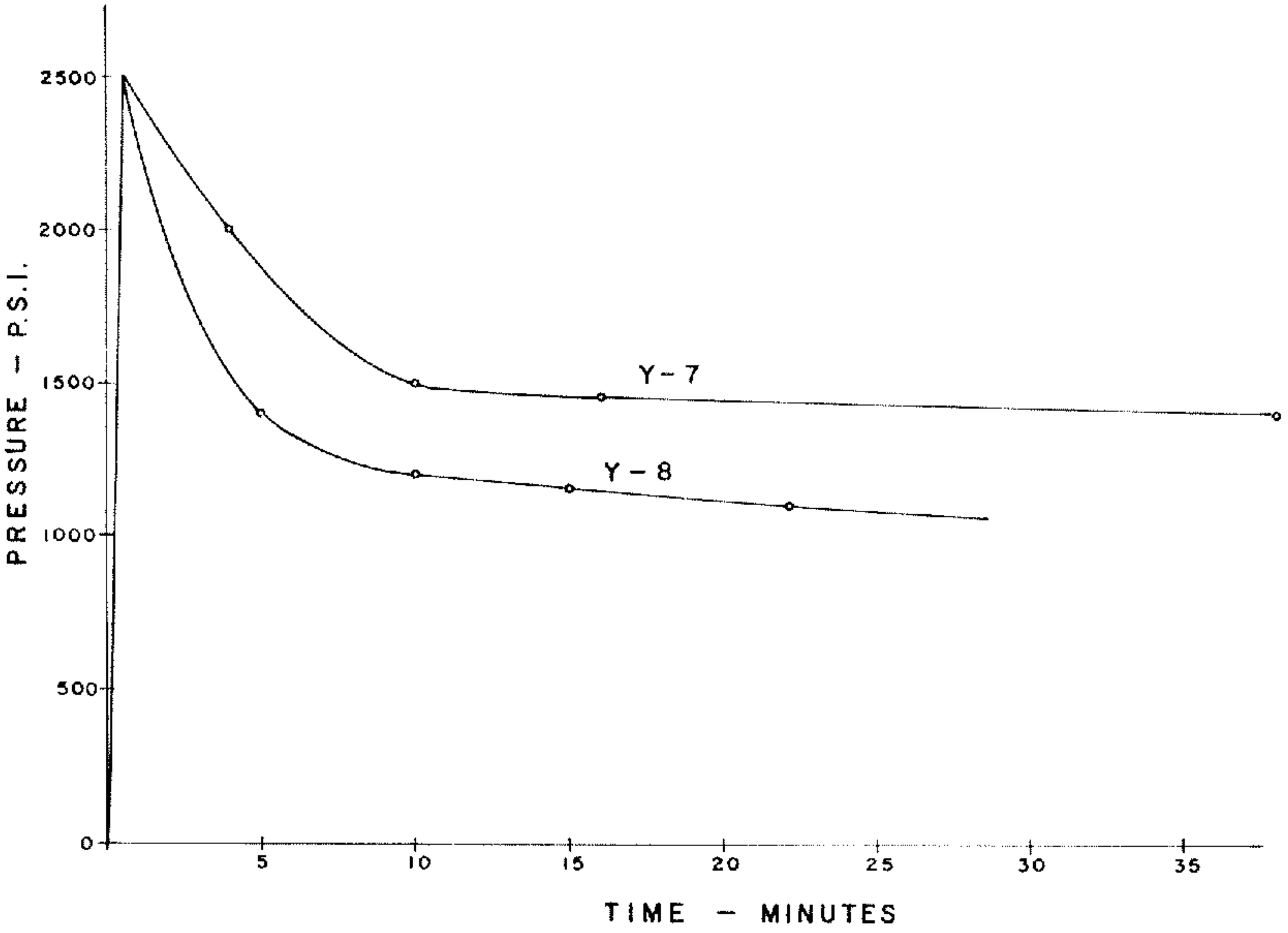

Figure 6. Typical Pressure-Time relationships during fracture initiation.

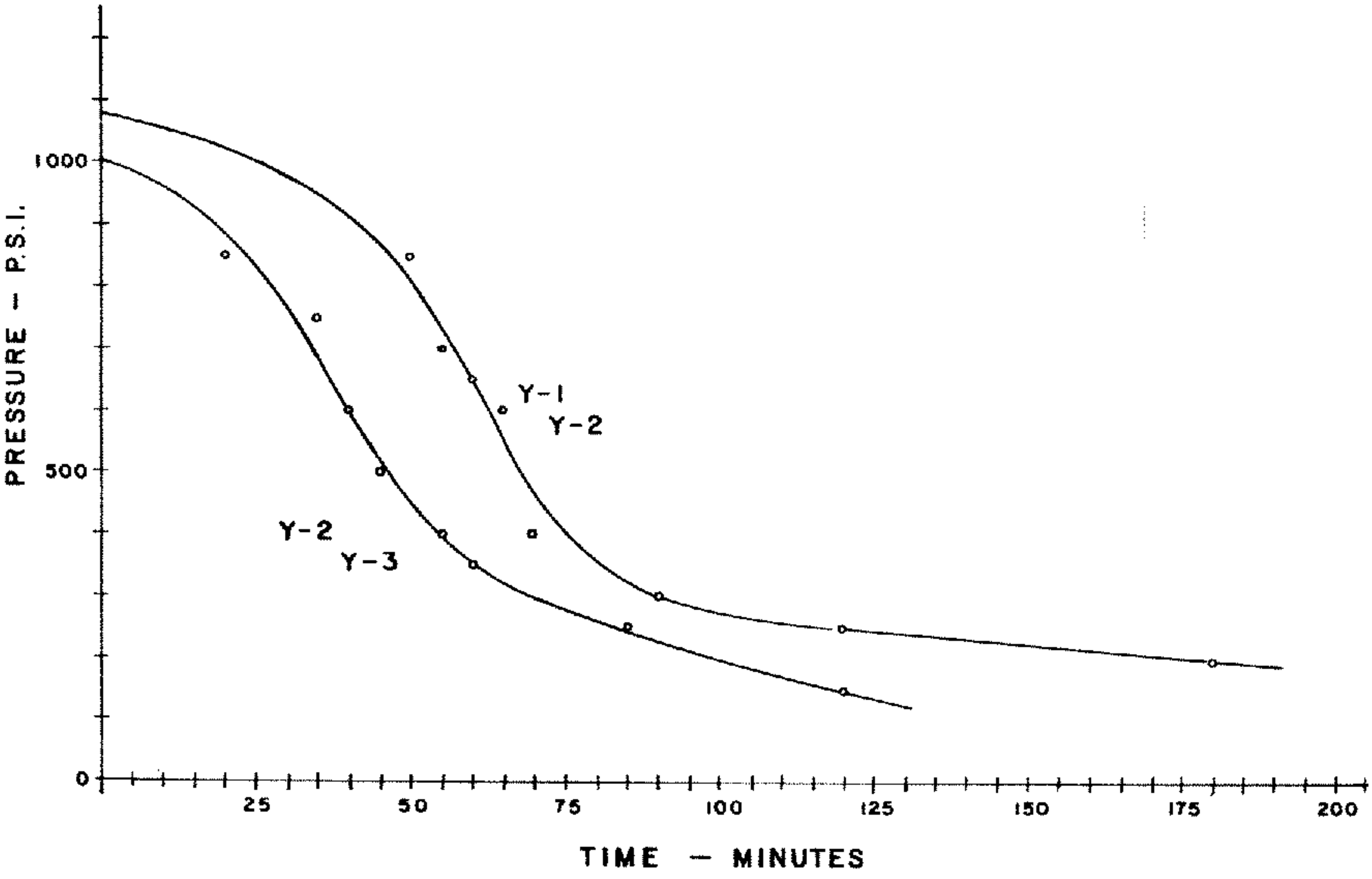

Figure 7. Typical Pressure-Time relationships at the end of the wash-through period.

were run in these wells to determine the point of entrance of the brine into the wells and this point was checked with the Radioactivity logs of the wells. When it was found that the brine was entering the uncased wells through the same stratum into which water in the input well was being injected, we had considerably more confidence in the casing cementing. As a further check, new adioactivity logs taken after two years' operation have shown that cavity development has taken place at the bottom of the salt formation in all wells.

A satisfactory explanation for the wide variations in time and in difficulty in washing through connections has not been developed. Some connections followed the typical pattern outlined previously. In other cases, it was necessary to reverse the flow between the two wells before a connection could be washed down to line pressure. In a few cases, a connection could not be established between two given wells and these wells were subsequently washed through into other adjacent wells. In general, it was found, as a sort of rule-of-thumb, that if the flow through a new connection did not build up within a few hours to equal the flow of the input water, the connection could not be washed out in that direction. If, however, the output flow did build up to equal the input, the connection could be washed out. As previously mentioned, the time required to wash a connection down to line pressure varied from a few hours to several days. No explanation for the variations can be made other than to postualte that the water takes a more circuitous route between wells in some instances than in others.

During the period since 1958, some thought has been given to the control of cavity formation. A Radioactivity log is run on each active well every eighteen months to determine cavity depths and on the basis of this information input and output wells are rotated. These logs will also show when the roof of the cavity is approaching the top of the salt bed and will thus permit abandonment of a well before the cavity reaches this horizon. As previously mentioned, the water input and brine output of each active well is metered and the salt removed can therefore be calculated. With this information and some assumptions, it is hoped that some order-of-magnitude calculations of the average area of the cavities can be made.

In summary, then, hydrofracing made possible the development of a brine field of substantial capacity in a relatively short time and with a minimum number of wells. Well maintenance ising from the tubing failures encountered in single well operation is eliminated and there is ome basis for the expectation that the maintenance of the hydrofraced wells over their useful life will be minor. It is also felt that the operation of hydrofraced wells lends itself to some form of control of cavity formation.

On the other hand, the experience at Windsor indicates the need for developing further information on the actual mechanism of hydraulic fracturing in the hope that this technique can be better controlled.