CHAPTER IV

PRESENTATION OF RESULTS AND DISCUSSION

4.1 General

The mixing system used was an agitated batch mixer. Fully turbulent mixing which is commonly used in industrial mixing of low viscosity liquid was developed for the whole range of speed of the agitator. The Renoulds number of mixing system are 1.6×10^5, 2.4×10^5, and 3.2×10^5 for speed of agitator of 200, 300, and 400 rpm respectively.

A set of 108 experiments was conducted using the radioactive tracer method and another set of 36 experiments was conducted using the conductivity method. The experiments were conducted to determined the required mixing time in an agitated batch mixer for the following conditions

1. position of impeller : 2 positions of impeller, 8 cm and 12 cm above bottom of the tank.

2. type of impeller : 3 types of impeller, 6 bladed open turbine, 6 bladed disc turbine, and 6 bladed 45 degree pitch turbine.

3. speed of impeller : 3 speeds of impeller, 200, 300, and 400 rpm.

4. baffles : with, and without baffles installations

The experiments were restricted to the rotational speed of impeller at 400 rpm, because a vortex was formed when the impeller was set at 12 cm above the bottom of the tank and when there was no baffles. If the speed of impeller was higher than 400 rpm the vortex would reach the impeller and bubbles of air would be formed which would interfere with the controling of the impeller rotational speed and would therefore affect the mixing efficiency.

4.2 Determination of Required Mixing Time Using Tracer Technique

In order to obtain the correct data from experimental informations the number of counts obtained from radioactive tracer after background substraction have to be corrected by decay correction to bring them back to the same reference time. In this study the reference time used was the time of injection. (The number of counts obtained from background radiation need not be corrected by decay correction.)

In the calibration procedure it was found that the variation of homogeneous solution show their variation from their mean within $\pm$ 3 times of their standard deviation. This may be caused by two main reasons. Firstly, the nature of radiation itself is randomly emitted from the radioactive substance so the radiation detected is never obtained at the same value. Secondly, the quality or efficiency of detection system in getting all radiation emitted from the radioactive material must be considered. Although these phenomena were present the linear relation of the activity and count rate was obtained as shown in Figure 4.1.

In the determination of required mixing time only one datum was obtained at each measuring interval. It was observed in all experiments that the homogeneous solution was obtained after the time of injection of 50 seconds. This was done by using the moving average method and comparison with the standard deviation of each set of 100 data. Their standard diviation is significantly constant. So a set of 100 radiation data after the time of injection was selected to represent the condition of a homogeneous solution. The acceptable variation limit of count rate was determined and extended back to the time of injection. To determine required mixing time, 3 positions of detection, 8, 12, and 16 cm. above the tank bottom, were used. The required mixing time as defined in 2.6 was determined by the shortest time in which the variation of count rates at the three detection positions are within those limits. The results of the experiments are summarized in Table 4.1 and some of them are shown in Figure 4.3 to Figure 4.11.

Another way to determine the required mixing time was done by plotting the standard deviation of each set of 100 data against time. The fairly constant of standard deviation was defined as acceptable standard deviation and the required mixing time was determined as the shortest time where standard deviation of the 3 positions of detection do not exceed the acceptable level. The required mixing time determined here by both 2 methods are the same as shown in Figure 4.12.

4.3 Determination of Required Mixing Time Using Conductivity Method

The calibration of concentration and electrical strength show a linear relationship as shown in Figure 4.2. The required mixing time using conductivity method was obtained when the reading was constant. The results are summarized in Table 4.1 and some of them are shown in Figure 4.13 to Figure 4.21.

4.4 Discussion on Results Obtained from 2 Method

The required mixing times determined by the conductivity method were slighly shorter than those obtained from the radioactive tracer technique (except for the short required mixing time). The possibility of these results may be caused by two main reasons. Firstly, the promotion of mass transfer by diffusion in using high concentration of sodium chloride solution in the conductivity method as mentioned in 2.1.2 and secondly, the limitation of sensitivity of measuring instrument, electrode probes, and conductimeter. In addition, in the conductivity method, it was difficult to distinguish tracer response when a homogeneous solution is obtained and which indicates that the required mixing time has been obtained.

4.5 Effect of Rotational Speed of Impeller

For the same type of impeller and tank configuration, the required mixing time was shorter as rotational speed of impeller was increased as shown in Table 4.1. This is caused by more convective mass tranfer occurring when the rotational speed of impeller is increased.

4.6 Effect of Type of Impeller

There is no distinct relationship between the required mixing time and types of impeller. However it can be noticed that in many cases for the disc and open type turbine impellers which generate radial flow the required mixing time was shorter than when the pitch type which generate axial flow was used.

4.7 Effect of Impeller Position

In almost all experiments the required mixing time of the impeller position set at 8 cm (1/3 of tank diameter) above tank bottom was shortter than the time of impeller position set at 12 cm (1/2 tank diameter) as shown in Table 4.1. It may possibly that impeller at the first position could generate better convective mass tranfer than the other position.

4.8 Effect of Baffle

In all experiments the required mixing time of tank with baffles was shorter than the time of the tank without baffles as shown in Table 4.1. It was because more eddy currents were generated in the mixer and those promoted mass convection of the tracer in the mixer. The result corresponds with finding from previous experiments cited in the literatures.[3,4,17,18]

4.9 Discussion on Additional Work

The continuous stirred tank and tubular vessel experiments were conducted to apply radioactive tracer technique in investigating on residence time of the tracer in the vessel. For the continuous stirred mixer, the volumetric flowrate of water and type of impeller are the parameters of interest. For the tubular vessel, the volumetric flowrate of water and pipe diameter are the parameters of interest.

Those parameters are listed as follows

1. volumetric flowrate : varied from 5.40, 8.85, 10.70, 11.80, and 14.10 litre/minute
2. type of impeller : 3 types of impeller as used in above experiment.
3. pipe diameter : 3 nominal pipe diameters, 3, 4, and 6 inch while keeping total volume of all tubes at 10.86 litre.

The results of the continuous stirred tank are shown in Table 4.2 and the results of the tubular vessel are shown in Table 4.3. Some of them are shown in Figure 4.22 to Figure 4.27

It can be noticed that the residence time in the continuous stirred tank using open and disc turbine is close to the theoretical value, but shorter than the theoretical value of the one using pitch turbine. These results are in agreement with the previous experiments.

For the tubular vessel, the residence time obtained from the 3 in. diameter pipe is close to the theoretical value, but shorter for the 4 in. diameter pipe. The residence time is very much shorter for the 6 in. diameter pipe. The tracer responds shown in Figure 4.28 to Figure 4.33 show that flow pattern of water through the 3 in. and 4 in. diameter pipes is close to the plug flow and close to the continuous stirred tank for the 6 in. diameter pipe.

The reasons of the shorter residence time could be: Firstly, the fluctuation of volumetric flow rate of inlet water which could affect the inlet mean flowrate to be lower than the desired value. Secondly, the nonuniform distribution of radioactive tracer in the vessel along its travelling path may causes short circuit or by passing of tracer through out the vessel. In industry, the shorter of the residence than theoretical value implies that either the nonuniform product or product under specification would be obtained.

Table 4.1 Experimental results for the detemination of required mixing time

Type of impeller	Detection level (cm.)	Speed of impeller (rpm.)											
		200				300				400			
		position of impeller				position of impeller				position of impeller			
		8 cm		12 cm		8 cm		12 cm		8 cm		12 cm	
		baffle		baffle		baffle		baffle		baffle		baffle	
		with	without	with	without	with	without	with	without	with	without	with	without
Disc	8	10.5	15.5	9.0	10.0	12.0	16.0	3.0	10.5	3.5	15.5	7.5	7.0
	12	11.0	3.0	15.0	15.0	9.5	7.5	7.0	11.5	6.0	6.5	7.0	10.0
	16	10.0	21.5	15.0	25.0	5.5	10.0	9.5	20.0	5.5	11.0	8.0	12.5
Required	Radioactive	11.0	21.5	15.0	25.0	12.0	16.0	9.5	20.0	6.0	15.5	8.0	12.5
mixing time	Conductivity	10.0	14.5	14.0	23.5	11.0	15.0	8.5	19.0	6.0	14.5	7.5	11.5
Open	8	9.5	13.5	12.0	12.0	6.5	12.0	4.0	8.0	4.0	6.5	4.0	12.0
	12	11.0	5.0	12.5	5.0	7.5	12.0	3.5	11.0	3.5	4.5	3.5	12.0
	16	3.5	7.0	8.0	20.5	7.5	10.5	7.5	13.5	6.0	4.0	6.0	12.5
Required	Radioactive	11.0	13.5	12.5	20.5	7.5	12.0	3.5	13.5	6.0	6.5	6.0	12.5
mixing time	Conductivity	10.0	12.5	11.5	19.0	7.0	11.0	8.5	12.5	5.0	6.5	6.0	11.5
pitch	8	9.0	17.0	9.0	9.0	4.0	16.0	4.0	10.0	6.0	12.5	4.5	11.5
	12	9.5	5.0	16.5	15.5	7.5	15.5	9.5	8.0	7.5	13.5	3.5	12.5
	16	10.0	4.5	11.5	20.5	7.0	6.0	5.0	14.0	7.0	9.0	3.5	12.5
Required	Radioactive	10.0	17.0	16.5	20.5	7.5	16.0	9.5	14.0	7.5	13.5	9.5	12.5
mixing time	Conductivity	9.5	16.0	15.5	19.0	7.0	15.0	8.5	13.0	7.0	12.5	3.5	11.5

Table 4.2 Retention time in Continuous Stirred Tank

Volumetric flowrate (litre/minute)	Theoretical residence time V/Q (second)	Residence time (second) Type of impeller Pitch	Disc	Open
5.40	120.69	103.51	120.40	121.87
8.85	73.64	72.79	73.87	73.51
10.70	60.91	51.20	60.70	61.08
11.80	55.23	45.63	51.54	57.28
14.10	46.22	42.48	44.31	47.38

Table 4.3 Residence time in Tubular Vessel

Volumetric flowrate (litre/minute)	Theoretical residence time V/Q (second)	Residence time (second) Nominal pipe diameter (inch) 3	4	6
5.40	120.69	120.97	114.89	101.50
8.85	73.64	73.42	70.60	69.10
10.70	60.91	60.80	60.74	67.22
11.80	55.23	56.12	57.37	61.27
14.10	46.22	46.97	48.12	49.41

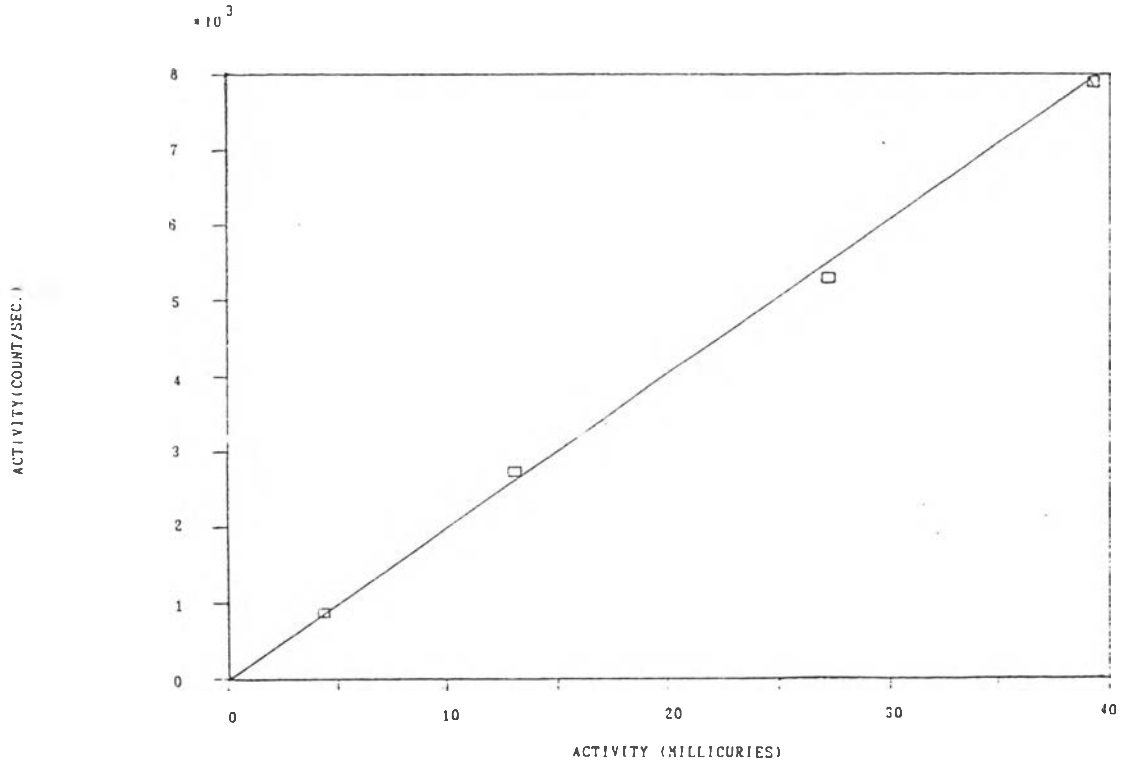


Figure 4.1 Calibration curve of radioactivity and count rate of ^{99m}Tc

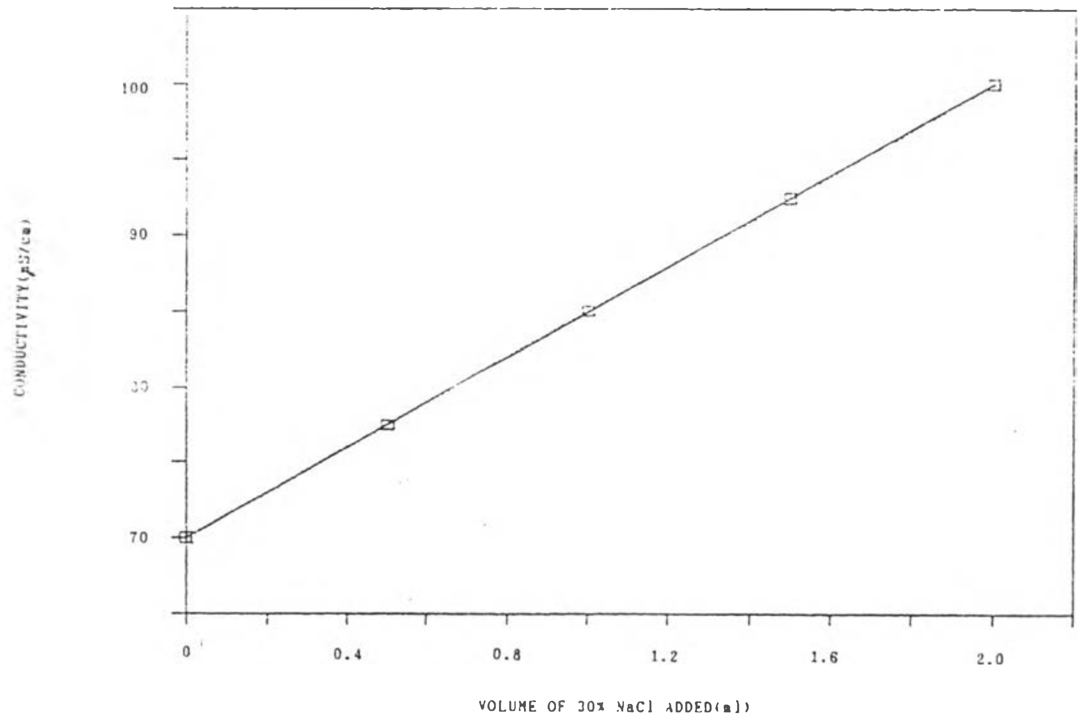


Figure 4.2 Calibration Curve of Concentration of Sodium Chloride and Measured Conductivity

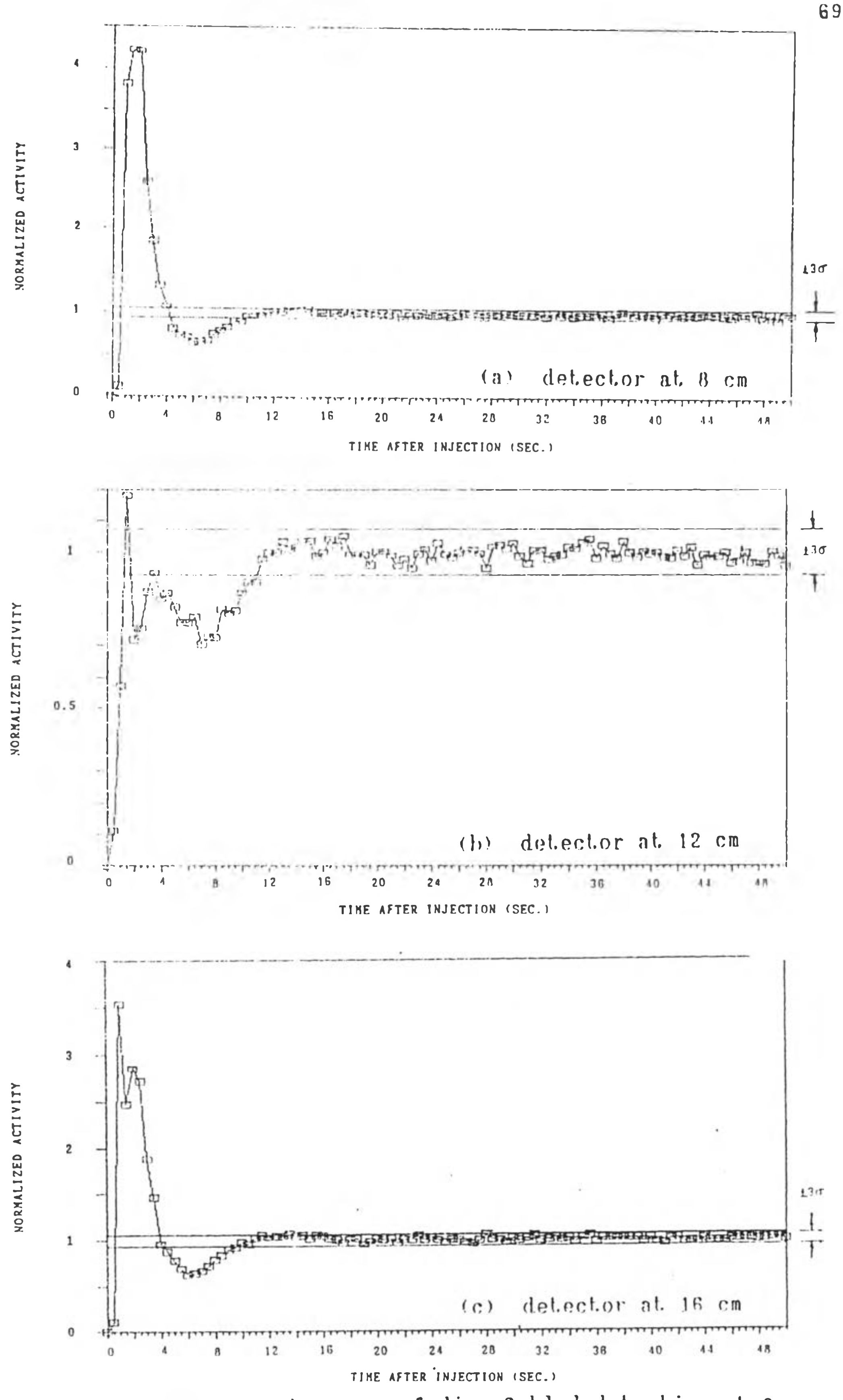
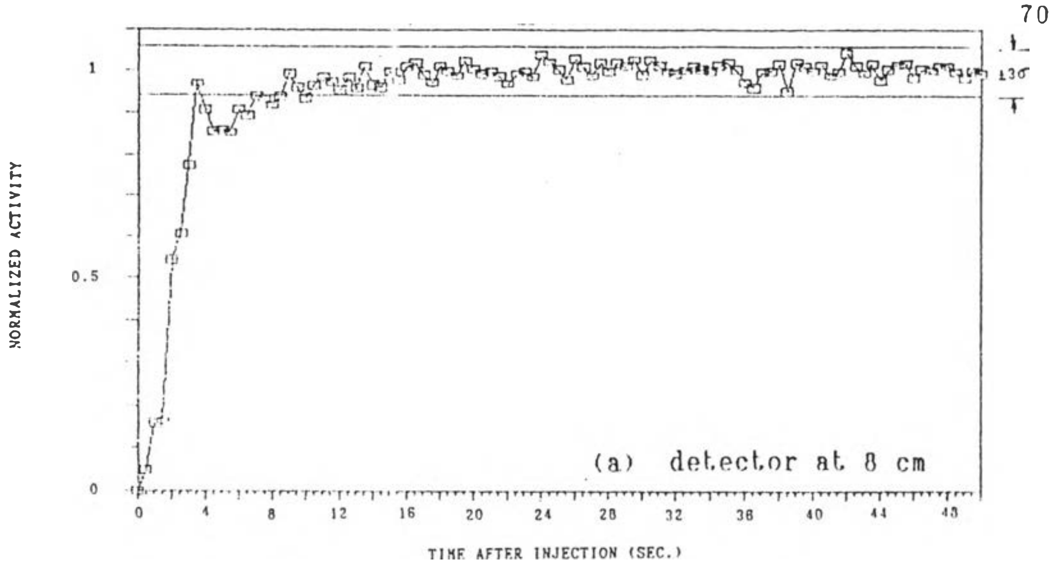
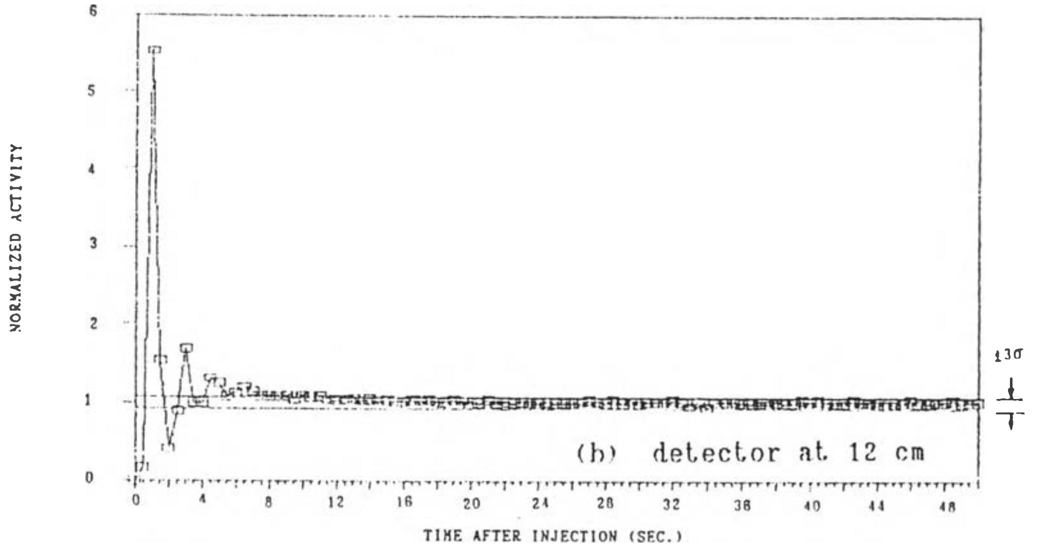


Figure 4.3 Tracer respond curves of disc 6 bladed turbine at 8 cm , speed of 200 rpm , and with baffles using radioactive tracer technique





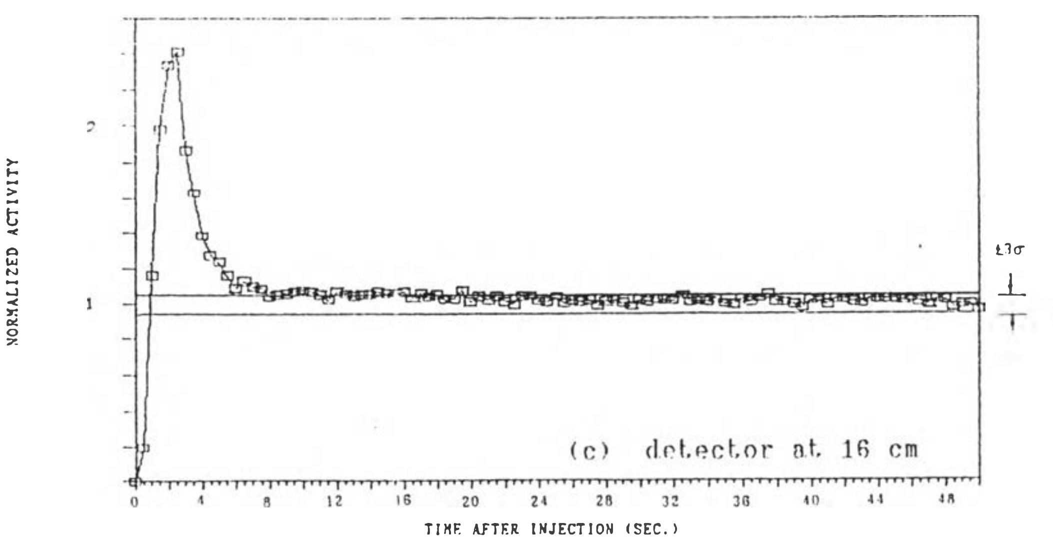


Figure 4.4 Tracer respond curves of disc 6 bladed turbine at 12 cm, speed of 300 rpm, and without baffles using radioactive tracer technique

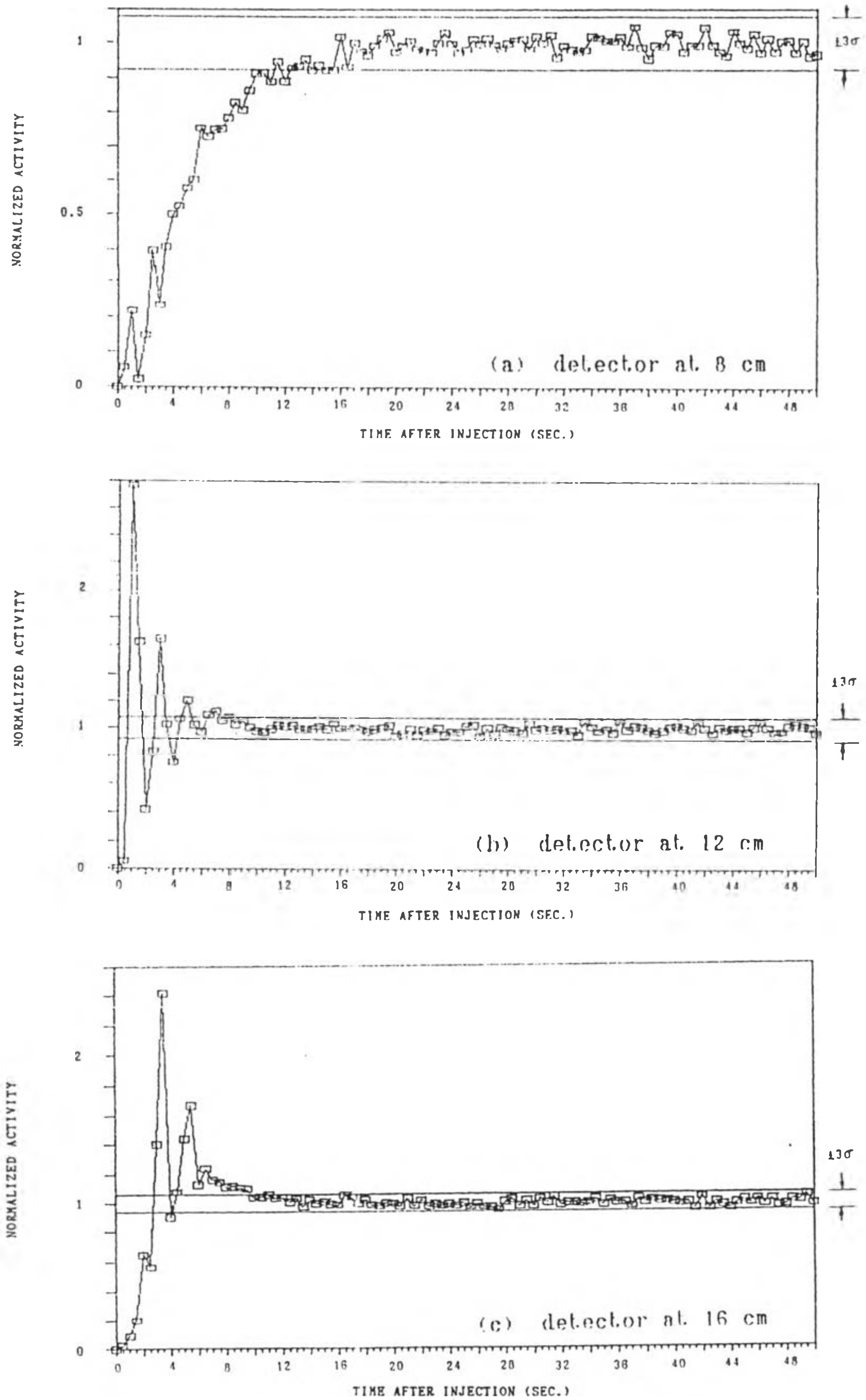


Figure 4.5 Tracer respond curves of disc 6 bladed turbine at 8 cm, speed of 200 rpm, and with baffles using radioactive tracer technique

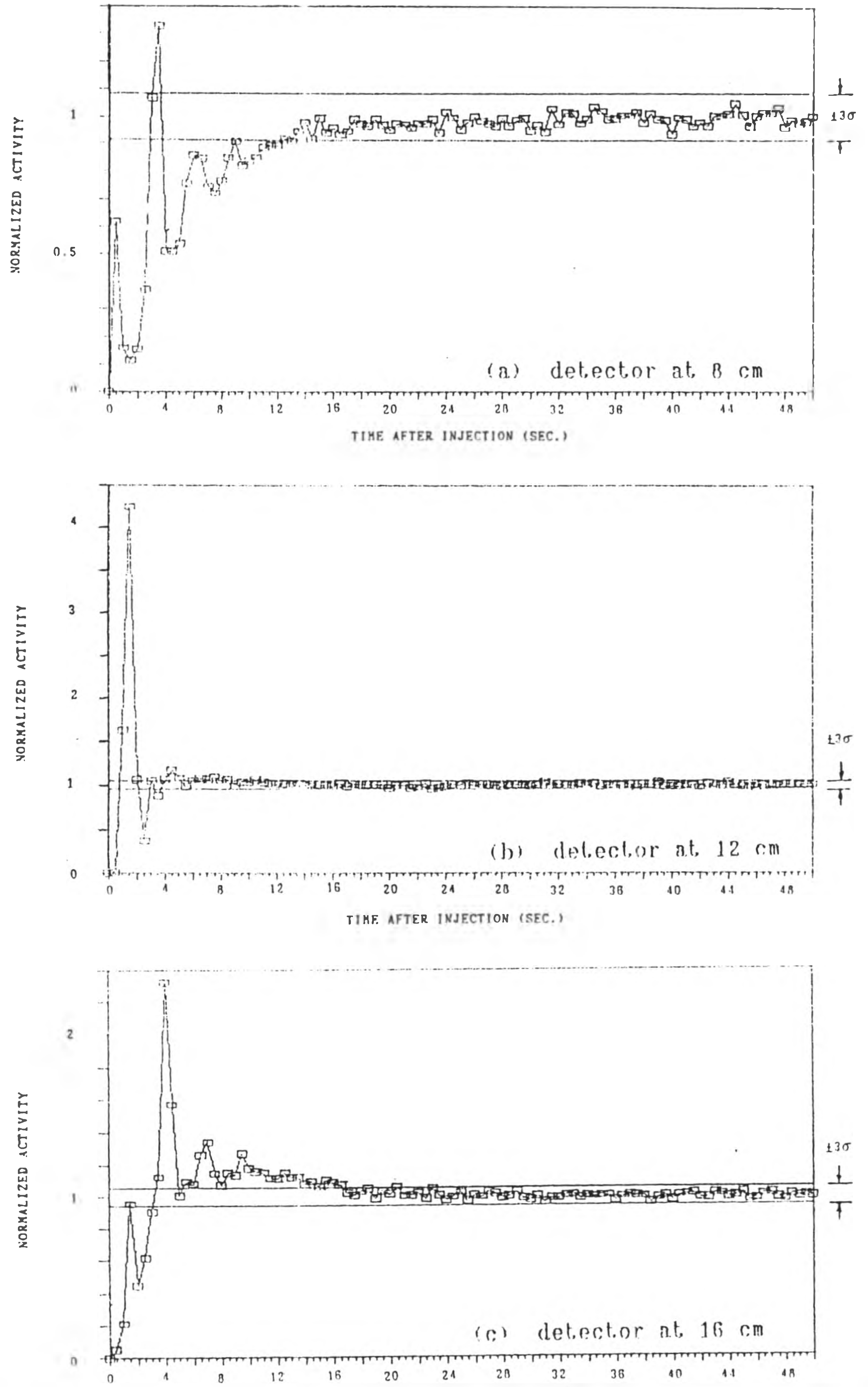


Figure 4.6 Tracer respond curves of open 6 bladed turbine at 12 cm, speed of 200 rpm, and without baffles using radioactive tracer technique

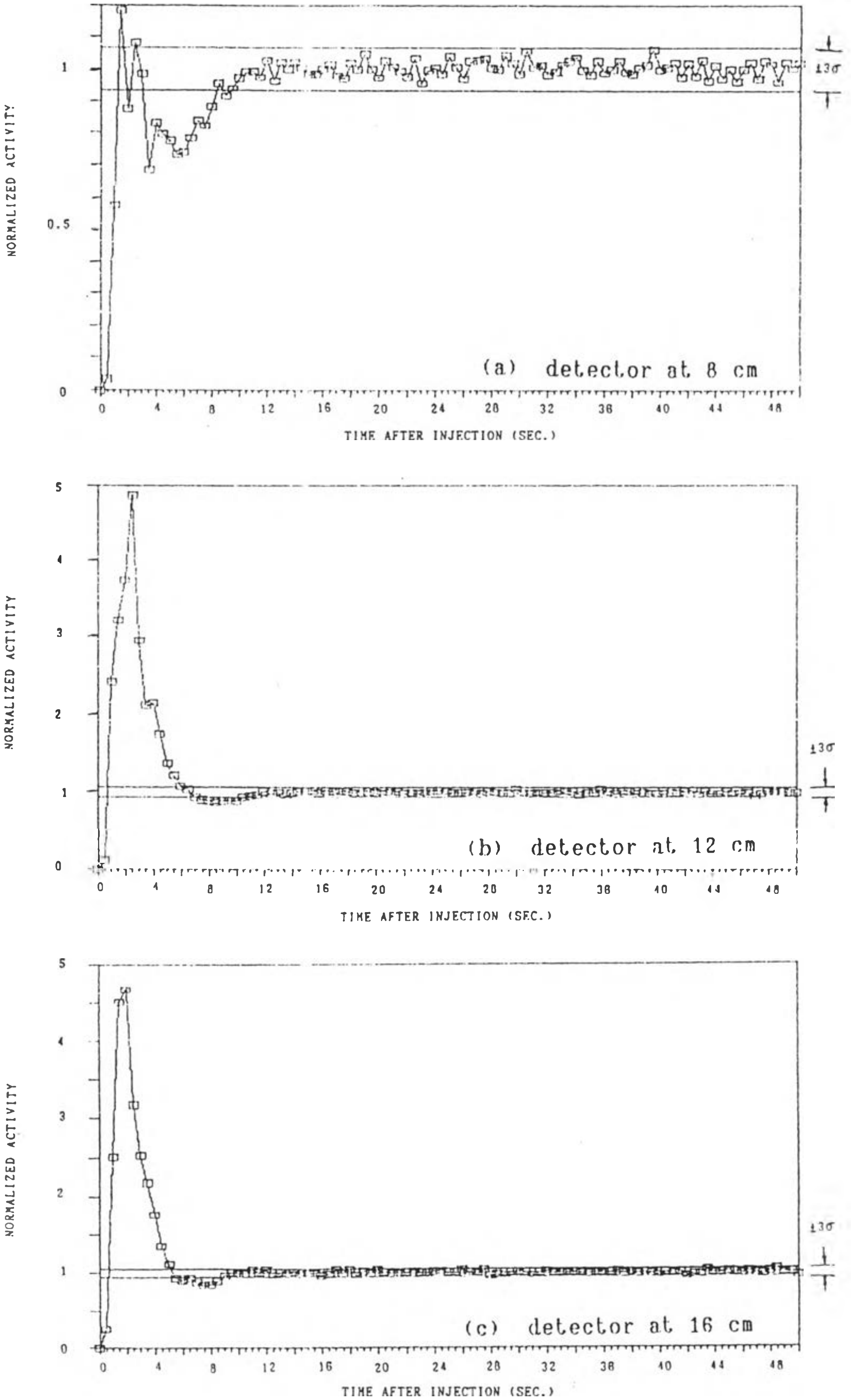


Figure 4.7 Tracer respond curves of open 6 bladed Turbine at 8 cm , speed of 200 rpm , and with baffles using radioactive tracer technique

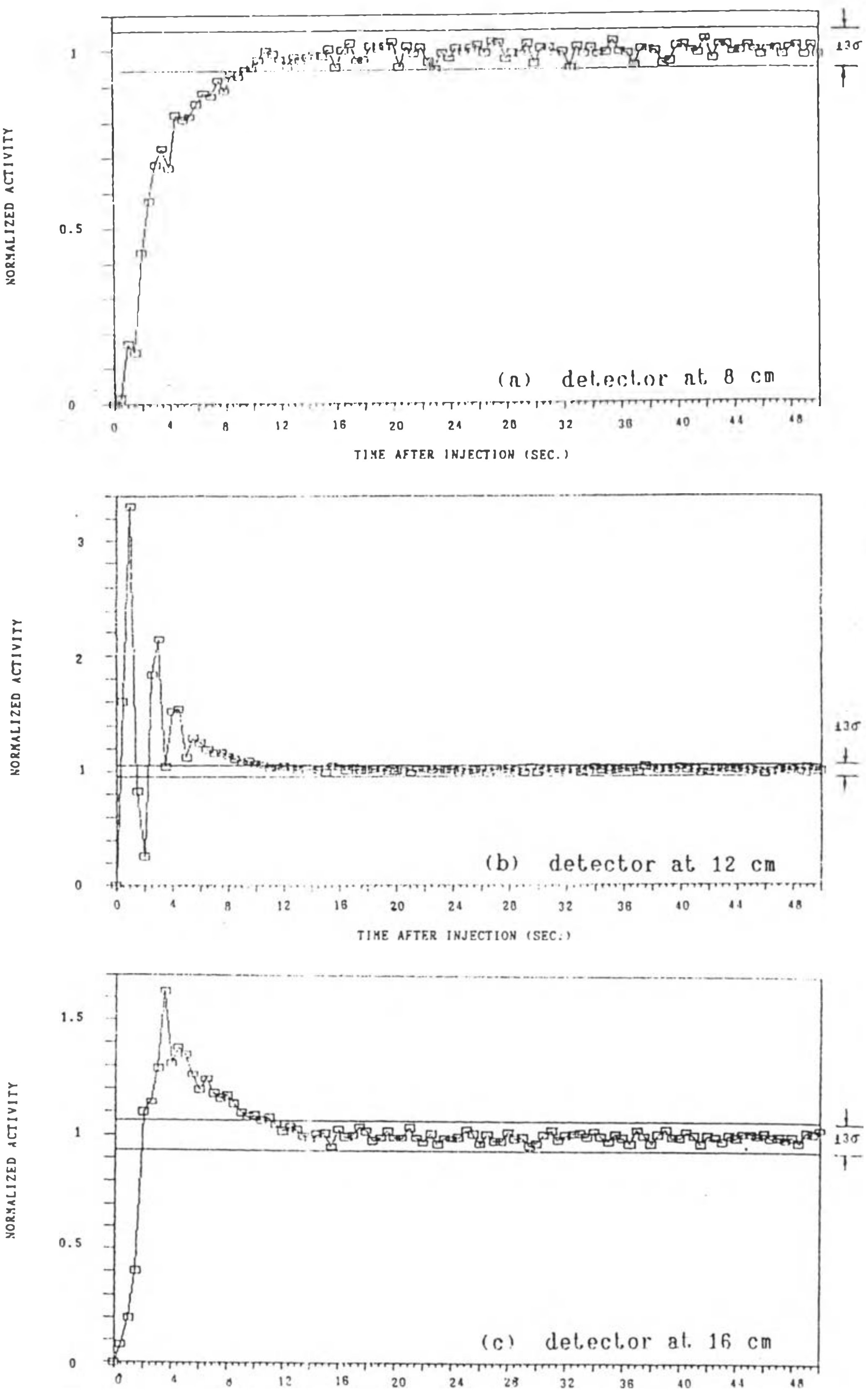


Figure 4.8 Tracer respond curves of open 6 bladed turbine at 8 cm, speed of 400 rpm, and without baffles using radioactive tracer technique

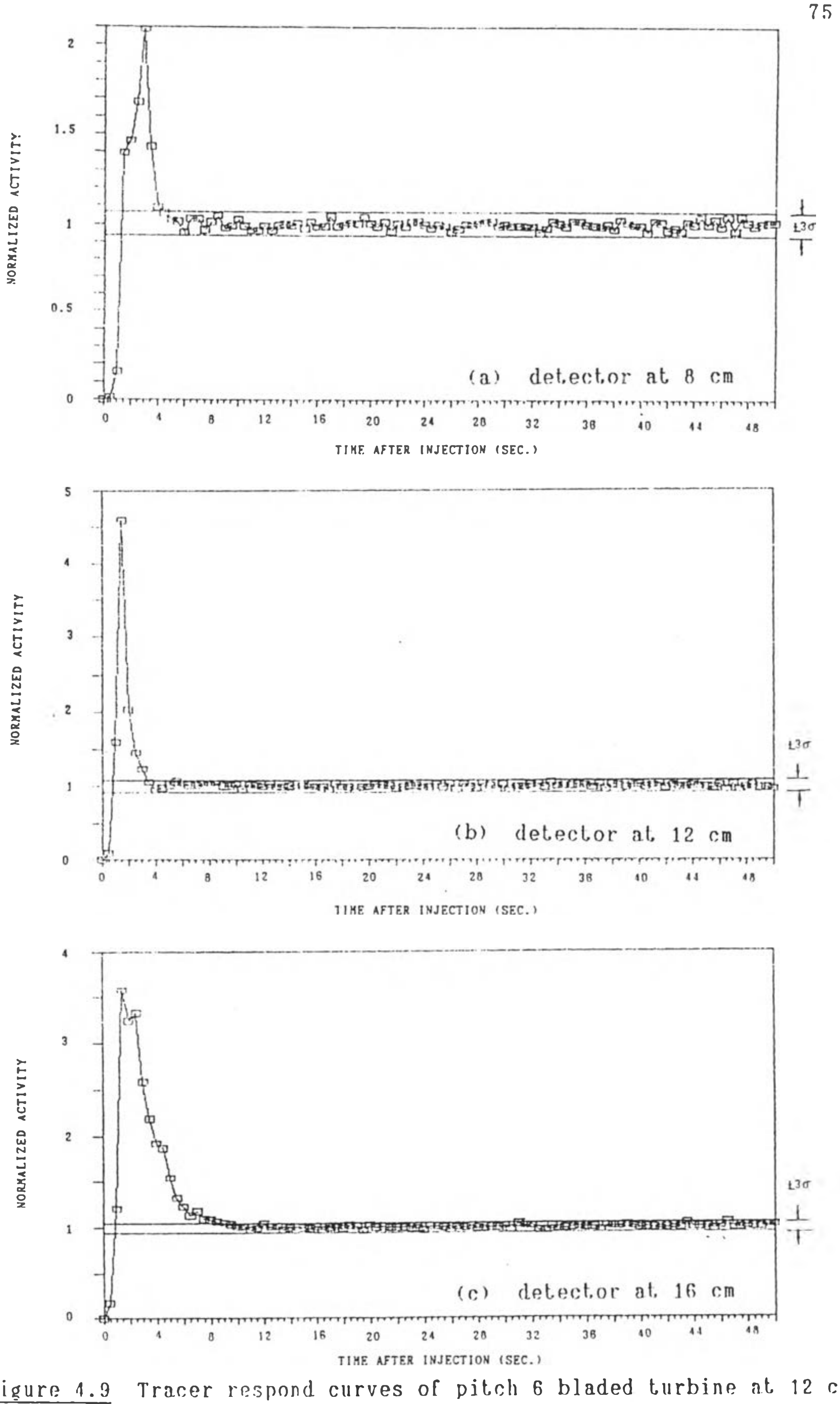


Figure 4.9 Tracer respond curves of pitch 6 bladed turbine at 12 cm , speed of 400 rpm , and with baffles using radioactive tracer technique

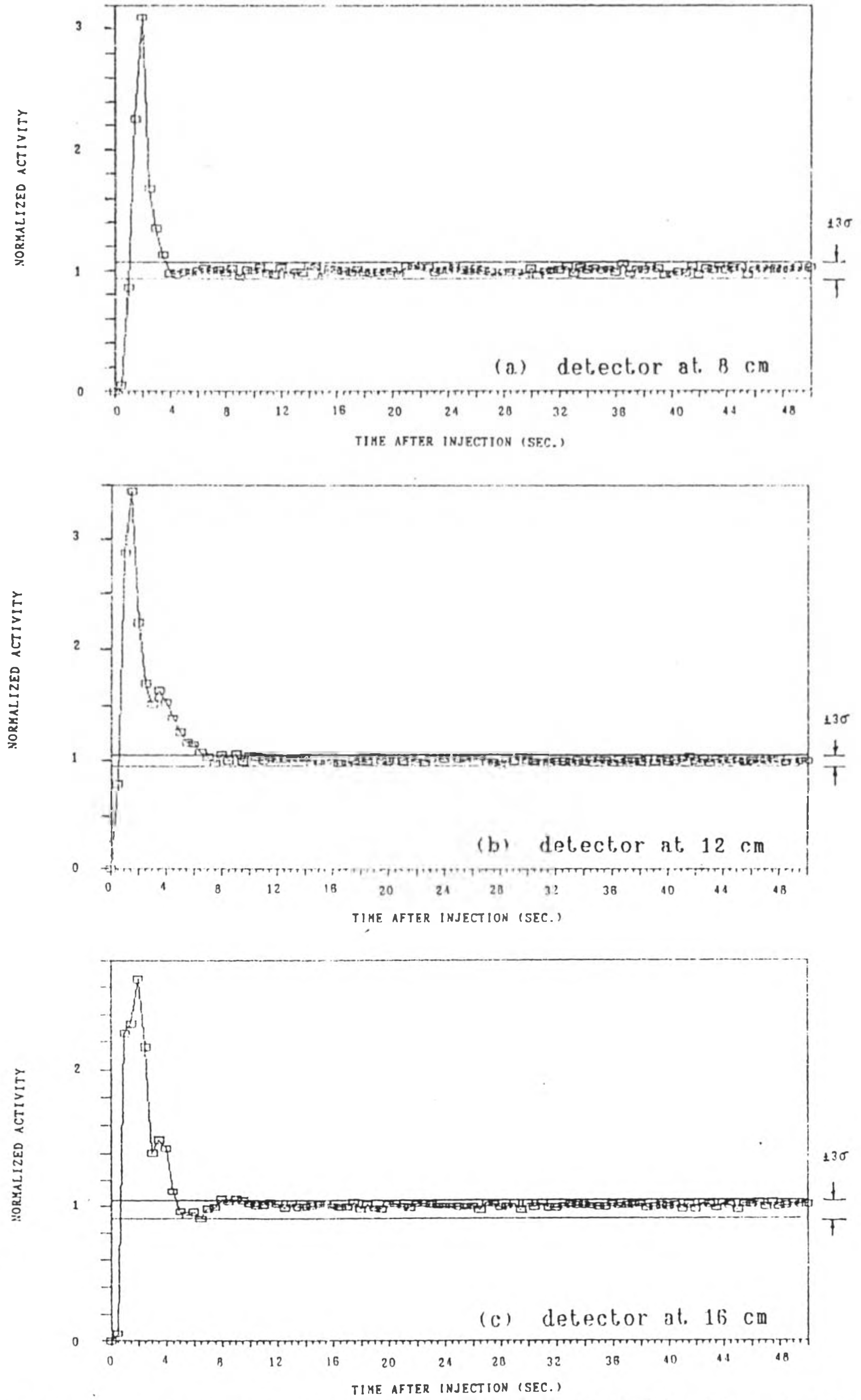


Figure 4.10 Tracer respond curves of pitch 6 bladed turbine at 12 cm, speed of 300 rpm, and with baffles using radioactive tracer technique

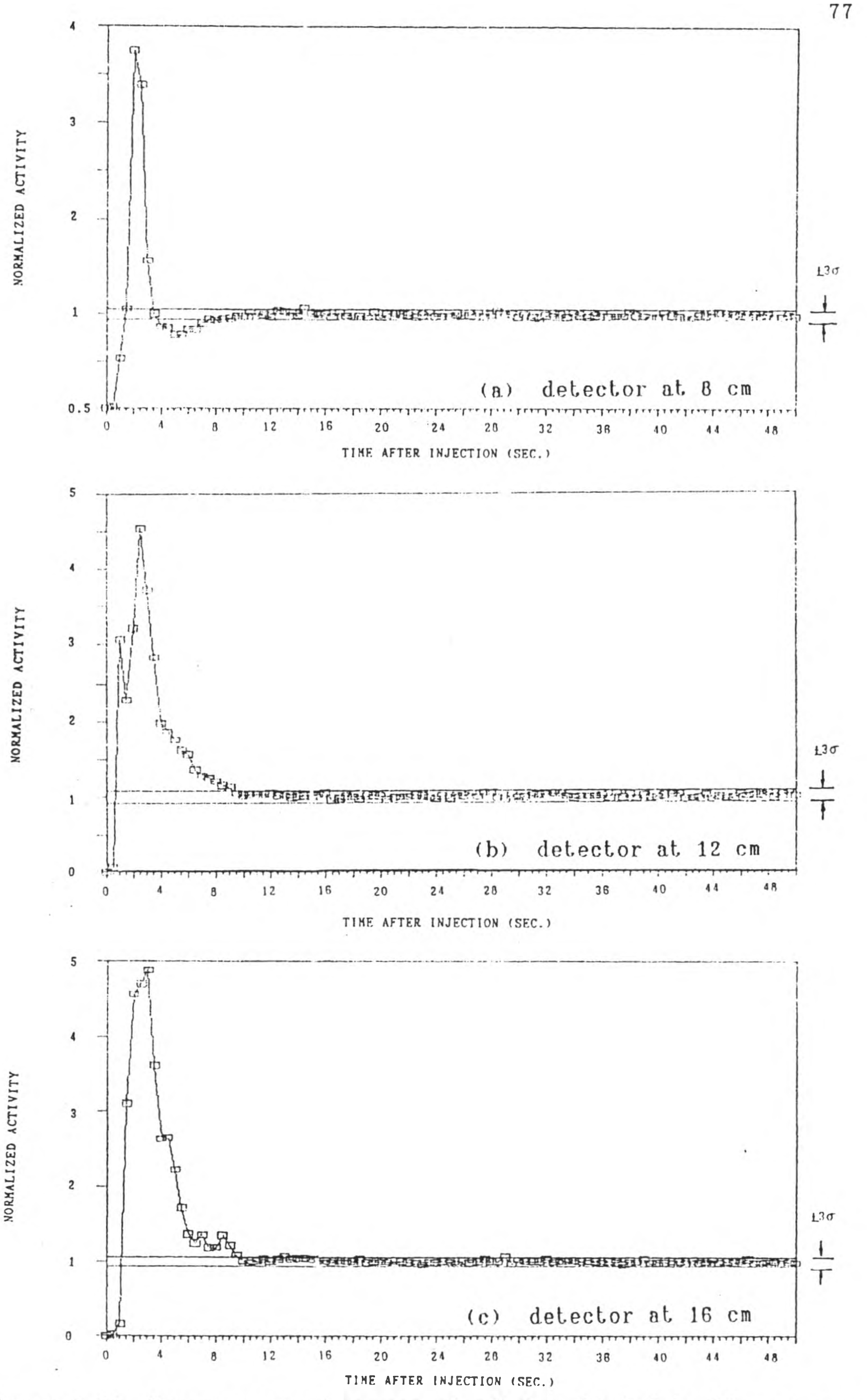


Figure 4.11 Tracer respond curves of pitch 6 bladed turbine at 8 cm, speed of 200 rpm., and with baffles using radioactive tracer technique

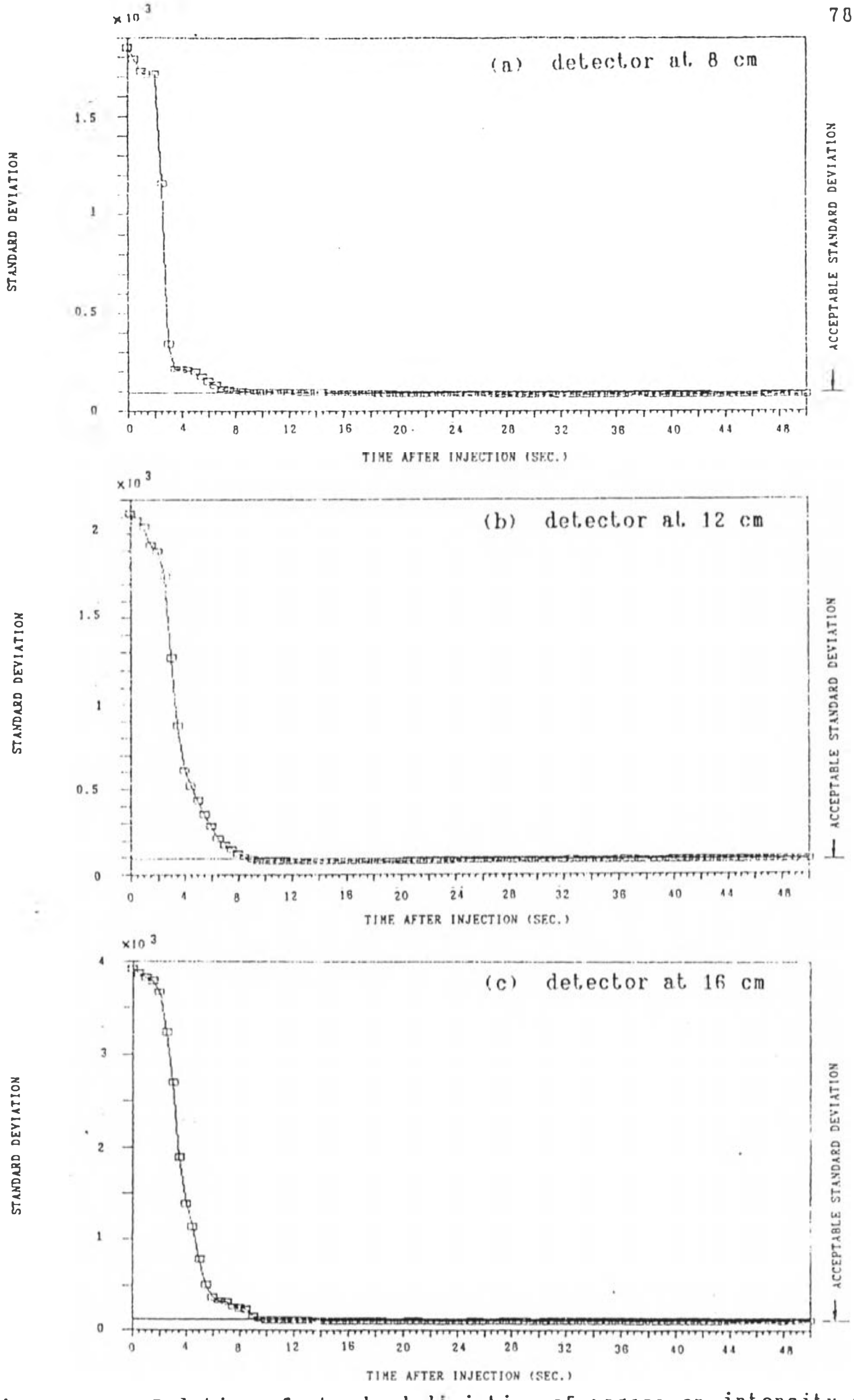


Figure 4.12 Relation of standard diviation of radiation intensity and time of mixing of pitch 6 bladed turbine at 8 cm, speed of 200 rpm, and with baffles using radioactive tracer technique

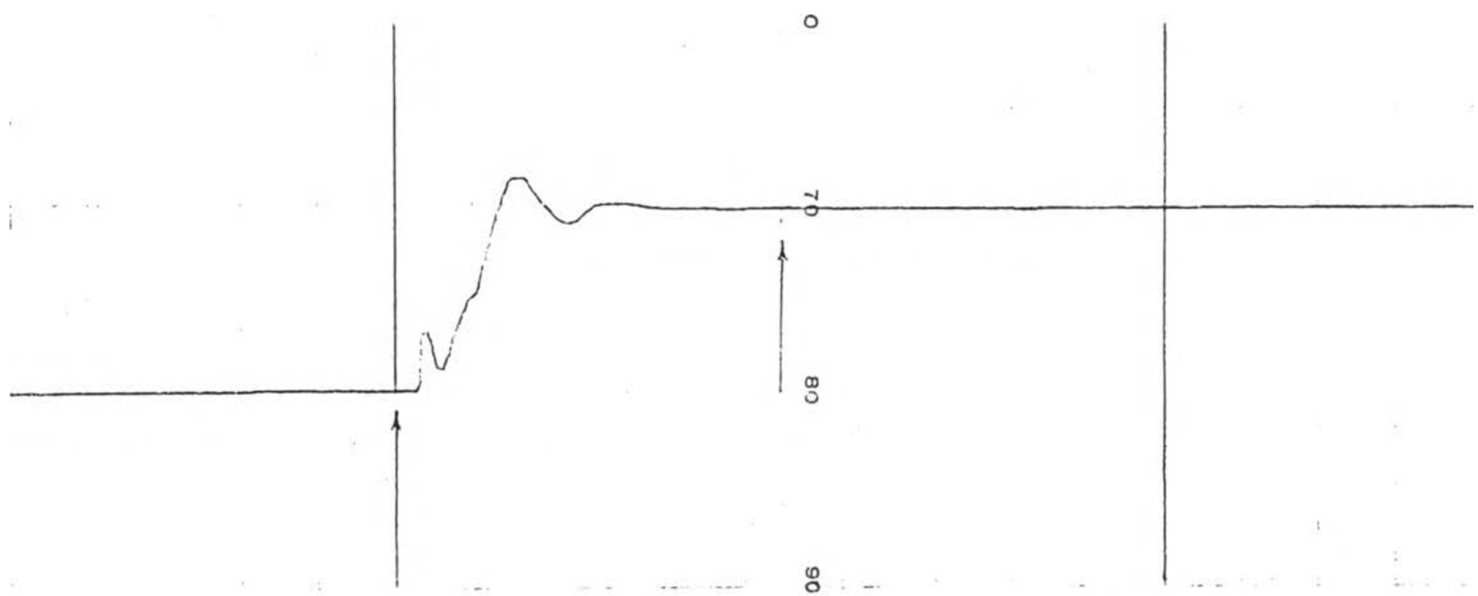


Figure 4.13 Tracer respond curves of disc 6 bladed turbine at 8 cm , speed of 200 rpm , and with baffles using conductivity method

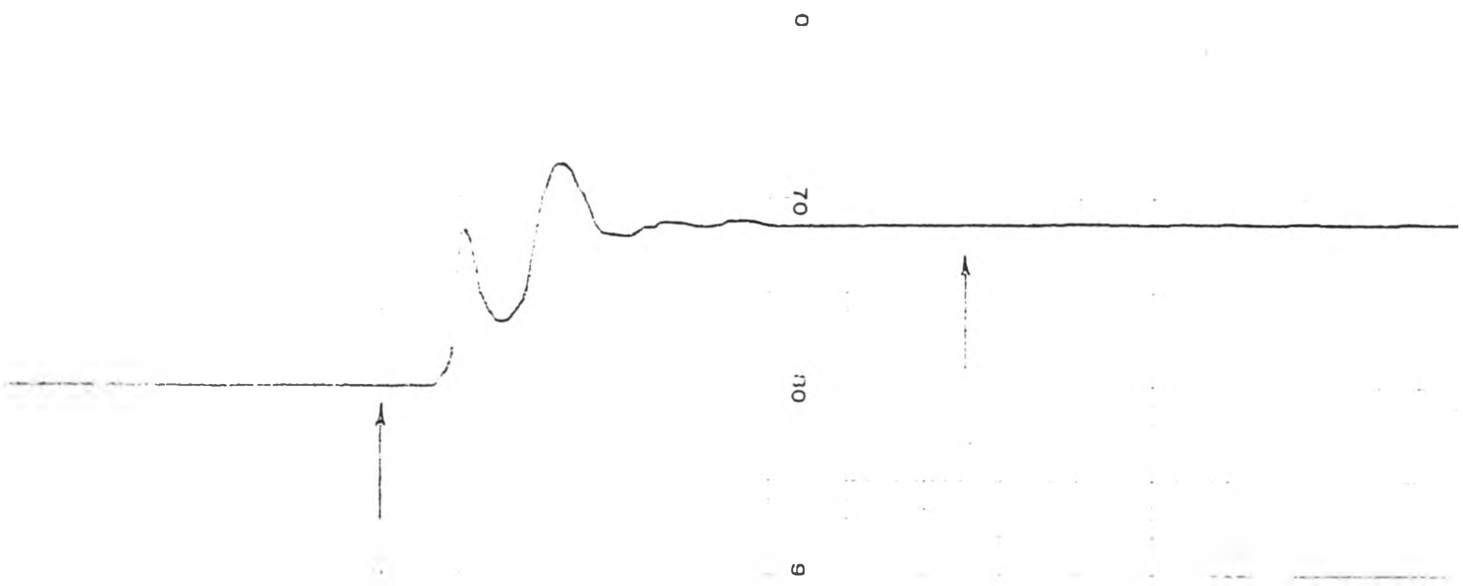
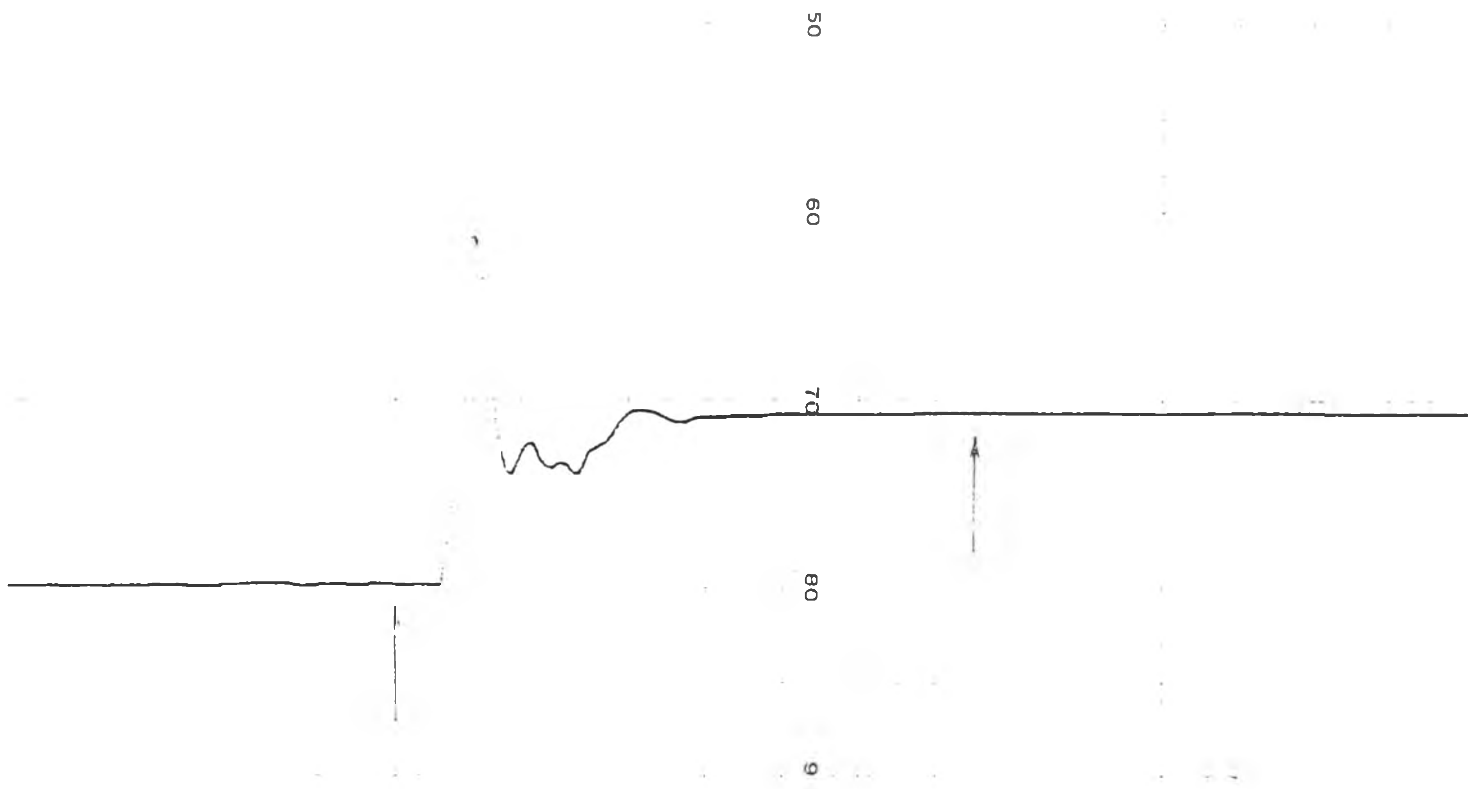


Figure 4.14 Tracer respond curves of disc 6 bladed turbine at 12 cm , speed of 300 rpm , and without baffles using conductivity method



Injection

chart speed 30 cm /min.

Figure 4.15 Tracer respond curves of disc 6 Bladed turbine at 8 cm , speed of 200 rpm , and with baffles using conductivity method

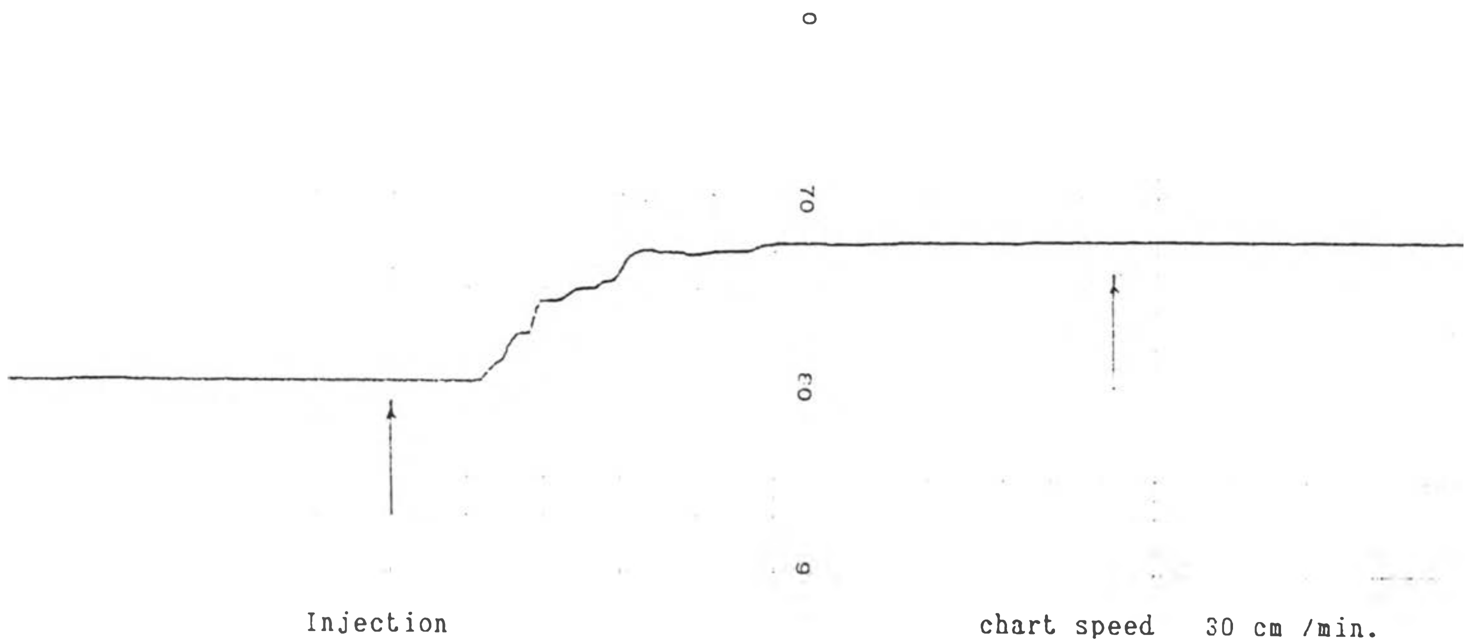


Figure 4.16 Tracer respond curves of open 6 bladed turbine at 12 cm , speed of 200 rpm , and without baffles using conductivity method

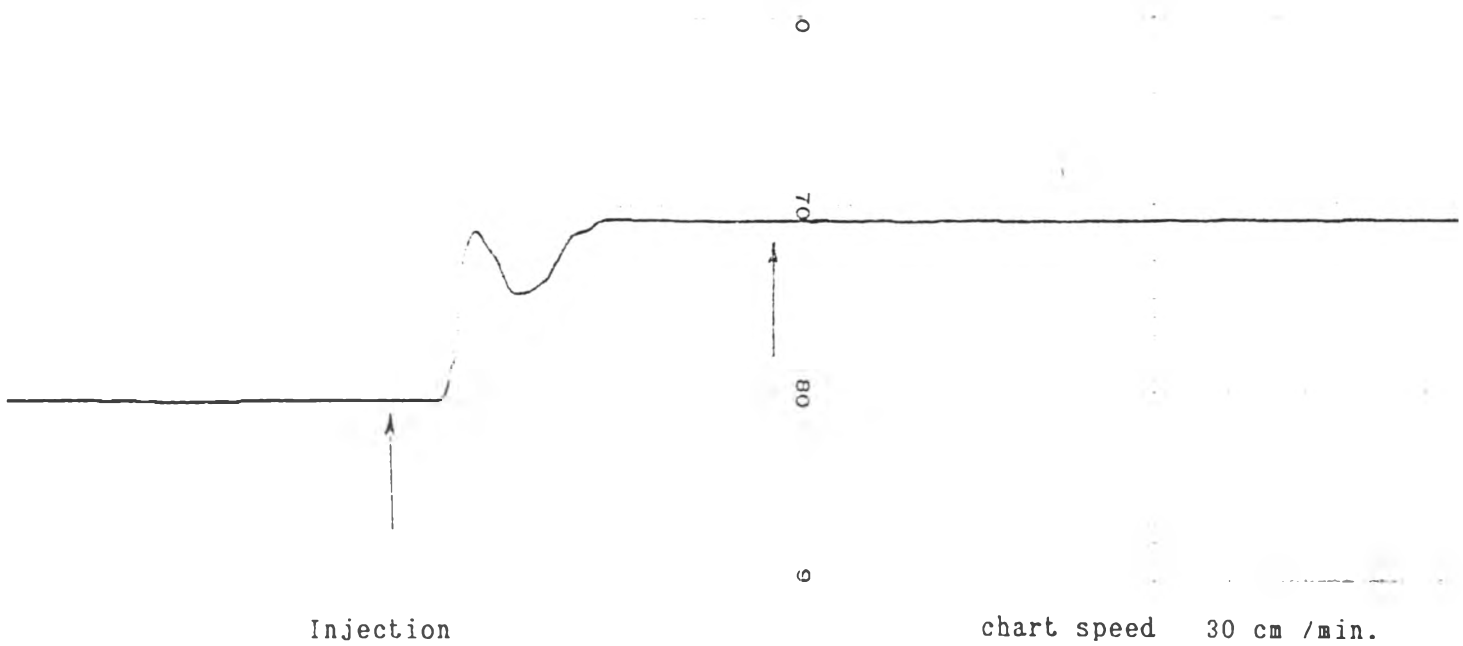
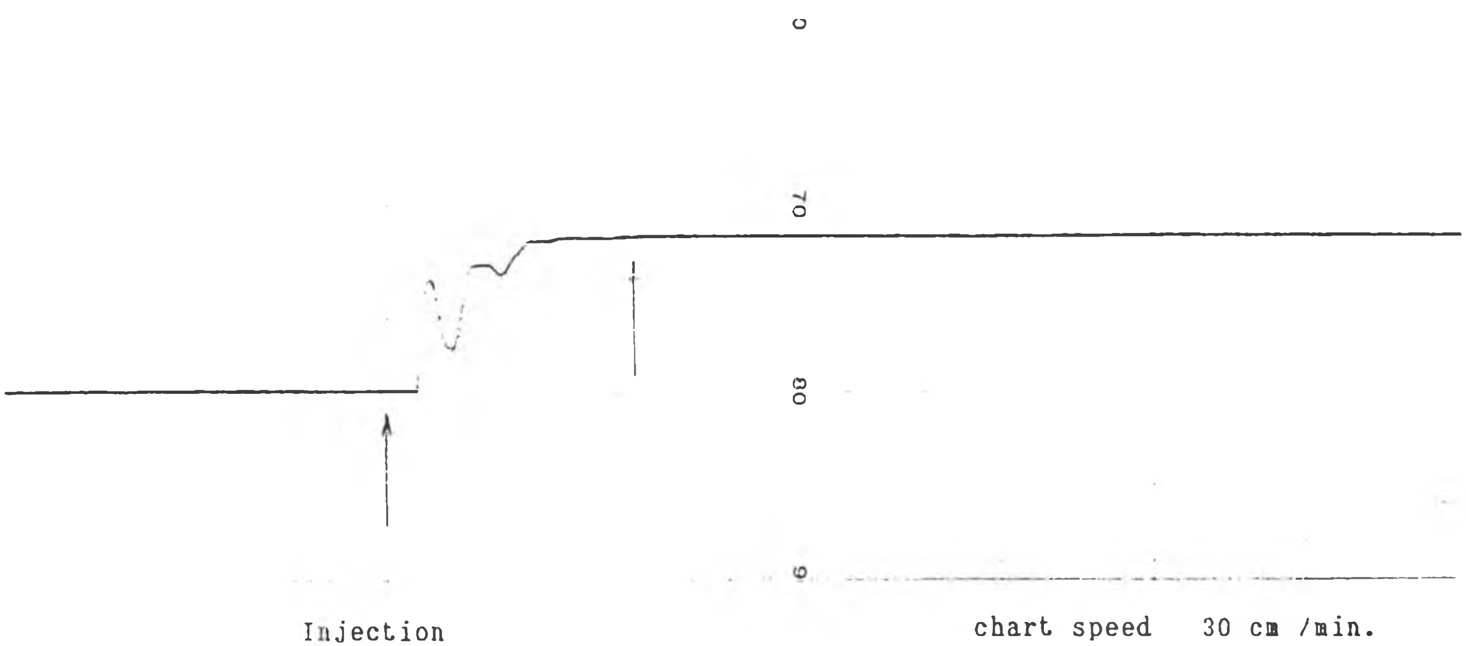


Figure 4.17 Tracer respond curves of open 6 bladed turbine at 8 cm , speed of 200 rpm , and with baffles using conductivity method



<u>Figure 4.18</u> Tracer respond curves of open 6 bladed turbine at 8 cm , speed of 400 rpm , and without baffles using conductivity method

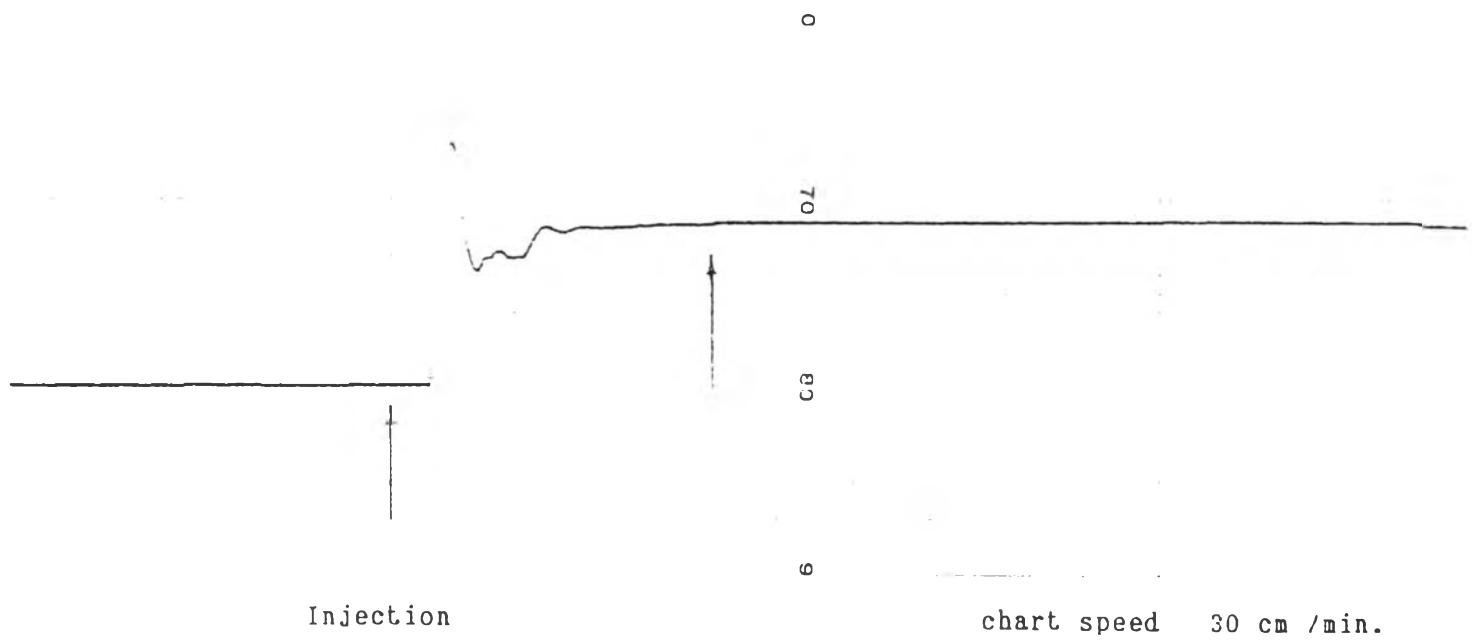


Figure 4.19 Tracer respond curves of pitch 6 bladed turbine at 12 cm , speed of 400 rpm , and with baffles using conductivity method

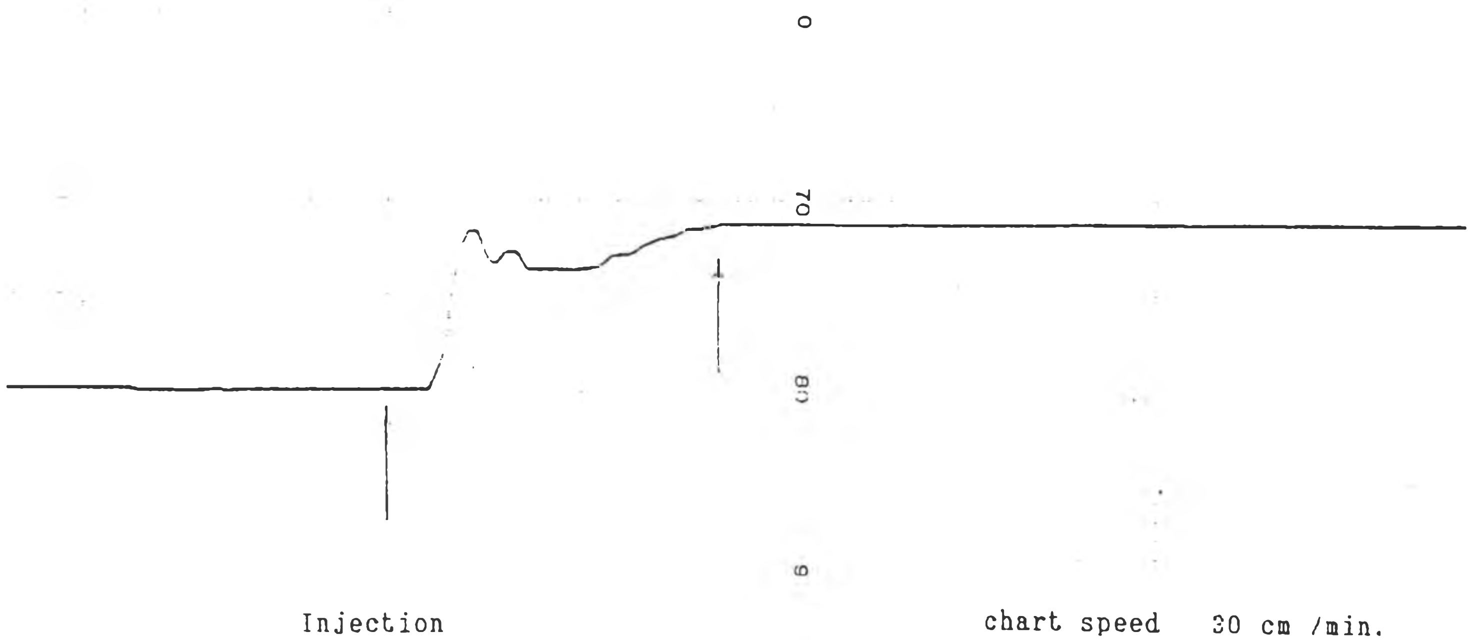


Figure 4.20 Tracer respond curves of pitch 6 bladed turbine at 12 cm , speed of 300 rpm , and with baffles using conductivity method

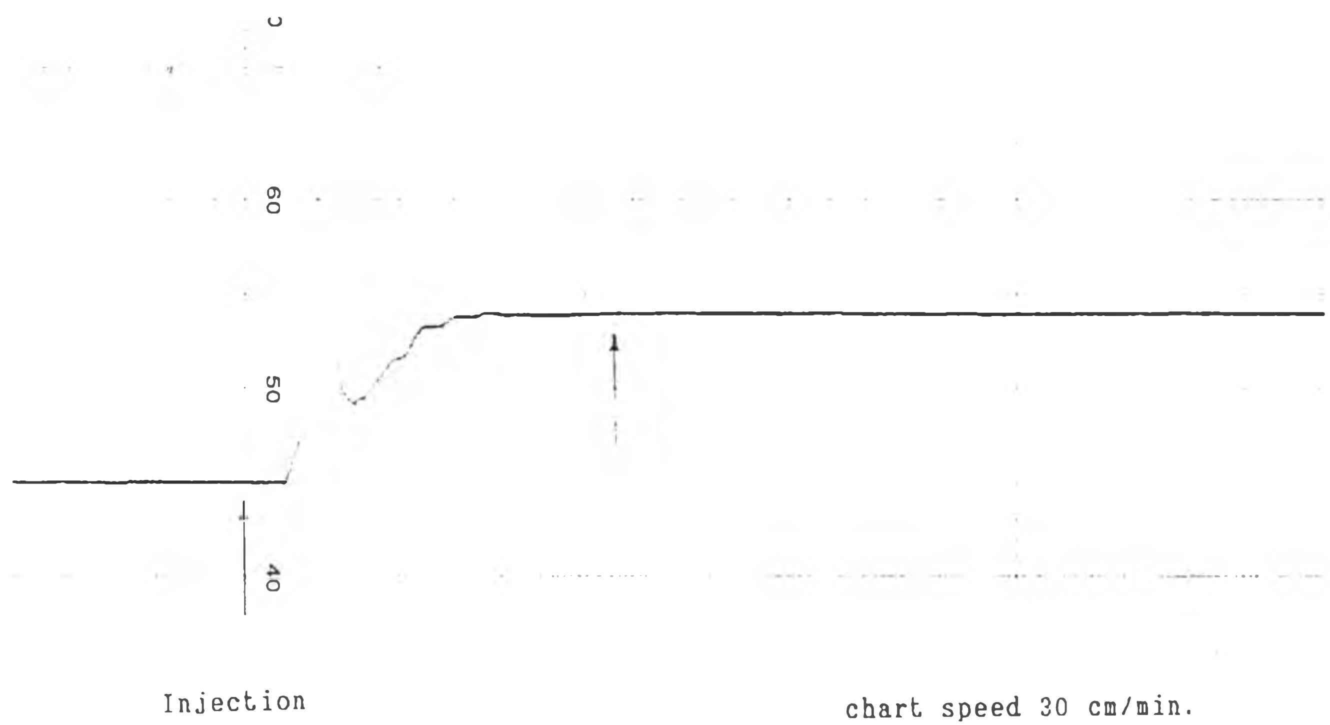


Figure 4.21 Tracer respond curves of pitch 6 bladed turbine at 8 cm , speed of 200 rpm , and with baffles using conductivity method

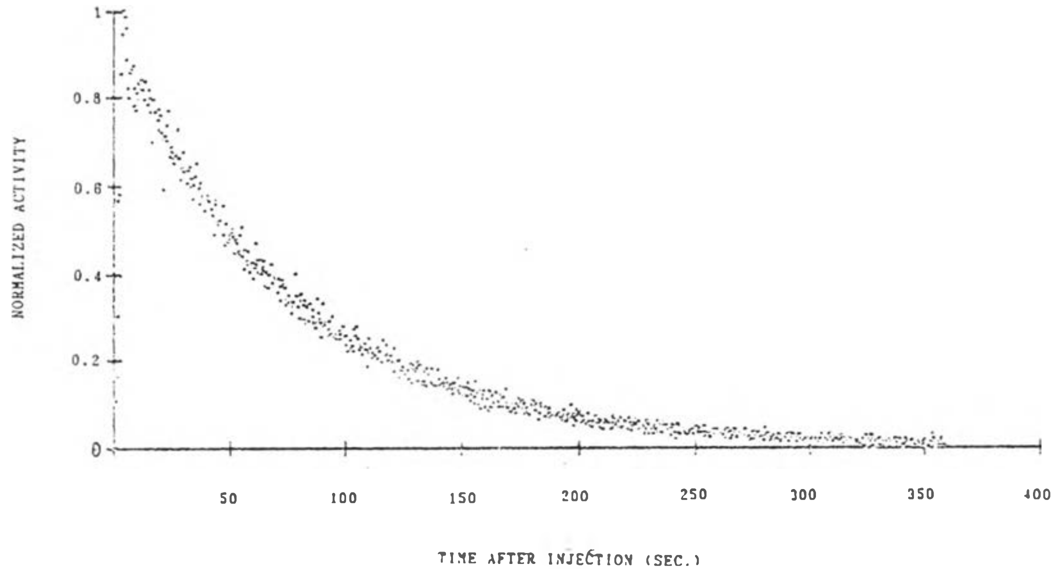


Figure 4.22 Tracer response curve of continuous stirred tank with disc 6 bladed turbine at volumetric flowrate of 8.85 litre/min.

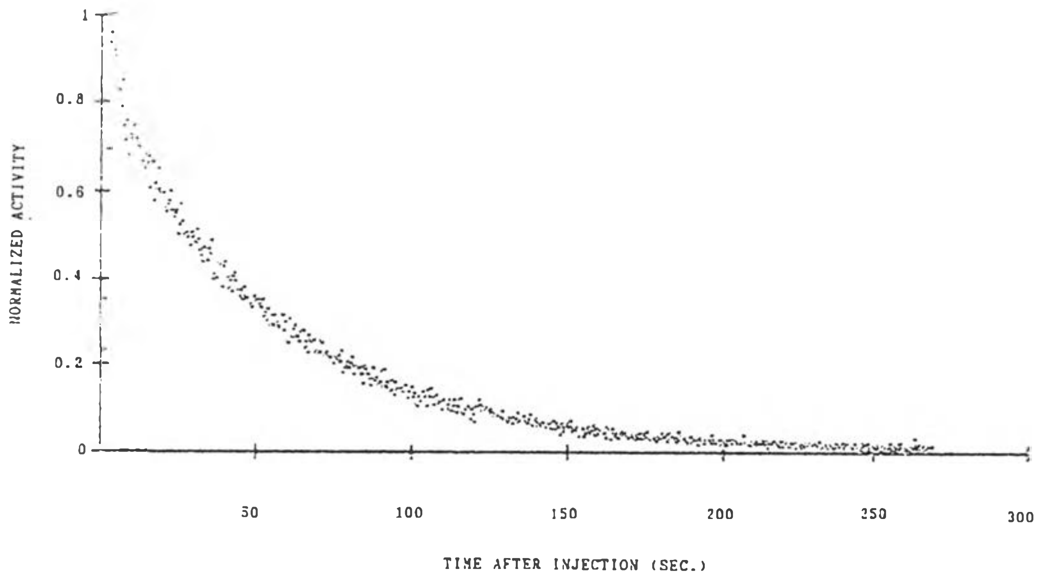


Figure 4.23 Tracer response curve of continuous stirred tank with disc 6 bladed turbine at volumetric flowrate of 11.80 litre/min.

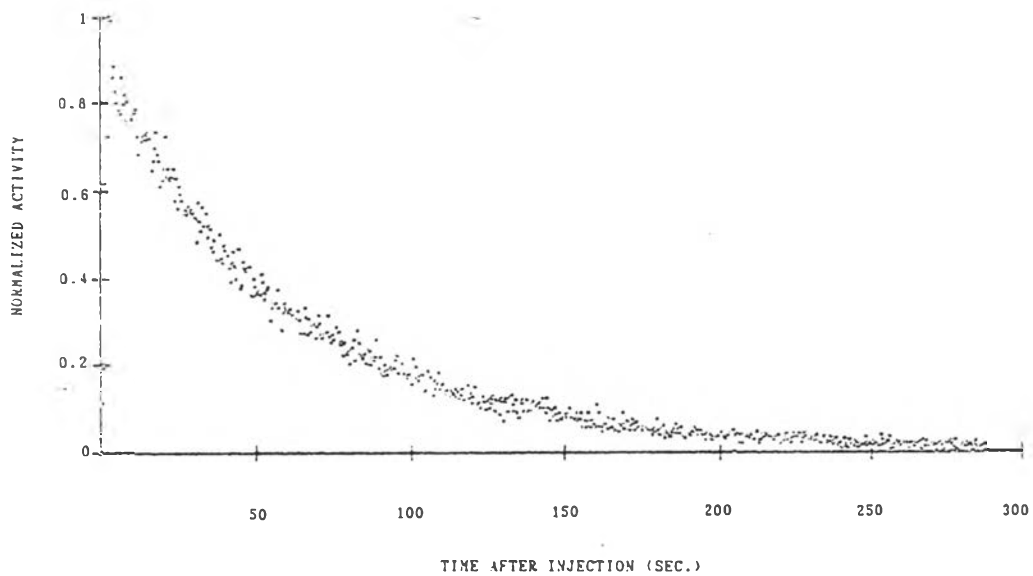


Figure 4.24 Tracer response curve of continuous stirred tank with open 6 bladed turbine at volumetric flowrate of 10.70 litre/min.

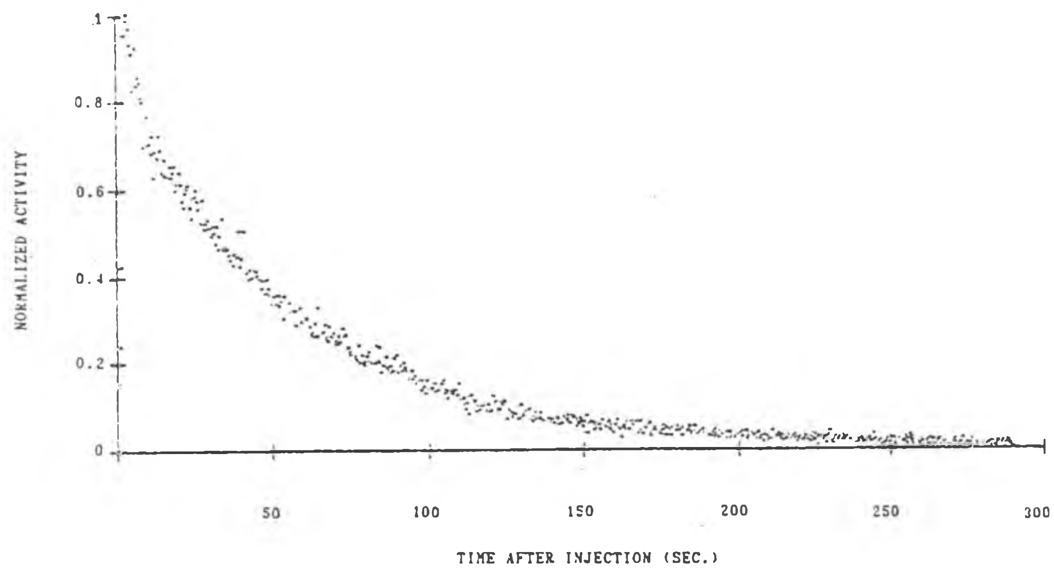


Figure 4.25 Tracer response curve of continuous stirred tank with open 6 bladed turbine at volumetric flowrate of 11.80 litre/min.

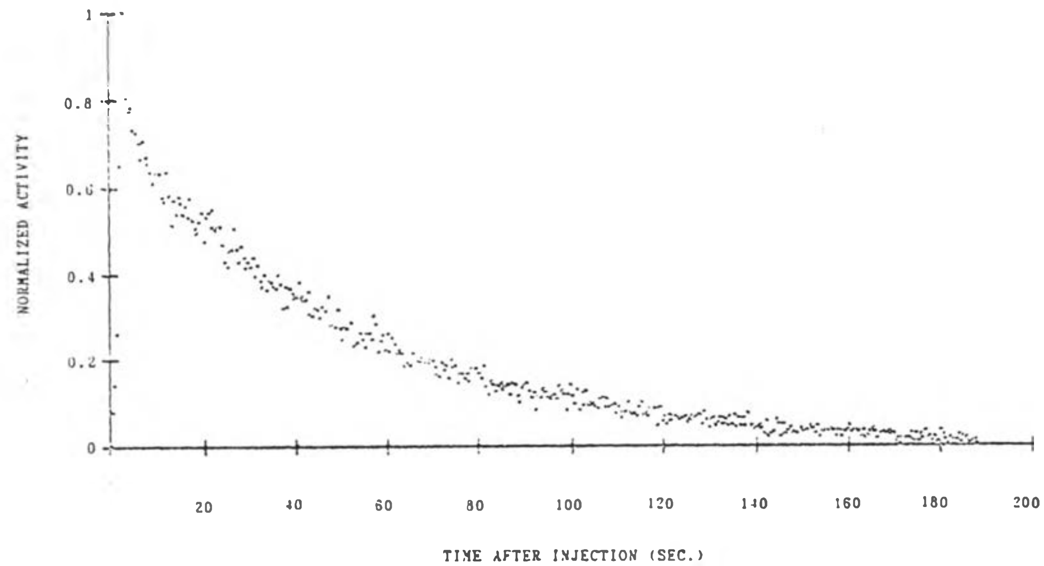


Figure 4.26 Tracer response curve of continuous stirred tank with pitch 6 Bladed turbine at volumetric flowrate of 11.80 litre/min.

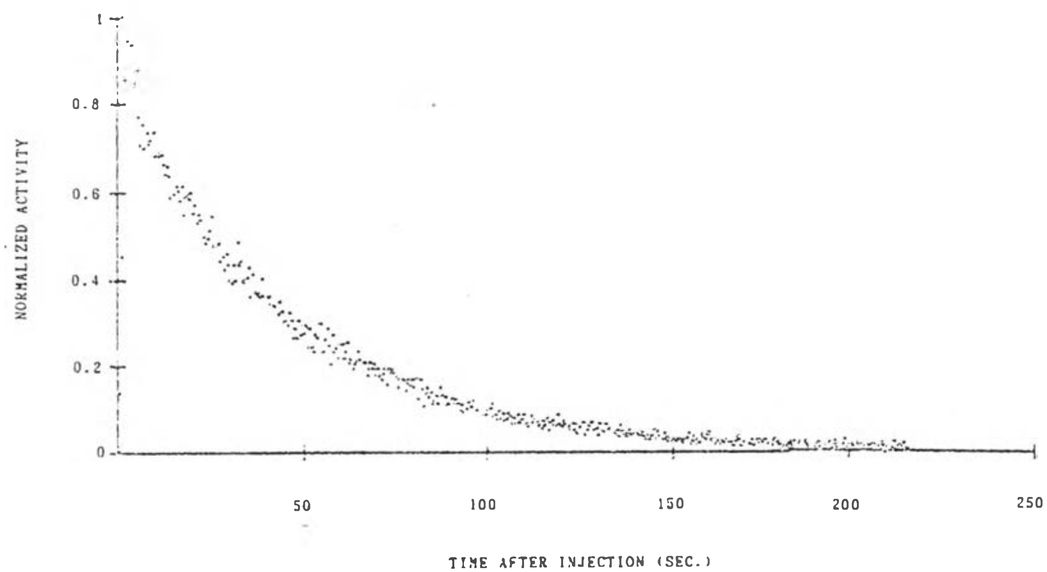


Figure 4.27 Tracer response curve of continuous stirred tank with pitch 6 bladed turbine at volumetric flowrate of 14.10 litre/min.

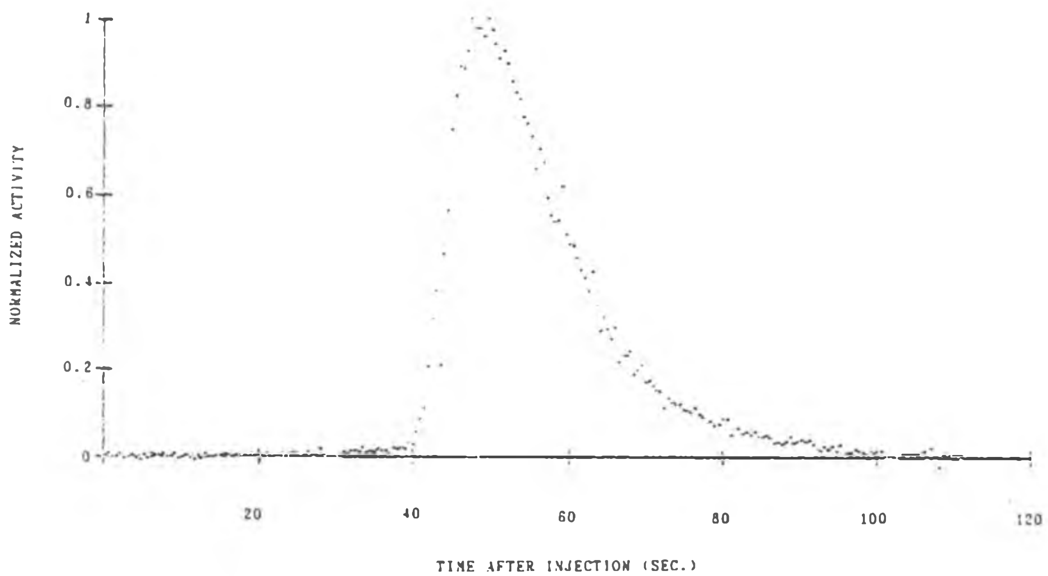


Figure 4.28 Tracer response curve of tubular vessel with 3 in. nominal diameter at volumetric flowrate of 11.80 litre/min.

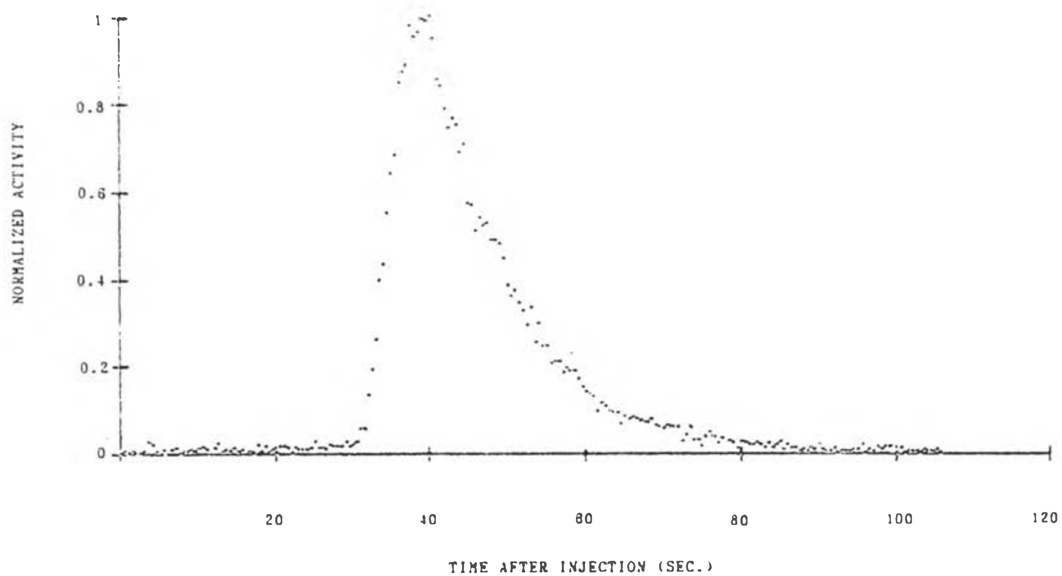


Figure 4.29 Tracer response curve of tubular vessel with 3 in. nominal diameter at volumetric flowrate of 14.10 litre/min.

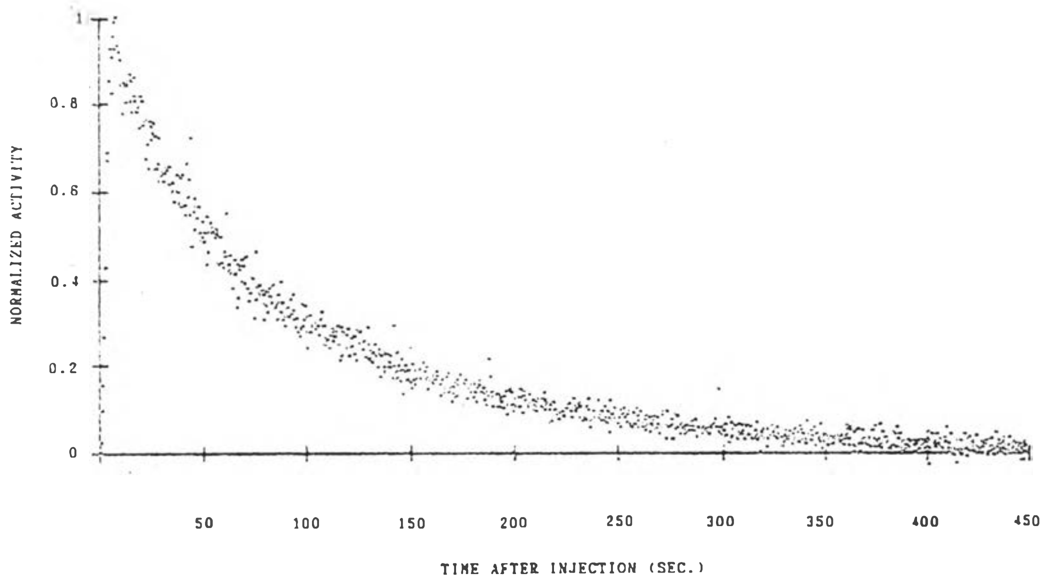


Figure 4.30 Tracer response curve of tubular vessel with 4 in. nominal diameter at volumetric flowrate of 5.40 litre/min.

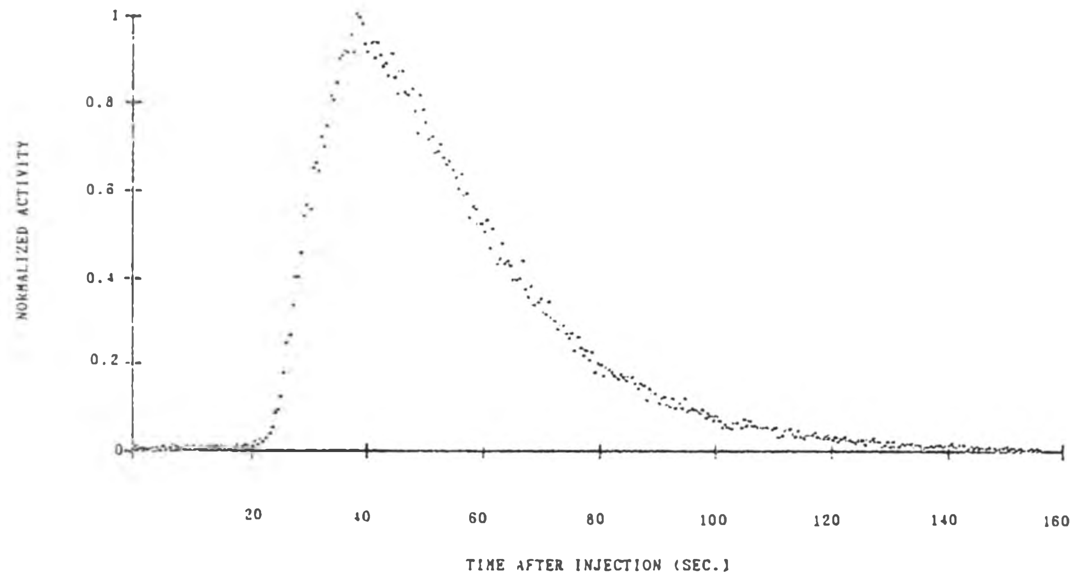


Figure 4.33 Tracer response curve of tubular vessel with 6 in. nominal diameter at volumetric flowrate of 14.10 litre/min.

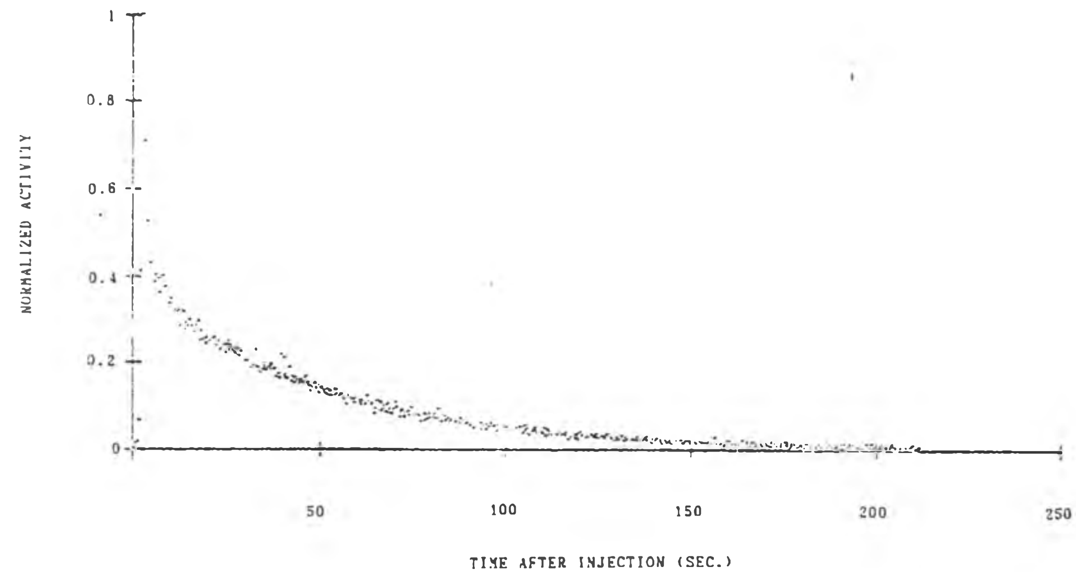


Figure 4.31 Tracer response curve of tubular vessel with 4 in. nominal diameter at volumetric flowrate of 11.80 litre/min.

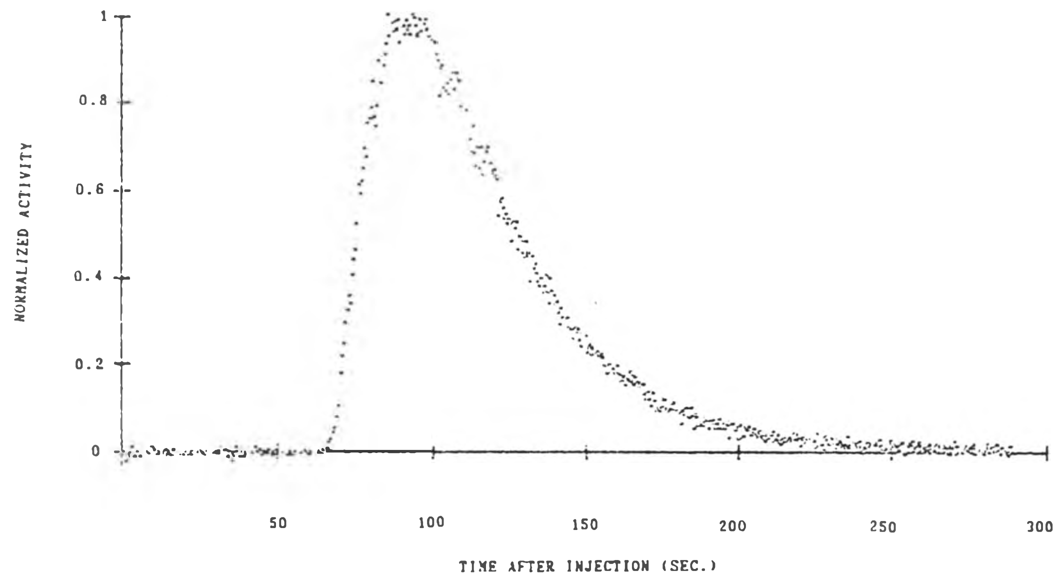


Figure 4.32 Tracer response curve of tubular vessel with 6 in. nominal diameter at volumetric flowrate of 5.40 litre/min.