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AN INVESTIGATION INTO TRANSIENT FLOW IN PIPES NETWORK VIA MOC METHOD

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ABSTRACT

One of the methods which are used to analyze transient flow in pipes network is proposed in the present research, which in following Tehran water supply pipe networks will be examined via the proposed method. Water supply pipe network is developed from different elements such as Valves, pumps, intersections, pipes and so forth, that such elements are divided into two active and passive groups in sake of exploitation; active elements include pipes and valves and passive elements include pipes and intersections. Control over exploitation from system is fulfilled by the active elements, which passive elements have just the duty for distribution. Here, through resolving continuity equation and momentum equation in pipes under the boundary conditions in the beginning and beginning and end of each pipe which is under influence of type of existing element in both sides of pipe, a solution has been proposed to examine flow in the pipes network. The considered method has been known with Method of Characteristic (MOC) discussed by John Wiley & Sons in different books on how to acquire the equations used in this method. Here, we have achieved a software package to analyze transient flow in network through resolving these equations; the proposed method requires early values to propose geometrical conditions of network such as number, size and area of pipes and type of elements and also the early hydraulic conditions in the network, for which the outputs of Loop 4 software design package have been used. This is one of the most important advantages of this software package which enables the person to propose an optimal design at economic and hydraulic areas under steady state. Further, with regard to the outputs of transient flow in the system, the person enables to design the transient flow and

design a network which paves the way for control over the exploitation from the system. The outputs are introduced by representation of the values for height of hydraulic line (H) and flow (Q) in the beginning and end of each pipe and two middle points at the pipe considering the extent of distance between each point from the element at the beginning of pipe.

INTRODUCTION

Nowadays, fluid network distribution is used in most of industrial centers and cities. Water supply pipe networks, Wastewater collection systems, and Hot water distribution systems are the samples of large hydraulic networks. Precise design and investigation are required to raise more return in pipes network, because optimal distribution of flow and balance pressure in network should have been acquired by minimum early cost and minimum exploitation cost. After designing the network, it should simulate the system for a proper exploitation so as to examine the function of system at any moment and exploit from it under the optimal function conditions [1]. In exploitation from the maneuvering system for flow and pressure distribution in network, it requires fulfilling proper operations which cause reduction in maintenance costs. Control over proper maneuvering of valves and/or maneuvering of pipes in system requires an analysis for transient flow in network. To avoid excessive pressures in network, after maneuvering valves or pipes and examining how to distribute flow in

different parts, some instruments must be considered to examine transient flow in the network [2]. These computational instruments cause reduction in early investment, increase in security of system and reduction in exploitation costs. A computational instrument to simulate transient flow in water supply pipe networks can be designed through method of characteristic (MOC). In general, transient conditions in a system develop due to the change which raises in an active element such as pipe or valve, which this significance reveals examination of active elements in network so as to simulate transient state in the network. For this, at first there must be hydraulic conditions for the considered network in the steady state. To achieve any other state, we can examine all the middle stages between these two states via resolving the network at transient state. It is obvious that ultimate steady solution will be acquired in this case, because steady state of network is a special state for transient flow in the network. Short pipes in network have been mentioned as the most important issue

which we involve with them in examining the network via MOC method [3]. In this study, an attempt has been made to propose the contents intertwined with each other in order that the reader enables to perceive the early concepts of extraction of equations of MOC method and how to use computer to resolve them and also develop the possibility to compare MOC method with other methods considered for examination of network.

Utilization of MOC method in design

The possibility for design of network via software has been regarded as the most common tasks which are fulfilled by the designers of network. After representing estimation and necessary examination concerning topography of cities, it can complete operations of design via computer software. These software work out based on steady state of water distribution in system, thus resolving network via these software is independent from time, in which parameter of time has no key role[4]. Software which can fulfill the operations of calculation in the network based on MOC method intervenes in the parameter of time in design, which this causes understanding the obtained results through bringing about changes in system. In following, the advantages from design of network via MOC method will be mentioned.

Examination of Tehran water supply pipe networks via program NET

With regard to extensiveness of Tehran water supply pipe networks, program NET manifests with one of the most important application in examination of water supply pipe networks, i.e. how will be rest of elements and dewatering systems at different periods of time during maneuvering on the elements of network and which maneuvering must be fulfilled in the network for dewatering system [5].

Entering Tehran water supply pipe networks

Regarding the explanations in Tehran water supply pipe networks at the peak consumption time based on data center telemetry of Water and Wastewater Company, about 30 m^2/s water is distributed in Tehran. In Tehran, consumption areas are seen in North West and West, North East and East as well as Centre and South of City. Here, since water is supplied in south of city by southern ring of city which is along tanks 15 and 16 and water is supplied by tanks 4, 5 and 6 in the center of city, thus water supply is western north, north and eastern north of city is considered, whereby this is continued so far as supplying water from a tank to several tanks. Therefore, tank 21 in western part of city and tank 22 in eastern part of city are neglected [6]. Hence, figure 1 is

represented which is the input basis for program NET. Geometry of input network is seen in figure 1 regarding the hydraulic conditions.

Geometry of network

As mentioned above, in program NET, number of pipes, valves and intersections is separated from each other at a certain area. This has been represented in the part represented with resolving transient flow in network. To enter geometry of water supply pipe networks, this has been taken into consideration and number of all the tanks has been summed with fixed number(200), developing number of considered tank in the program. Thus, when we treat with node (257), we know that tank (no. 57) is considered. Valves are started with no.1 and numbered based on figure 1 in water supply system. Valves are generally the input

valves at tanks that their number adapts with number of related tank. Number of all the intersections starts with number 6, numbered in Tehran water supply system. To introduce the pipes existing in Tehran water supply system to the program, their characteristic curve should have been provided. Since existing pipes in water supply system are from type KSB and similarity of existing pipes and relations with our pipes, characteristic of the pipes used in this system has been acquired [7]. The characteristic curve of our considered pipe which has been proposed by the manufacturing factory and used in Tehran water supply system is as follow:

$$KSB \quad ETanorm \quad 125 - 200 \quad \begin{cases} N = 2600 \, rpm \\ d = 0.22 \, m \end{cases}$$

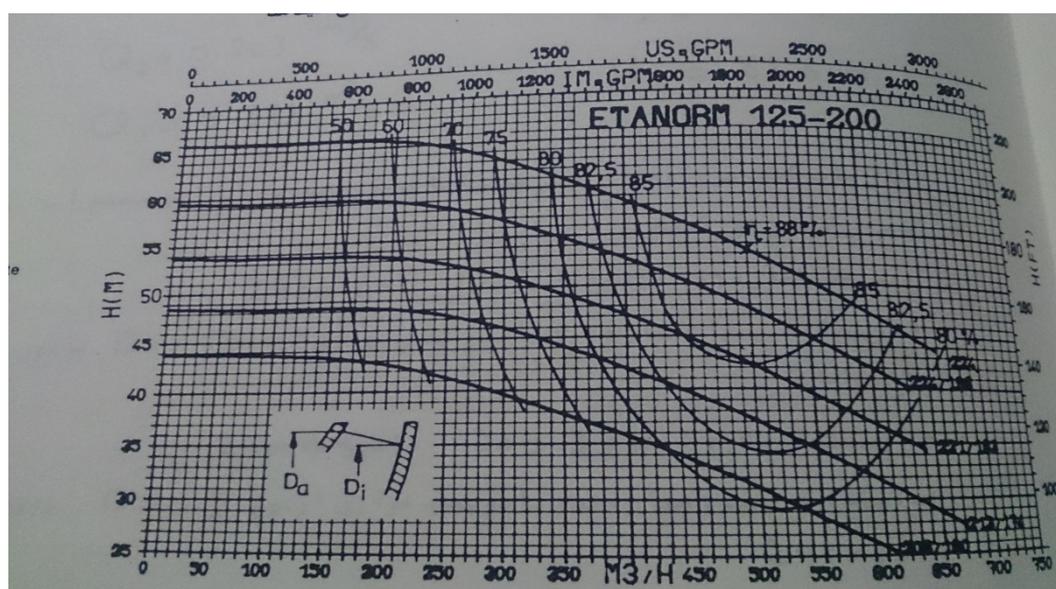Figure 1 indicates characteristic curve of this pipe.

Figure 1: Characteristic curve of pipe ETANORM125-200[13]

According to figure above and the equations between the similar pipes as follows:

Q/ND^3=fixed

$H/N2D^2$=fixed

We consider two other pipes.

The first pipe with characteristic dimension 0.4 M

$$\begin{cases} N = 2600 \, rpm \\ \quad D = 0.4 \end{cases}$$

$Q_1 = 0.3 \, m^3/s 1$ $\qquad\qquad\qquad$ $H_1 = 214 \, M$

$Q_2 = 0.48 \, m^3/s$ $\qquad\qquad\qquad$ $H_2 = 208 \, M$

$Q_m = 0.78 \, m^3/s$ $\qquad\qquad\qquad$ $H_z = 181.8 \, M$

The second pipe with characteristic dimension

$$\begin{cases} N = 2600 \, rpm \\ \quad D = 0.3 \, m \end{cases}$$

$Q_1 = 0.126 \, m^3/s$ $\qquad\qquad\qquad$ $H_1 = 120 \, M$

$Q_2 = 0.208 \, m^3/s$ $\qquad\qquad\qquad$ $H_2 = 117 \, M$

$Q_m = 0.332 \, m^3/s$ $\qquad\qquad\qquad$ $H_3 = 83.6 \, M$

Now, pipes in series or parallel connection are considered to specify status of pumping in water supply pipe networks.

1-pipe no. 3010 from type of D=0.4 at round 2900

2-pipe no. 302 with five parallel pipes from type of D=0.22 at round 2900rpm

3-pipe no. 314 from type of D=0.3 at round 2900rpm

4-pumping station no.356 with two parallel pipes from type of D=0.03 at round 2900rpm

5- pumping station no.357 with two parallel pipes from type of D=0. 3 at round 2900rpm

6- pumping station no.358 with seven parallel pipes from type of D=0.22 at round 2900rpm

7- pumping station no.391 with two parallel pipes from type of D=0.4 at round 2900rpm

8- pumping station no.394 with three parallel pipes from type of D=0. 3 at round 2900rpm

As observed, number of all the pipes existing in network starts with 3, numbered based on figure 1 regarding Tehran water supply system.

Entering the early hydraulic conditions

Here, it should mention this point that program loop4 has not the capability for

receiving conditions of valves, whereby this causes failing to implement the program under steady state with program loop4. On the other hand, program loop4 just enables to resolve annular networks and fails to resolve branch network. Yet program Branch which is the complementary for program loop4 has the capability to resolve branch network lacking use of important elements such as pump. Two important points are in this way that the file for response of output differs from the file for response of loop4. As a result, we were forced to make calculations separately in entering hydraulic conditions of program and coefficients of valves and enter the result in form of output file of loop4. Result of these calculations has not been represented in this article, but a sample of these calculations concerning calculation of coefficient of valve no.101 in entering to tank 201 is as follow [8].

Height of tank 601=1321.5 m

Height of tank 201=1315 m

Difference of height=6.5 m

Diameter of pipe (D) =1000 mm

Resistance coefficient of pipe (f) =0.025

Flow (Q)=13237 m^3/nr

Velocity (v) =4.68 m/s

$$K = \Delta H \times \frac{2g}{V^2} - F\frac{L}{D} \rightarrow K = 0.81$$

$$C_d A_r = 0.87$$

This early approximation in calculation has been $C_d A_r$, equaled to 0.6 in the program. Using output file of loop4 and file for information of valves and tanks, the program has sufficient inputs to deliver analysis of network, enabling to announce height of tanks, pressure and flow in each pipe.

Maneuvering for dewatering tank 2

Now, with regard to the predictions, we assume that consumption of tank 2 will increase in next hours, thus we make an attempt to increase height of this tank and not to bring about severe changes in the height of tanks 1 and 14 as much as possible, thus we consider two ways to achieve this:

The first way: closing valves 101, 108, 194, 192 and opening valve 102 and dewatering from refinery 2.

It should be noted that as we face limitation in changing height of tanks 1 and 14, we must consider this limitation through closing valves 192 and 194; further since output of refinery 2 is constant, we maintain continuity law.

Valves 192, 194, 108 and 101 are closed during 30 seconds at some rounds, during which valve 102 is opened at some rounds.

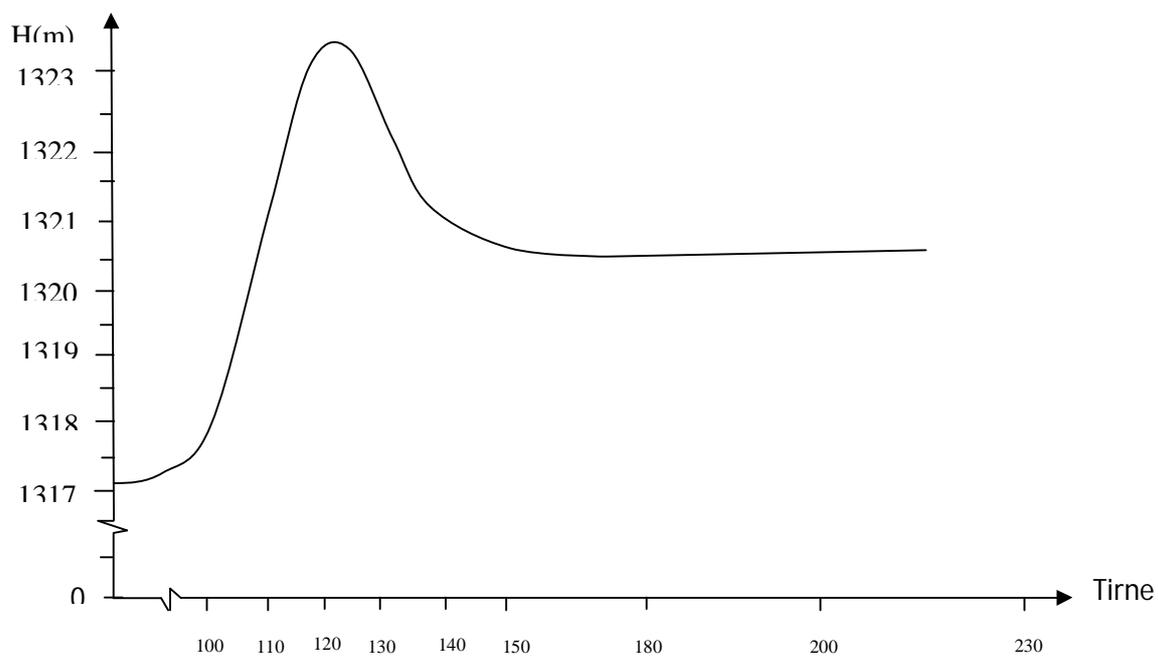The early and final values of $C_d A_r$ in these valves are as follows [9]:

Figure 1: Changes of pressure against time in the first maneuver at line 22 at the distance of 1300 meter from intersection 601
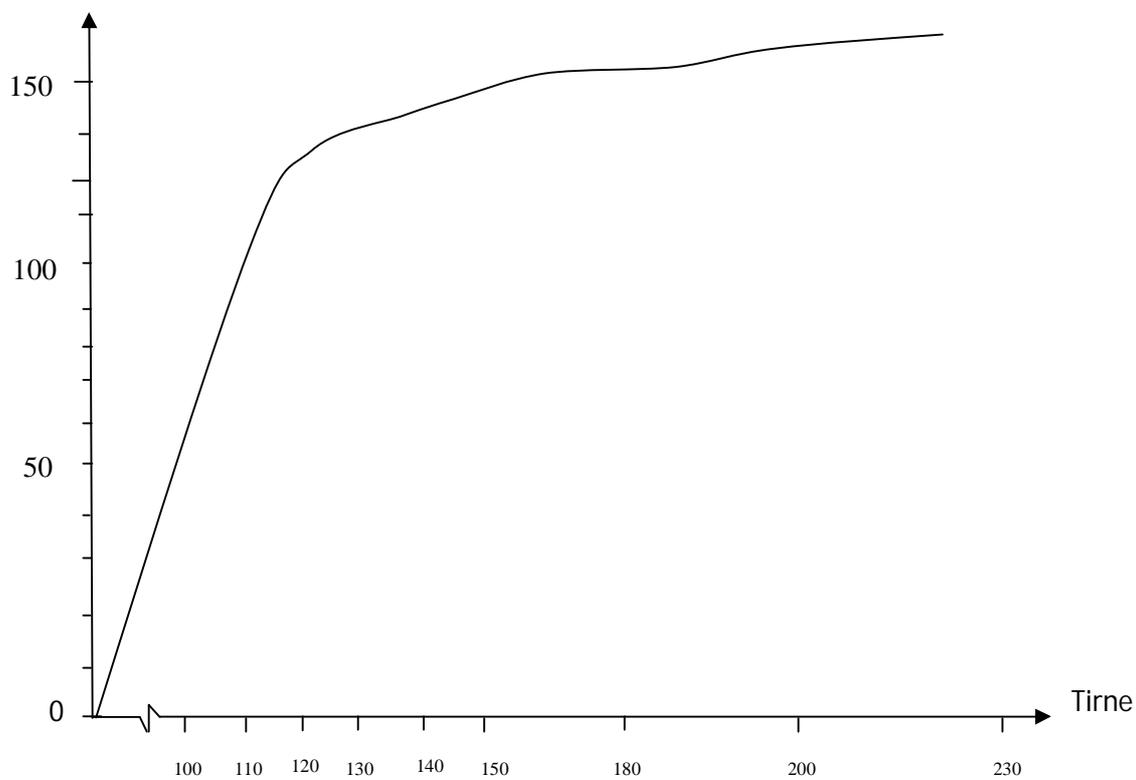

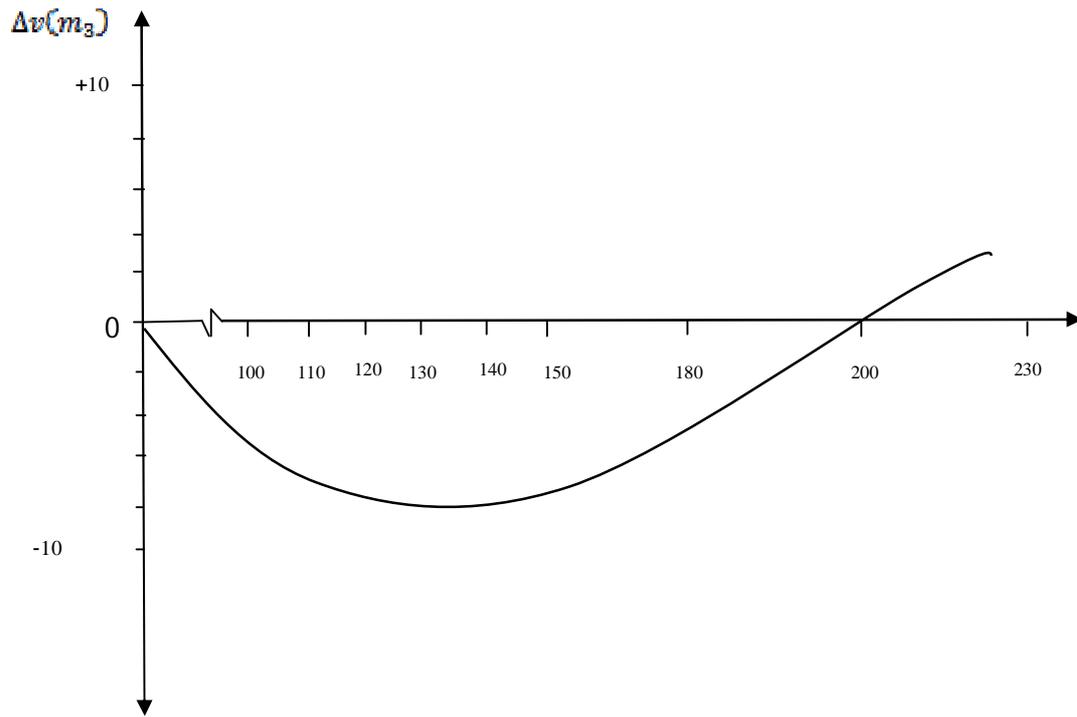**Figure 2: Changes of volume in tank 1 against time in the first maneuver**

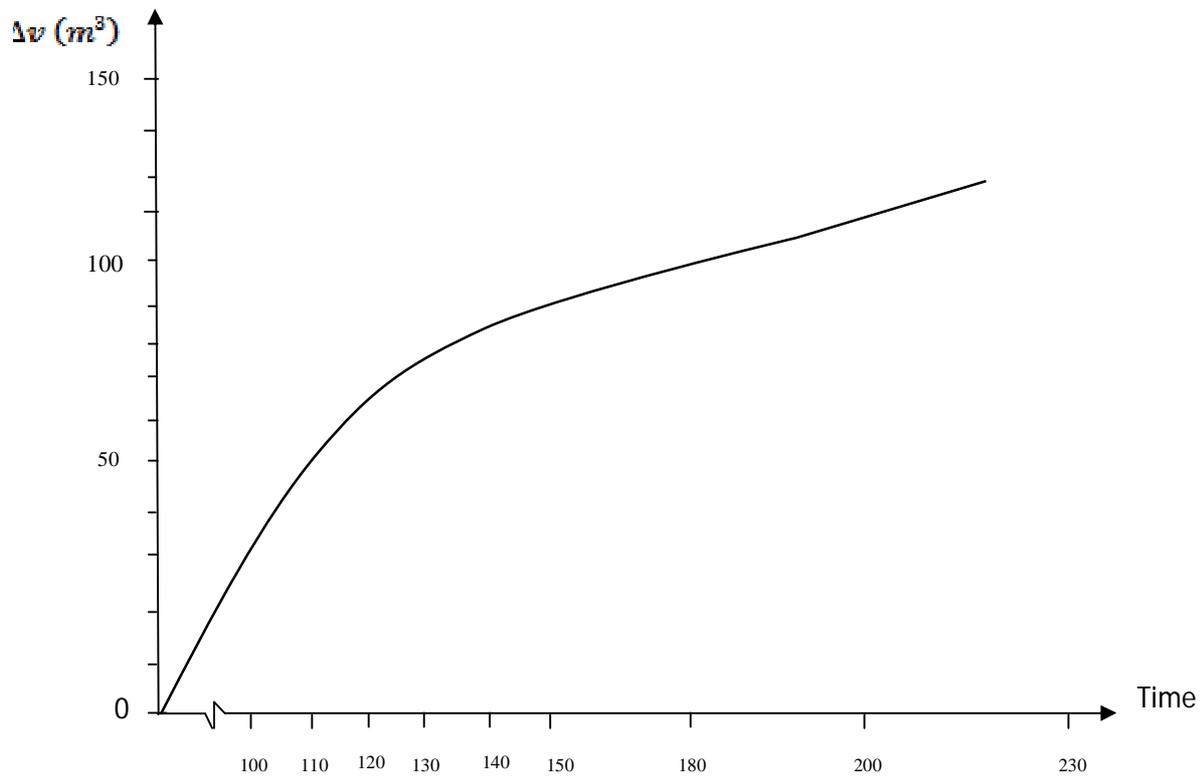**Figure 3: Changes of volume in tank 2 against time in the first maneuver**

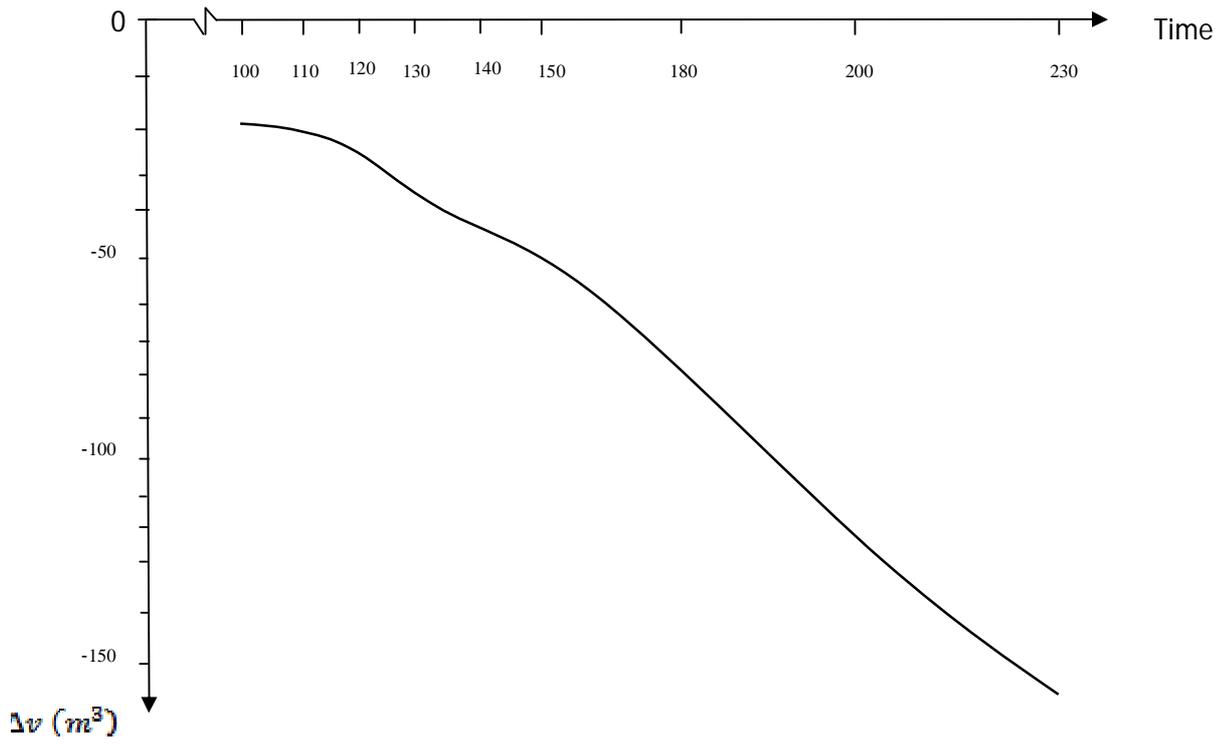**Figure 4: Changes of volume in tank 22 against time in the first maneuver**

Figure 5: Changes of volume in tank 8 against time in the first maneuver
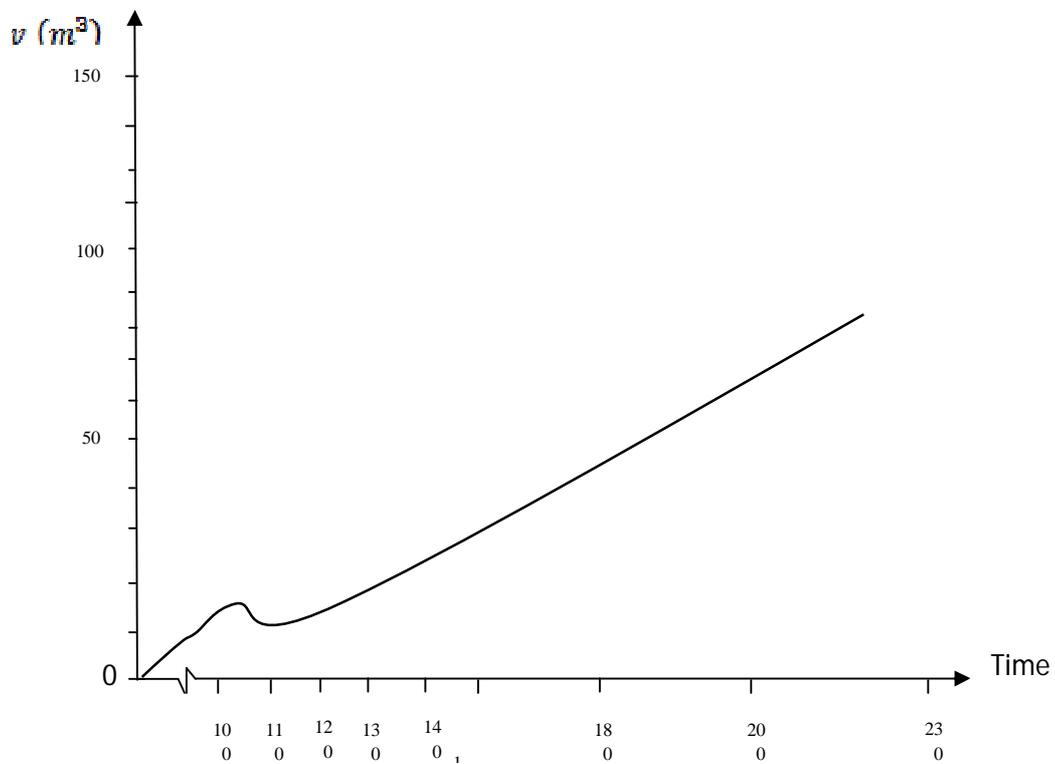

Figure 6: Changes of volume in tank 14 against time in the first maneuver

No of valve	$C_d A_r \, I$	$C_d A_r \, II$
101	0.6	0.3
108	0.2	0.1
192	0.043	0.02
194	0.061	0.051
102	0.22	0.42

Result of this action has been acquired during 100 to 130 seconds.

The second way: closing valve 108 and opening valves 102 and 172 and dewatering from refineries 2, 3, 4 concurrently.

In this regards, tank 2 dewaters through transmitting line 1850 from refinery 2 and through the routing path from tank 11 to tank 2. Valves 102 and 172 are opened during 30 seconds at several rounds and valve 108 is closed during this period. The early and final values of $C_d A_r$ **in these valves are as follows:**

Number of valve	$C_d A_r \, I$	$C_d A_r \, II$
108	0.2	0.1
172	0.005	0.01
102	0.22	0.32

Result of this action has been acquired during 100 to 130 seconds. In this regards, curve 8, 9, 10, 11 indicate the changes of height in tanks 1, 2, 8 and 11.
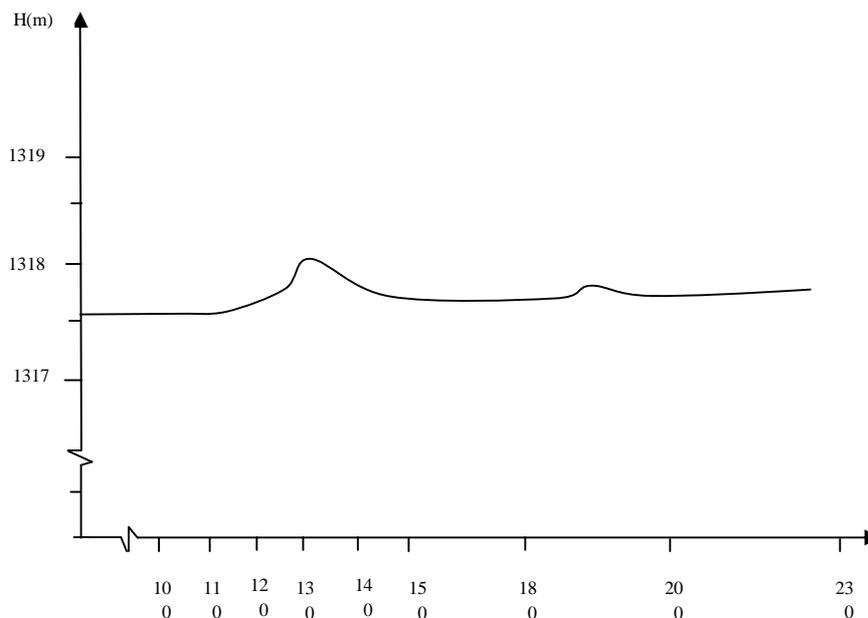

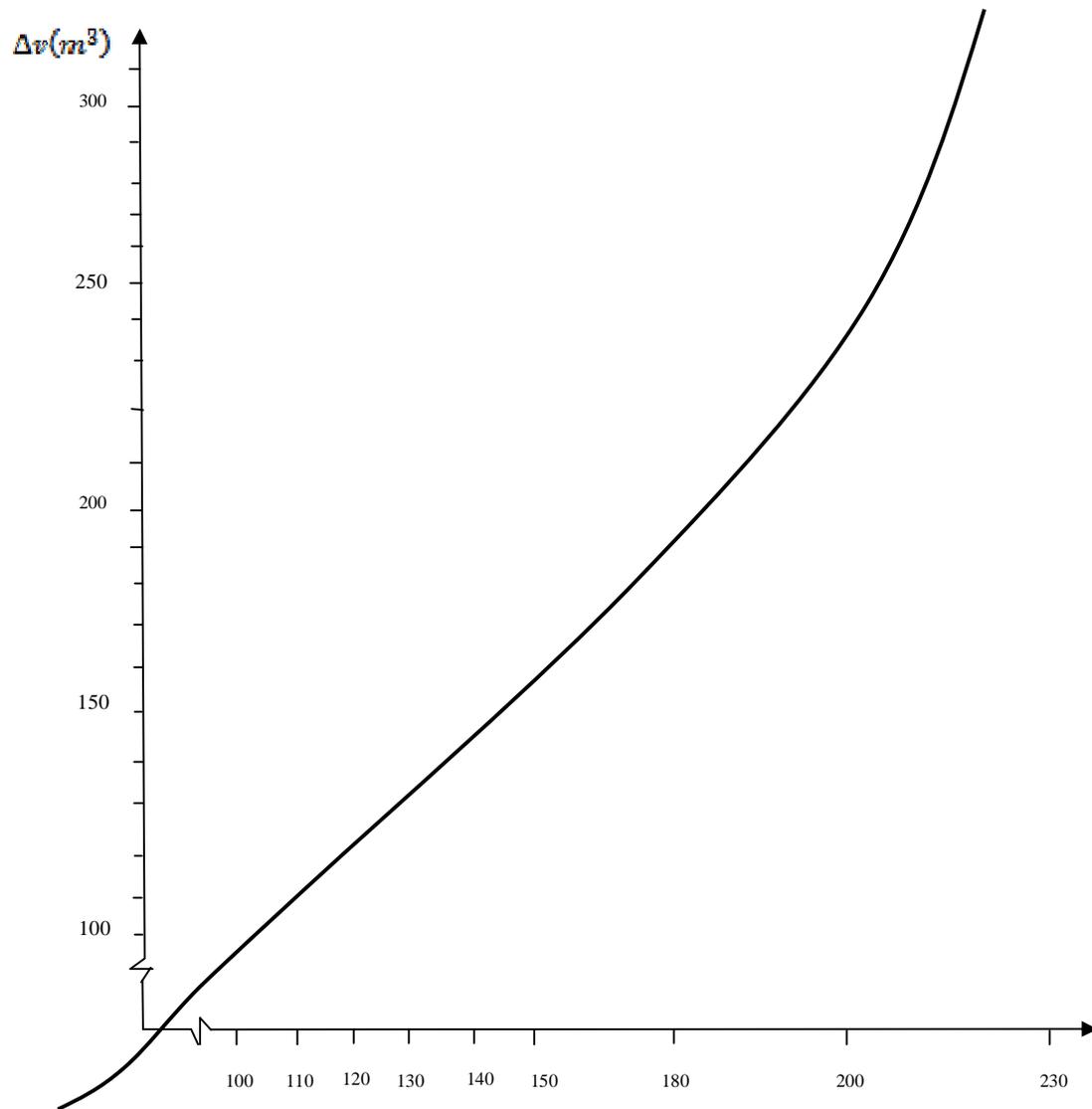**Figure 7: Changes of pressure against time in second maneuver at pipeline 22 at distance 1300 meter from intersection 601**

Figure 8: Changes in volume of tank 1 against time in the second maneuver
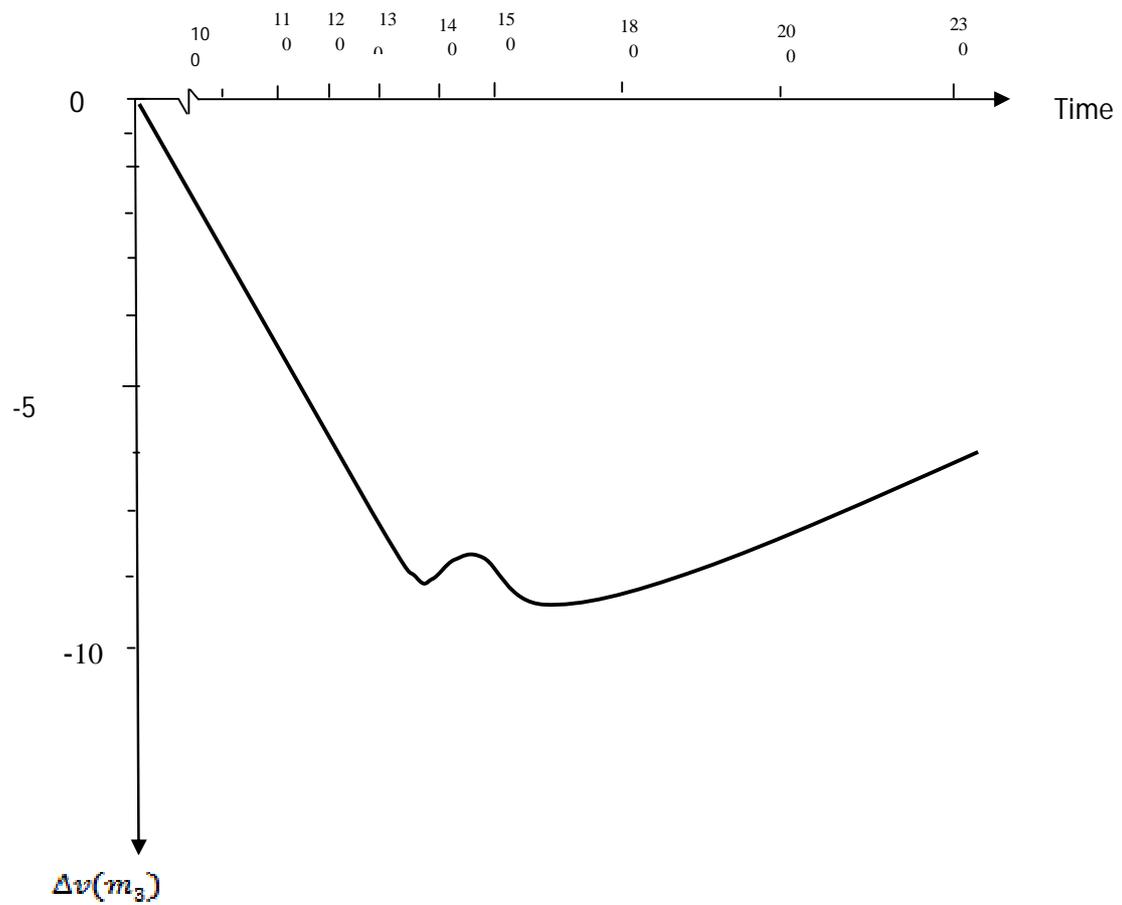
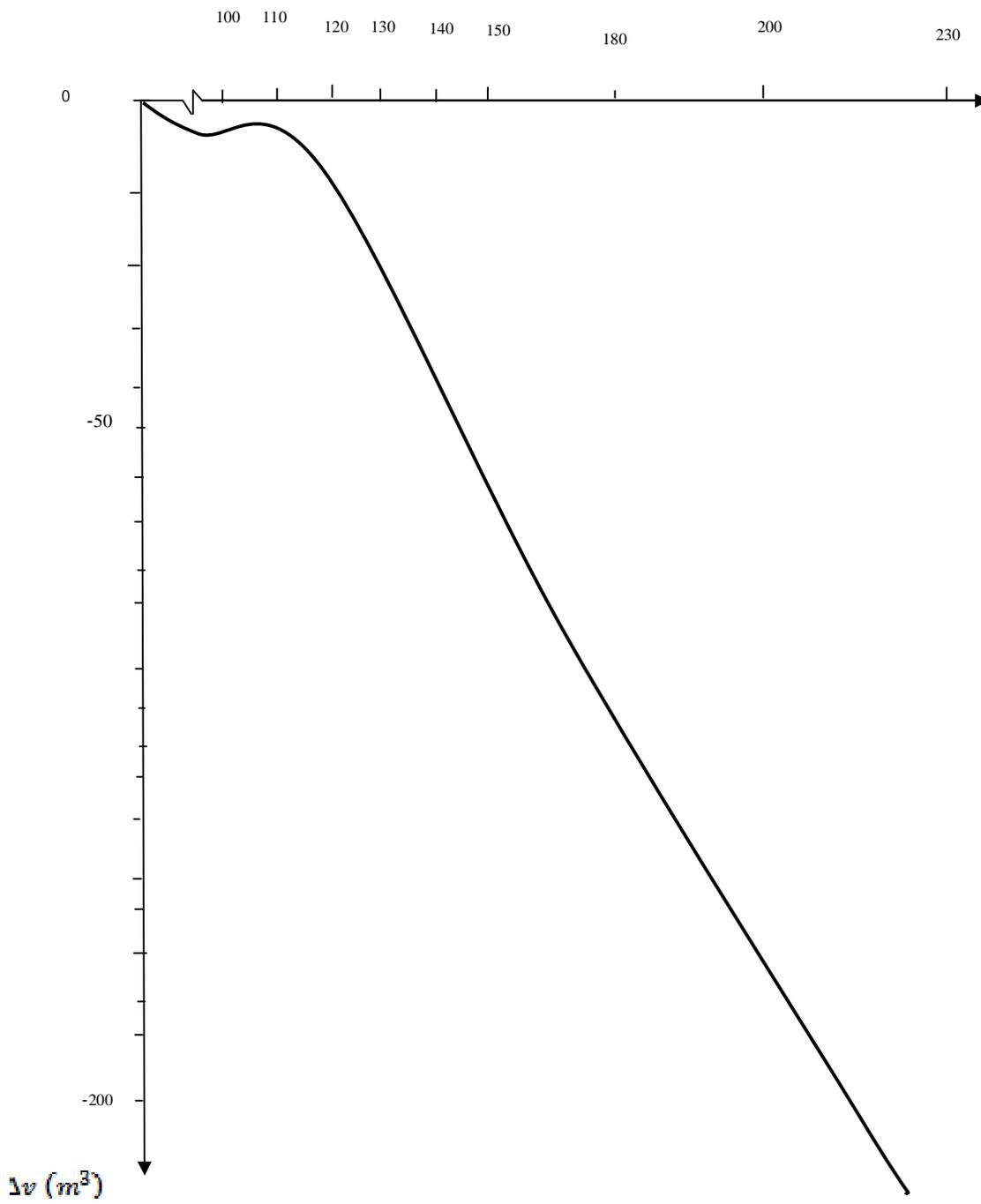**Figure 9: Changes in volume of tank 2 against time in the second maneuver**

Figure 10. Changes in volume of tank 8 against time in the second maneuver
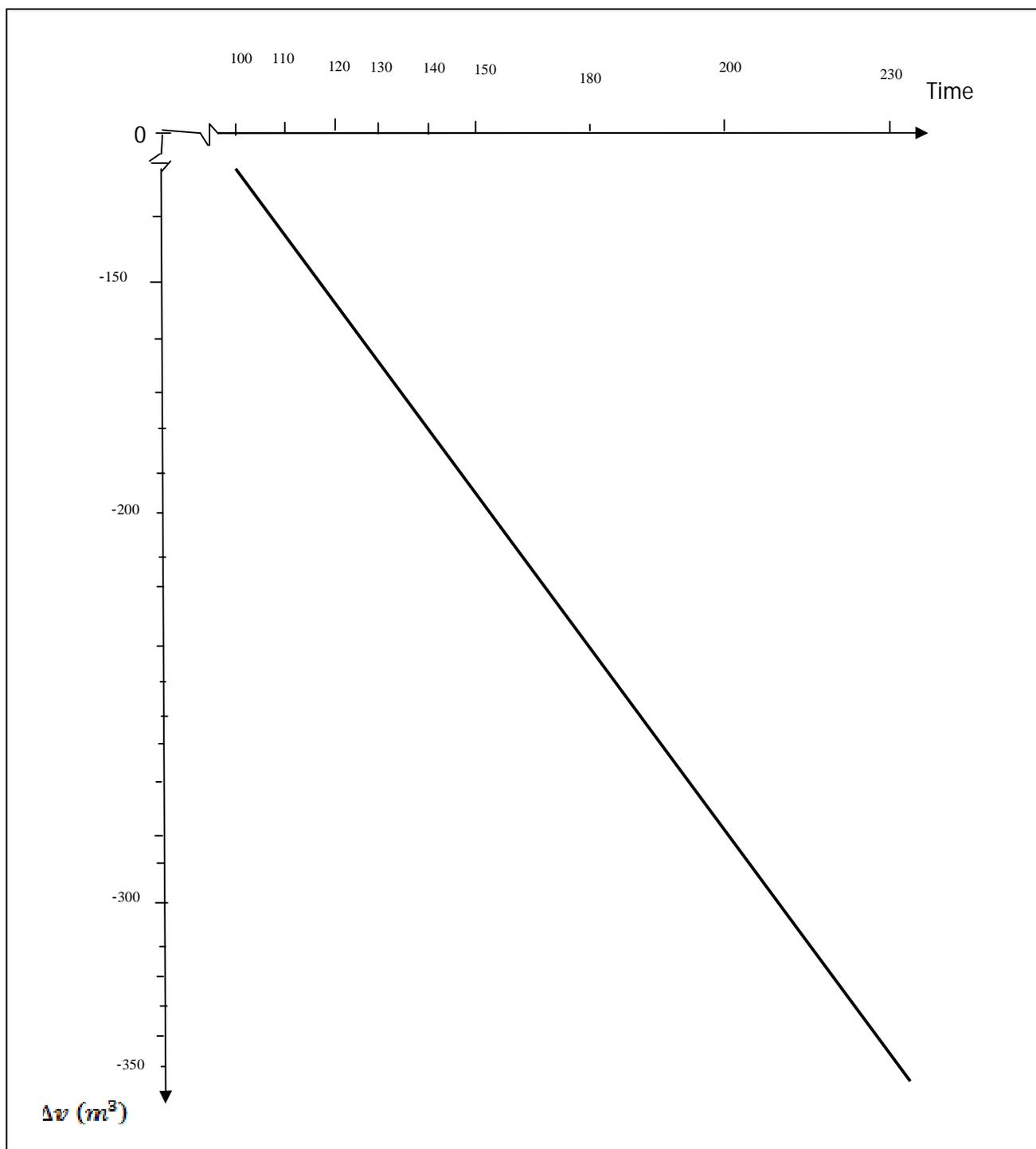
Figure 11: Changes in volume of tank 11 against time in the second maneuver

ANALYSIS AND CONCLUSION

The curves shown above indicate the changes in volume of considered tanks after maneuvering on valves at two separate states. Now it can perceive that software NET has paved the way to achieve the considered aims of analysis of network at the stage of design and exploitation, because this has enabled us to bring about changes in elements of network and examine results from the new state. Secondly this has paved the way for examination of the network under steady state, whereby we can observe that we can

simply monitor hydraulic conditions of network and the changes applied on the considered elements. Thirdly examination of waret hammer is possible during brining about changes in elements of network and a proper period of time after bringing about changes, thus it can detect the critical points of network in this way and/or analyze the maneuvers at high risk coefficients. Fourthly it can reach to the ultimate response under the steady state of network after brining about change in elements of network, which this is of great importance in design of network, whereby it can analyze different facilities of flow distribution in water supply system. In this example under examination of water supply system, it can control hydraulic conditions of all the mentioned pipes at any moment and apply any maneuver on the active elements of network. Now it requires examining the results from maneuvering the valves to achieve the considered aims and observing which of two methods have helped us to get close to the aims. In this maneuver, we aimed to increase level of tank, such that no change is brought about the height of tanks 1 and 14. After performing the program in two states, we can observe the both methods have helped us to achieve our aims. If we consider curves above, we can see that curve 2 has been witnessed with decreasing height, yet

curves of changing the volume of tanks against time at the last period of time are ascending through maneuvering. On the other hand, tanks 1 and 14 at the first state are under heighting and tank 1 at the second state is under dewatering and tank 14 remains without explanation because no change has been brought about in the input and output of this tank. As shown in examination of curves for changes in volume of tanks against time and curves for changes in pressure at intersection 1300 meter from intersection pipe 601 to intersection 602, tank 2 has been witnessed with proper height and tanks 1 and 14 have been witnessed with fixed height under the first maneuver, i.e. heighting has been faster in tank 2 and few changes have been brought about in tanks 1 and 14, so that tank 2 which has been witnessed with descending height before maneuvering has increased in volume. On the other hand, changes of pressure are more severe in the first maneuver, and this can be known as the result of interference of pressure waves due to closing values in tanks 1 and 2, whereby closing input valve in tank 1 has resulted in increasing the flow in pipe 22. Therefore, advantage of the first maneuver to the second maneuver has been witnessed in the changes in height of tanks 1, 2 and 14, yet weakness of this maneuver than second maneuver has been due to more

severe changes in pressure at distance of 1300 meter in intersection 601 to 602.

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