

**CHAPTER 3**  
**RESULTES**  
**AND**  
**DISCUSSION**

**PART I**  
**RESULTES**

## Chapter 3

# Results and discussion

## Part 1

### Results

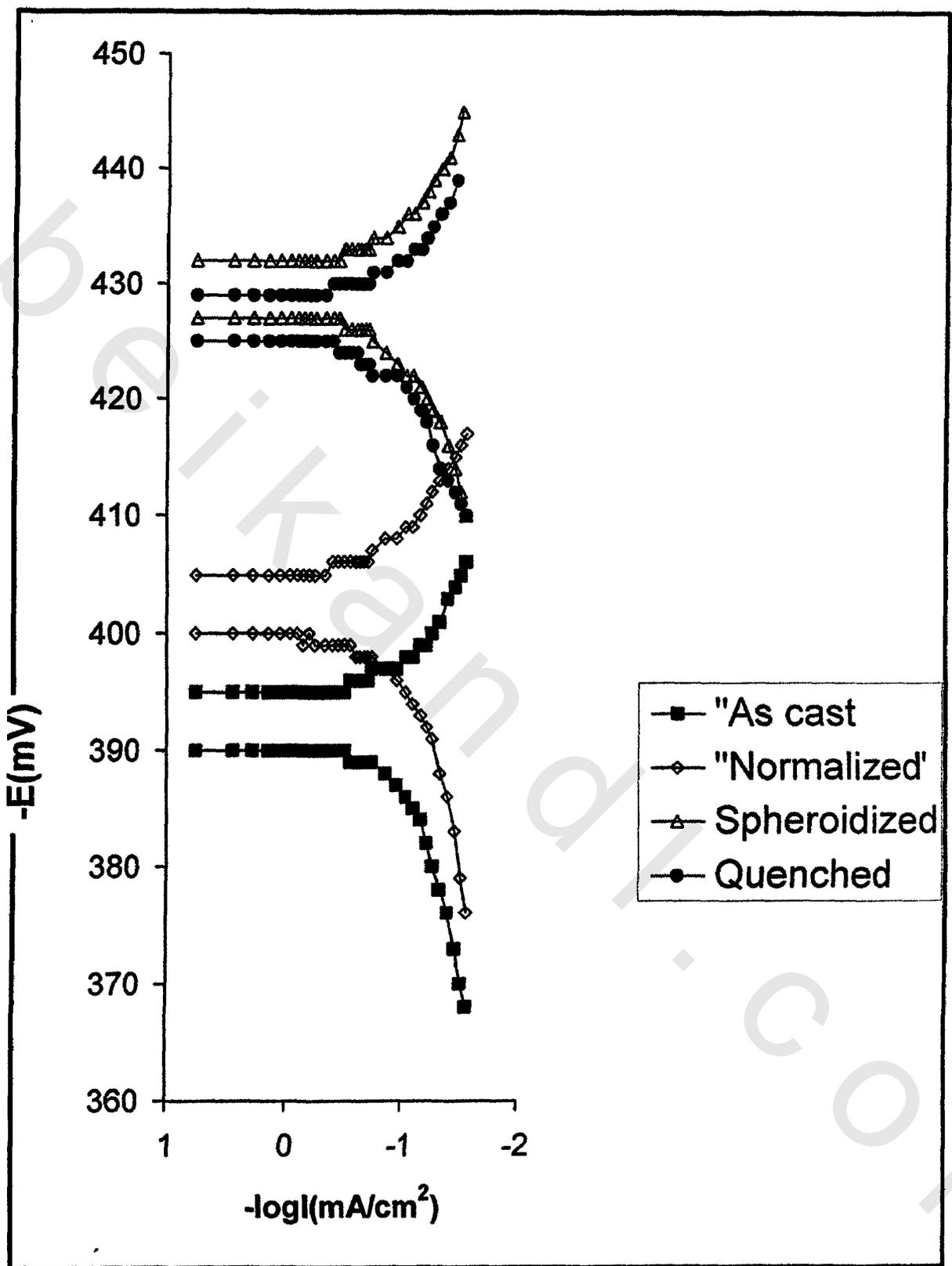
In this part, the experimental data of polarization technique were treated mathematically using Tafel equation, to deduce the corrosion resistance values for two types of C.V. steel (L&M) as its and after heat treatment in different corrosion media (0.1, 0.3 and 0.5 M HNO<sub>3</sub>) at different temperatures. Also, effect of HEAA, as inhibitor in the corrosion processes of different samples under study was studied and discussed.

#### A) Data treatment for the polarization technique

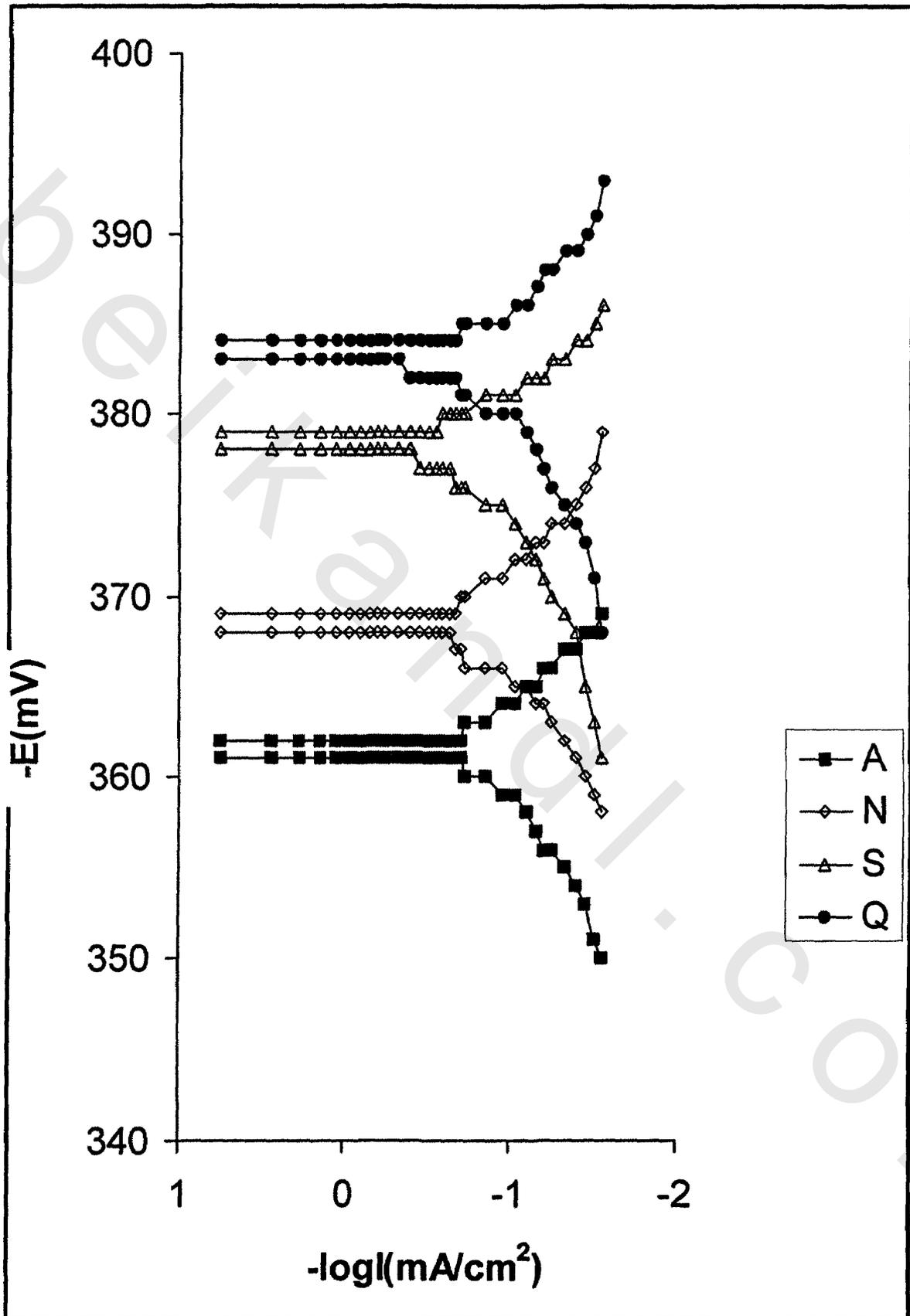
The cathodic and anodic current,  $i_c$  &  $i_a$ , were used to calculate the cathodic and anodic polarization current density  $i_c$  or  $i_a$ , by surface area of the working electrode, for every metal sample. Also, the corresponding over potential (E), values were recorded. The above data were plotted diagrammatically where (-E) values were plotted against (-log I) values according to Tafel's equation, for all systems under study.

Figures (16-47) represent Tafel's lines for low carbon vanadium steel samples in (0.1, 0.3, and 0.5 M) of HNO<sub>3</sub> and in 0.1 M HNO<sub>3</sub> in various concentration of HEAA ( $2 \times 10^{-5}$ ,  $4 \times 10^{-5}$ ,  $6 \times 10^{-5}$ ,  $8 \times 10^{-5}$  and  $10^{-4}$  M) at 25, 35, 45 and 55°C respectively.

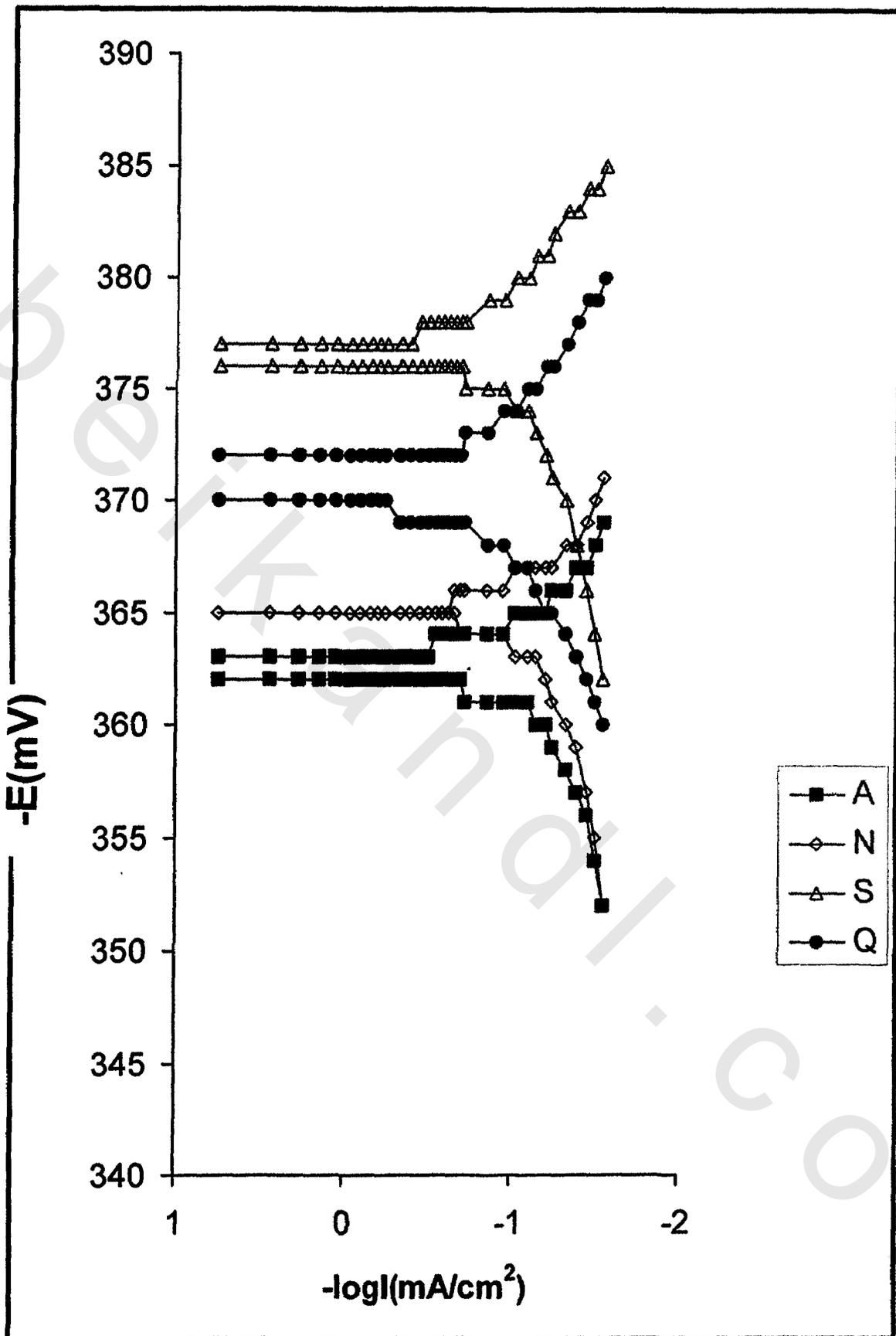
Figures (48-79) represent Tafel's lines for medium carbon vanadium steel samples in (0.1, 0.3, and 0.5 M) of HNO<sub>3</sub> and in 0.1 M HNO<sub>3</sub> in various concentration of HEAA ( $2 \times 10^{-5}$ ,  $4 \times 10^{-5}$ ,  $6 \times 10^{-5}$ ,  $8 \times 10^{-5}$  and  $10^{-4}$  M) at 25, 35, 45 and 55°C respectively.



**Fig(16): Tafel lines for L.C.V. steel samples in 0.1M HNO<sub>3</sub> at 25°C**



Fig(17): Tafel lines for L.C.V. steel samples in 0.3 M HNO<sub>3</sub> at 25°C



**Fig (18): Tafel lines for L.C.V. steel samples in 0.5M HNO<sub>3</sub> at 25°C**

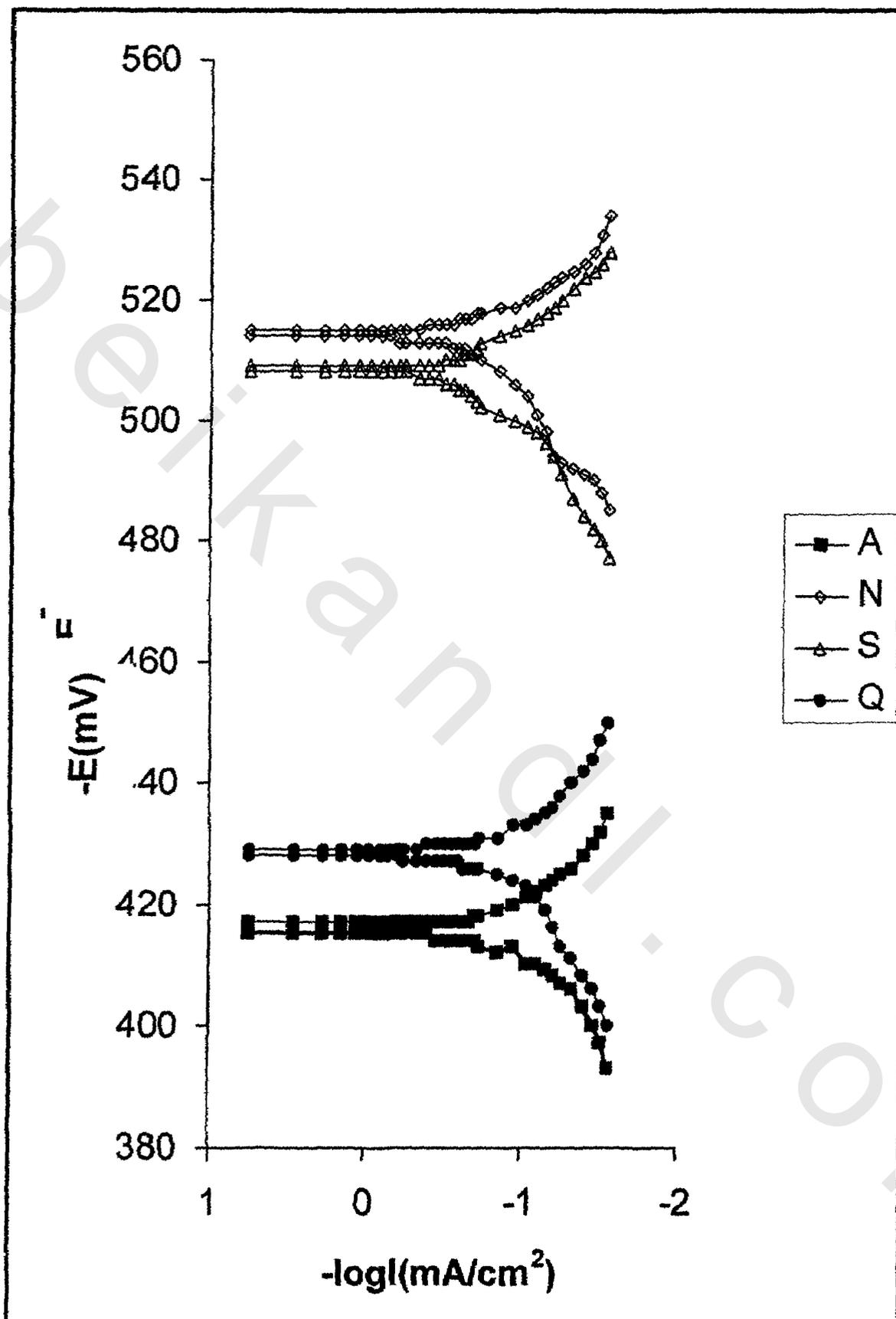
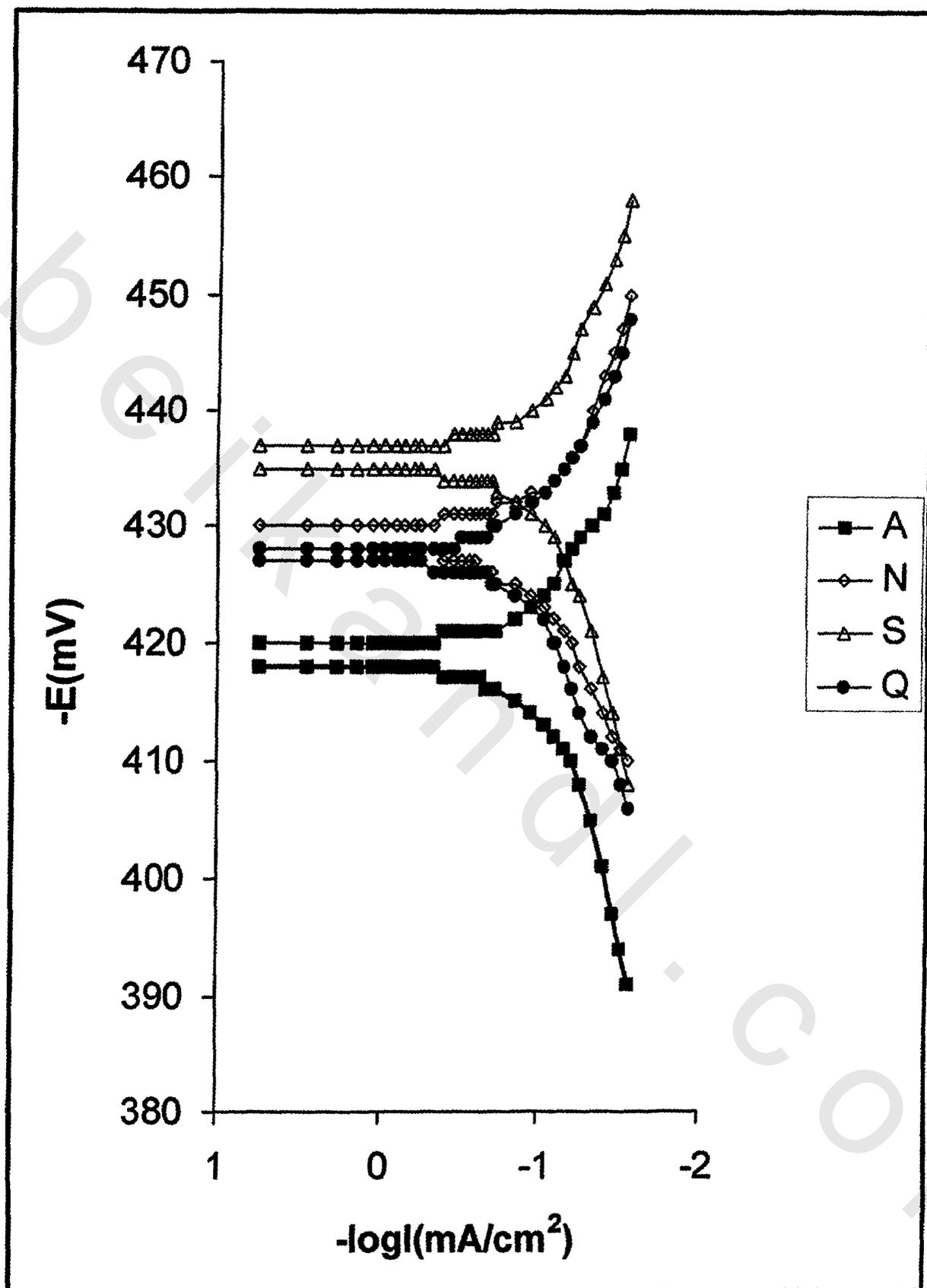
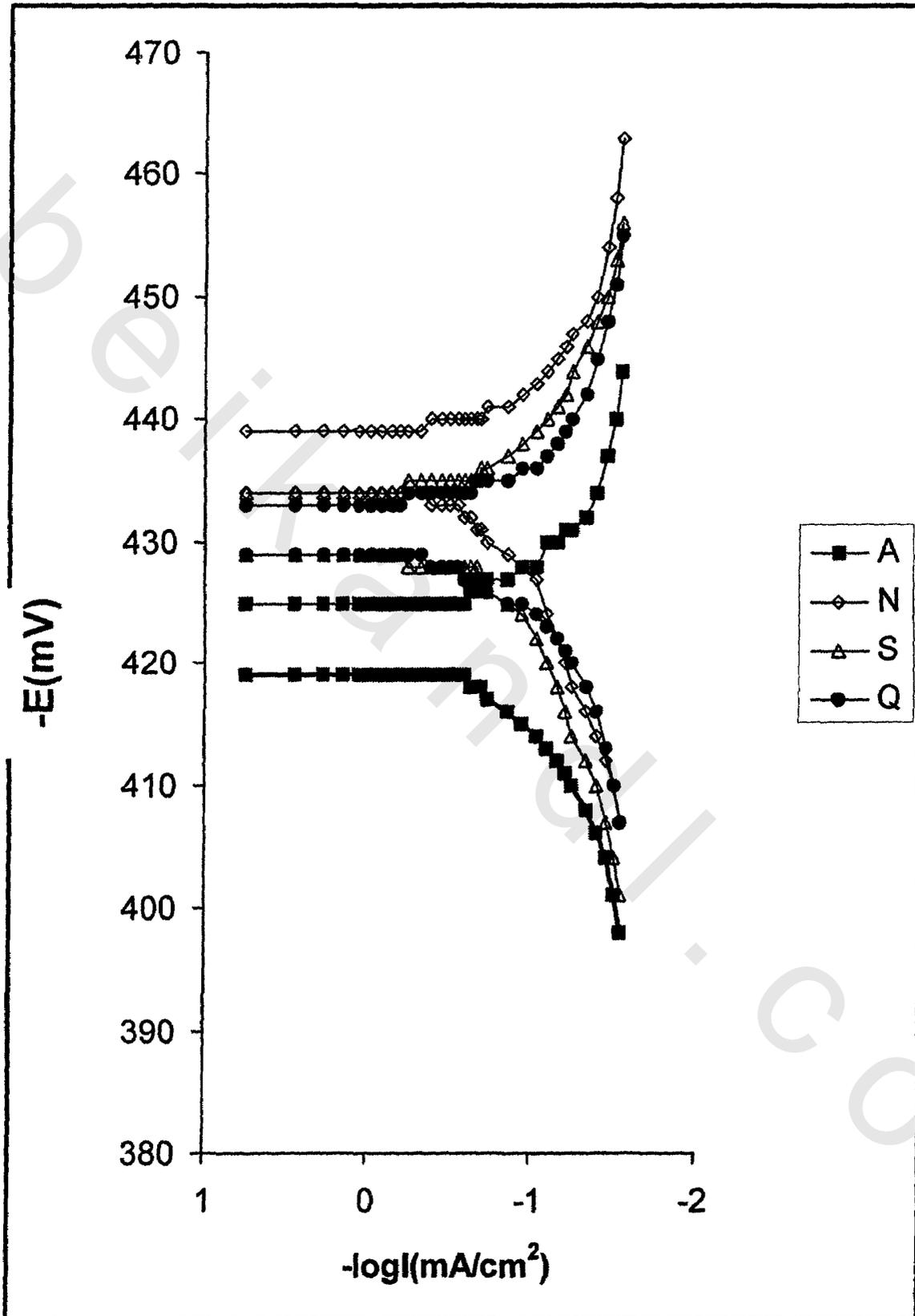


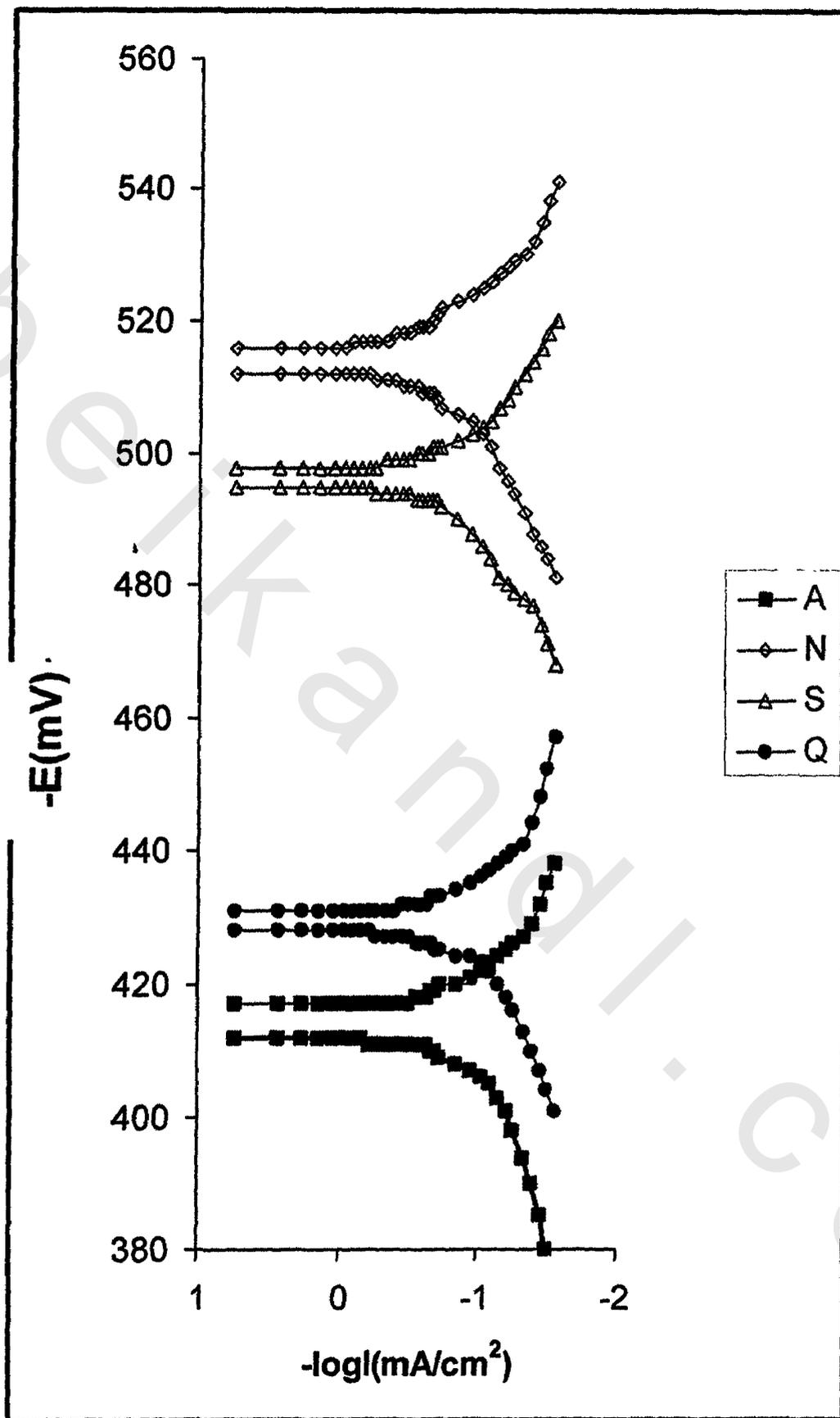
Fig (19): Tafel lines for L.C.V. steel samples in 0.1M HNO<sub>3</sub> and in presence of  $2 \times 10^{-5}$  M of HEAA at 25°C



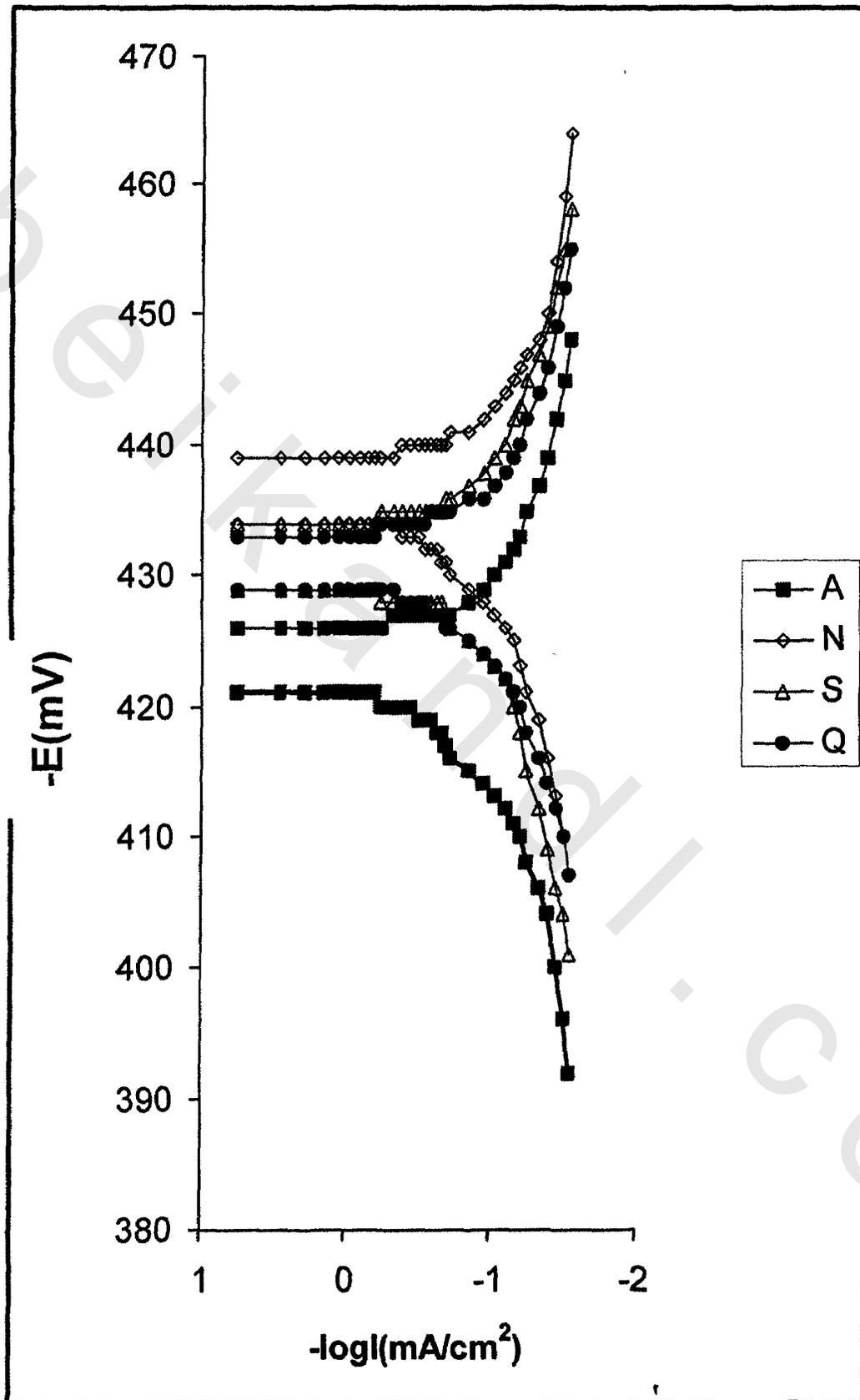
**Fig(20): Tafel lines for L.C.V. steel samples in 0.1M HNO<sub>3</sub> and in presence of 4 x 10<sup>-5</sup>M of HEAA at 25 °C**



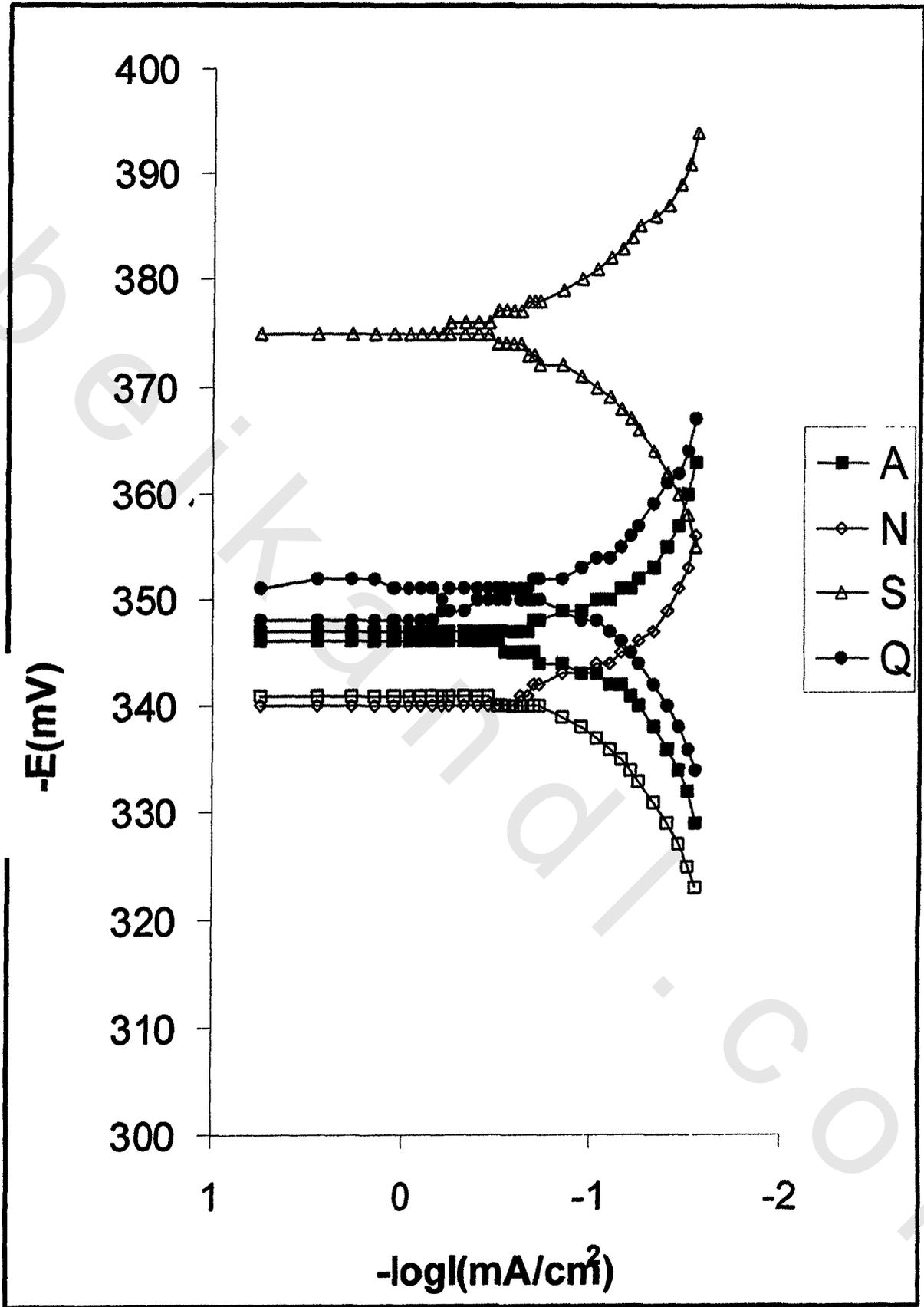
**Fig(21): Tafel lines for L.C.V. steel samples in 0.1M HNO<sub>3</sub> and in presence of 6 x 10<sup>-5</sup> M of HEAA at 25 °C**



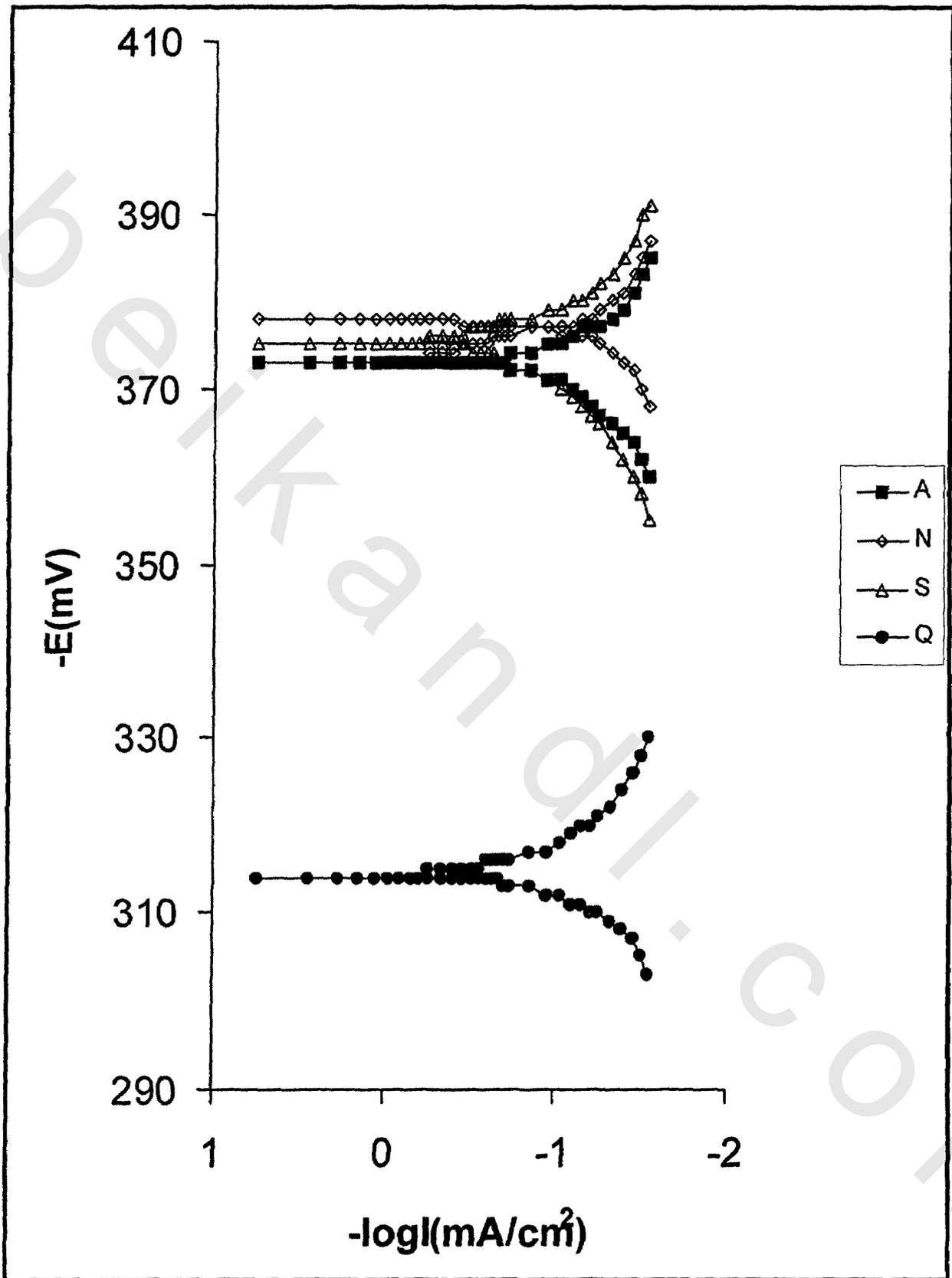
**Fig(22): Tafel lines for L.C.V. steel samples in 0.1M HNO<sub>3</sub> and in presence of 8 x 10<sup>-5</sup> M of HEAA at 25 °C**



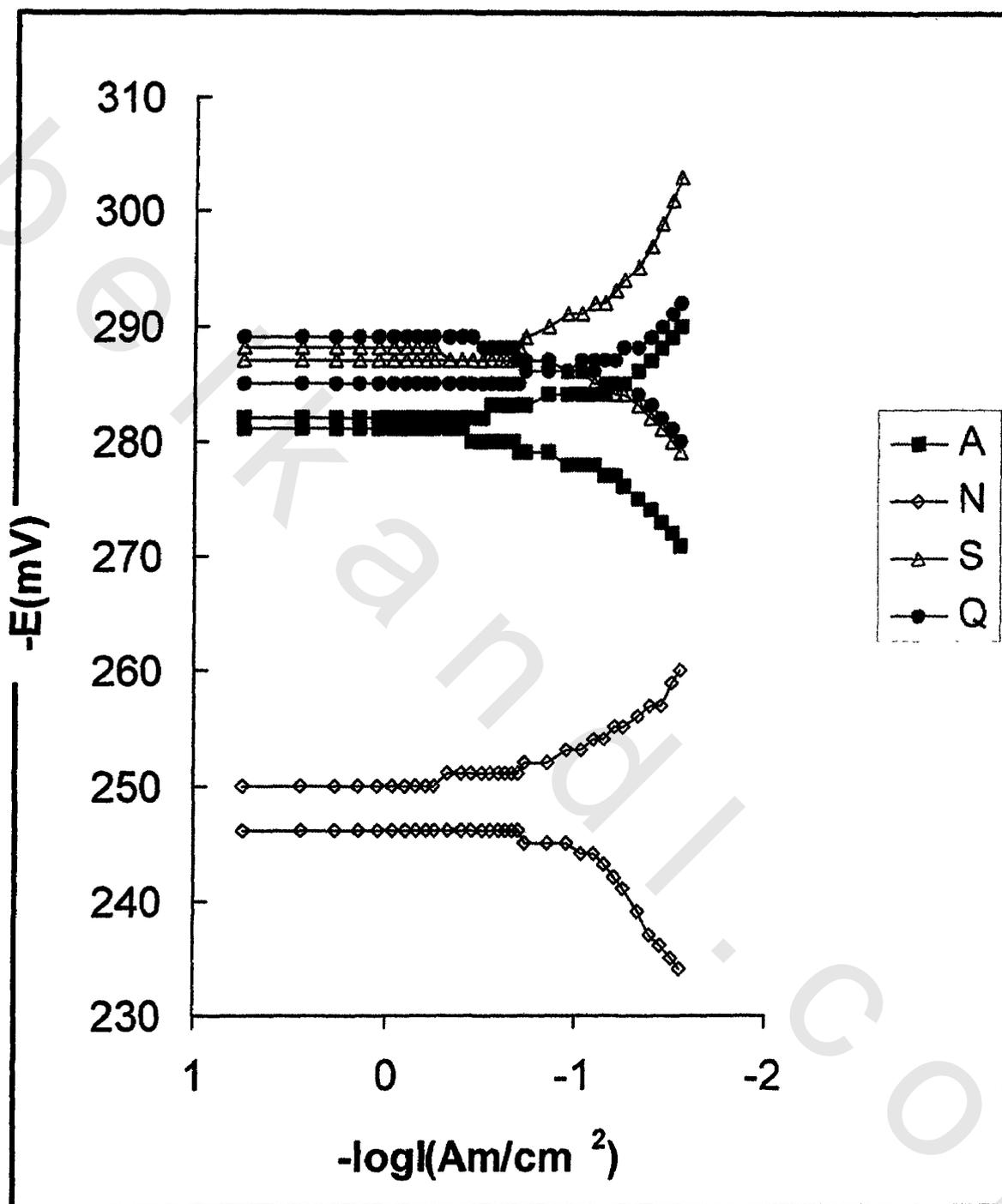
**Fig(23): Tafel lines for L.C.V. steel samples in 0.1M HNO<sub>3</sub> and in presence of 10<sup>-4</sup>M of HEAA at 25 °C**



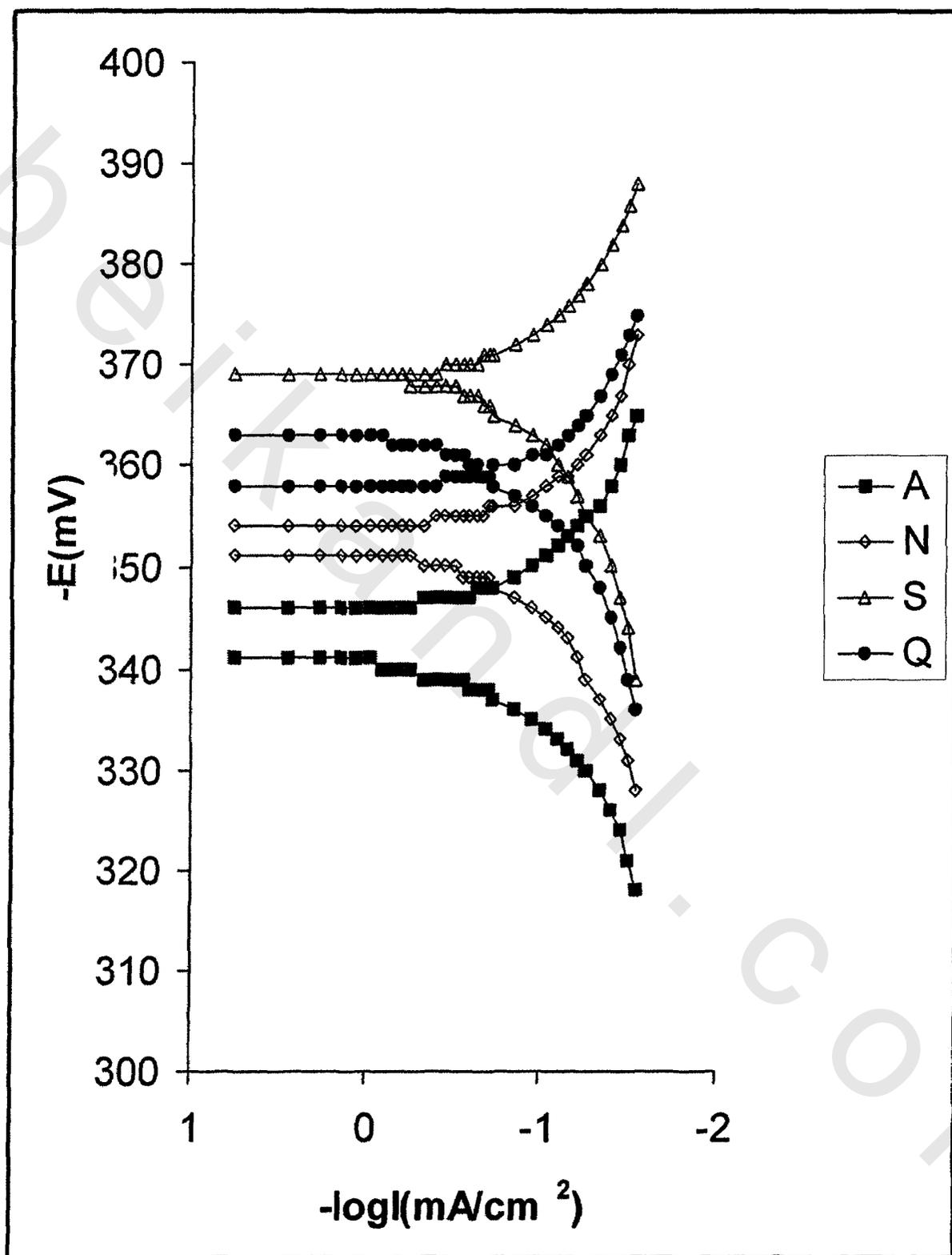
Fig(24): Tafel lines for L.C.V. steel samples in 0.1M HNO<sub>3</sub> at 35°C



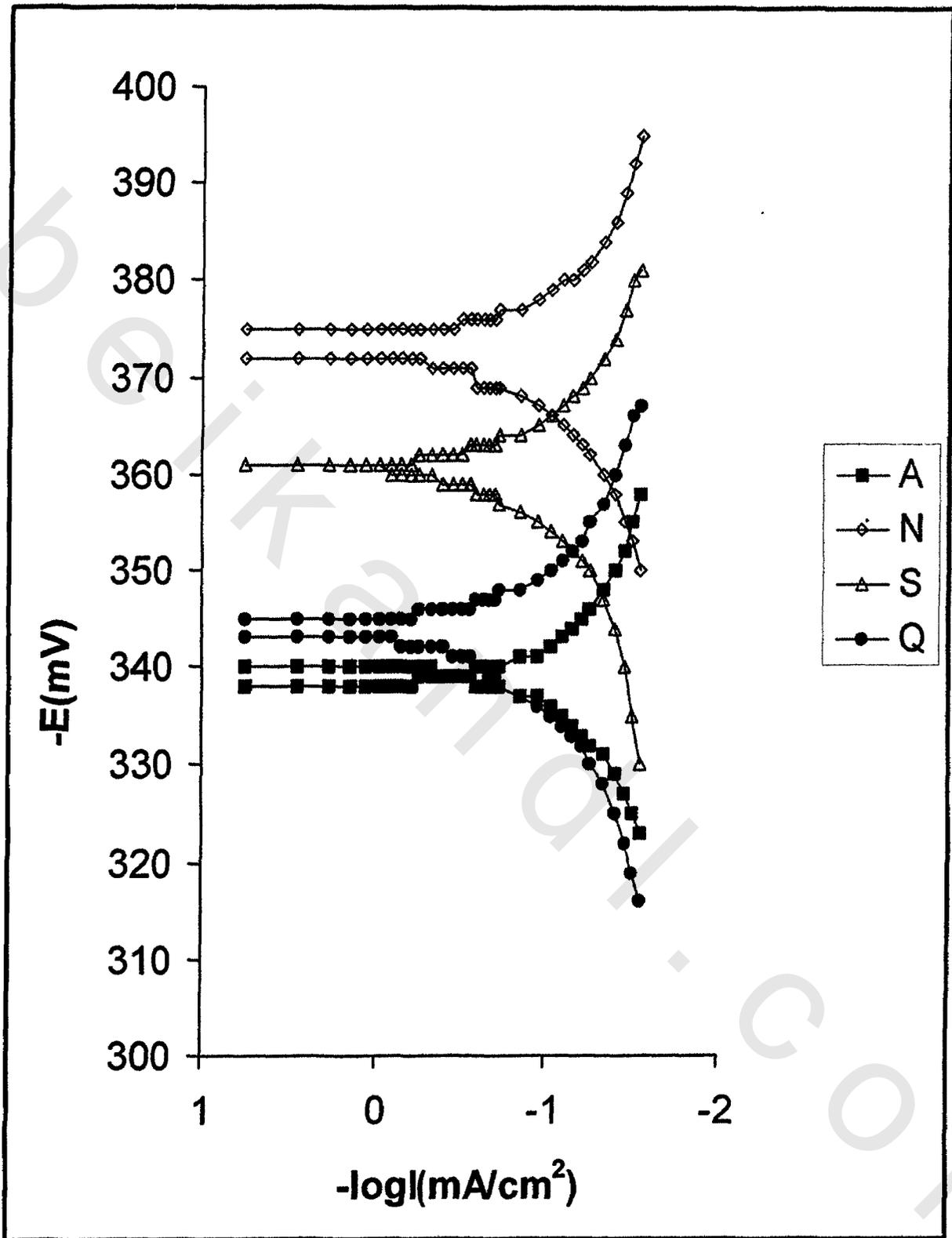
Fig(25): Tafel lines for L.C.V. steel samples in 0.3M HNO<sub>3</sub> at 35 °C



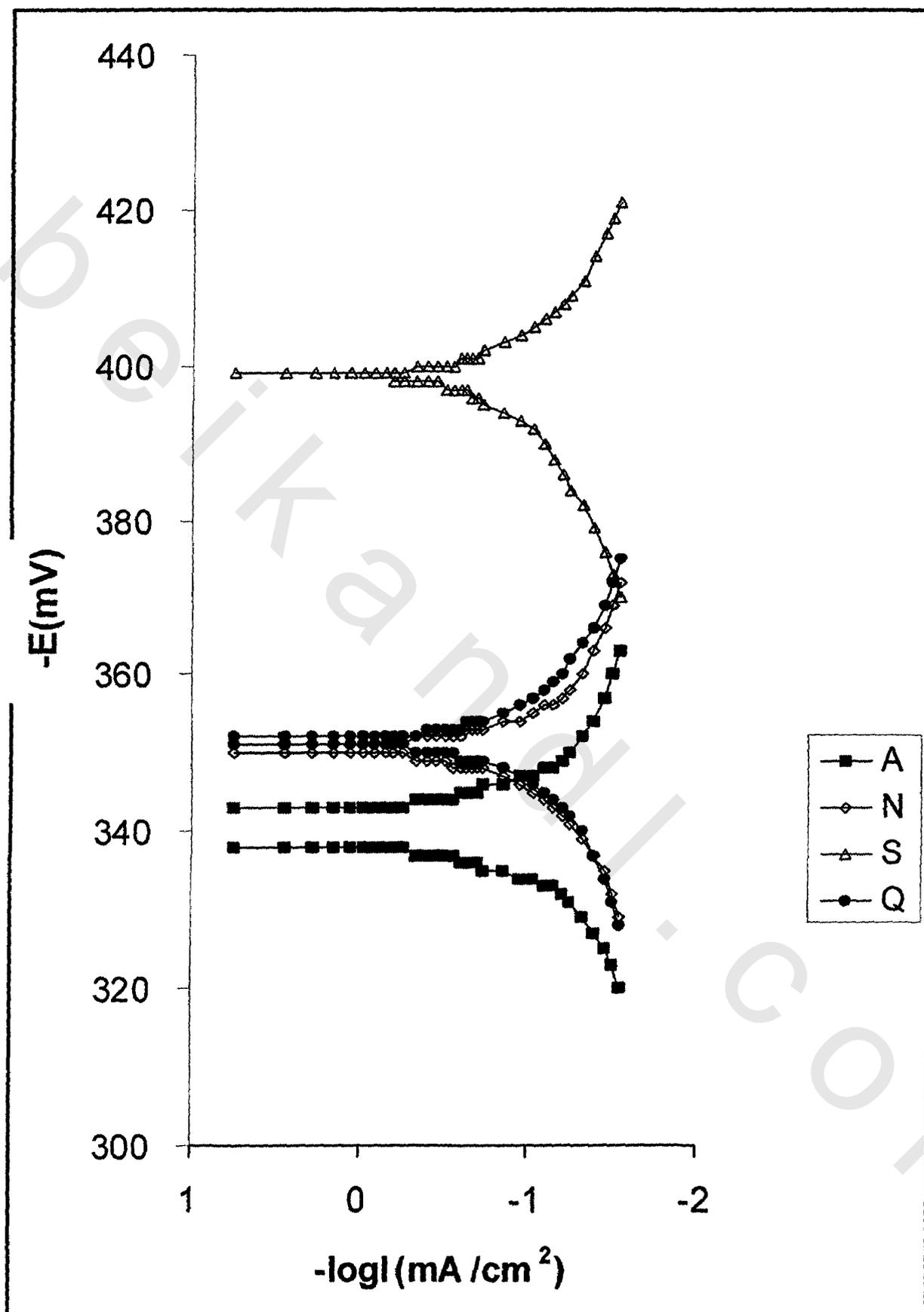
Fig(26): Tafel lines for L.C.V. steel samples in 0.5M HNO<sub>3</sub> at 35 °C



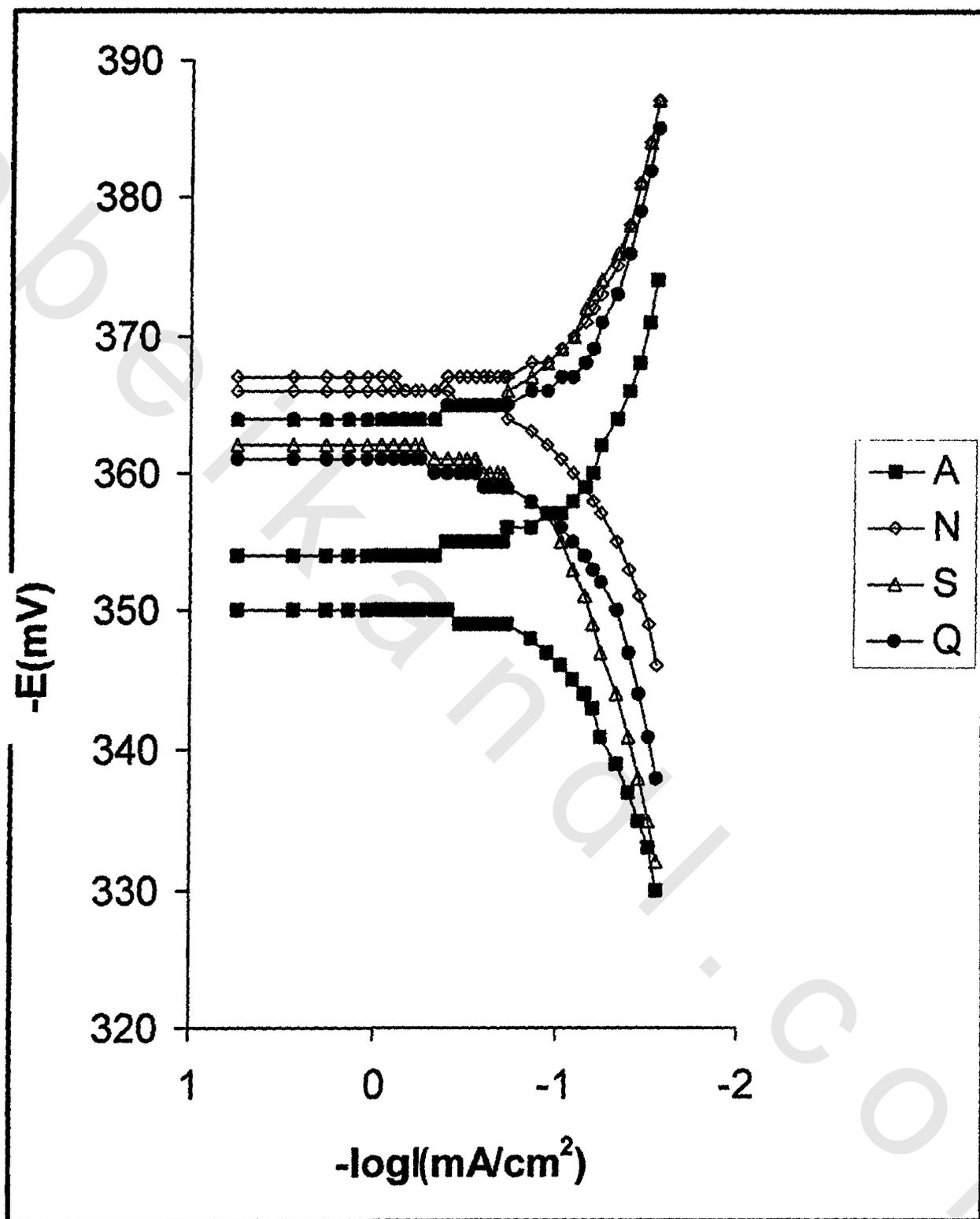
Fig(27): Tafel lines for L.C.V. steel samples in 0.1M HNO<sub>3</sub> and in presence of 2 x 10<sup>-5</sup> M of HEAA at 35 °C



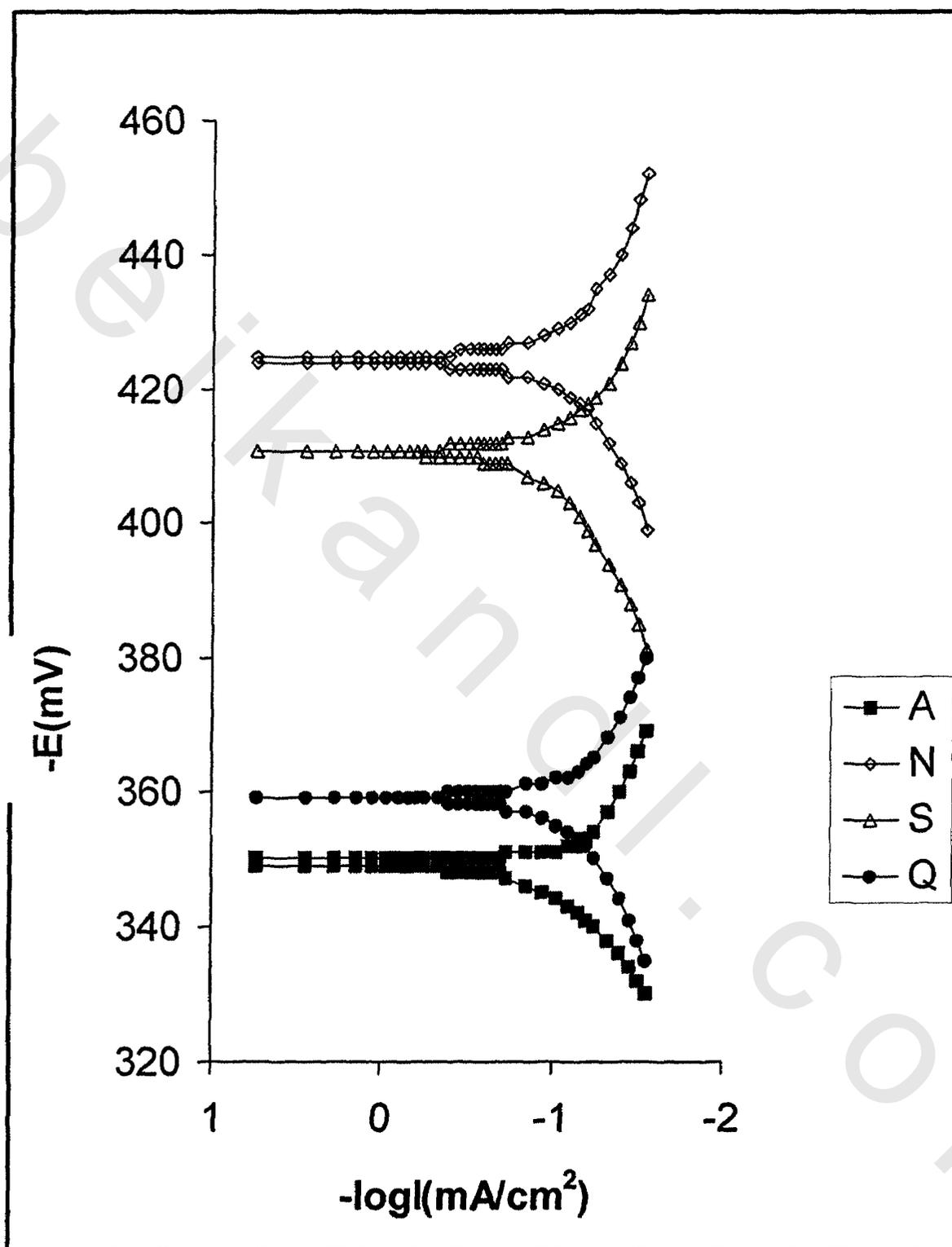
**Fig(28):**Tafle lines for L.C.V. steel samples in 0.1M HNO<sub>3</sub> and in presence of 4 x 10<sup>-5</sup>M of HEAA at 35 °C



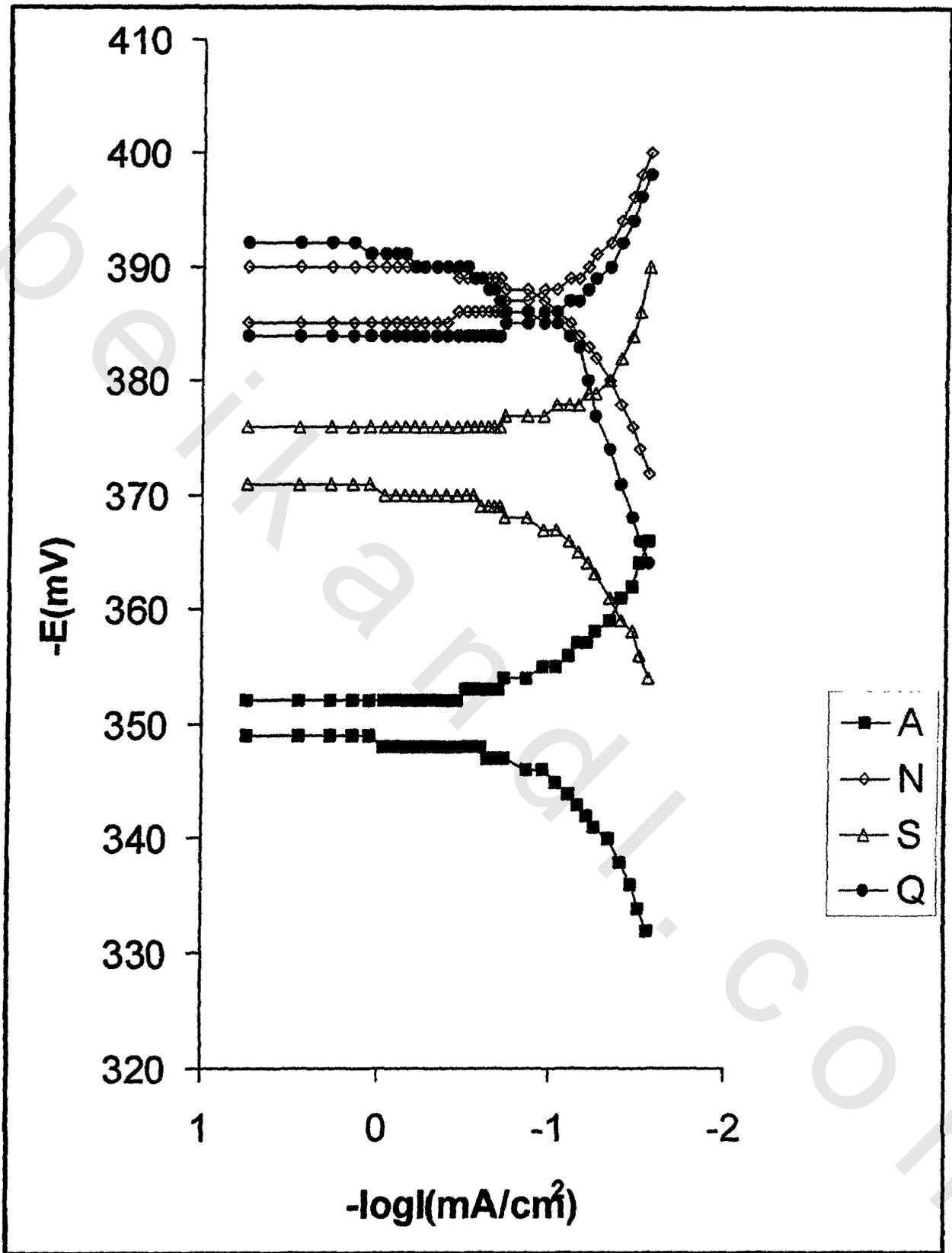
Fig(29): Tafel lines for L.C.V. steel samples in 0.1M HNO<sub>3</sub> and in presence of 6 x 10<sup>-5</sup> M of HEAA at 35 °C



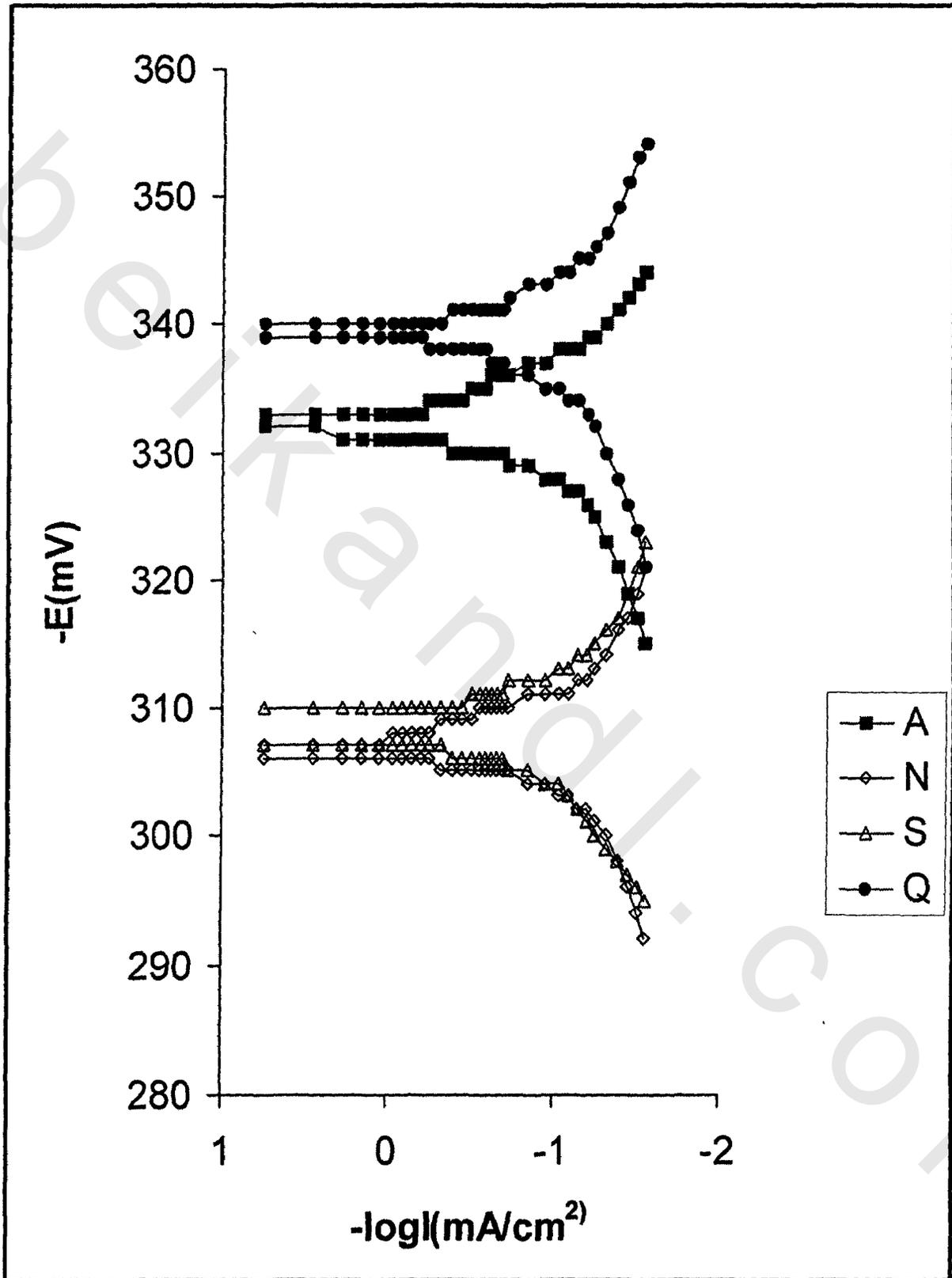
**Fig(30): Tafel lines for L.C.V. steel samples in 0.1M HNO<sub>3</sub> and in presence of 8 x 10<sup>-5</sup> M of HEAA at 35 °C**



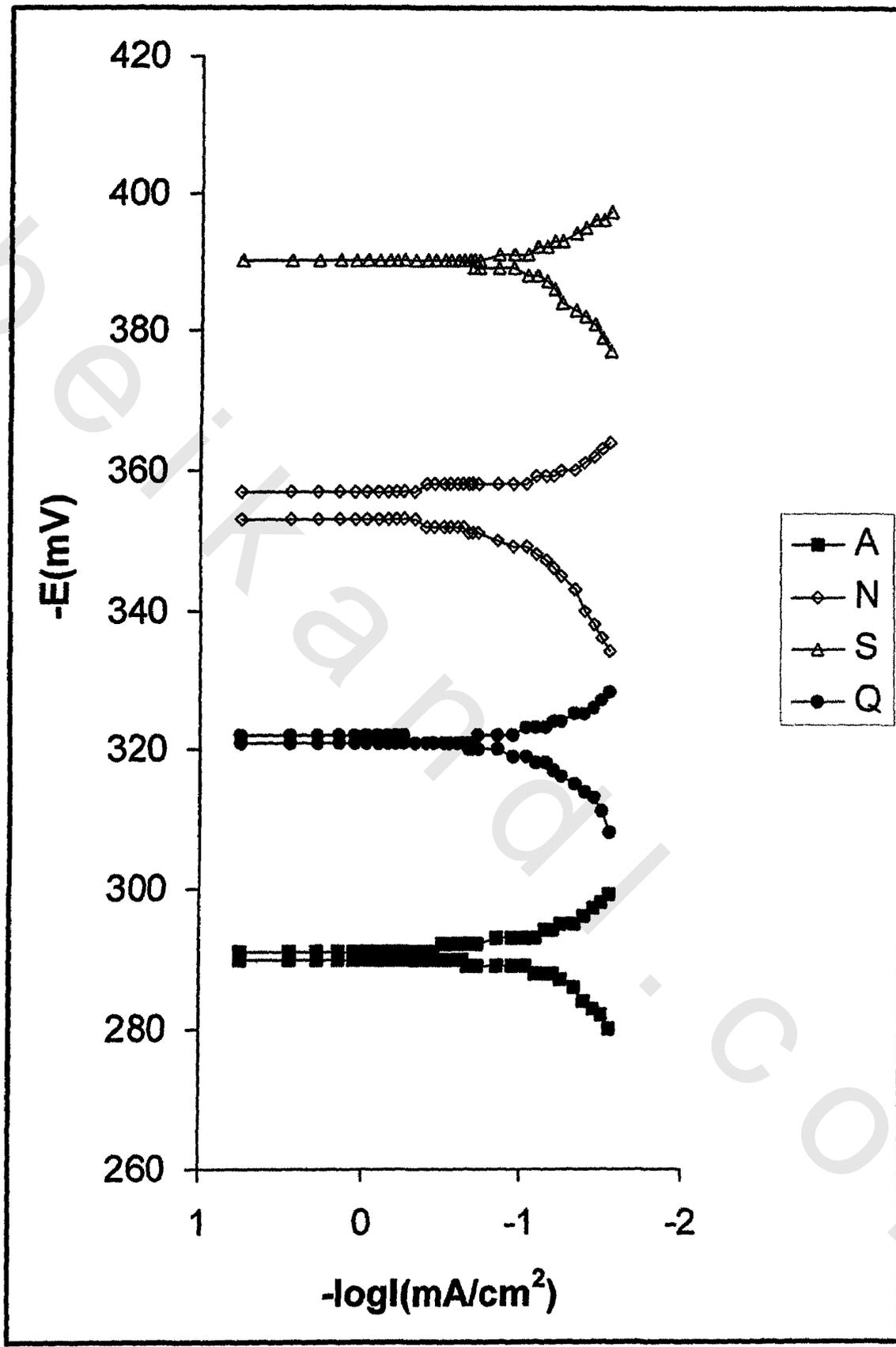
Fig( 31):Tafel lines for L.C.V. steel samples in 0.1M HNO<sub>3</sub> and in presence of 10<sup>-4</sup>M of HEAA at 35 °C



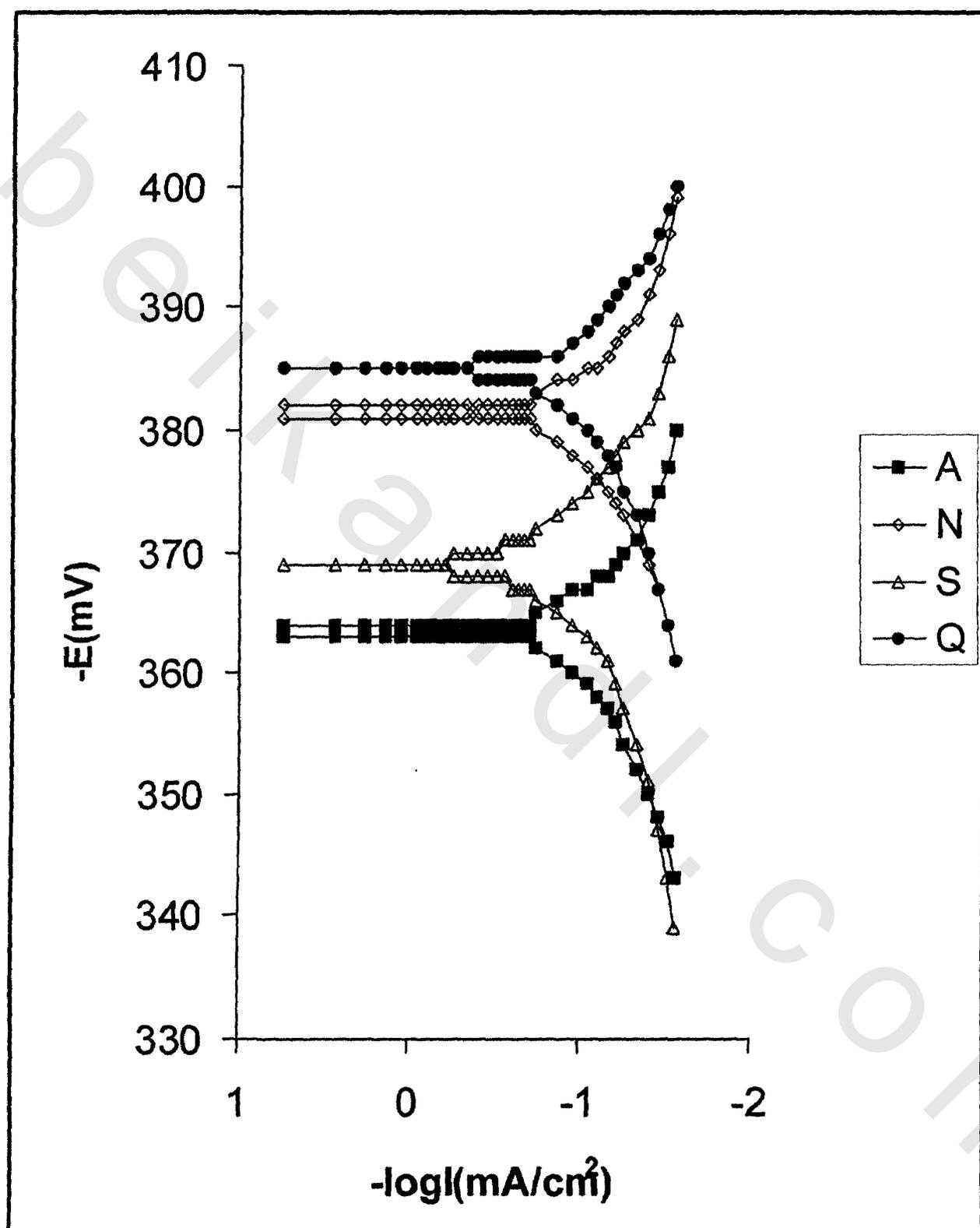
Fig( 32):Tafle lines for L.C.V. steel samples in 0.1M HNO<sub>3</sub> at 45°C



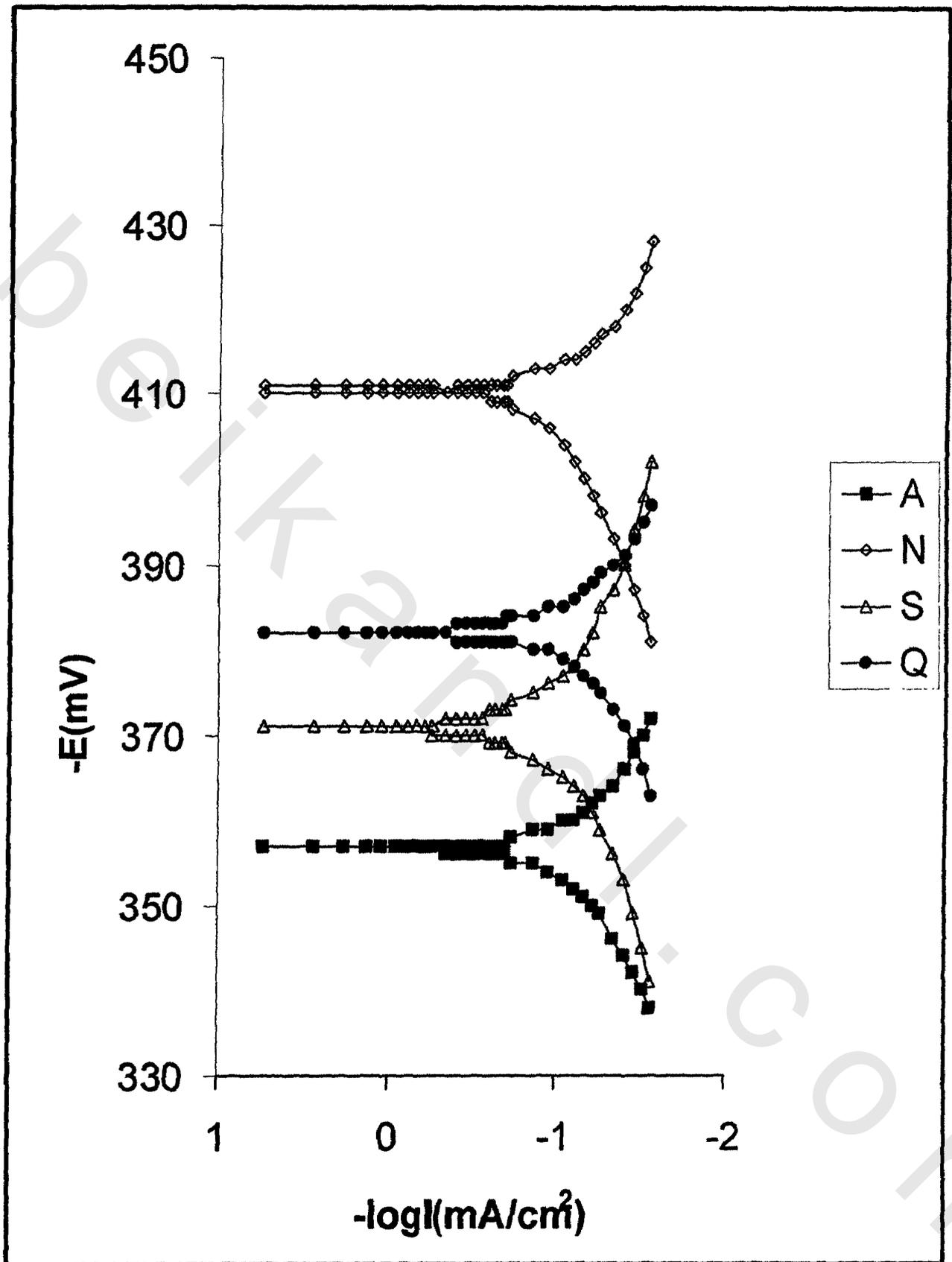
Fig(33): Tafel lines for L.C.V. steel samples in 0.3M HNO<sub>3</sub> at 45°C



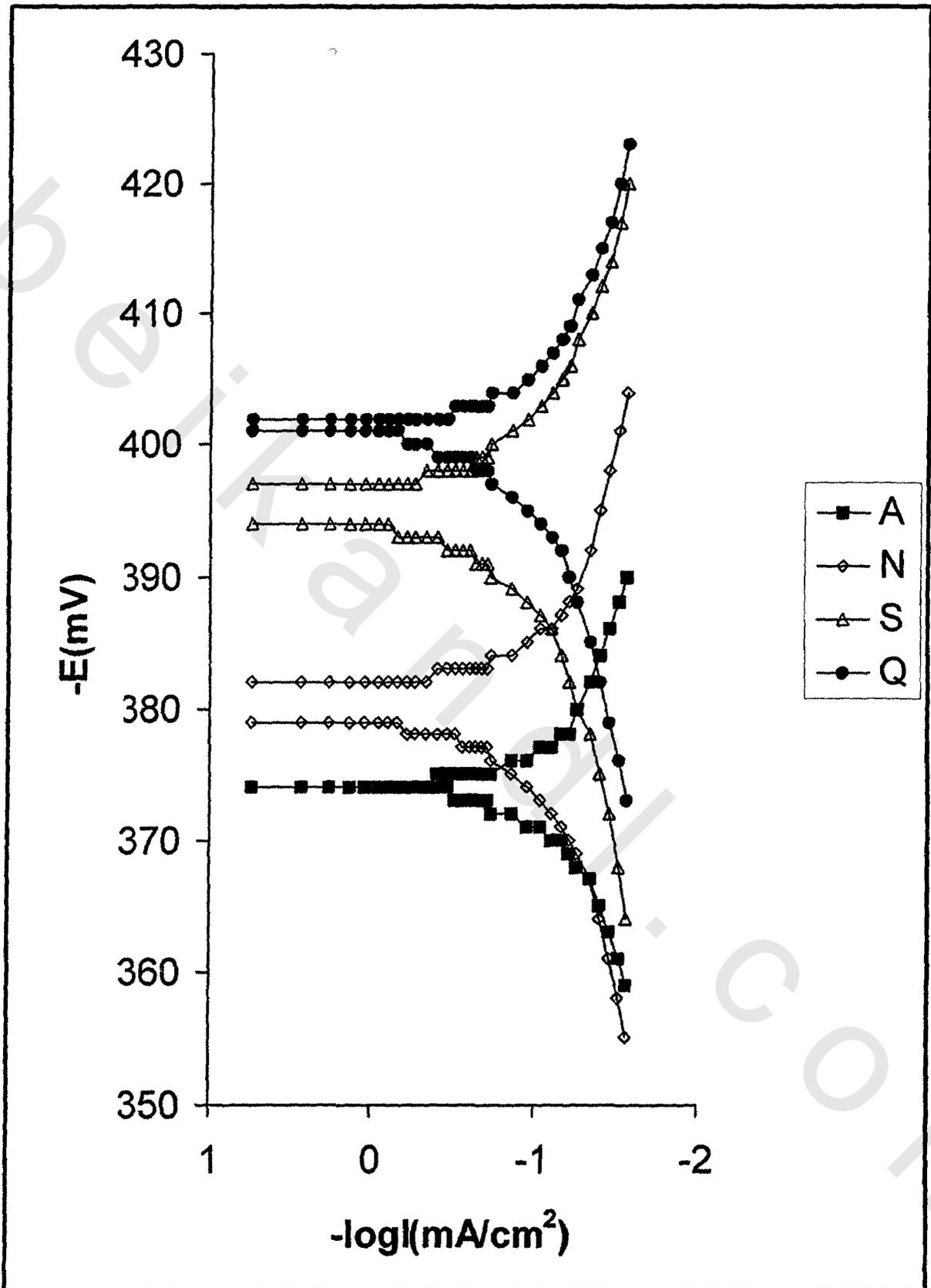
Fig(34): Tafel lines for L.C.V. steel samples in 0.5M HNO<sub>3</sub> at 45°C



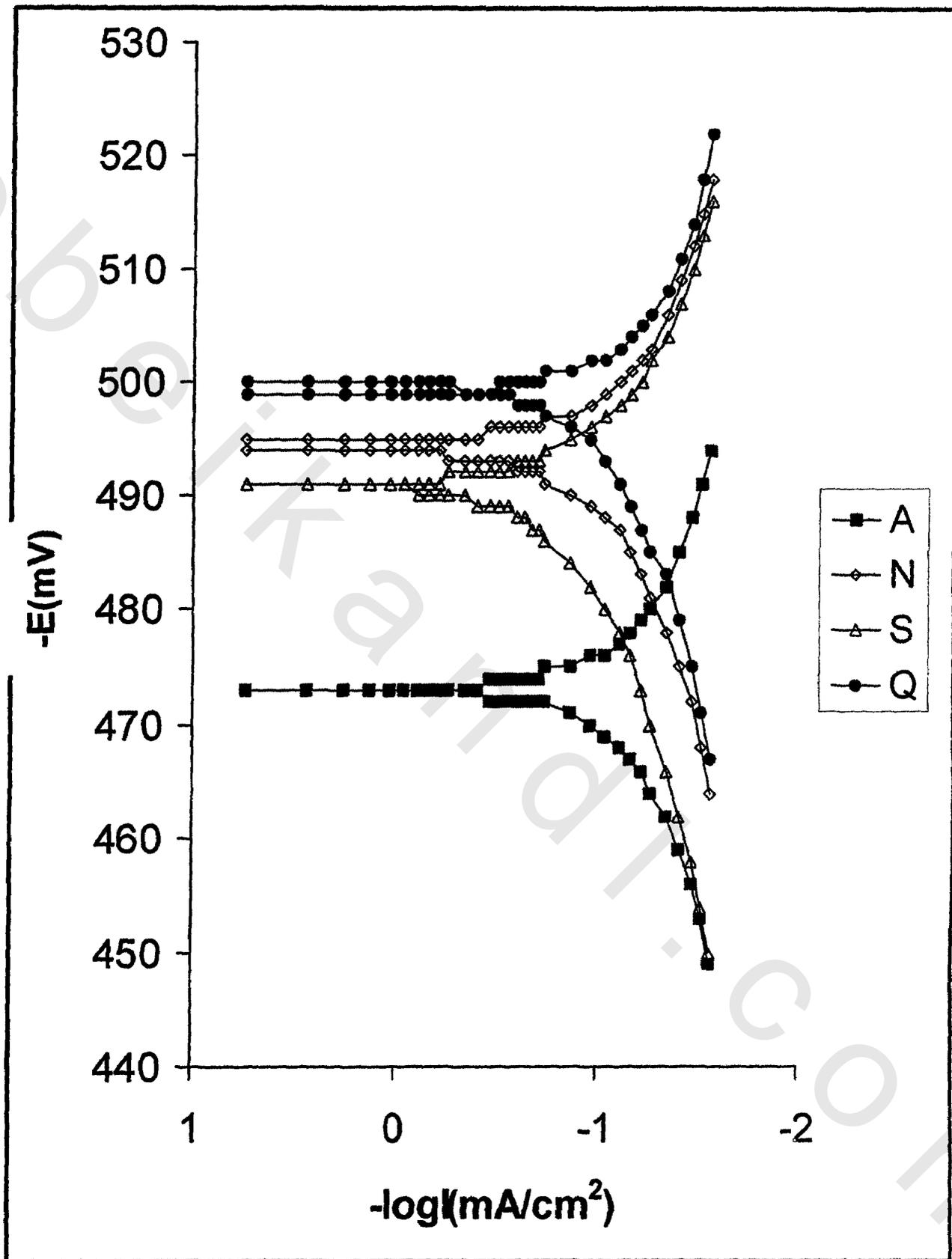
Fig(35): Tafel lines for L.C.V. steel samples in 0.1M HNO<sub>3</sub> and in presence of 2 x 10<sup>-5</sup> M of HEAA at 45 °C



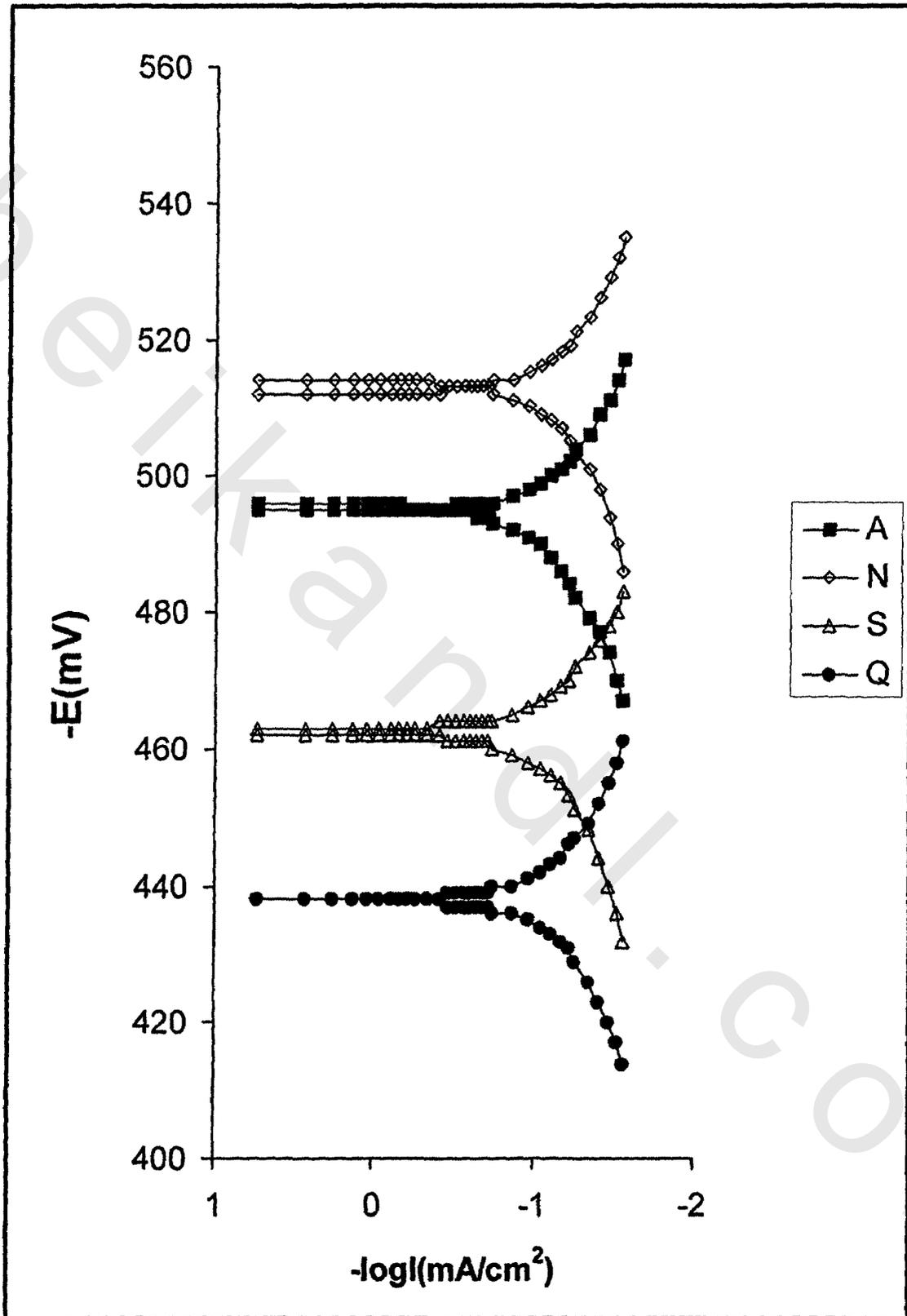
**Fig(36): Tafel lines for L.C.V. steel samples in 0.1M HNO<sub>3</sub> and in presence of 4 x 10<sup>-5</sup> M of HEAA at 45 °C**



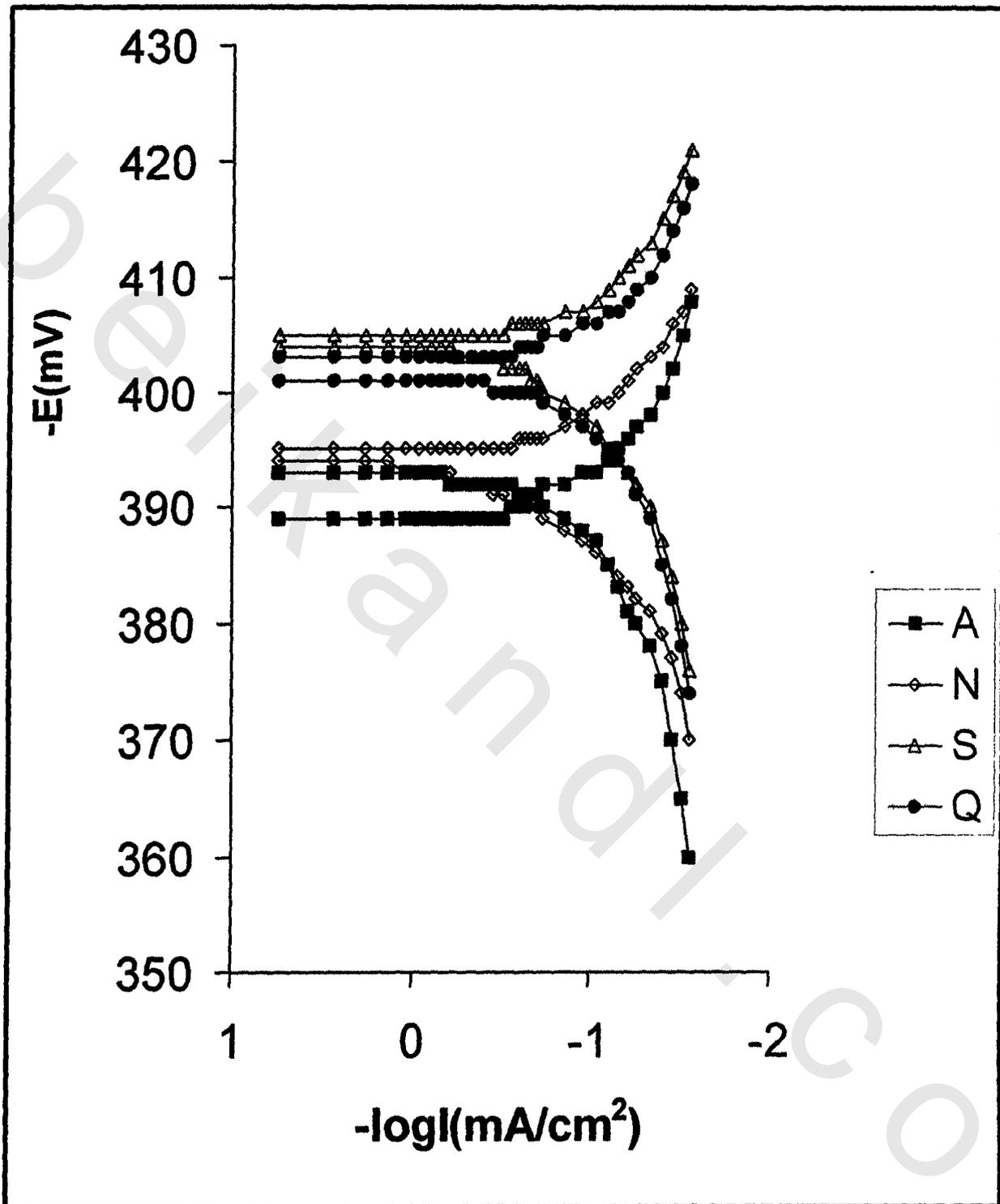
Fig(37): Tafel lines for L.C.V. steel samples in 0.1M HNO<sub>3</sub> and in presence of 6 x 10<sup>-5</sup> M of HEAA at 45 °C



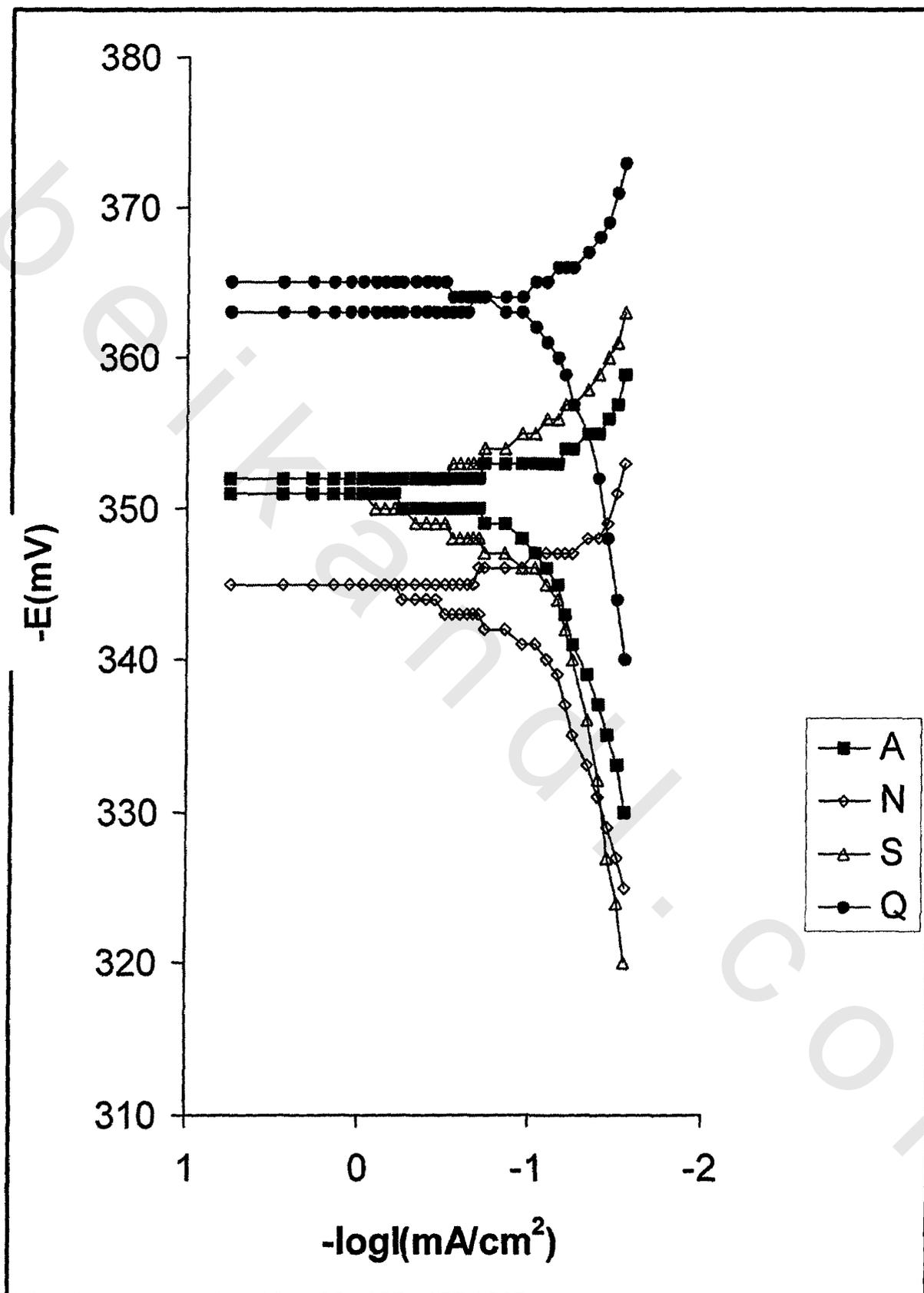
**Fig(38):**Tafel lines for L.C.V. steel samples in 0.1M HNO<sub>3</sub> and in presence of 8 x 10<sup>-5</sup>M of HEAA at 45 °C



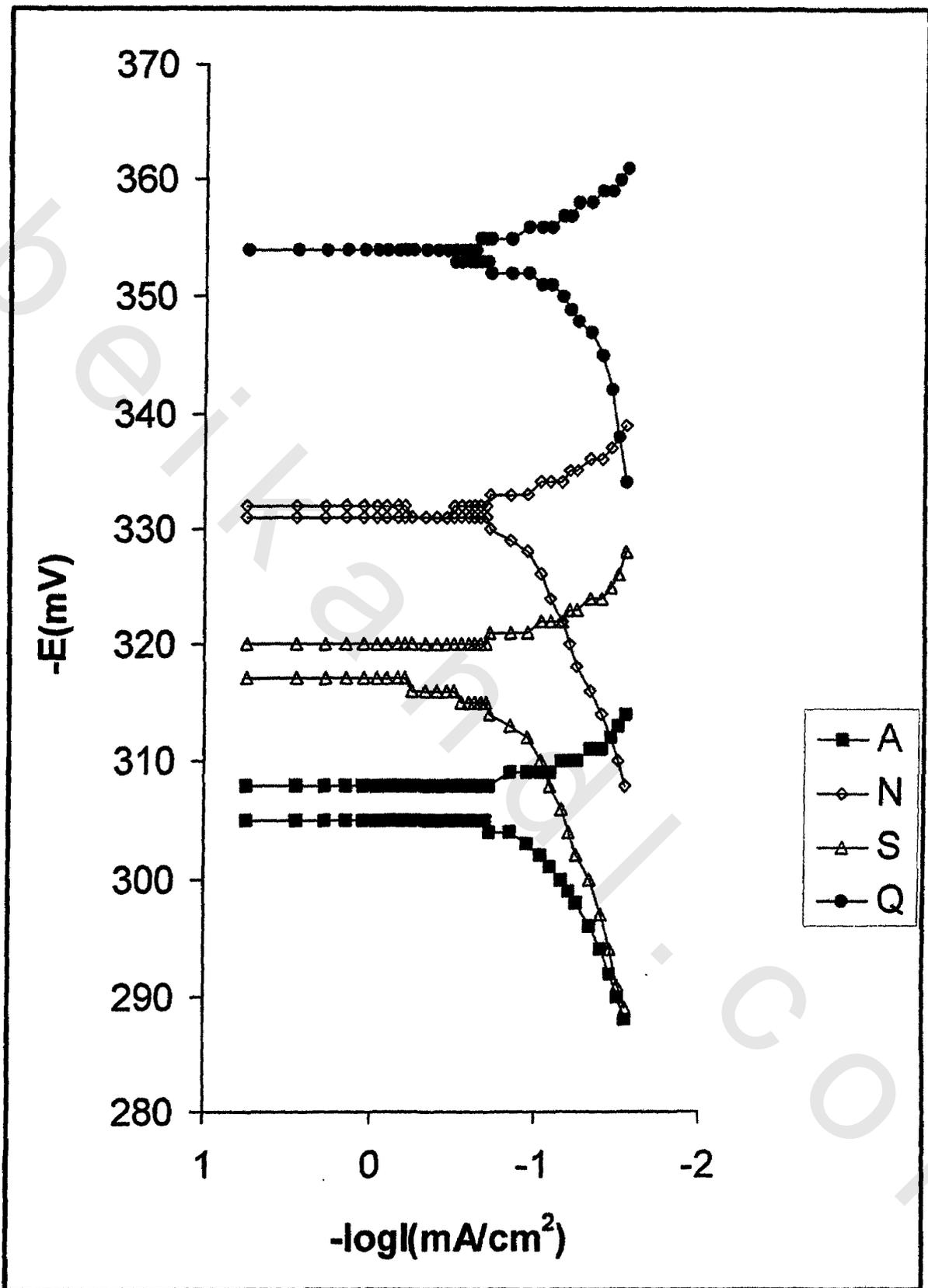
Fig(39): Tafel lines for L.C.V. steel samples in 0.1M HNO<sub>3</sub> and in presence of 10<sup>-4</sup>M of HEAA at 45 °C



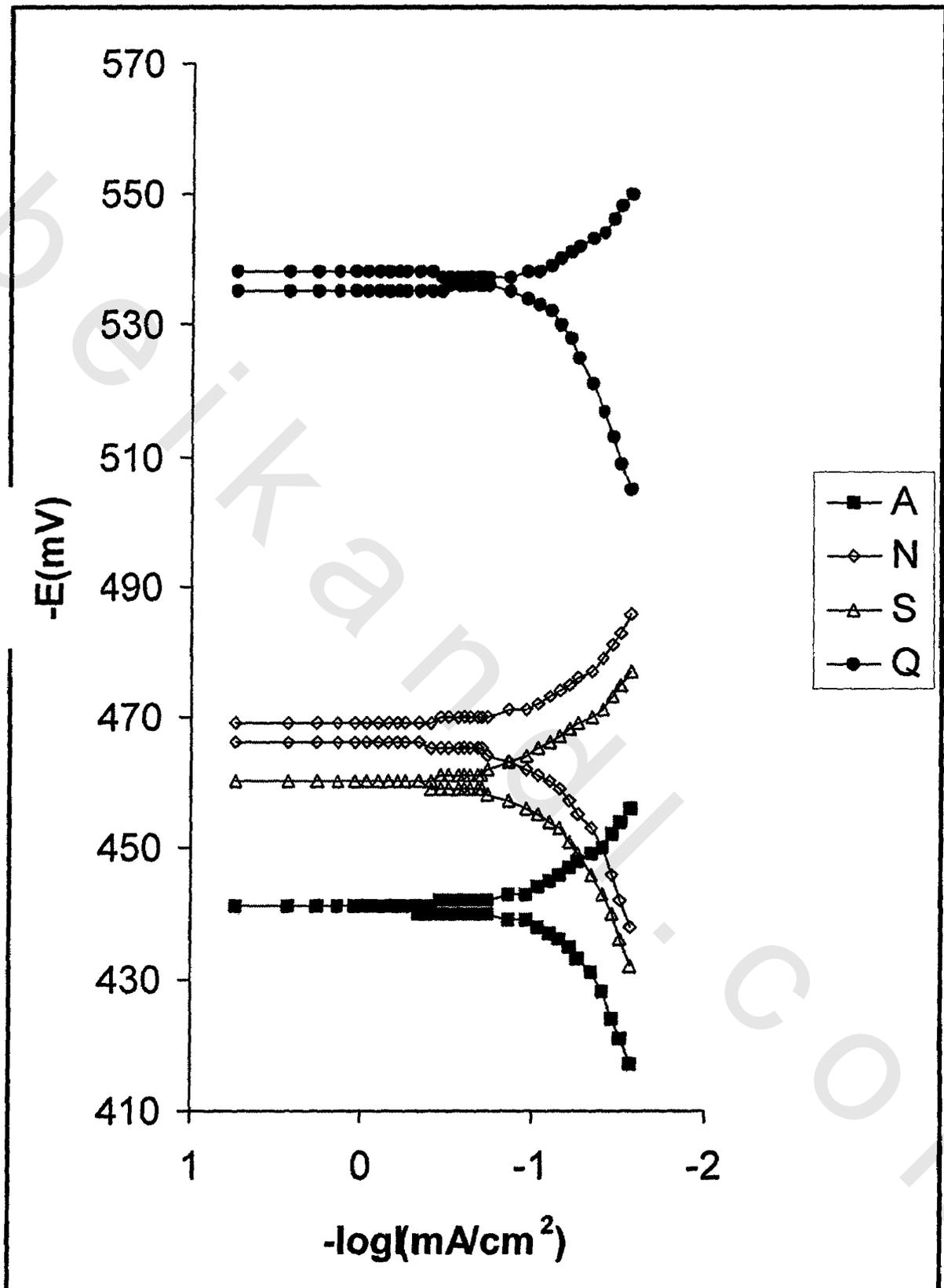
**Fig(40): Tafel lines for L.C.V. steel samples in 0.1M HNO<sub>3</sub> at 55°C**



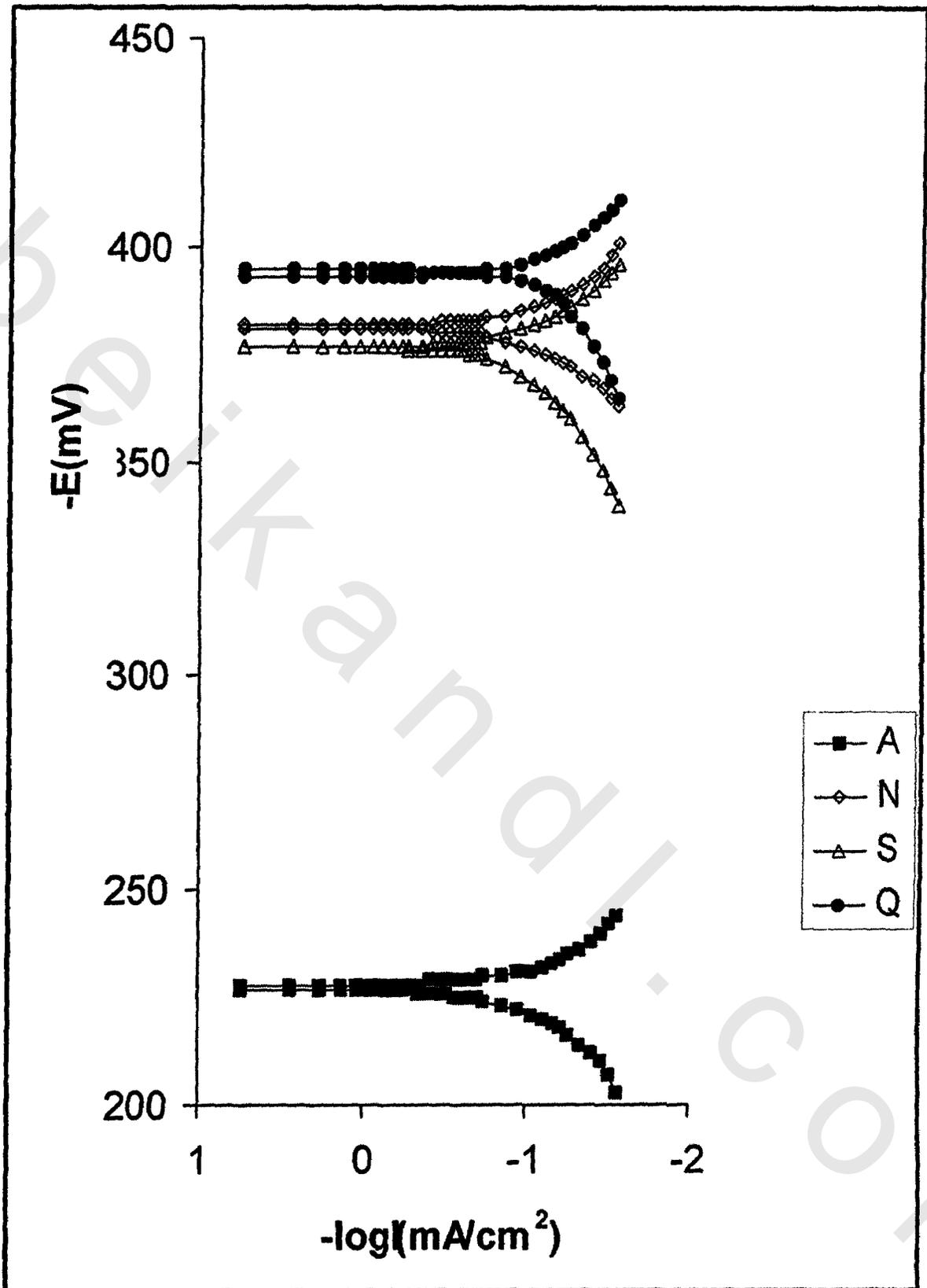
Fig(41): Tafel lines for L.C.V. steel samples in 0.3 M HNO<sub>3</sub> at 55°C



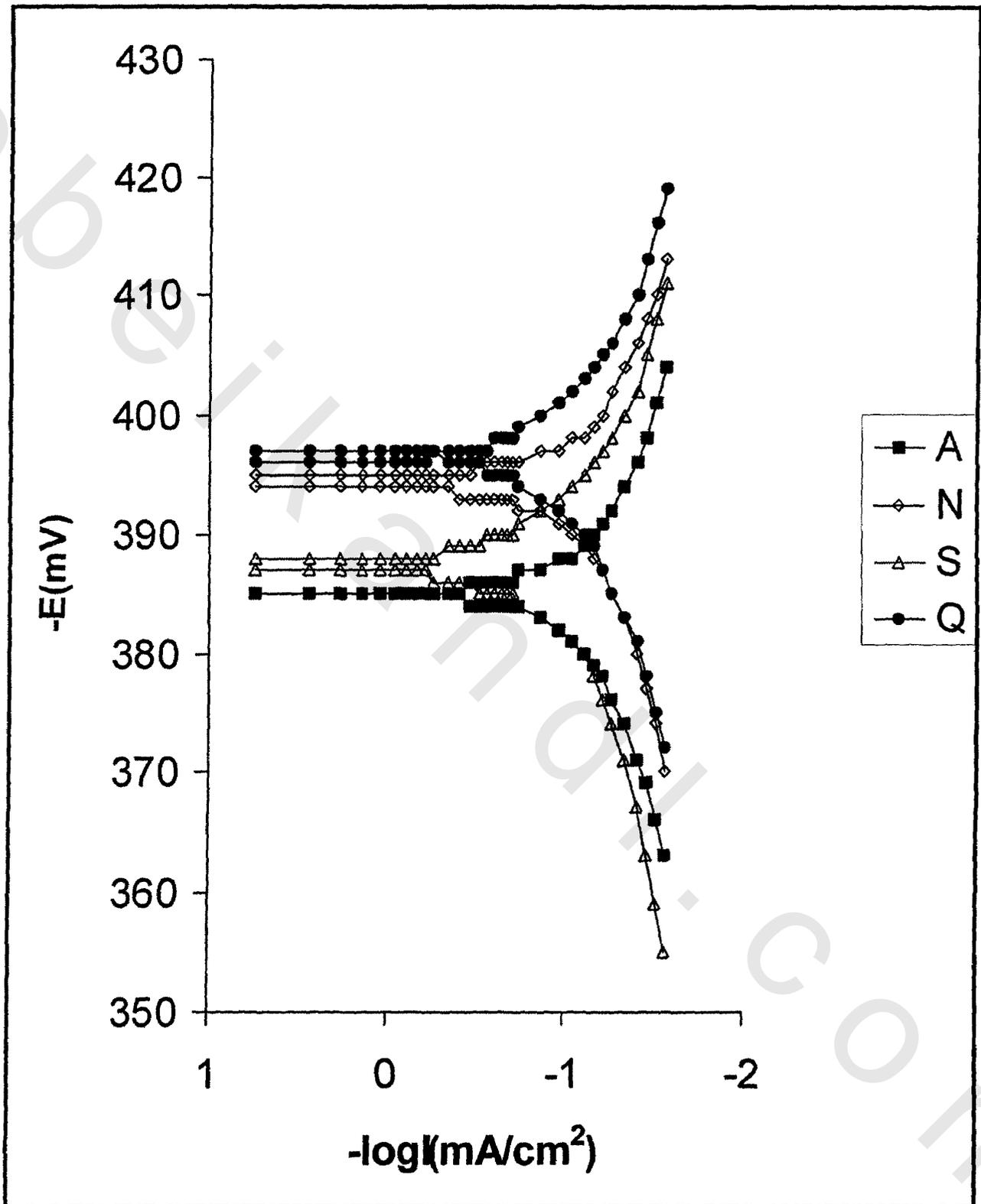
Fig(42): Tafel lines for L.C.V. steel samples in 0.5 M HNO<sub>3</sub> at 55°C



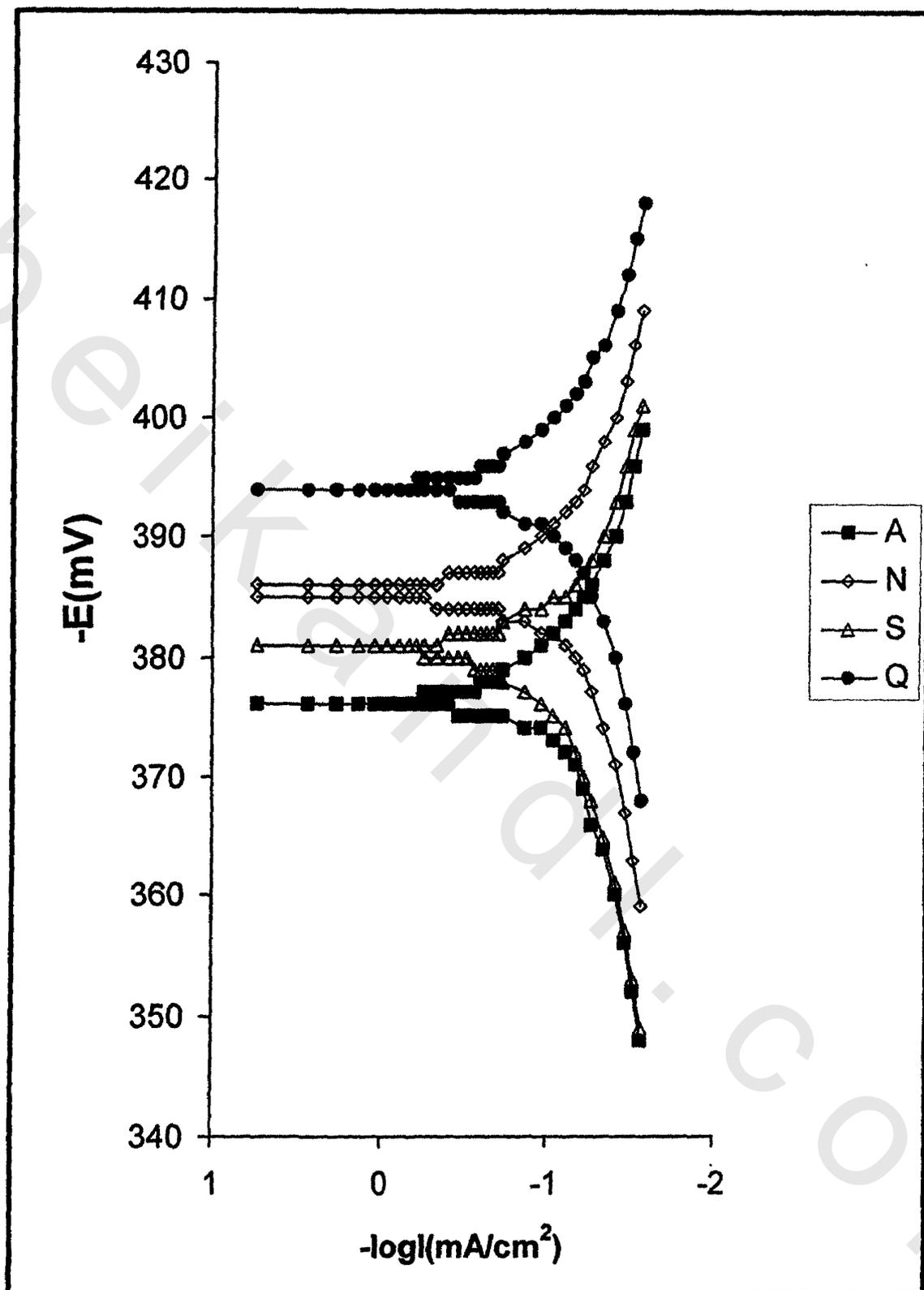
Fig(43): Tafel lines for L.C.V. steel samples in 0.1M HNO<sub>3</sub> and in presence of 2 x 10<sup>-5</sup> M of HEAA at 55 °C



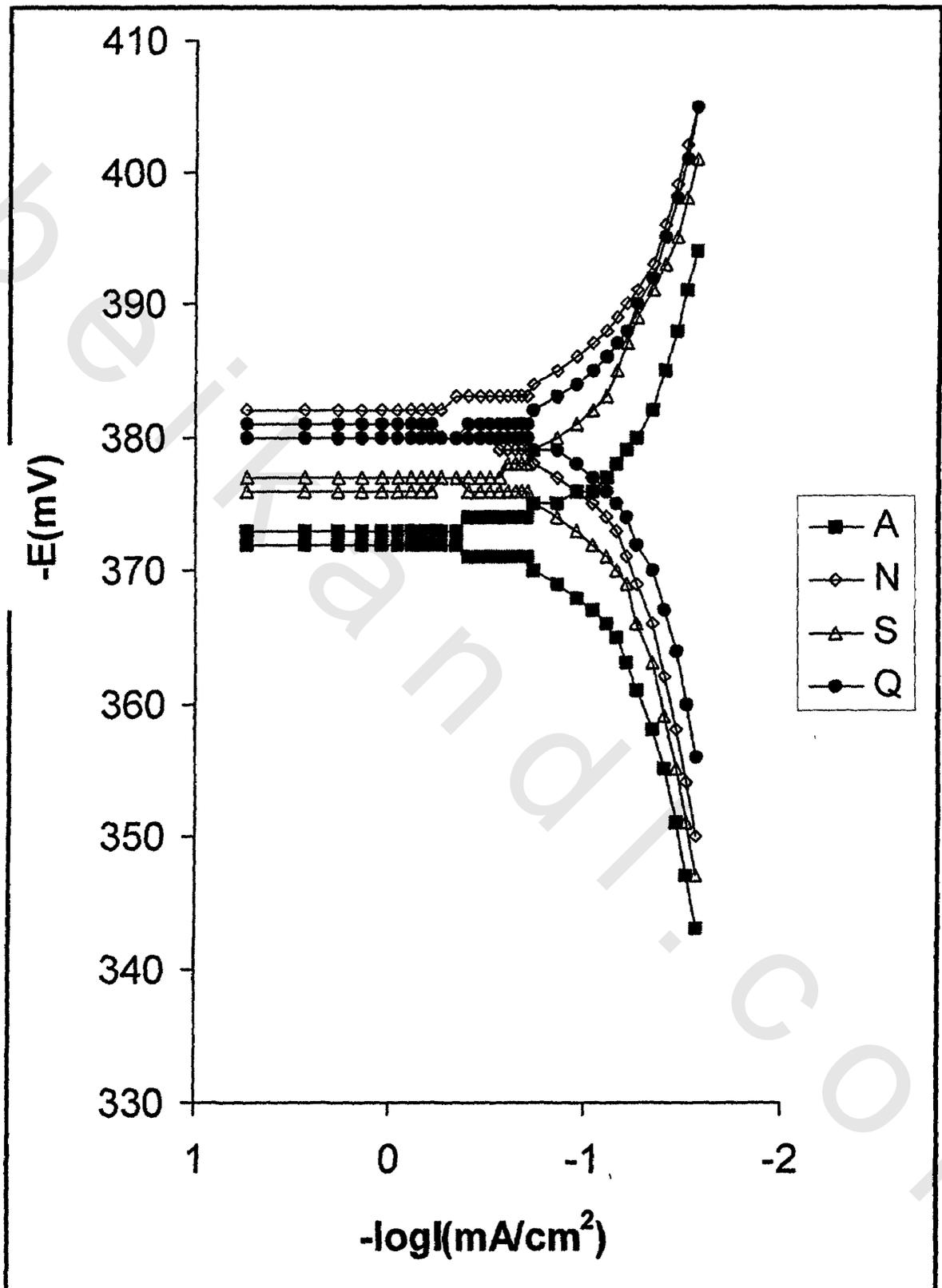
**Fig(44): Tafel lines for L.C.V. steel samples in 0.1M HNO<sub>3</sub> and in presence of 4 x 10<sup>-5</sup>M of HEAA at 55 °C**



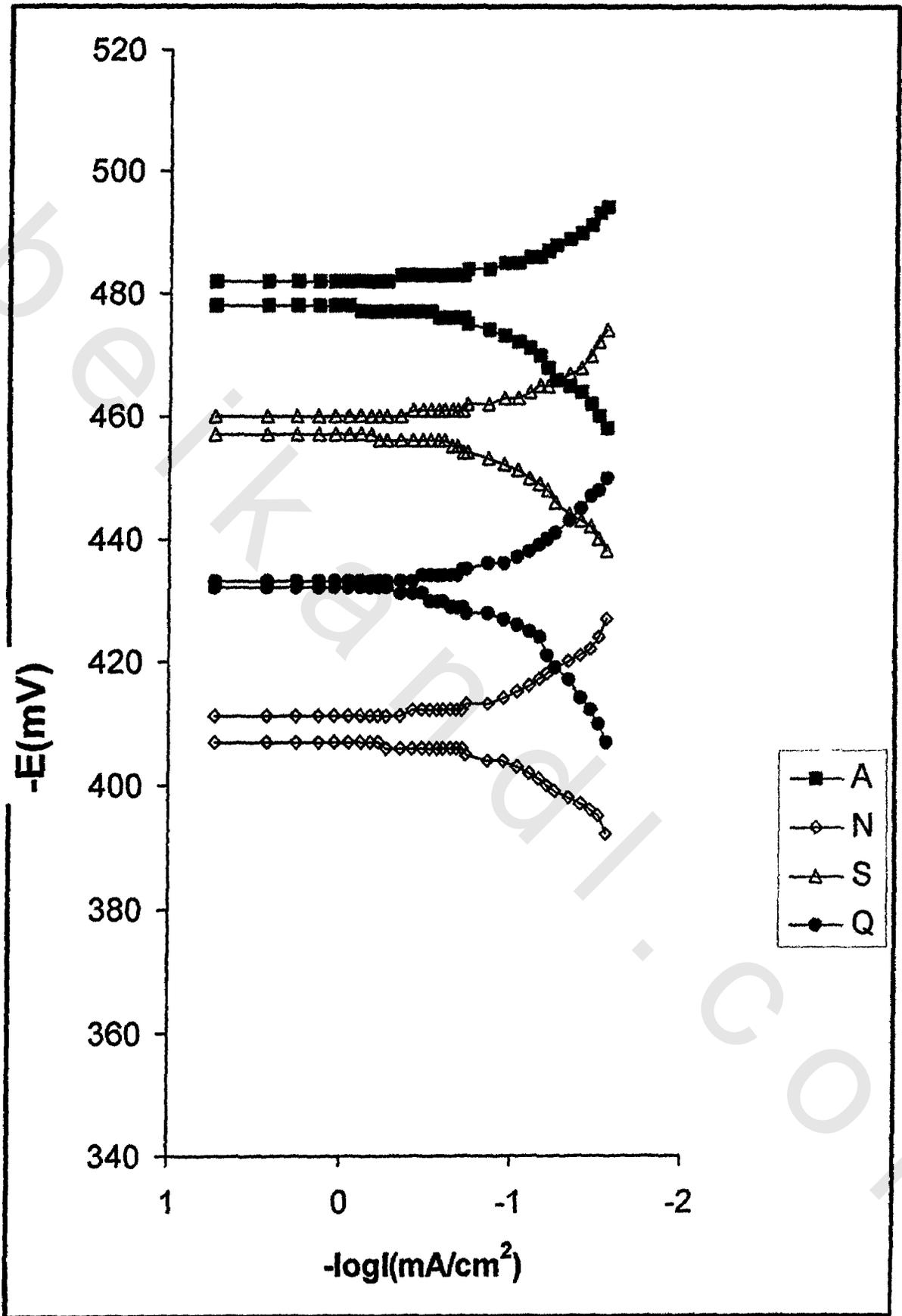
Fig(45): Tafel lines for L.C.V. steel samples in 0.1M HNO<sub>3</sub> and in presence of 6 x 10<sup>-5</sup> M of HEAA at 55 °C



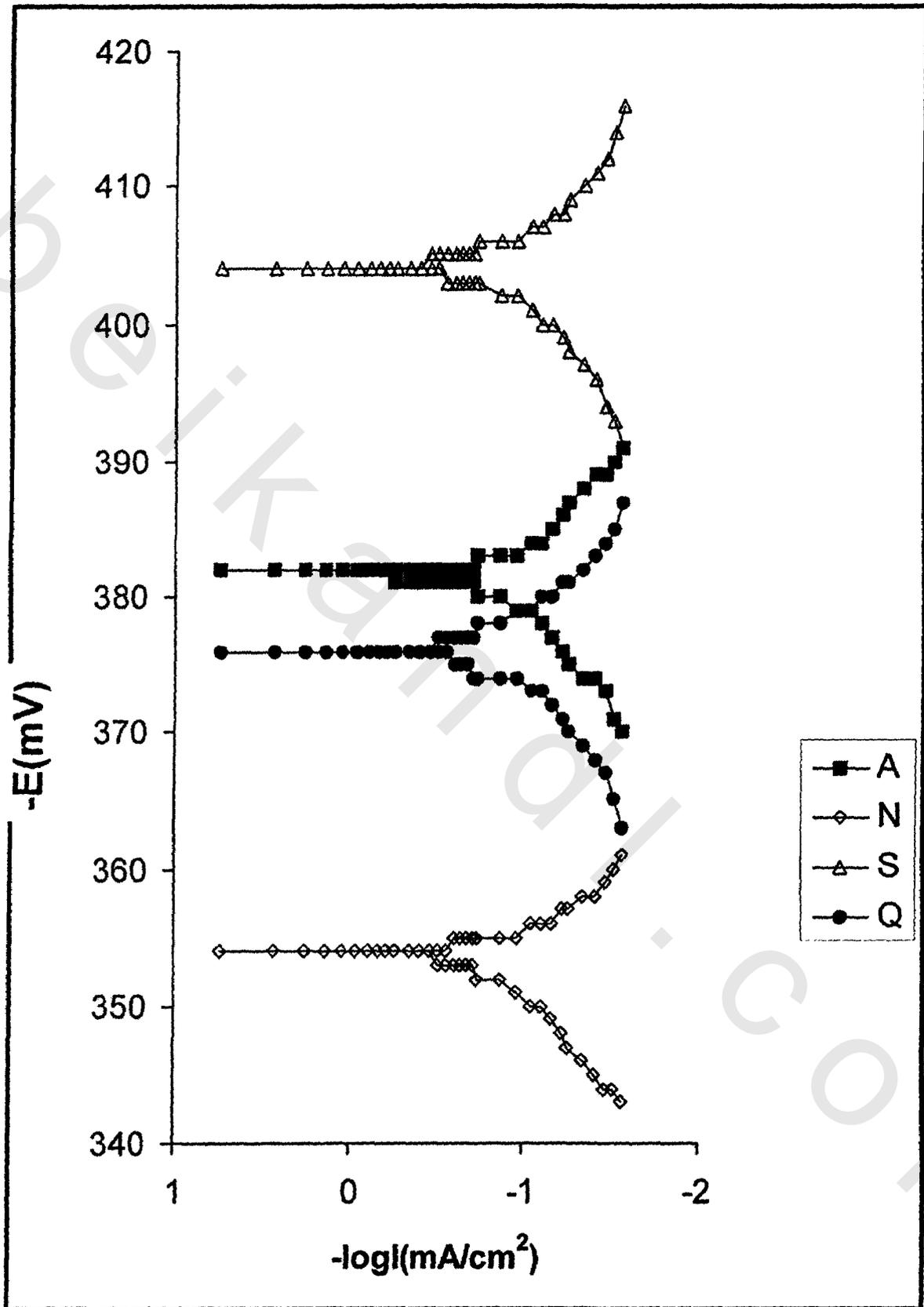
**Fig(46): Tafel lines for L.C.V. steel samples in 0.1M HNO<sub>3</sub> and in presence of 8 x 10<sup>-5</sup> M of HEAA at 55 °C**



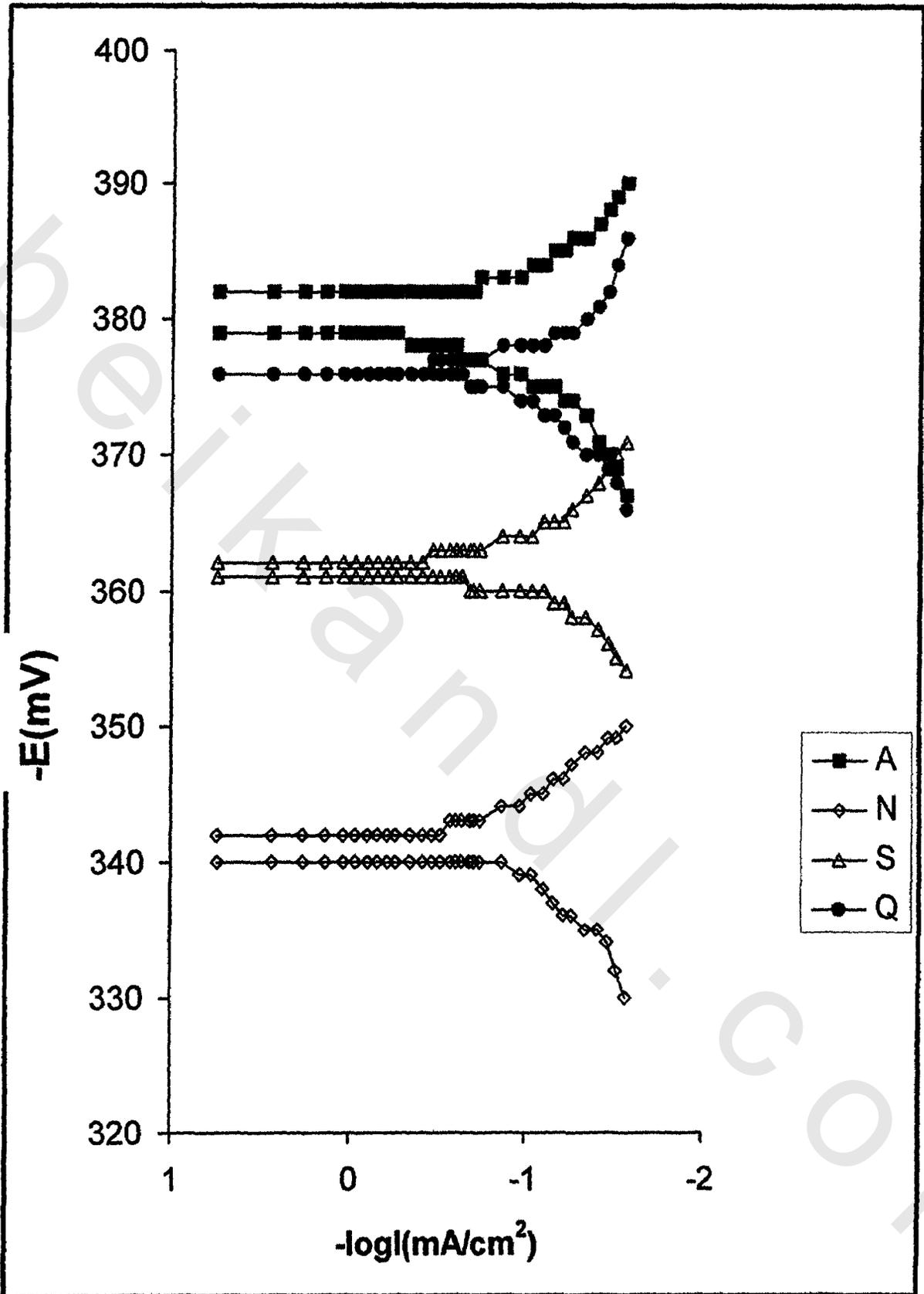
Fig(47): Tafel lines for L.C.V. steel samples in 0.1M HNO<sub>3</sub> and in presence of 10<sup>-4</sup>M of HEAA at 55 °C



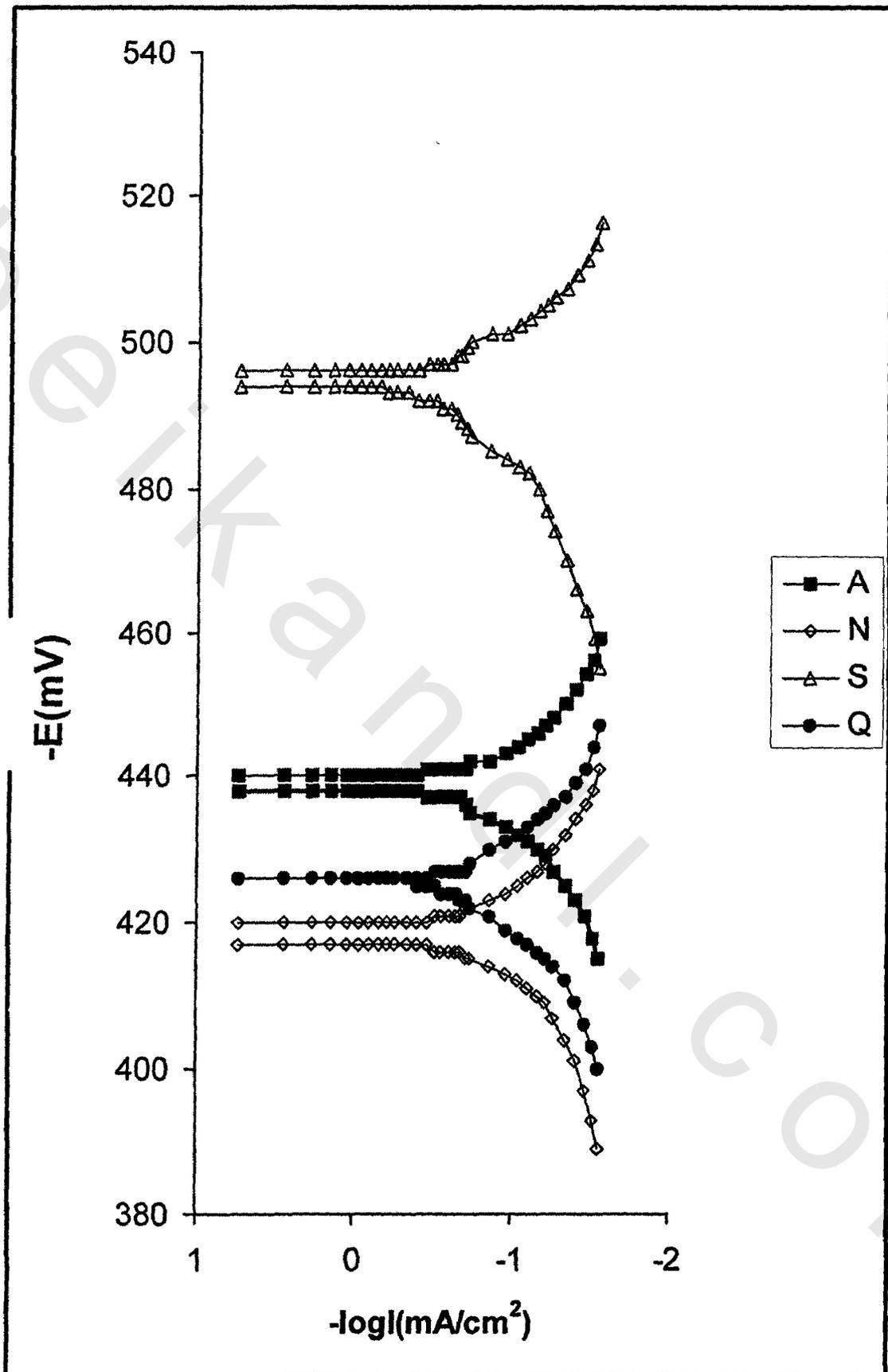
**Fig(48):**Tafel lines for M.C.V. steel samples in 0.1 M HNO<sub>3</sub> at 25 °C



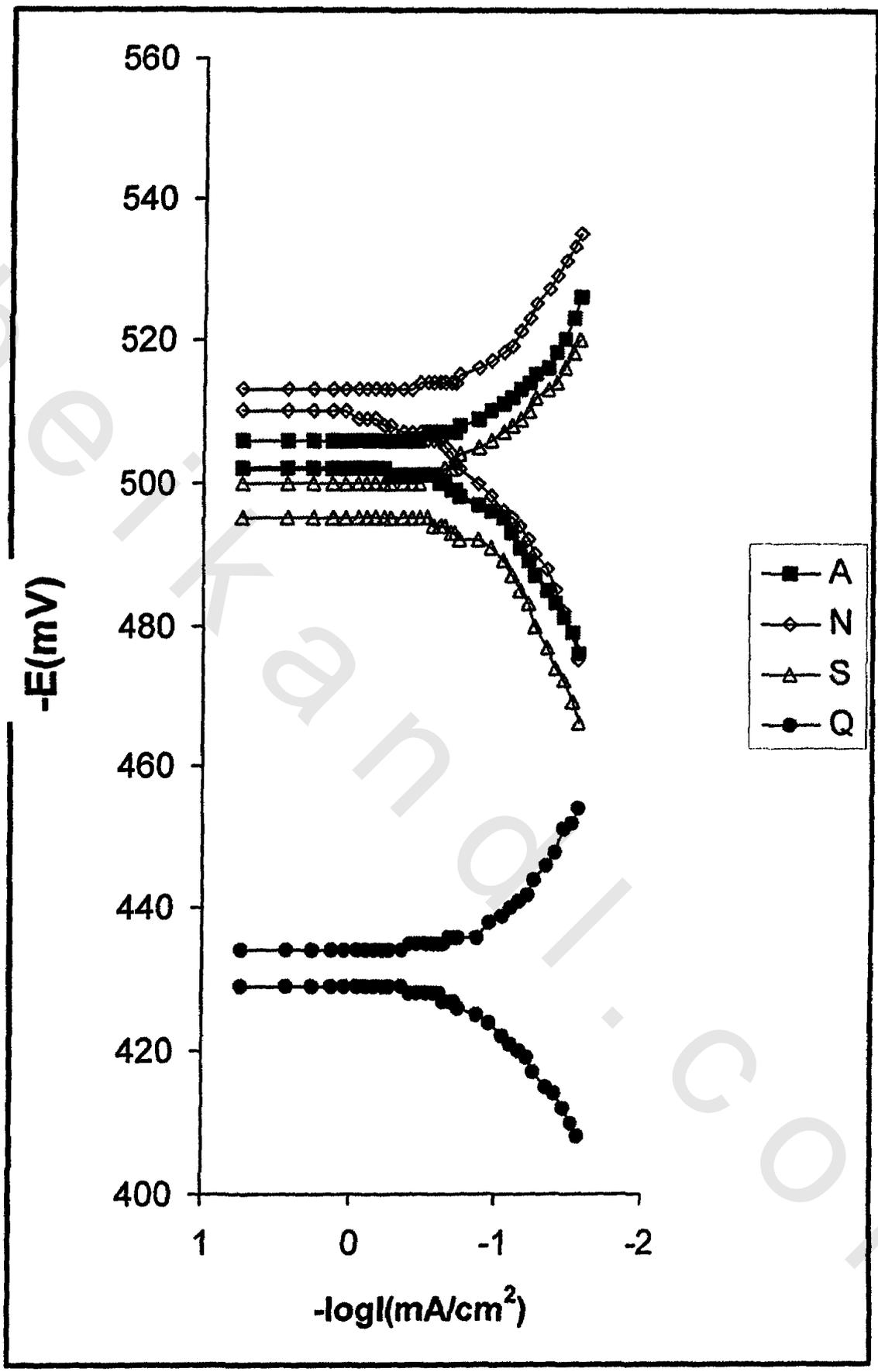
Fig(49): Tafel lines for M.C.V. steel samples in 0.3 M HNO<sub>3</sub> at 25°C



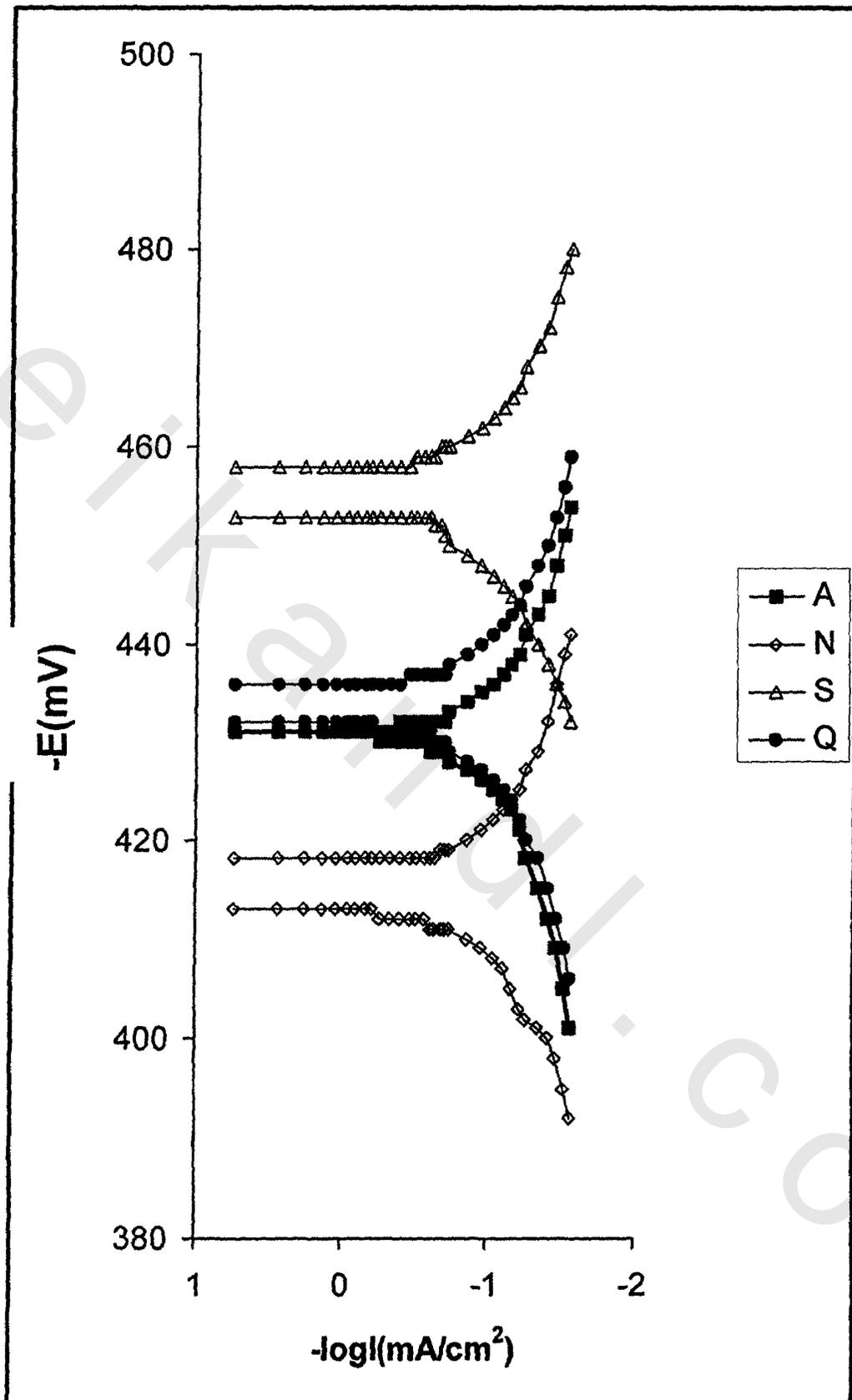
**Fig(50): Tafel lines for M.C.V. steel samples in 0.5 M HNO<sub>3</sub> at 25°C**



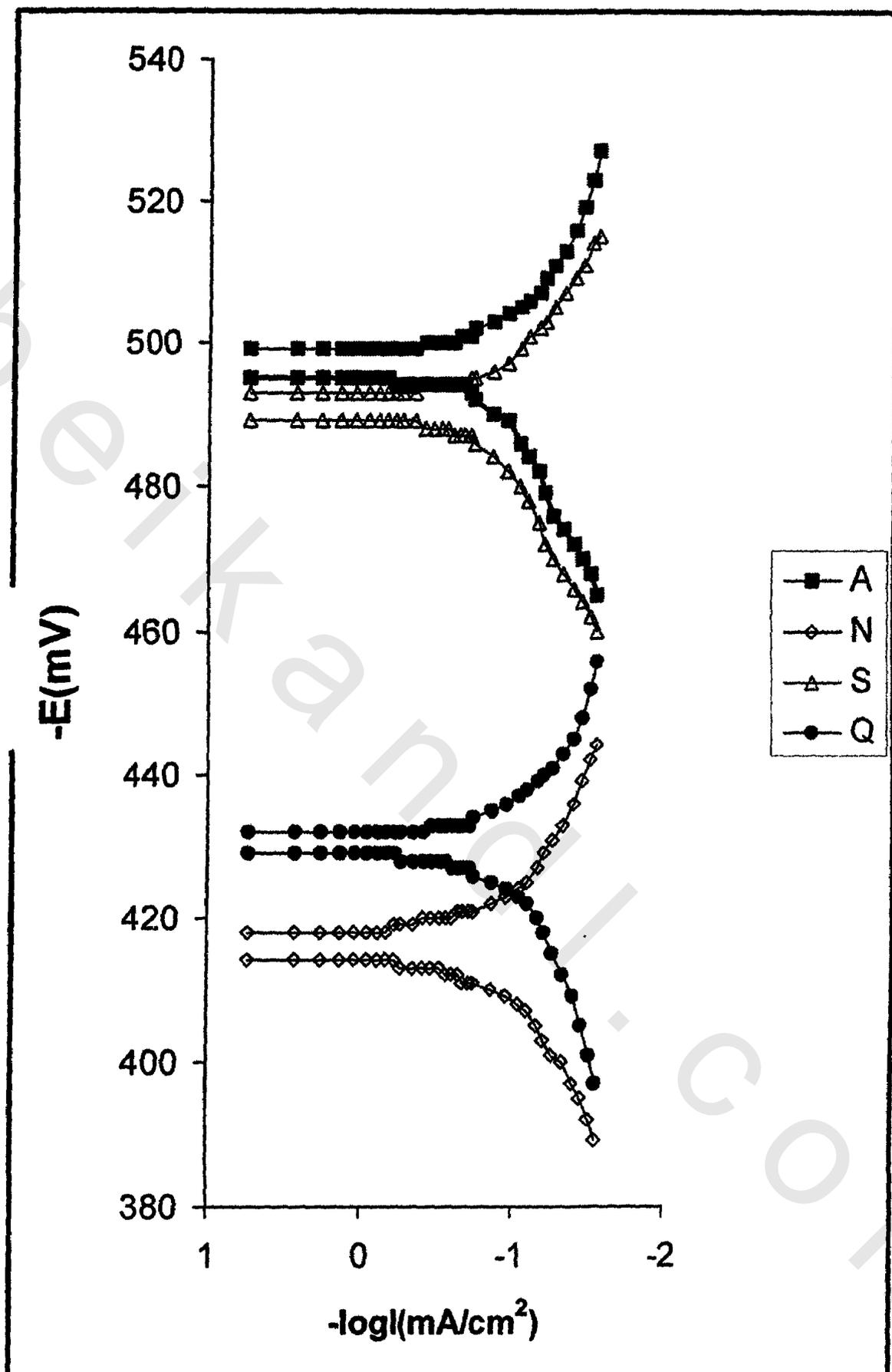
Fig(51): Tafel lines for M.C.V. steel samples in 0.1M HNO<sub>3</sub> and in presence of 2 x 10<sup>-5</sup> M of HEAA at 25 °C



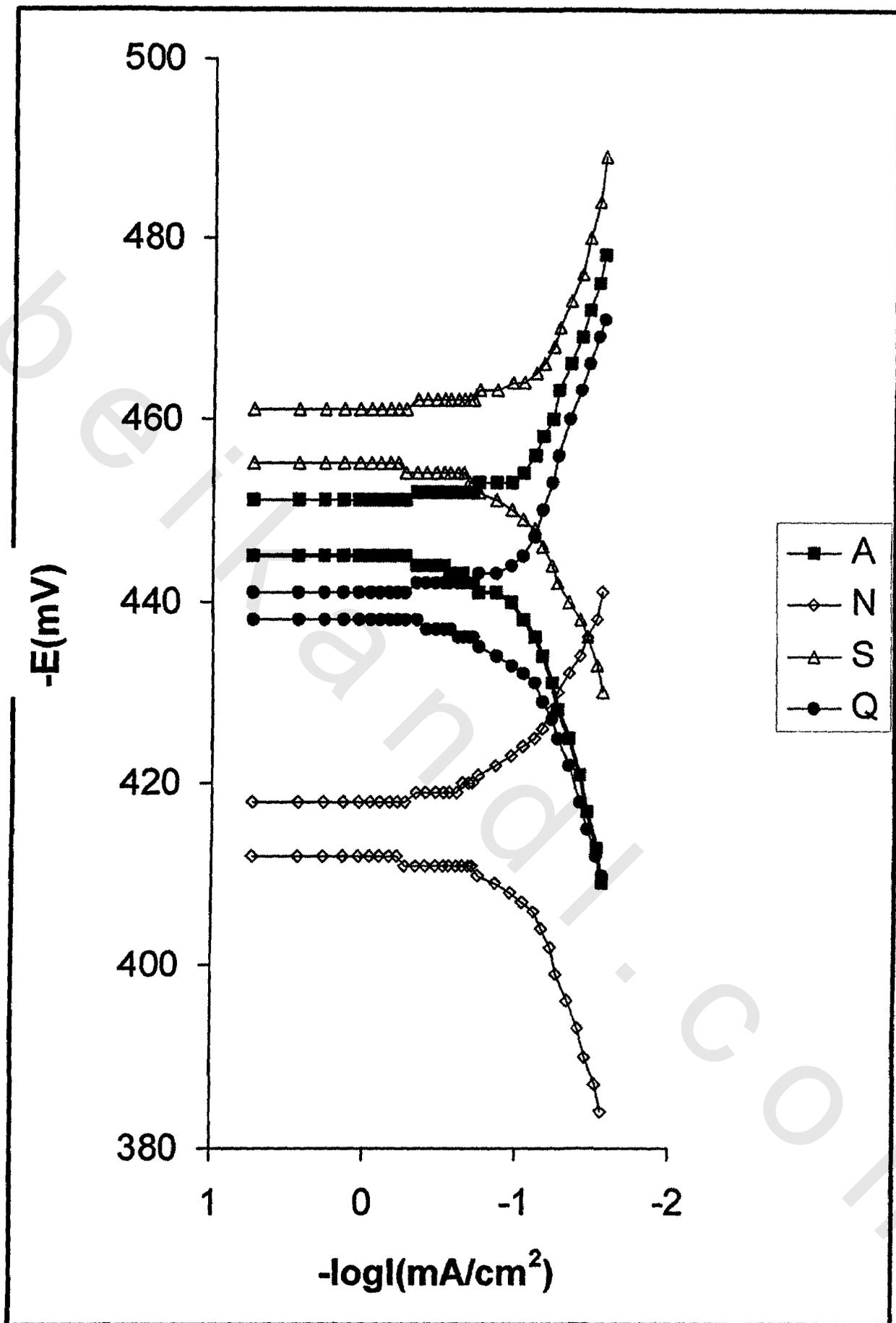
**Fig(52): Tafel lines for M.C.V. steel samples in 0.1M HNO<sub>3</sub> and in presence of 4 x 10<sup>-5</sup>M of HEAA at 25 °C**



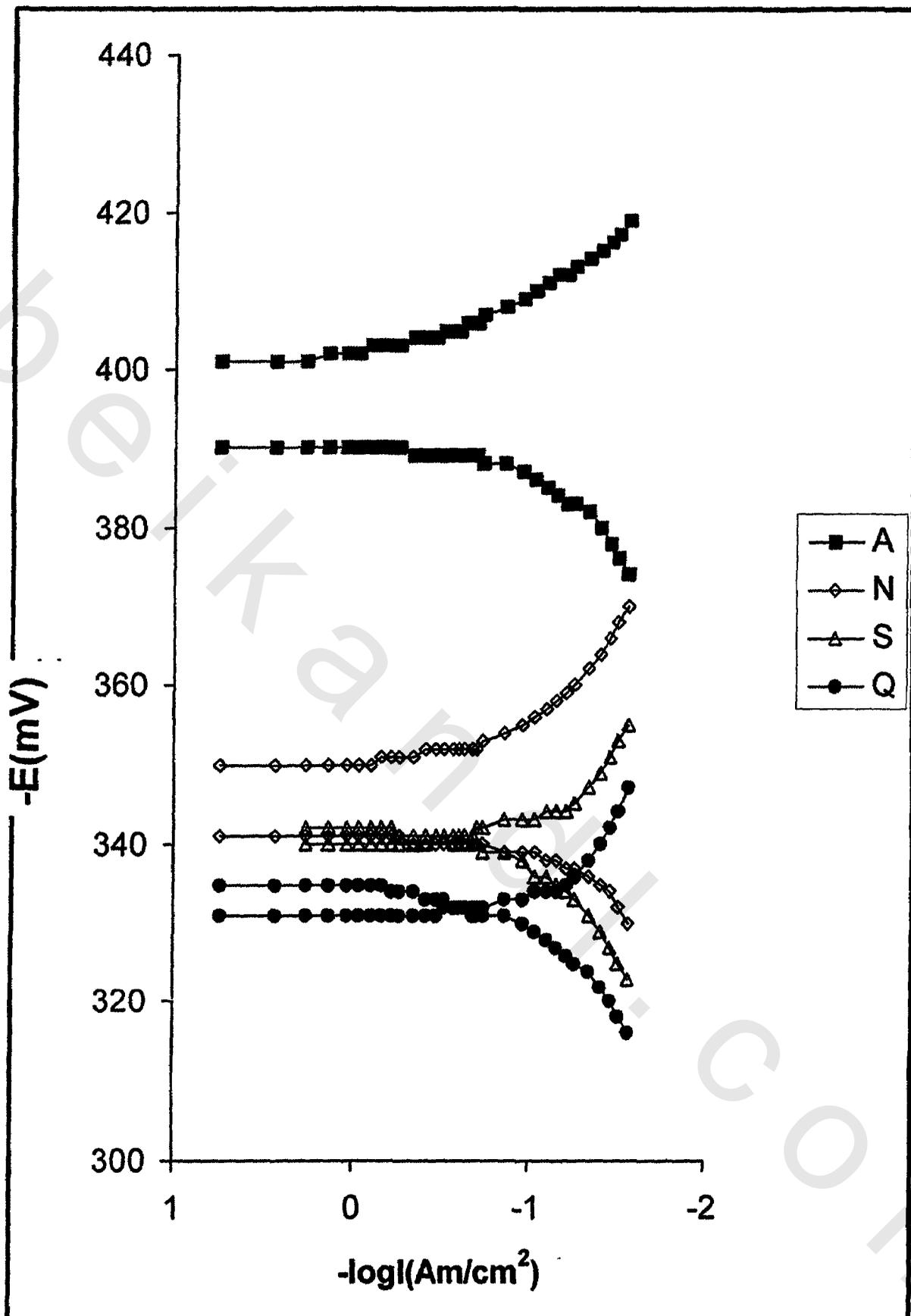
Fig(53): Tafel lines for M.C.V. steel samples in 0.1M HNO<sub>3</sub> and in presence of 6 x 10<sup>-5</sup> M of HEAA at 25 °C



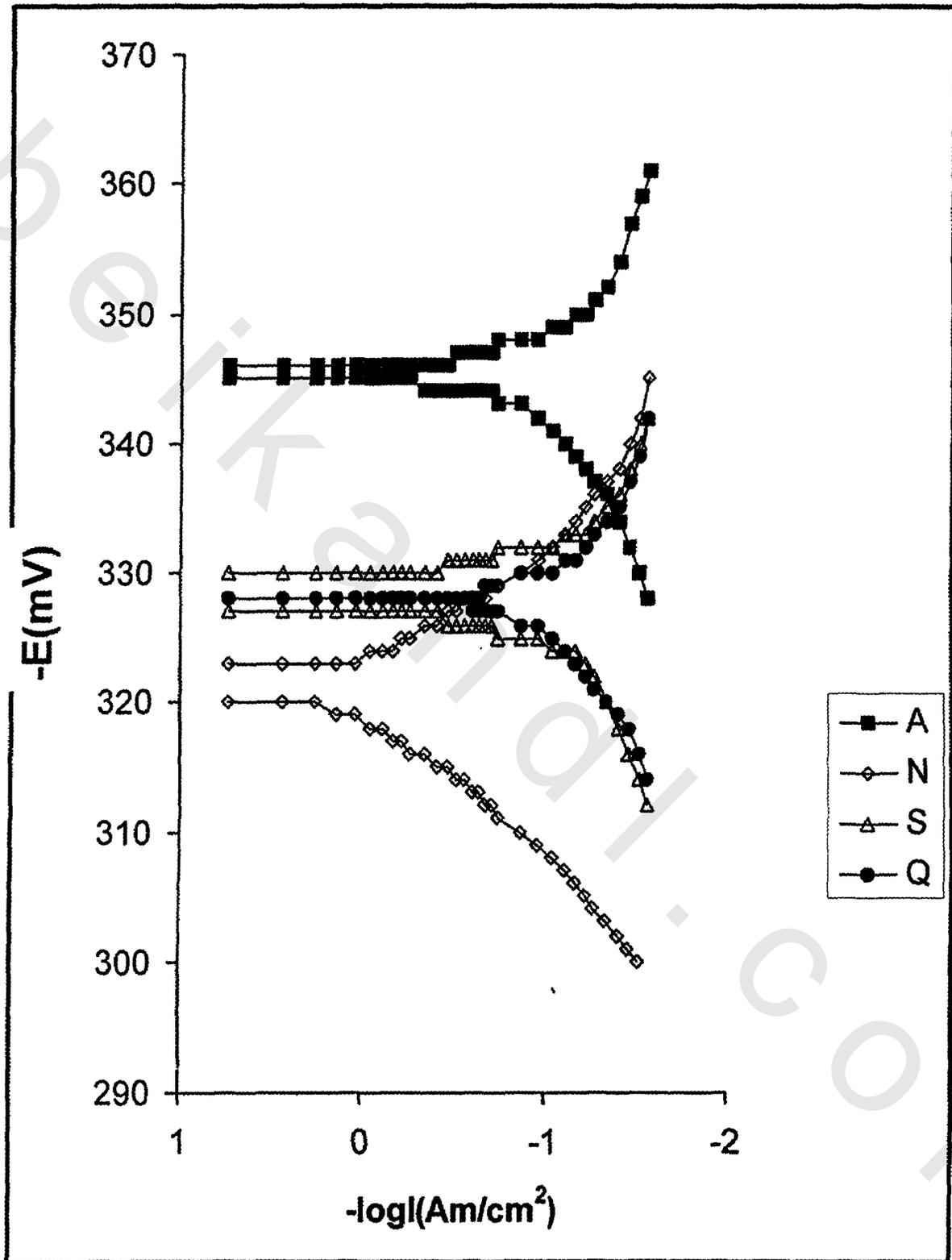
**Fig(54): Tafel lines for M.C.V. steel samples in 0.1M HNO<sub>3</sub> and in presence of 8 x 10<sup>-5</sup> M of HEAA at 25 °C**



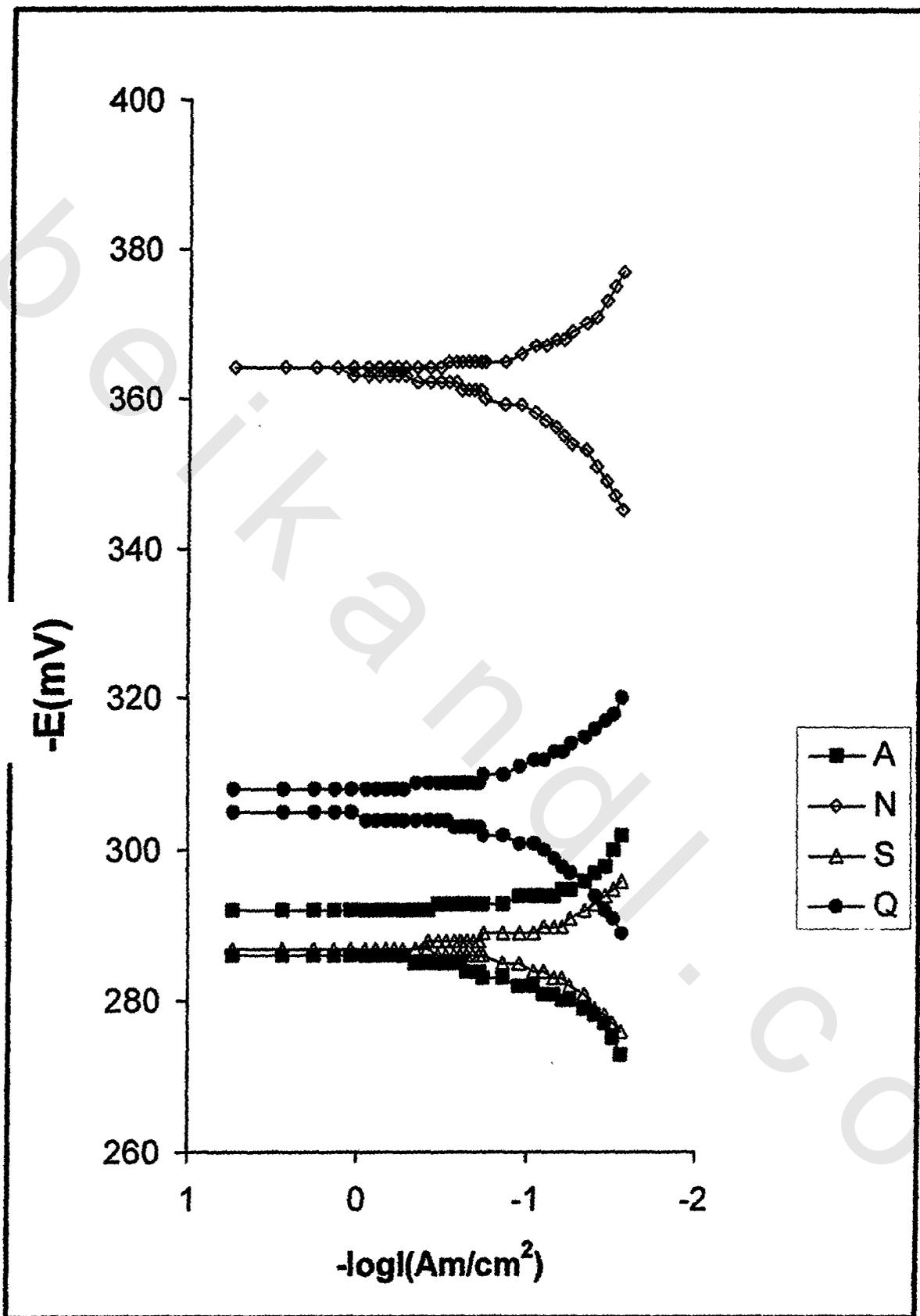
**Fig(55): Tafel lines for M.C.V. steel samples in 0.1M HNO<sub>3</sub> and in presence of 10<sup>-4</sup>M of HEAA at 25 °C**



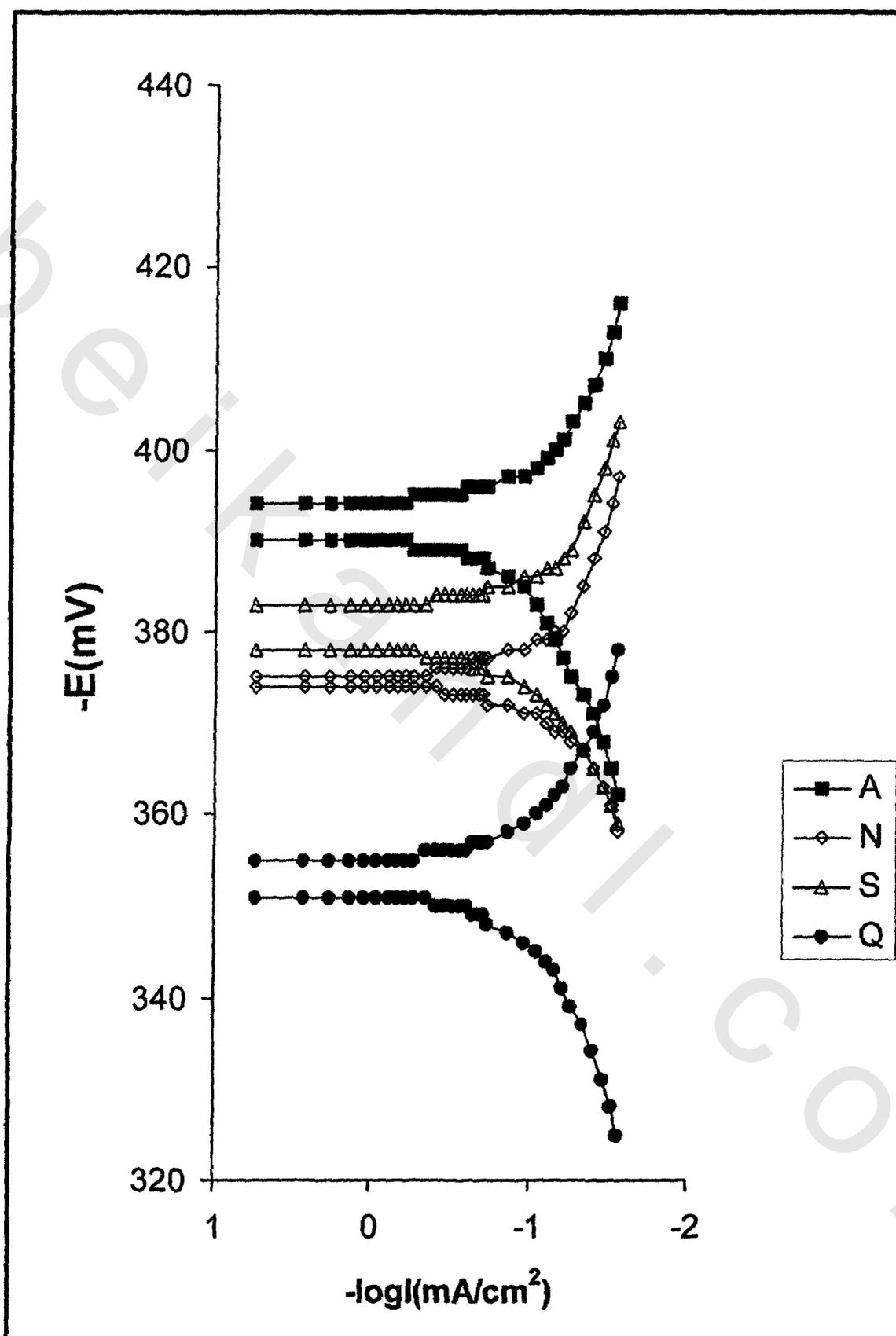
**Fig(56): Tafel lines for M.C.V. steel samples in 0.1M  $\text{HNO}_3$  at  $35^\circ\text{C}$**



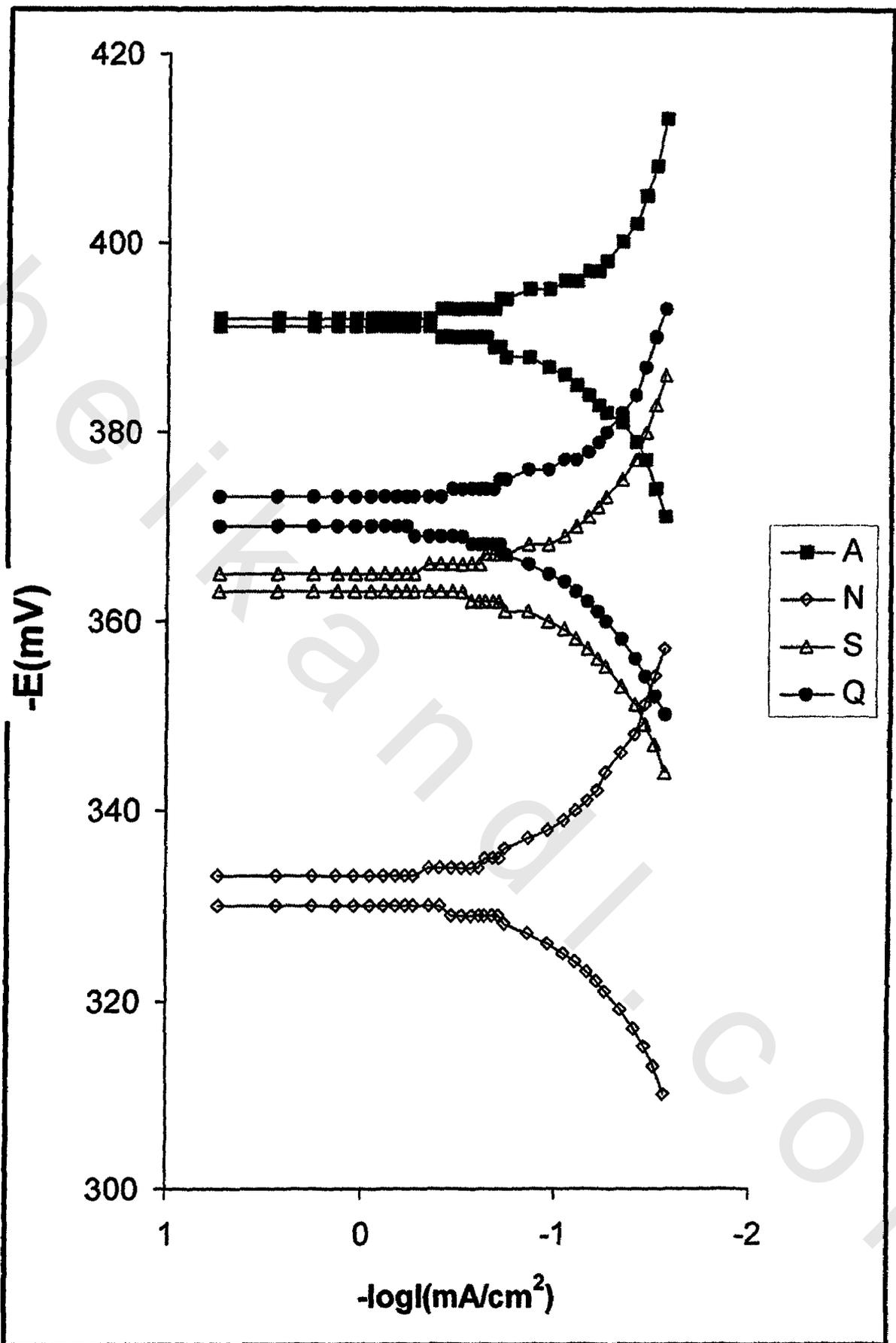
Fig(57): Tafel lines for M.C.V. steel samples in 0.3M HNO<sub>3</sub> at 35°C



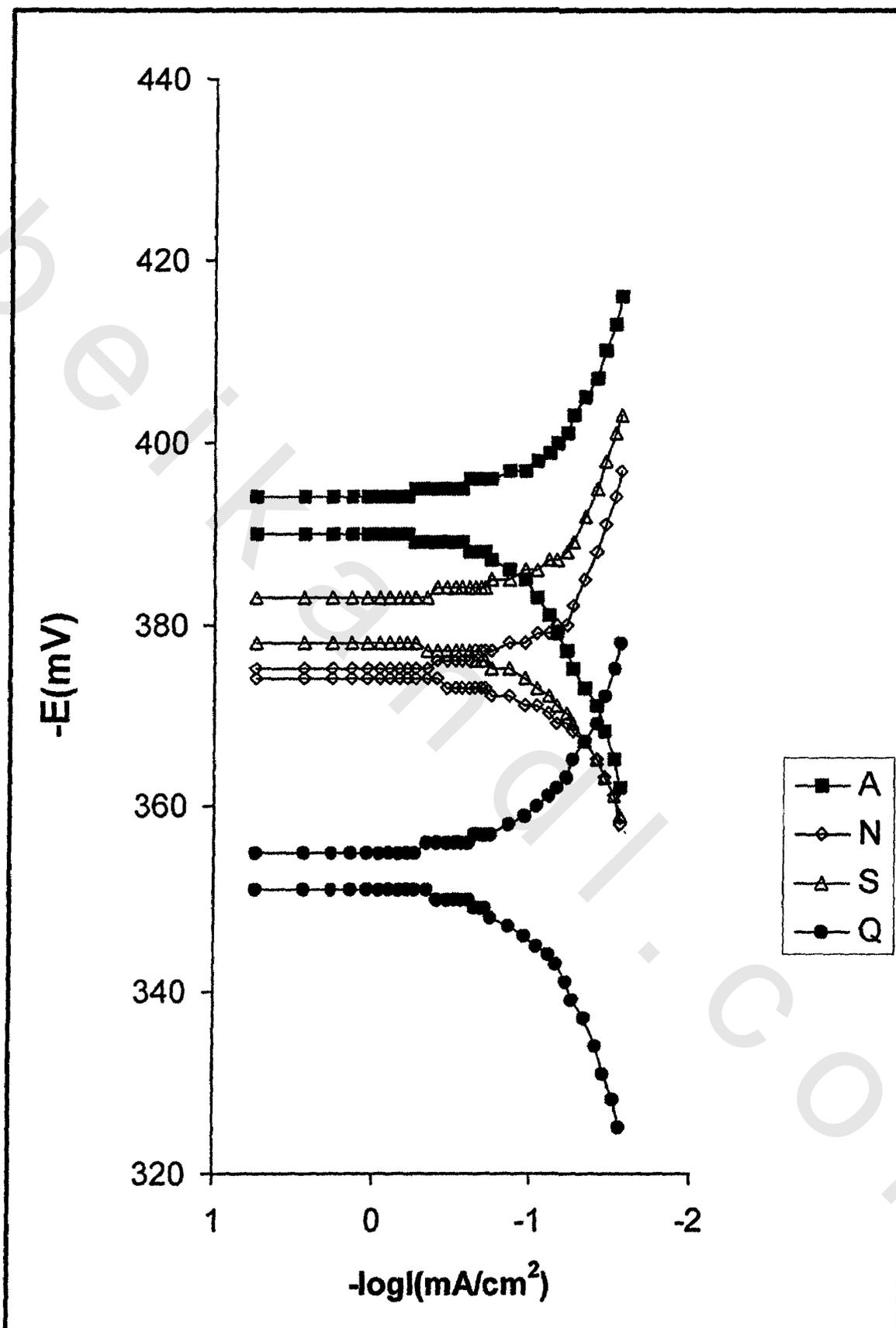
**Fig(58): Tafel lines for M.C.V. steel samples in 0.5M HNO<sub>3</sub> at 35 °C**



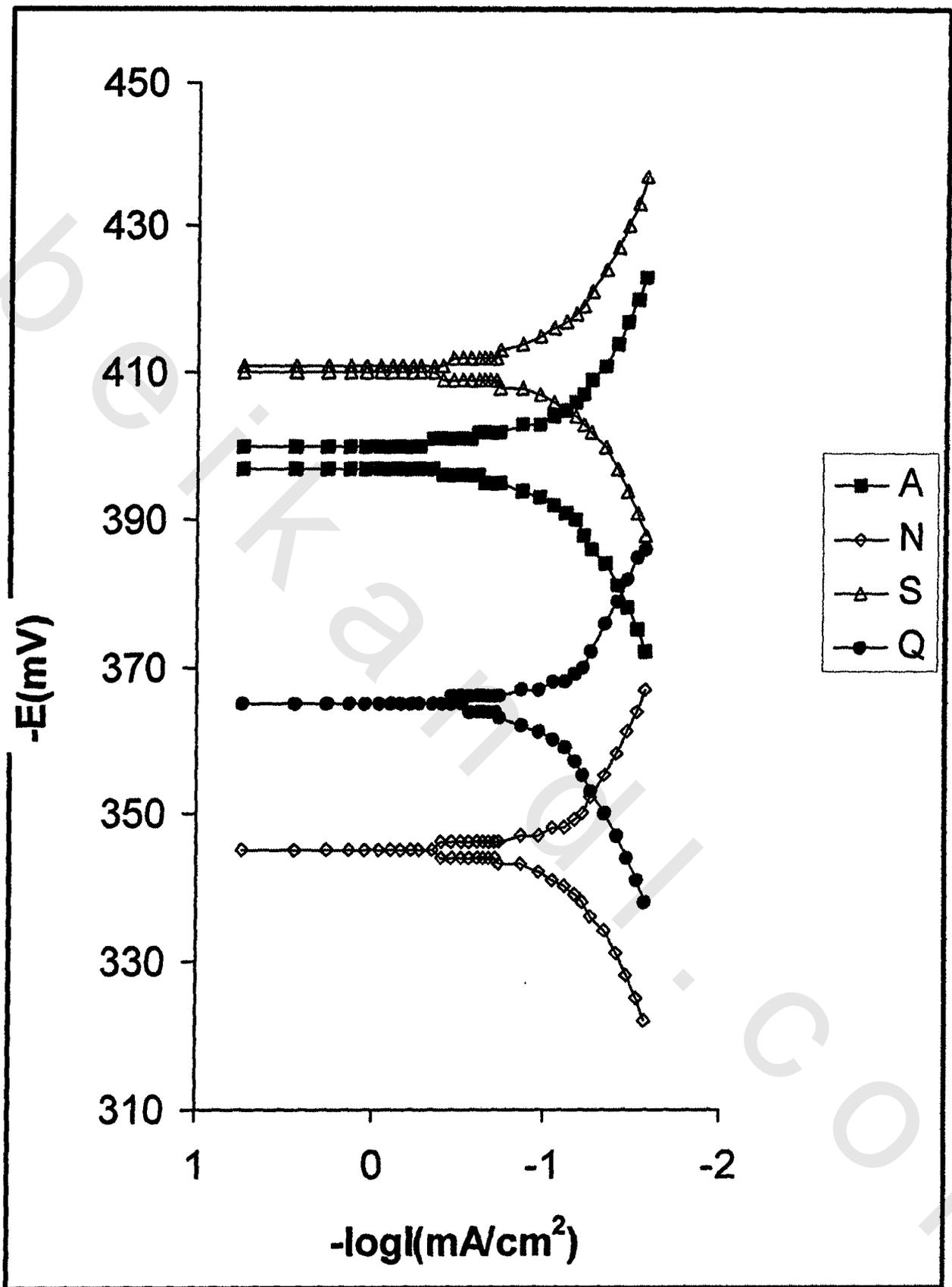
**Fig(59):**Tafel lines for M.C.V. steel samples in 0.1 M HNO<sub>3</sub> in presence of  $2 \times 10^{-5}$  M of HEAA at 35 °C



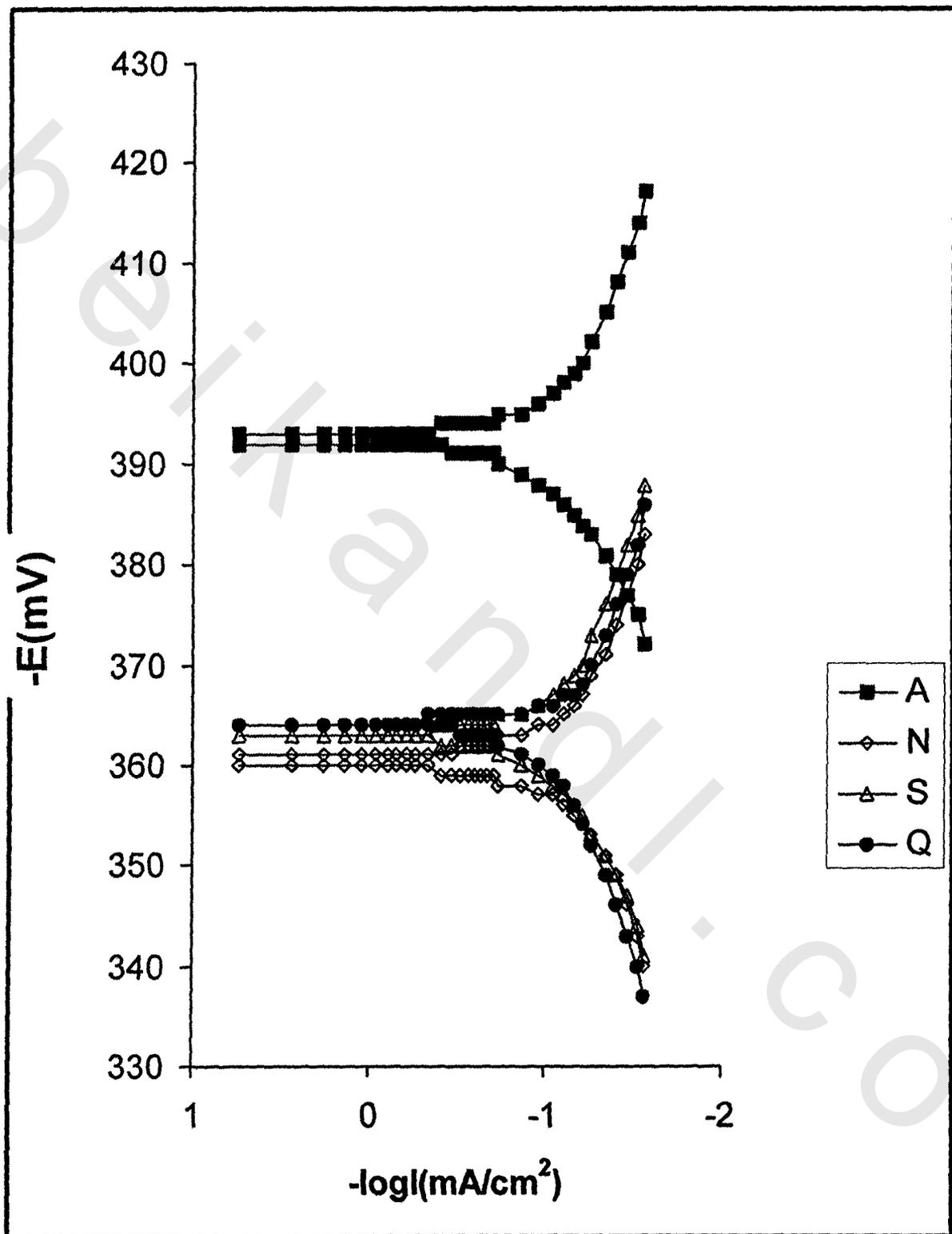
**Fig(60): Tafel lines for M.C.V. steel samples in 0.1 M  $\text{HNO}_3$  in presence of  $4 \times 10^{-5}$  M of HEAA at 35 °C**



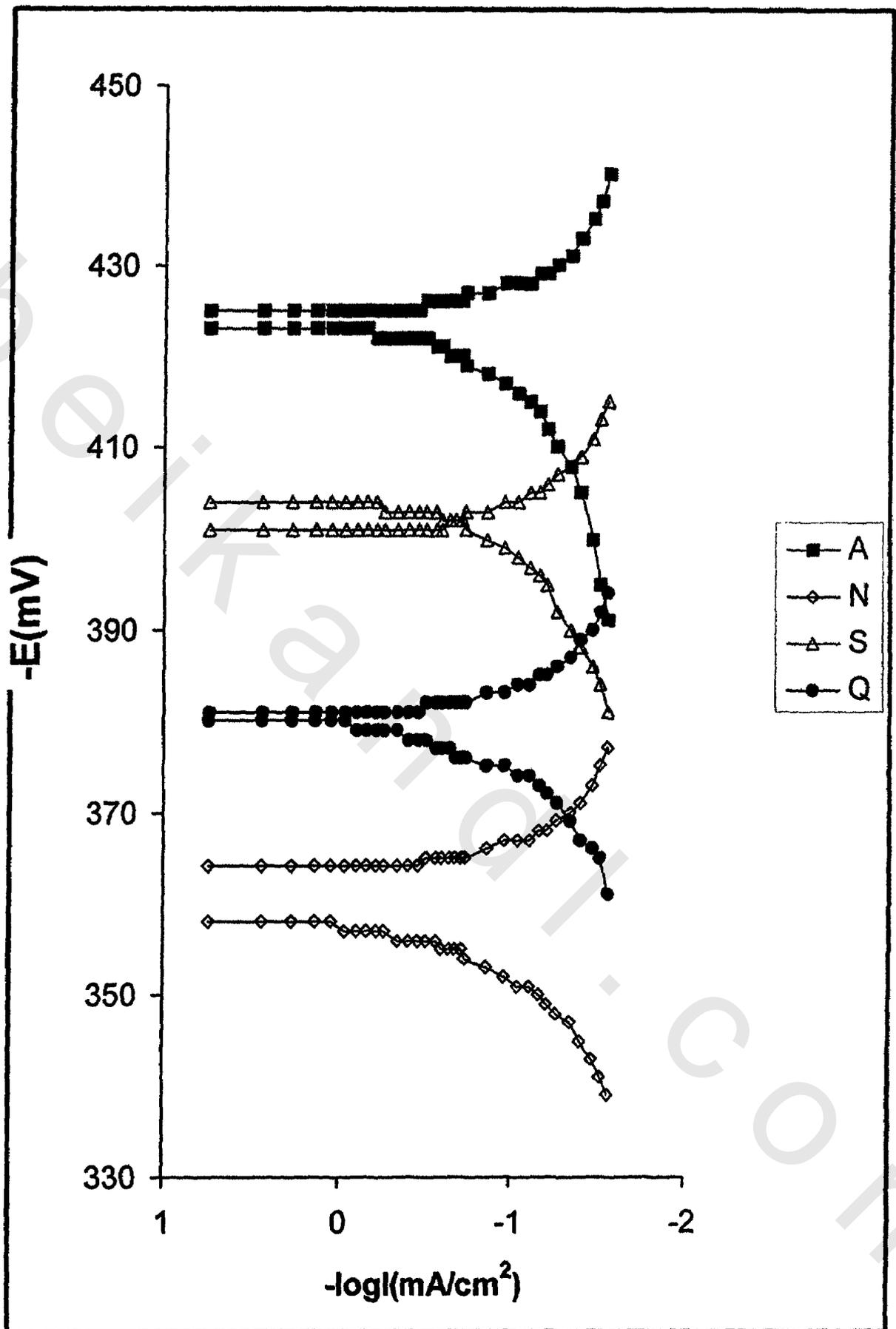
Fig(61): Tafel lines for M.C.V. steel samples in 0.1 M HNO<sub>3</sub> in presence of 6 x 10<sup>-5</sup> M of HEAA at 35 °C



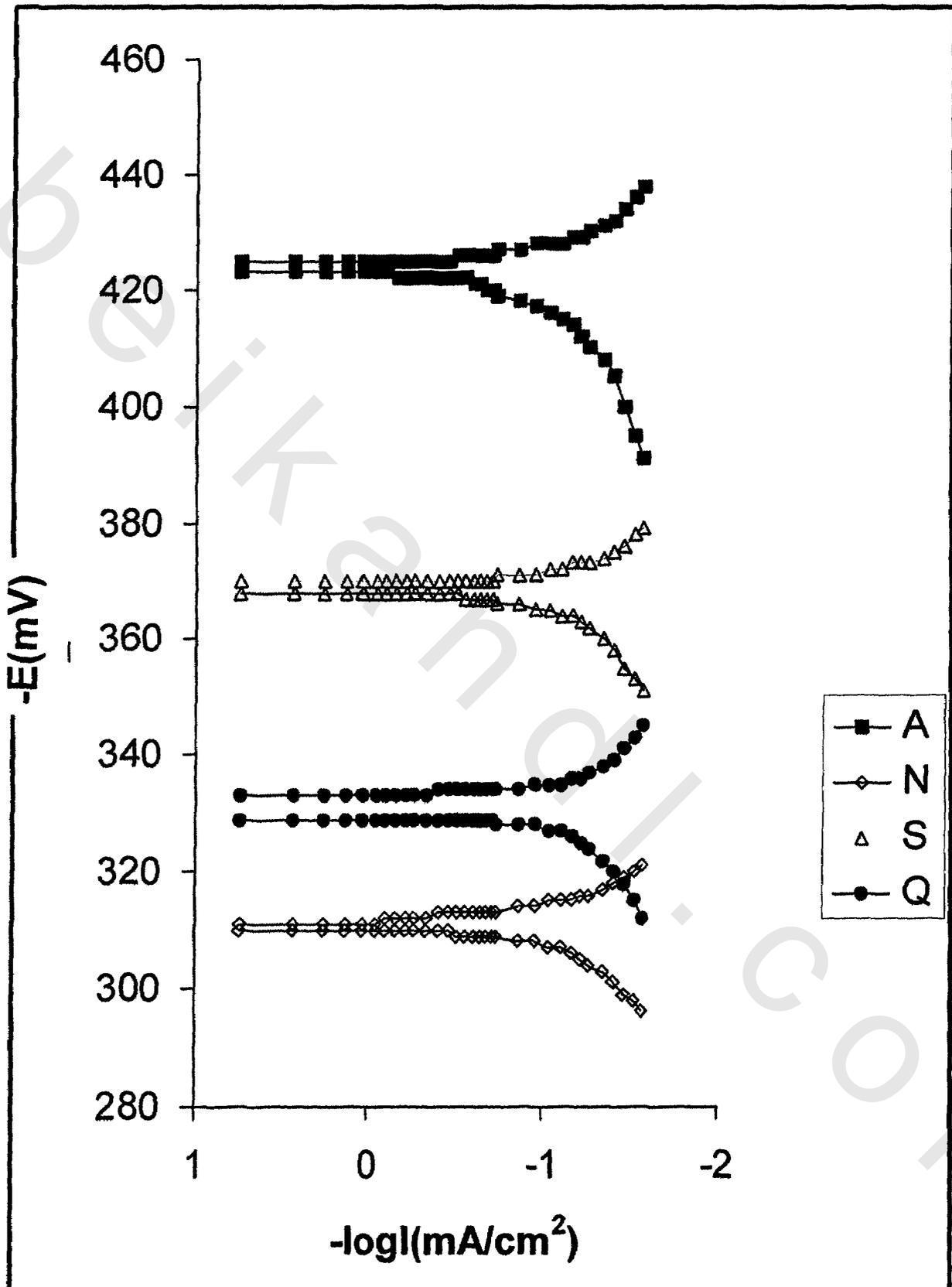
**Fig(62): Tafel lines for M.C.V. steel samples in 0.1 M HNO<sub>3</sub> in presence of 8 x 10<sup>-5</sup> M of HEAA at 35 °C**



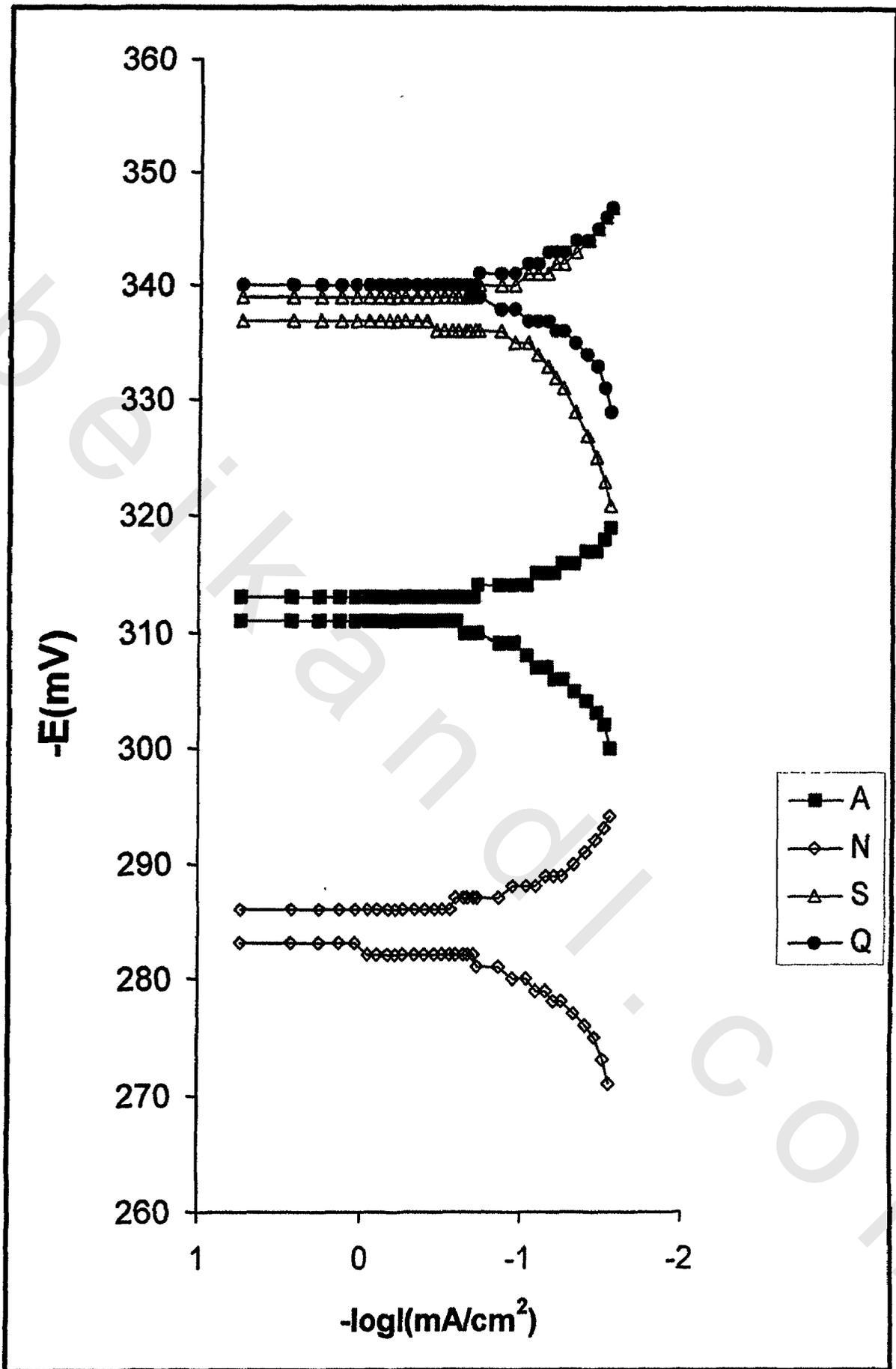
**Fig(63): Tafel lines for M.C.V. steel samples in 0.1 M HNO<sub>3</sub> in presence of 10<sup>-4</sup> M of HEAA at 35 °C**



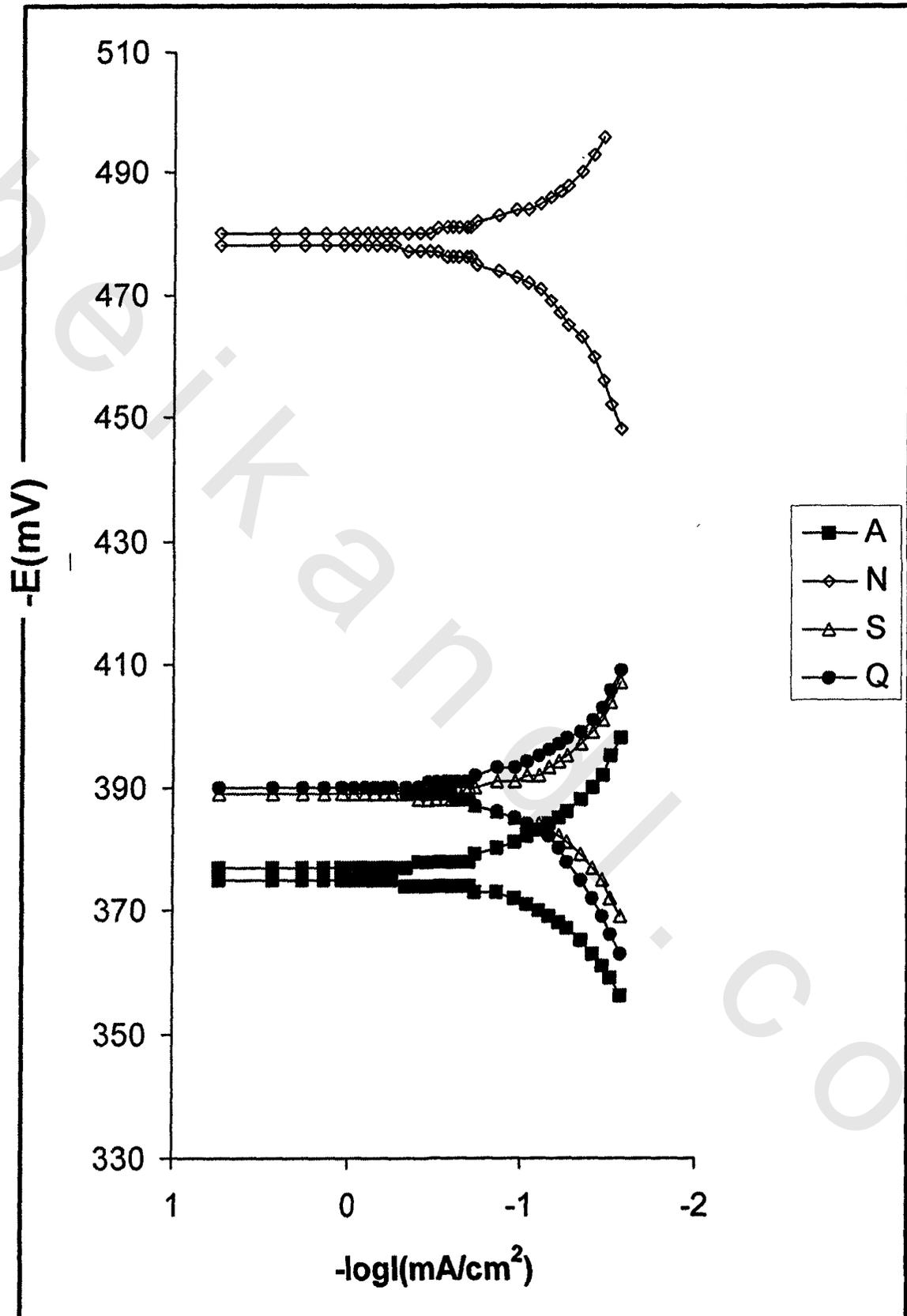
**Fig(64): Tafel lines for M.C.V. steel samples in 0.1M  $\text{HNO}_3$  at  $45^\circ\text{C}$**



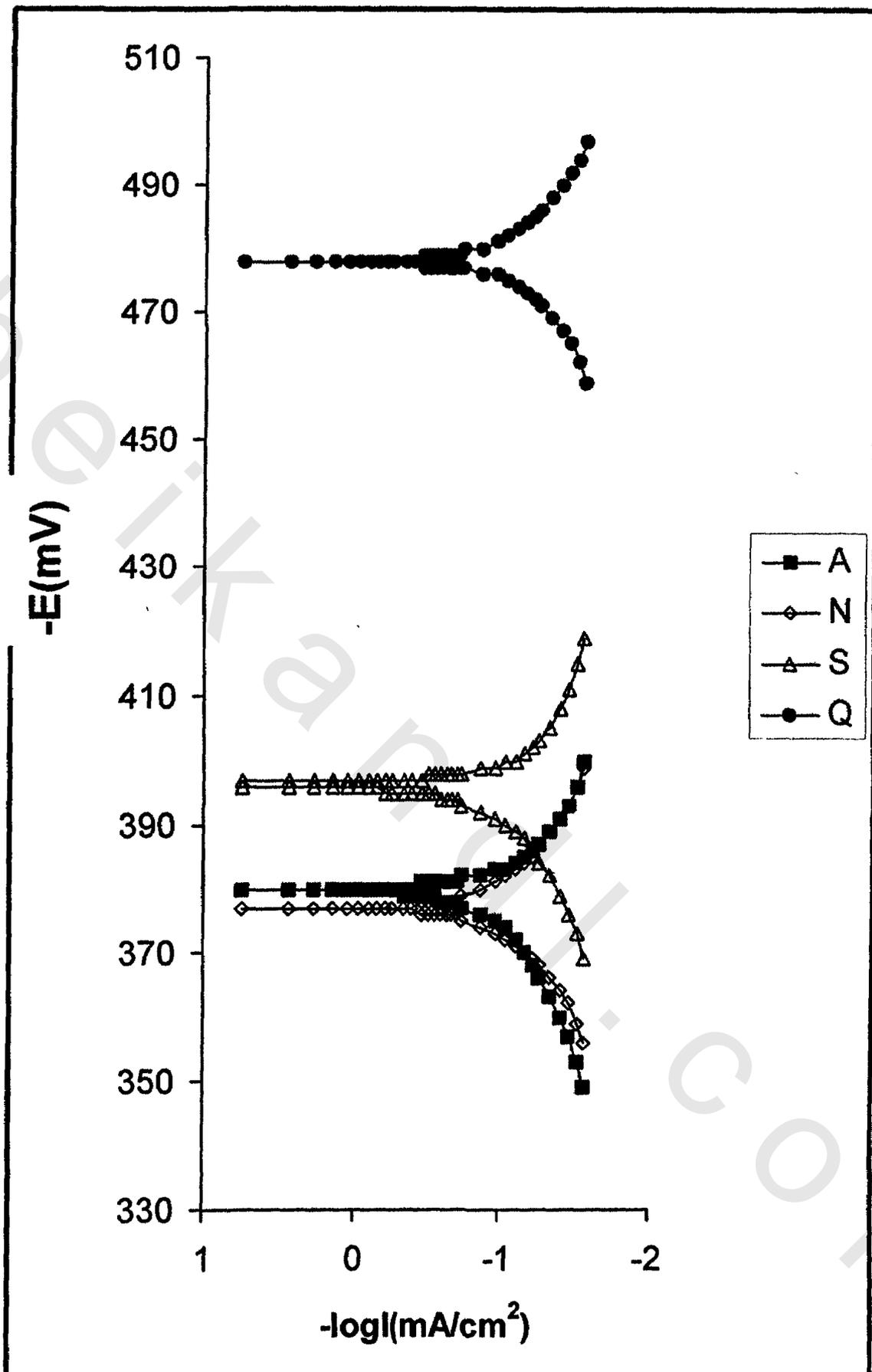
Fig(65): Tafel lines for M.C.V. steel samples in 0.3M HNO<sub>3</sub> at 45°C



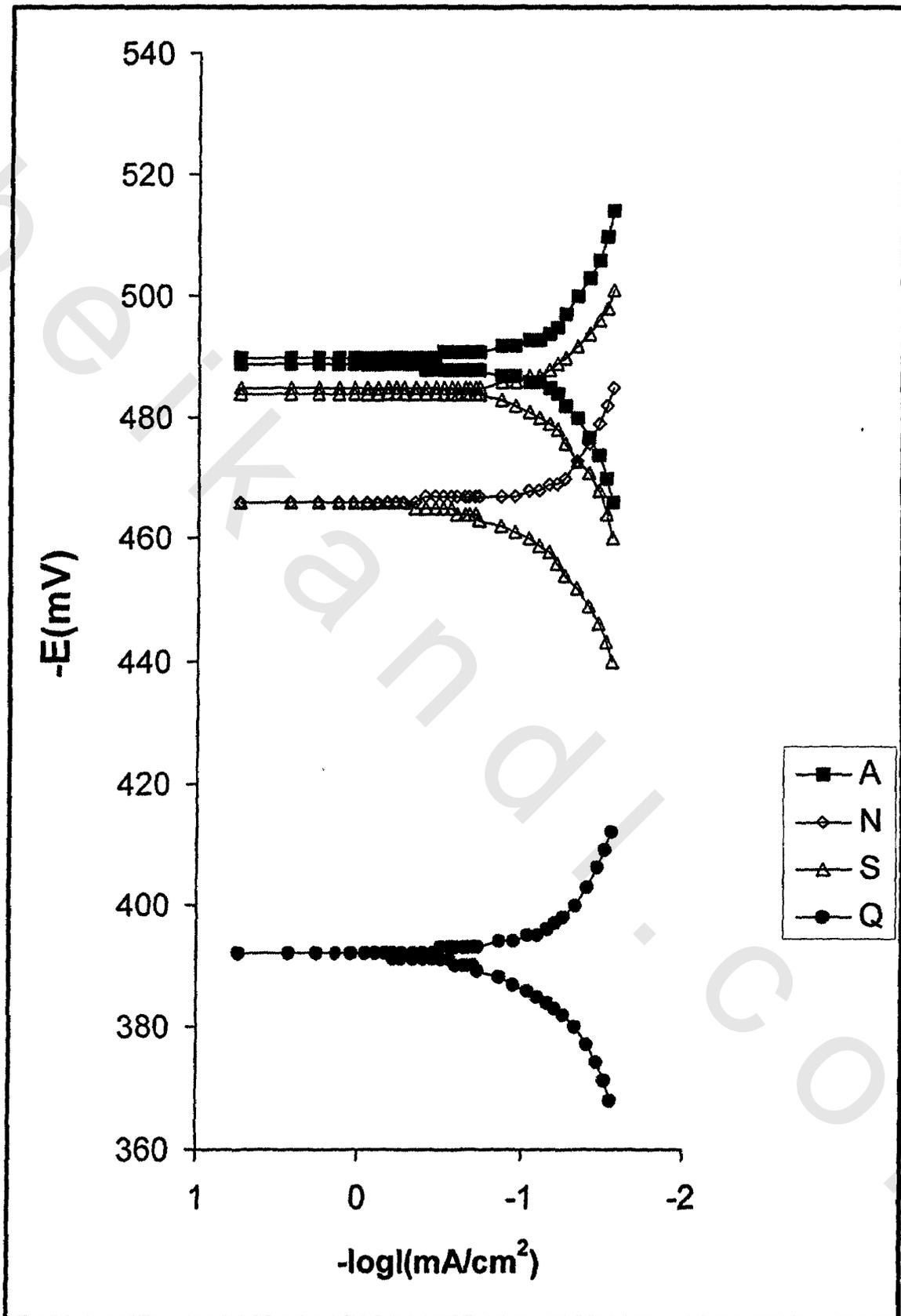
**Fig(66): Tafel lines for M.C.V. steel samples in 0.5M HNO<sub>3</sub> at 45°C**



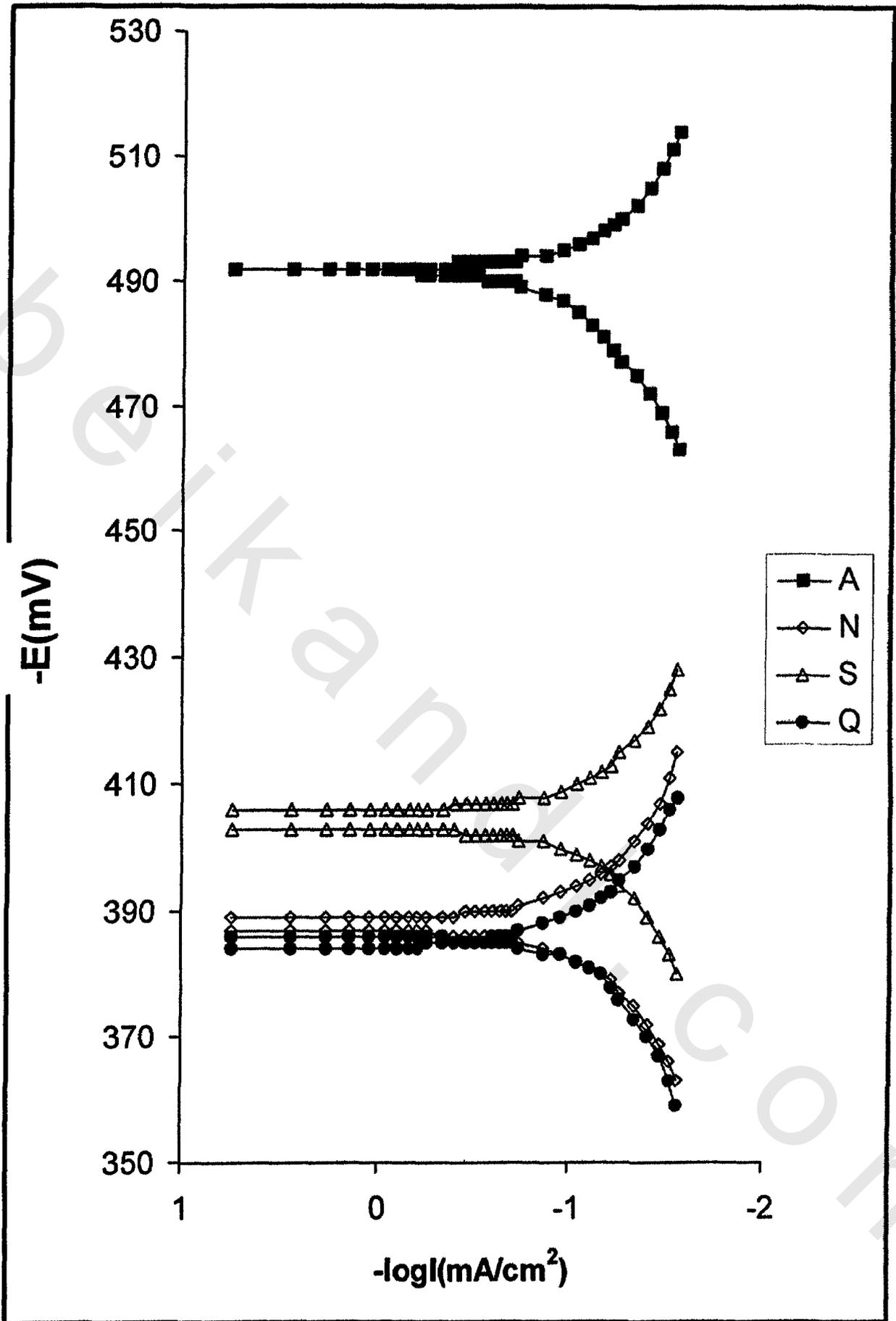
Fig(67): Tafel lines for M.C.V. steel samples in 0.1M HNO<sub>3</sub> and in presence of 2x10<sup>-5</sup>M of HEAA at 45 °C



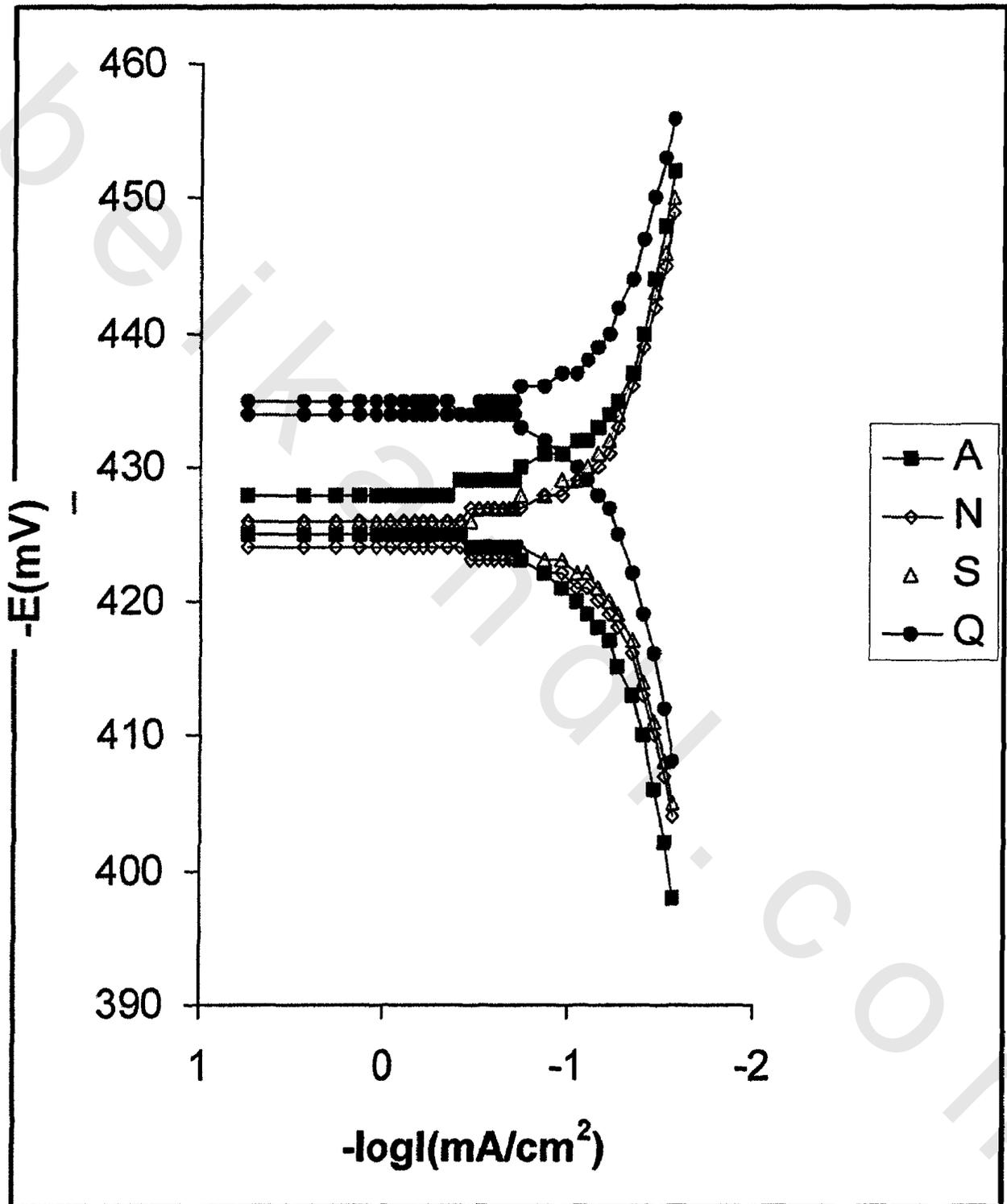
**Fig(68): Tafel lines for M.C.V. steel samples in 0.1M HNO<sub>3</sub> and in presence of 4x10<sup>-5</sup>M of HEAA at 45 °C**



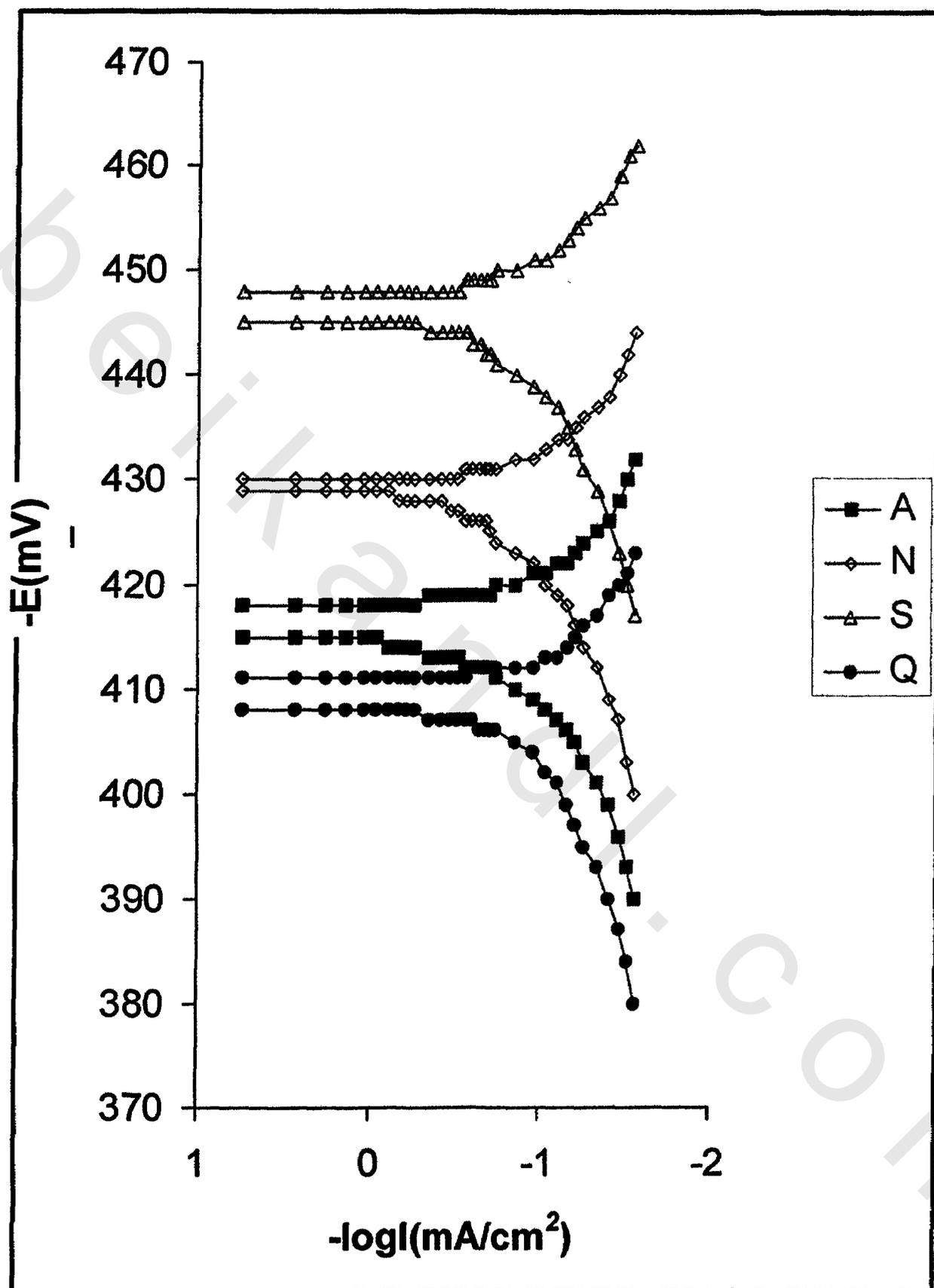
Fig(69): Tafel lines for M.C.V. steel samples in 0.1M HNO<sub>3</sub> and in presence of 6x10<sup>-5</sup> M of HEAA at 45°C



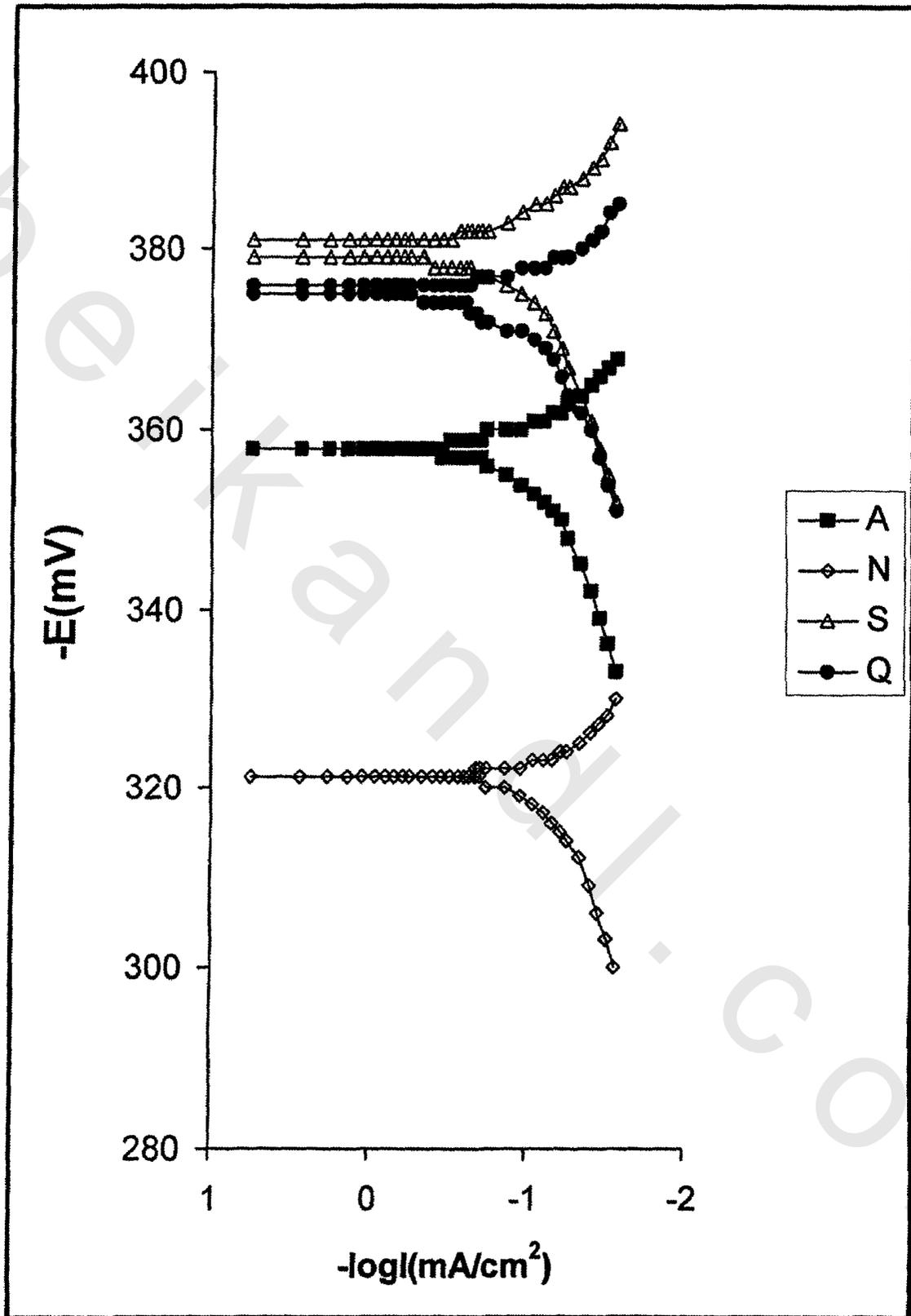
**Fig(70):Tafel lines for M.C.V. steel samples in 0.1M HNO<sub>3</sub> and in presence of  $8 \times 10^{-5}$  M of HEAA at 45 °C**



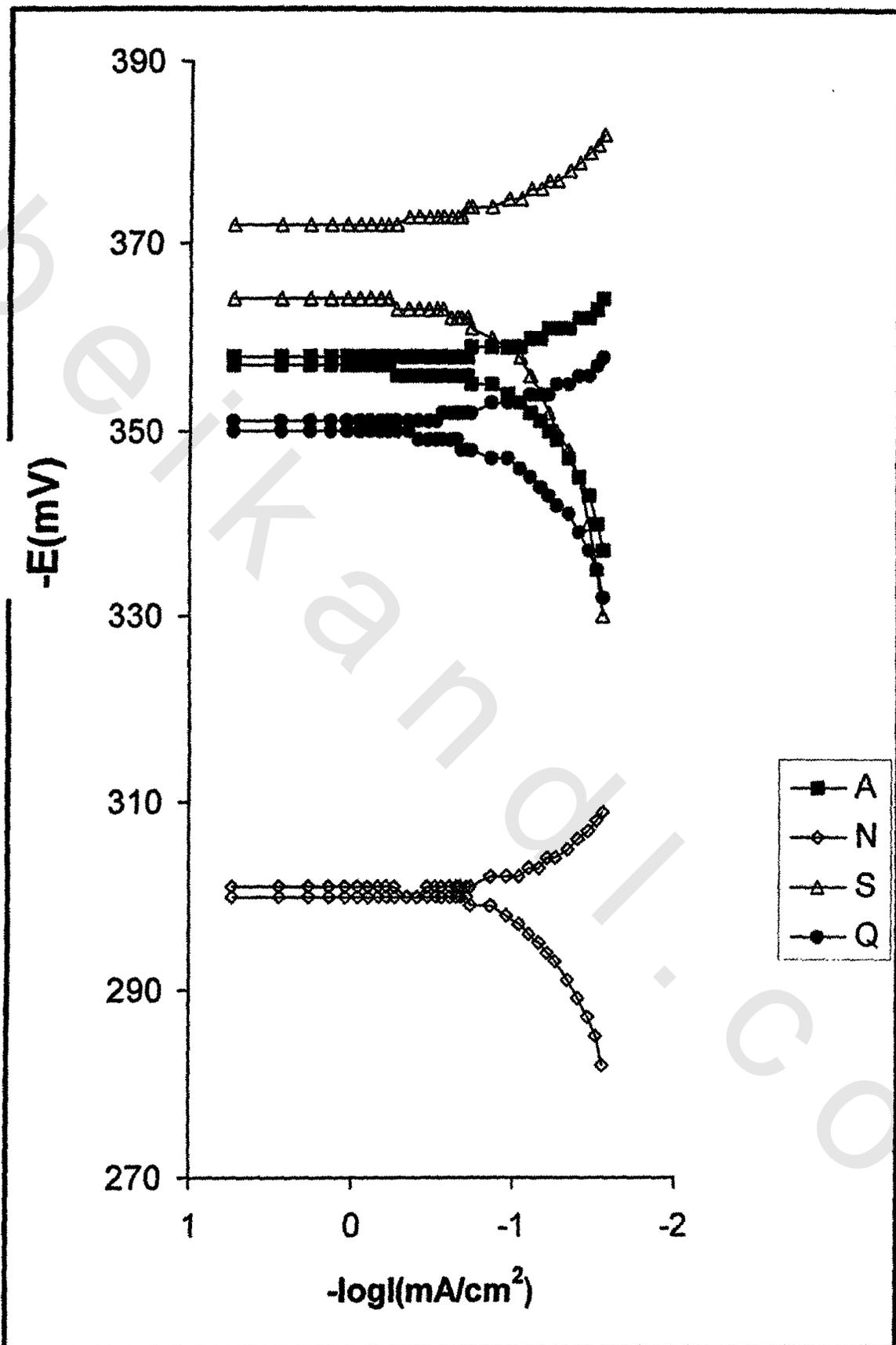
**Fig(71): Tafel lines for M.C.V. steel samples in 0.1M HNO<sub>3</sub> and in presence of 10<sup>-4</sup>M of HEAA at 45 °C**



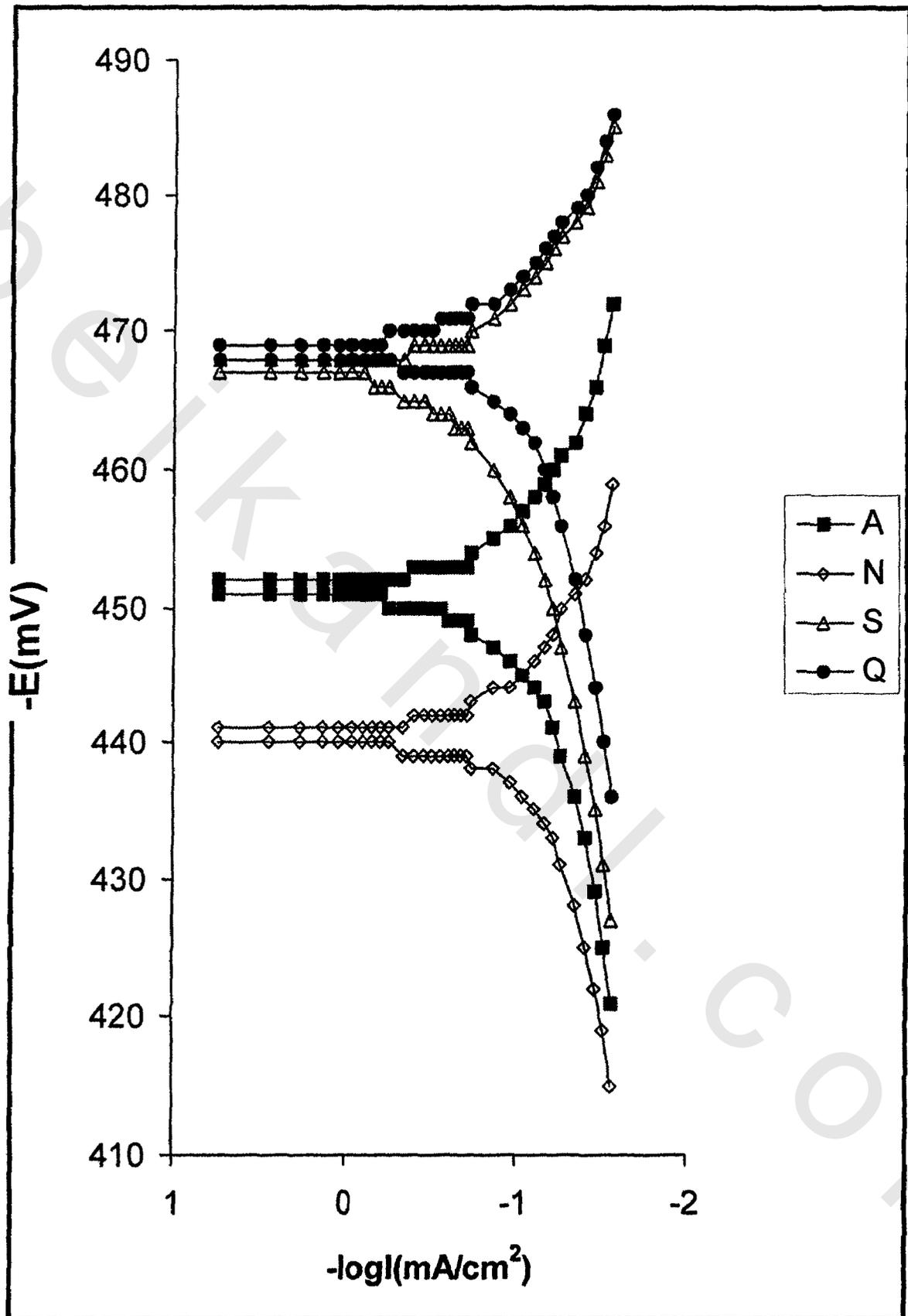
Fig(72): Tafel lines for M.C.V. steel samples in 0.1M HNO<sub>3</sub> at 55°C



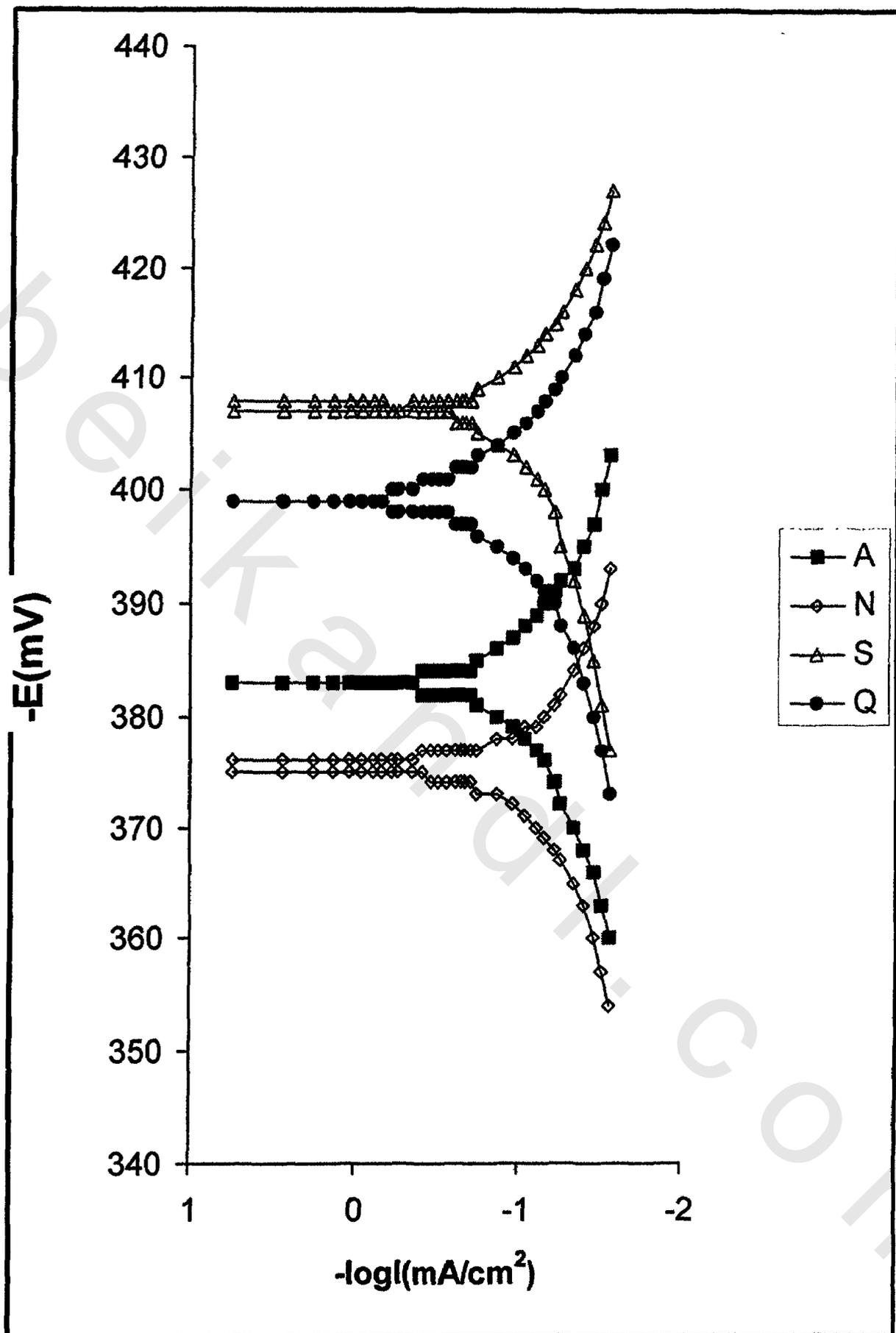
**Fig(73):**Tafel lines for M.C.V. steel samples in 0.3 M HNO<sub>3</sub> at 55°C



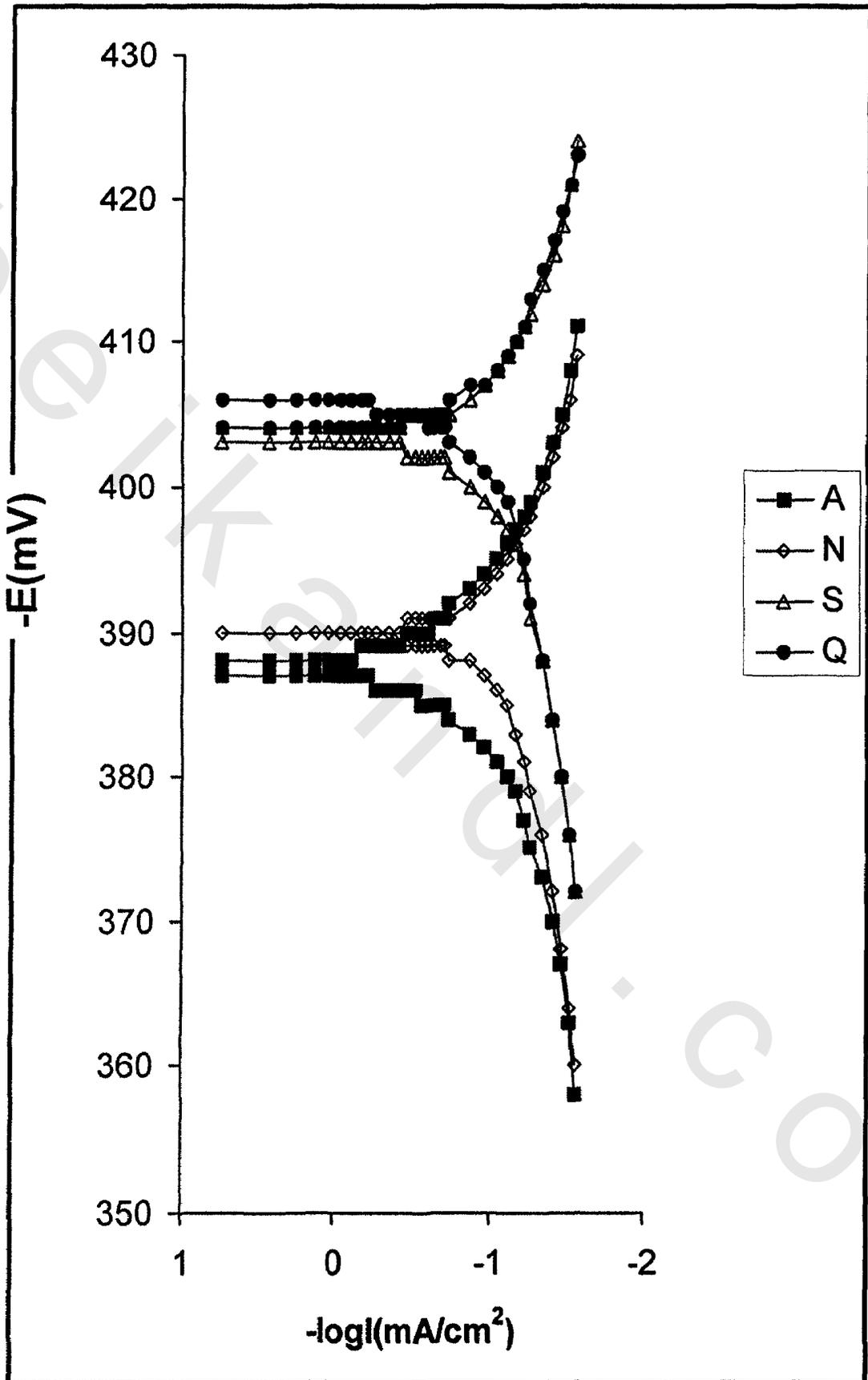
Fig(74): Tafel lines for M.C.V. steel samples in 0.5 M HNO<sub>3</sub> at 55°C



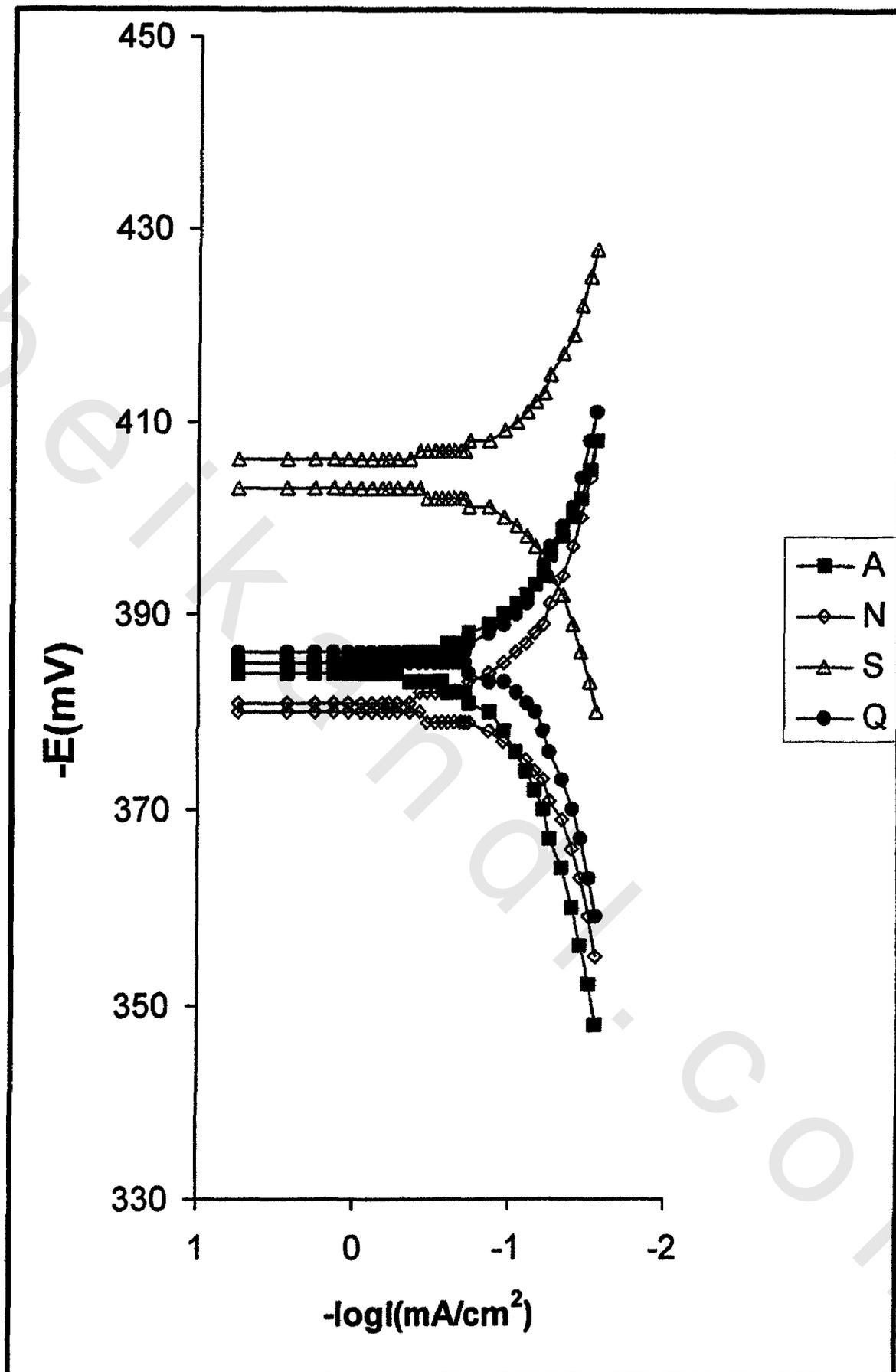
Fig(75): Tafel lines for M.C.V. steel samples in 0.1M HNO<sub>3</sub> and in presence of 2 x 10<sup>-5</sup> M of HEAA at 55 °C



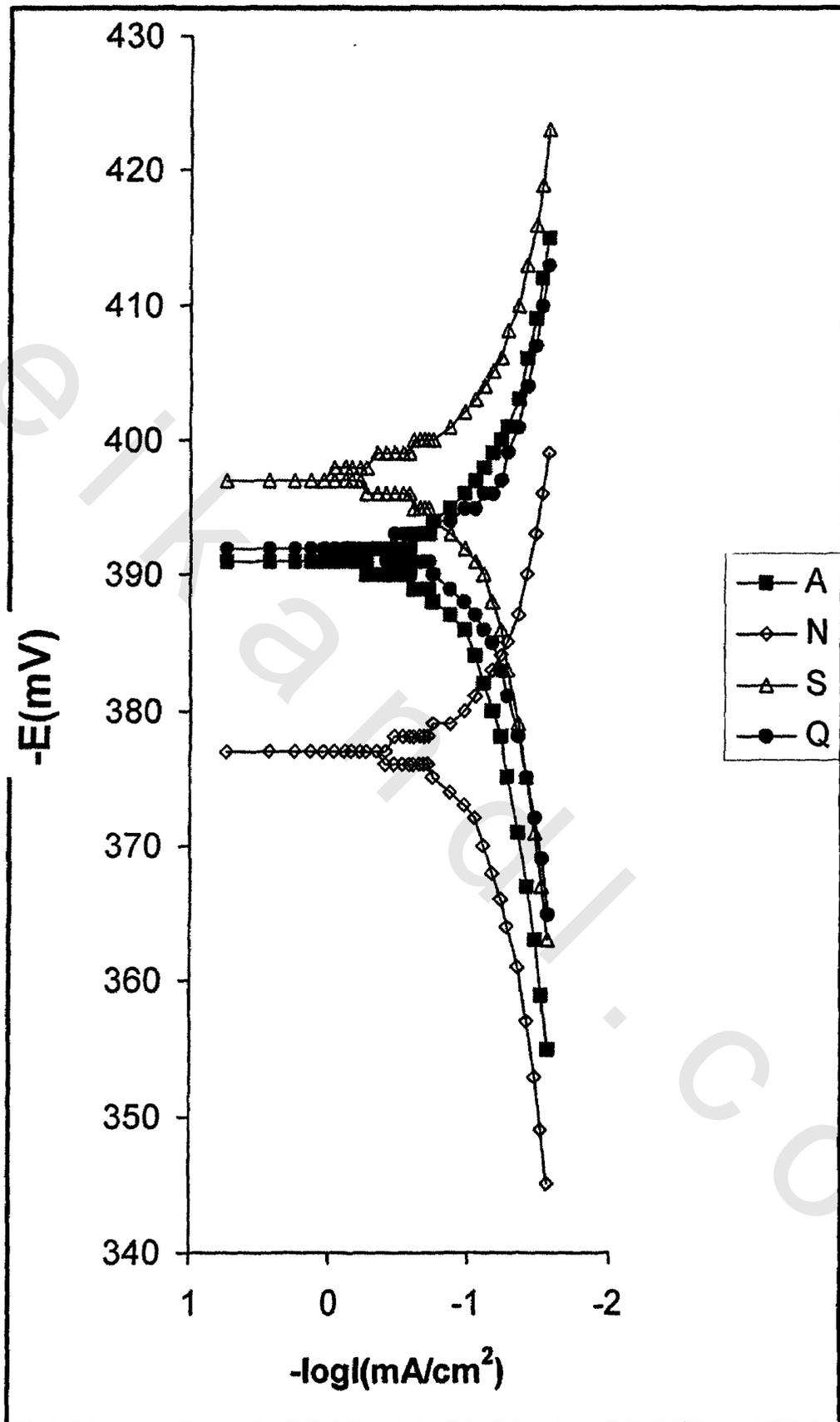
**Fig(76): Tafel lines for M.C.V. steel samples in 0.1M HNO<sub>3</sub> and in presence of 4 x 10<sup>-5</sup> M of HEAA at 55 °C**



**Fig(77): Tafel lines for M.C.V. steel samples in 0.1M HNO<sub>3</sub> and in presence of 6 x 10<sup>-5</sup> M of HEAA at 55 °C**



**Fig(78):**Tafel lines for M.C.V. steel samples in  $0.1\text{M HNO}_3$  and in presence of  $8 \times 10^{-5}\text{M}$  of HEAA at  $55^\circ\text{C}$



**Fig(79): Tafel lines for M.C.V. steel samples in 0.1M HNO<sub>3</sub> and in presence of 10<sup>-4</sup>M of HEAA at 55 °C**

## B) Calculations of corrosion resistance<sup>(6-13)</sup>

From Tafel lines for all samples under study, the corresponding  $E_{corr}$  can be determined.

Therefore,  $E_s$  can be determined from the following equation<sup>(6-13)</sup>:

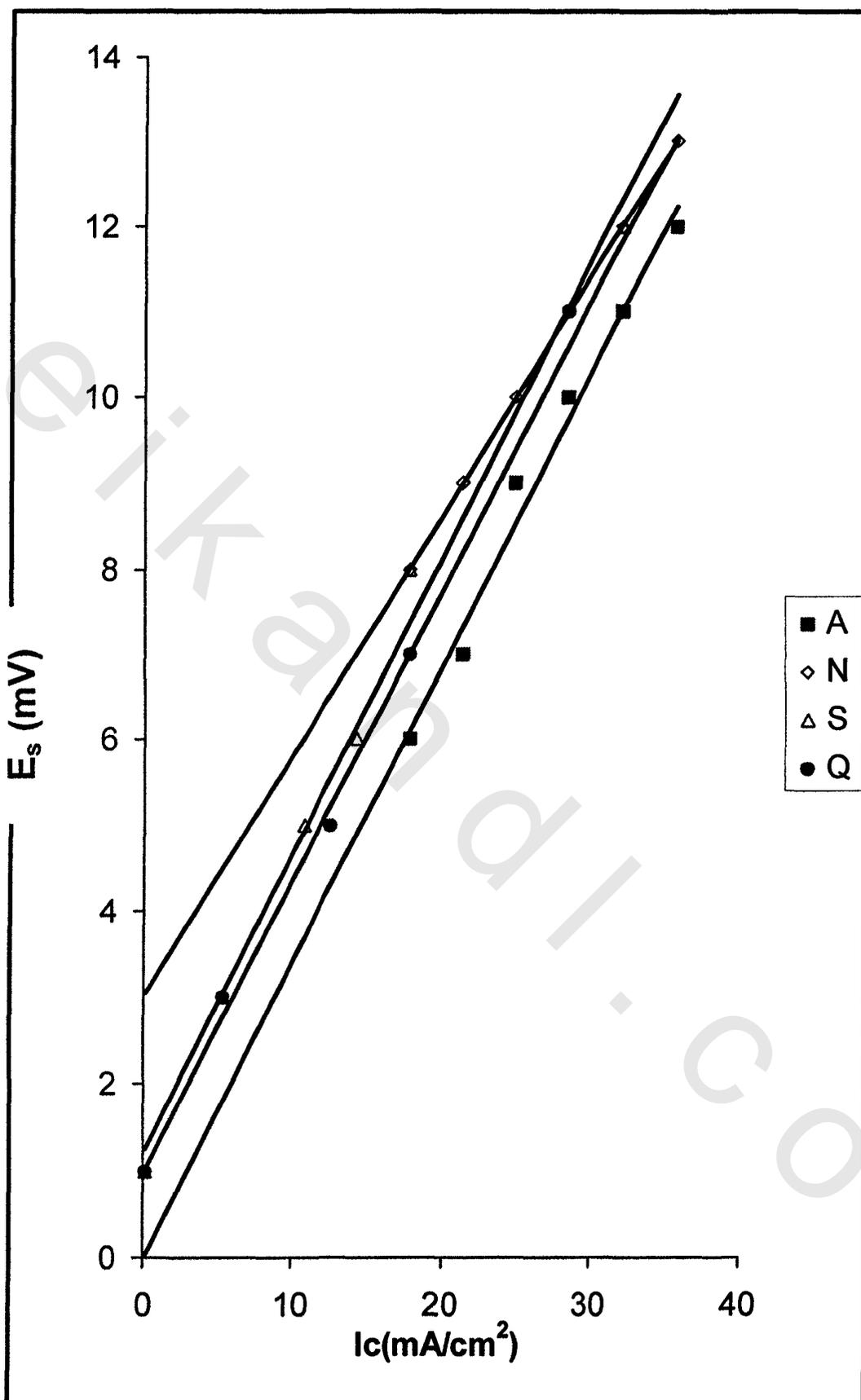
$$E_s = E - E_{corr} \quad (20)$$

Where  $E$  is the measured potential.

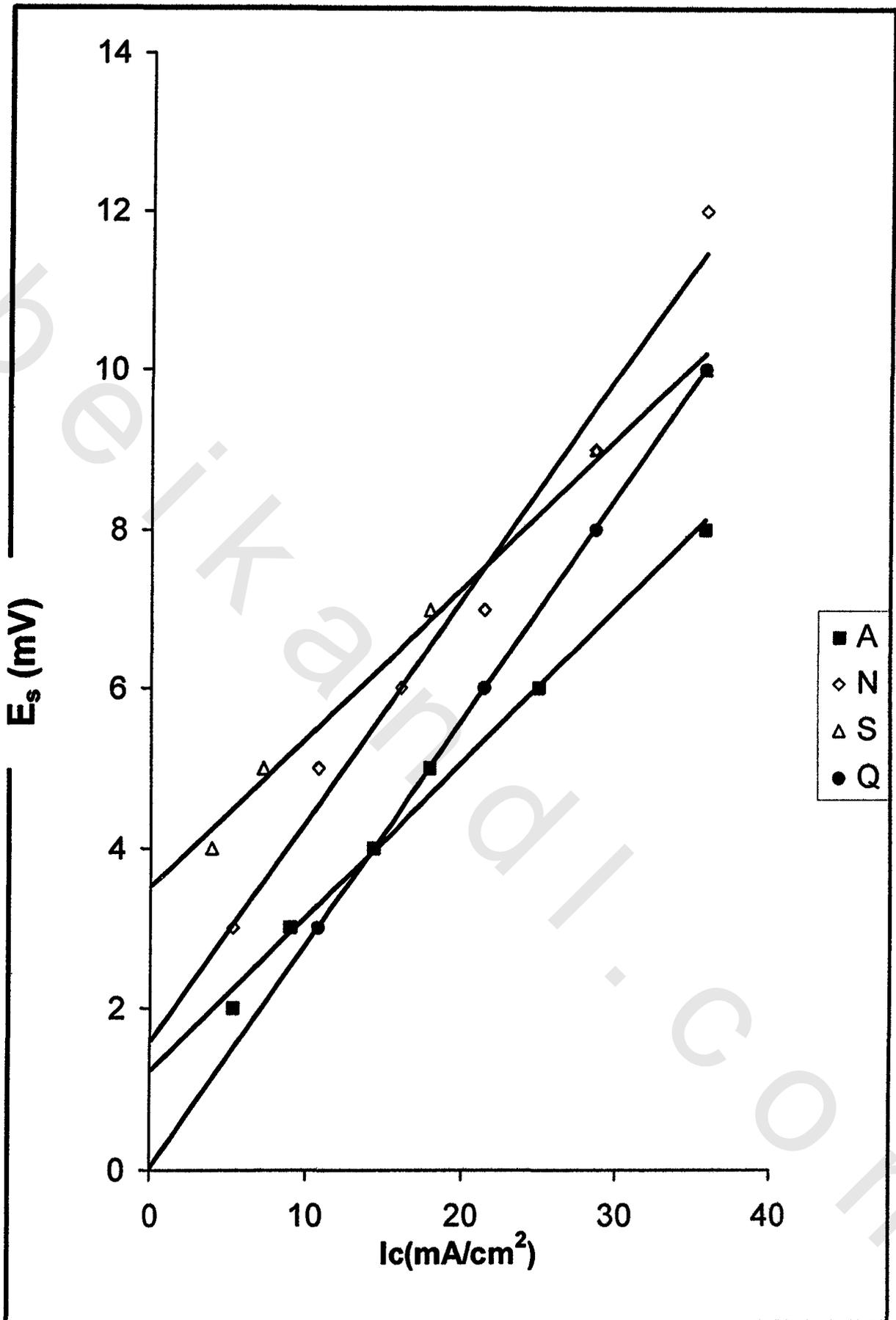
Then, plotting  $E_s$  against  $I_c$  (cathodic current density), which in straight line relationship, with slop equal corrosion resistance.

Figures(80-111) represent plotting  $E_s$  vs.  $I_c$  for L.C.V.steel samples in (0.1, 0.3, and 0.5 M)  $HNO_3$  acid and 0.1 M  $HNO_3$  in different concentrations of HEAA ( $2 \times 10^{-5}$ ,  $4 \times 10^{-5}$ ,  $6 \times 10^{-5}$ ,  $8 \times 10^{-5}$  and  $10^{-4}$ M) at 25, 35, 45 and 55°C respectively.

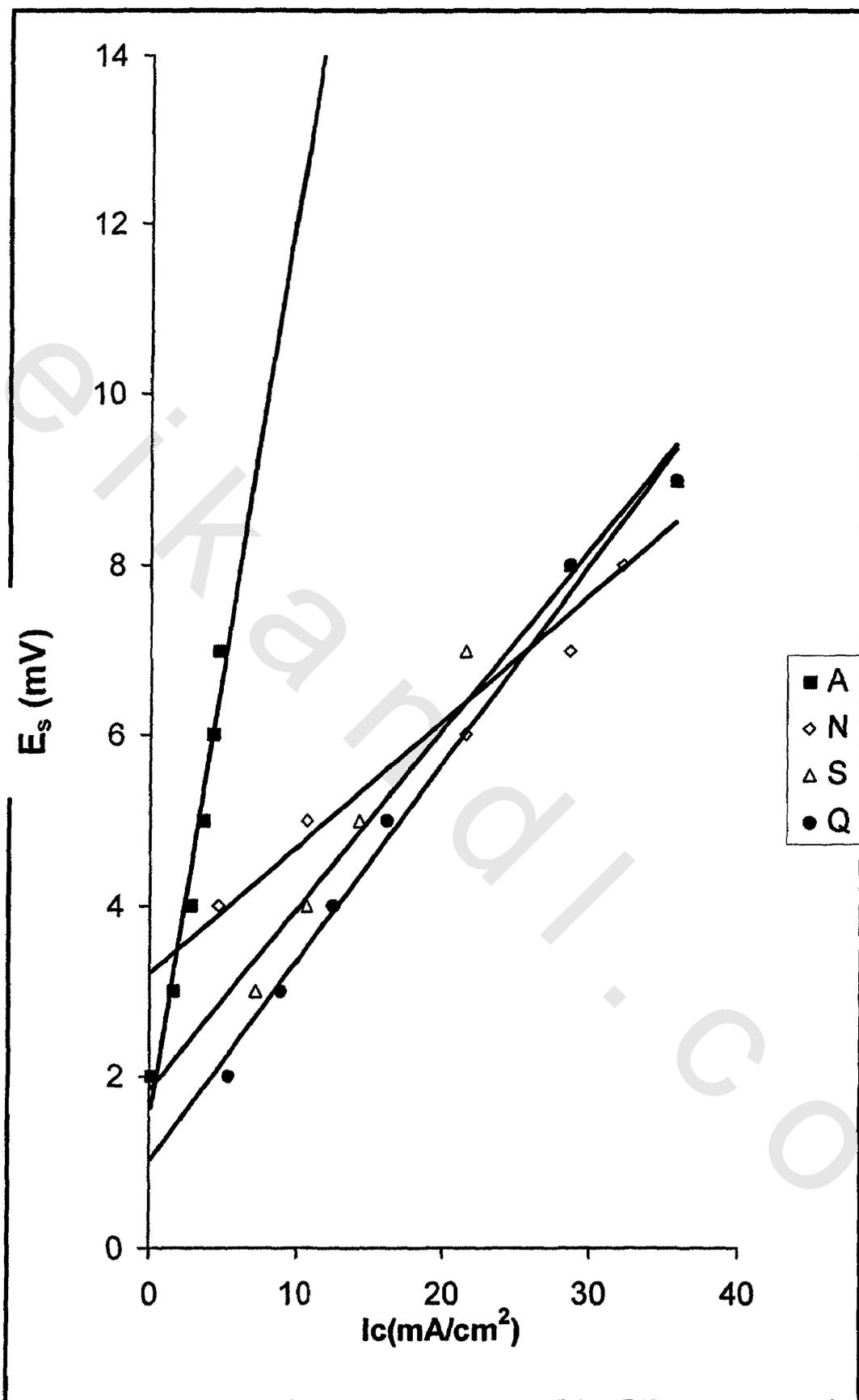
Figures(112-143) represent plotting  $E_s$  vs.  $I_c$  for M.C.V.steel samples in (0.1,0.3, and 0.5 M)  $HNO_3$  acid and 0.1 M  $HNO_3$  in different concentrations of HEAA ( $2 \times 10^{-5}$ ,  $4 \times 10^{-5}$ ,  $6 \times 10^{-5}$ ,  $8 \times 10^{-5}$  and  $10^{-4}$ M) at 25, 35, 45 and 55°C respectively.



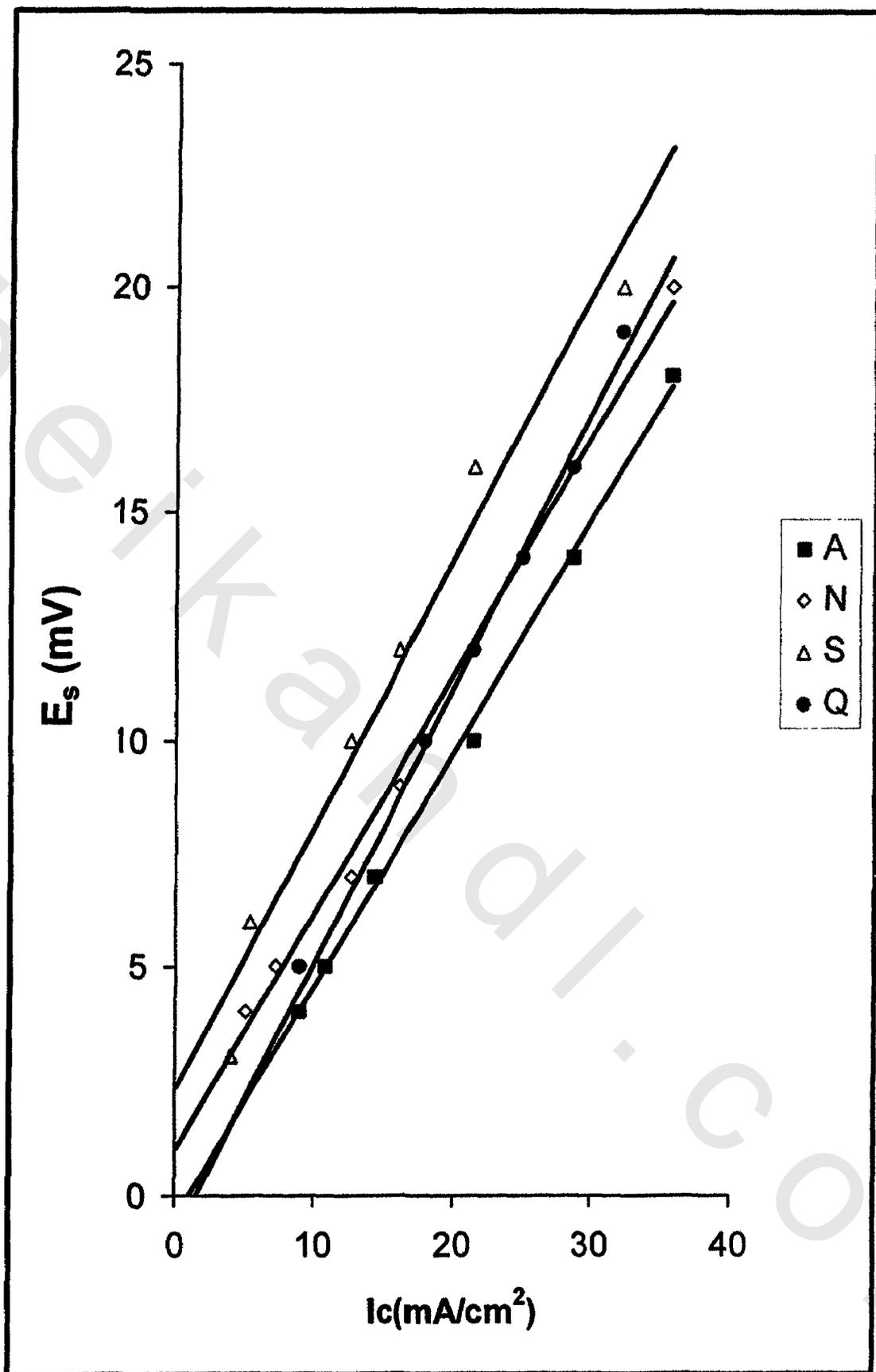
Fig(80):  $E_s$  values vs. cathodic current density ( $I_c$ ) for L.C.V steel samples in 0.1M HNO<sub>3</sub> at 25 °C



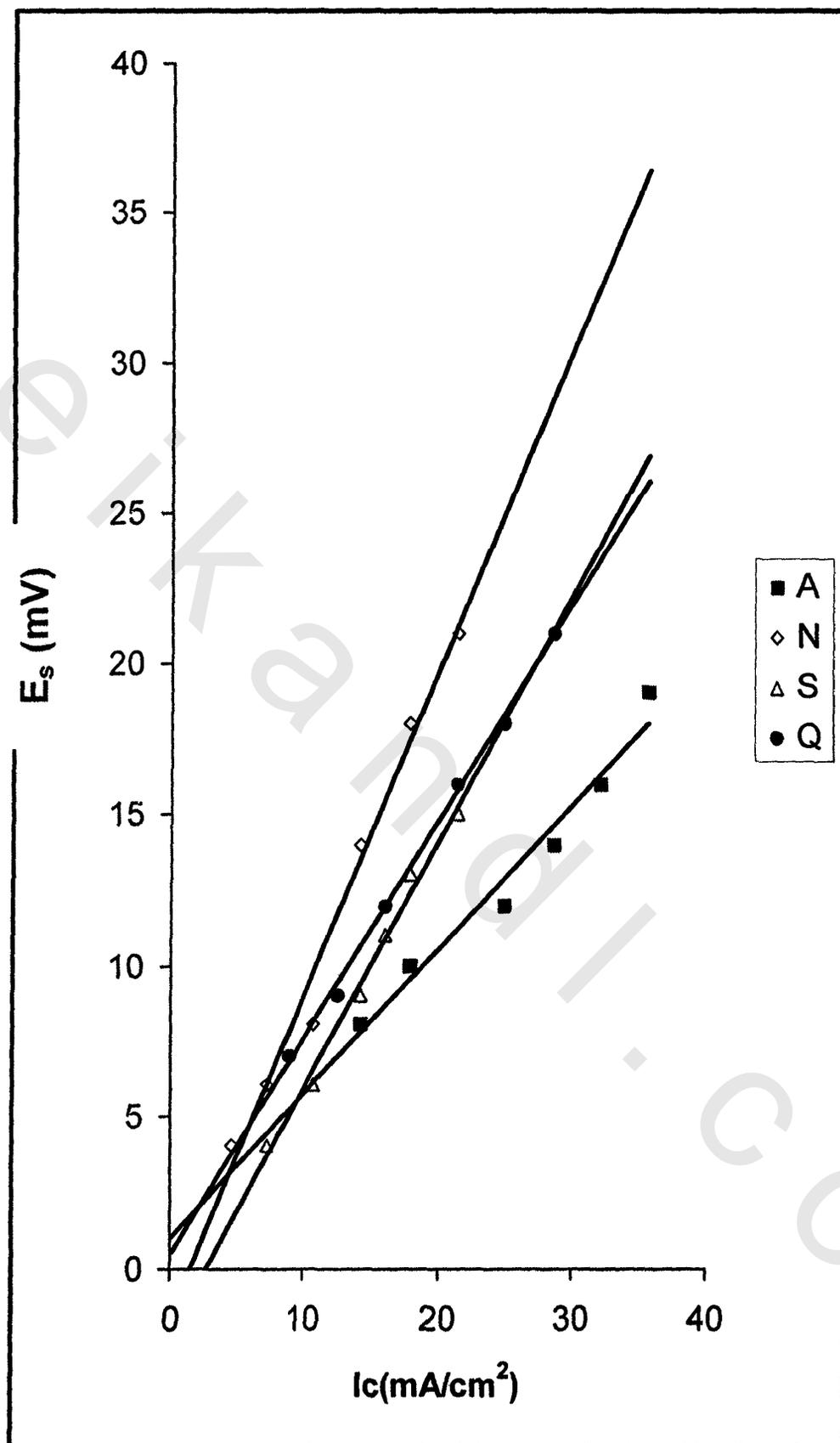
**Fig(81):  $E_s$  values vs. cathodic current density ( $I_c$ ) for L.C.V. steel samples in 0.3M HNO<sub>3</sub> at 25 °C**



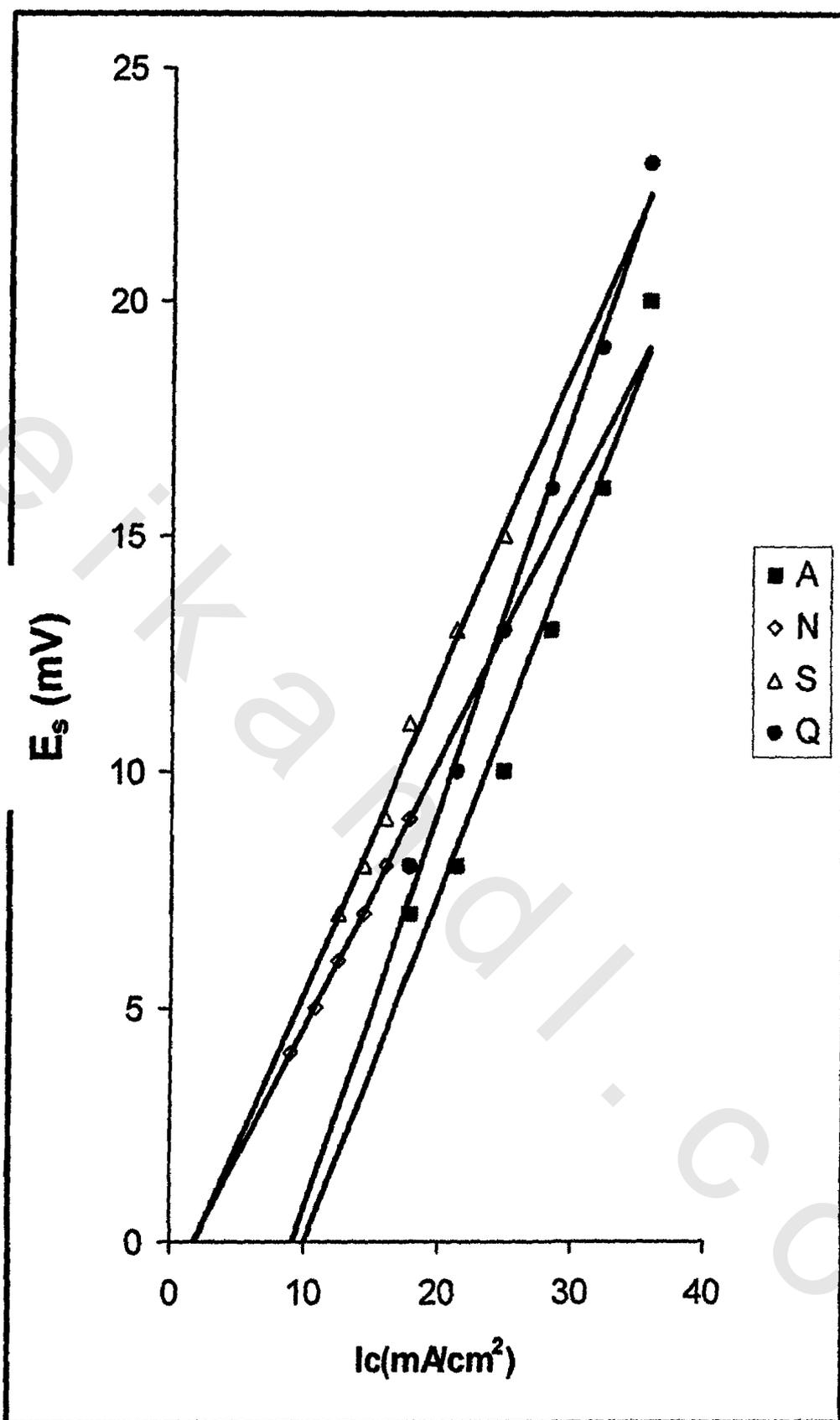
Fig(82):  $E_s$  values vs. cathodic current density ( $I_c$ ) for L.C.V steel samples in 0.5 M  $\text{HNO}_3$  at 25 °C



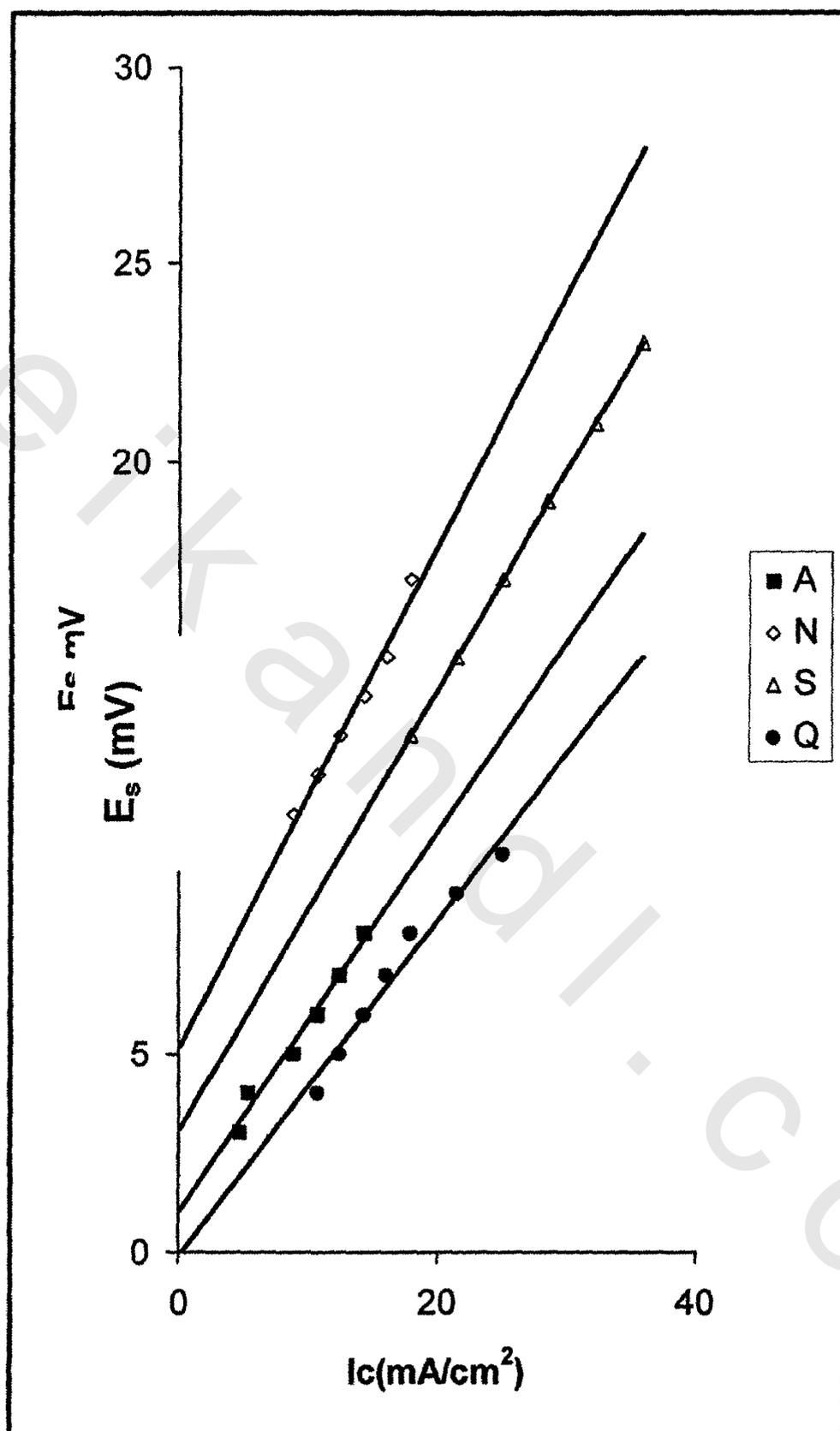
**Fig(83):  $E_s$  values vs. cathodic current density ( $I_c$ ) for L.C.V. steel samples in 0.1 M  $HNO_3$  at 25 °C in presence of  $2 \times 10^{-5}$  M HEAA**



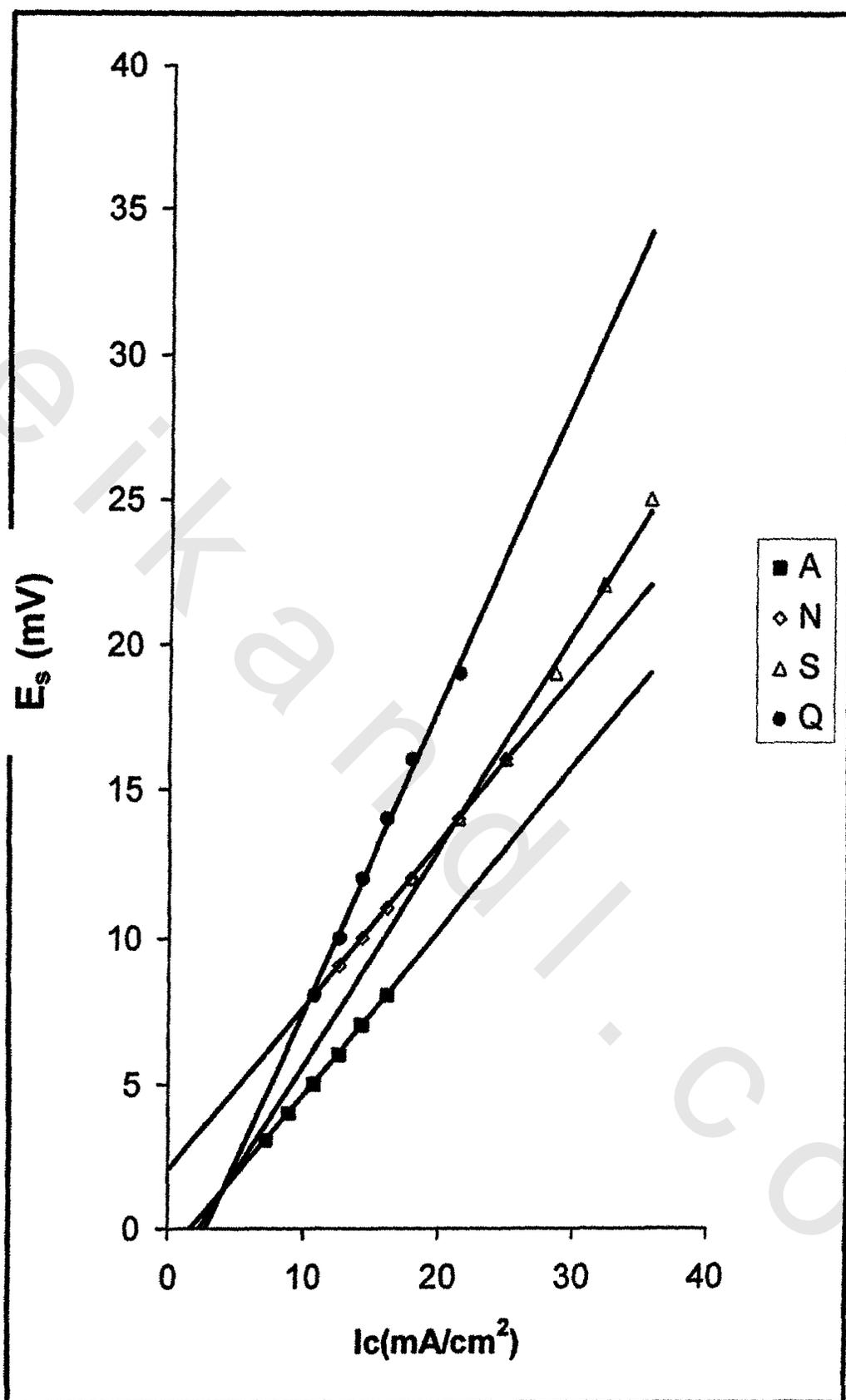
**Fig(84):  $E_s$  values vs. cathodic current density ( $I_c$ ) for L.C.V. steel samples in 0.1 M  $HNO_3$  at 25 °C in presence of  $4 \times 10^{-5}$  M HEAA**



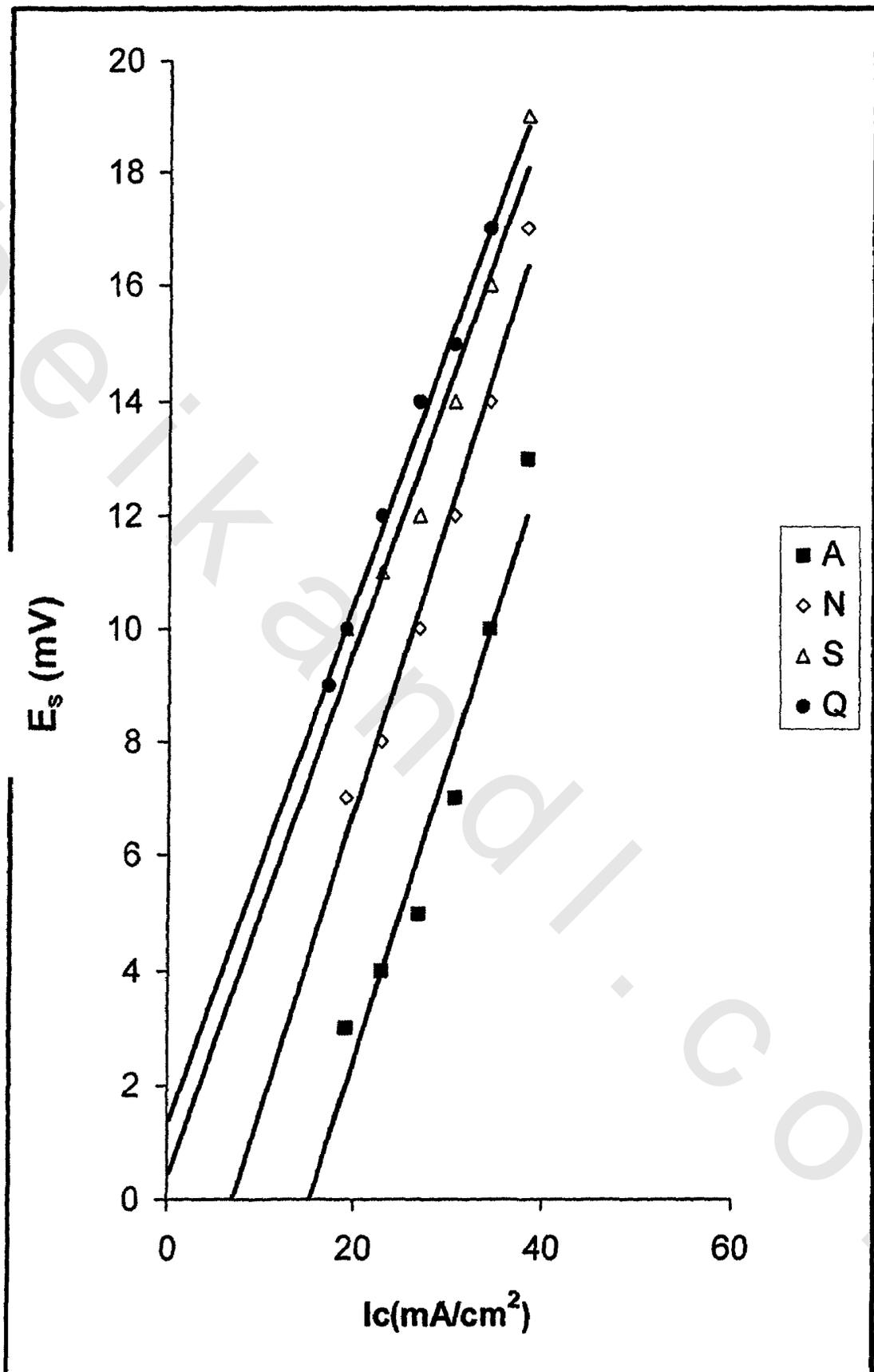
**Fig(85):  $E_s$  values vs. cathodic current density ( $I_c$ ) for L.C.V. steel samples in 0.1 M  $HNO_3$  at 25 °C in presence of  $6 \times 10^{-5}$  M HEAA**



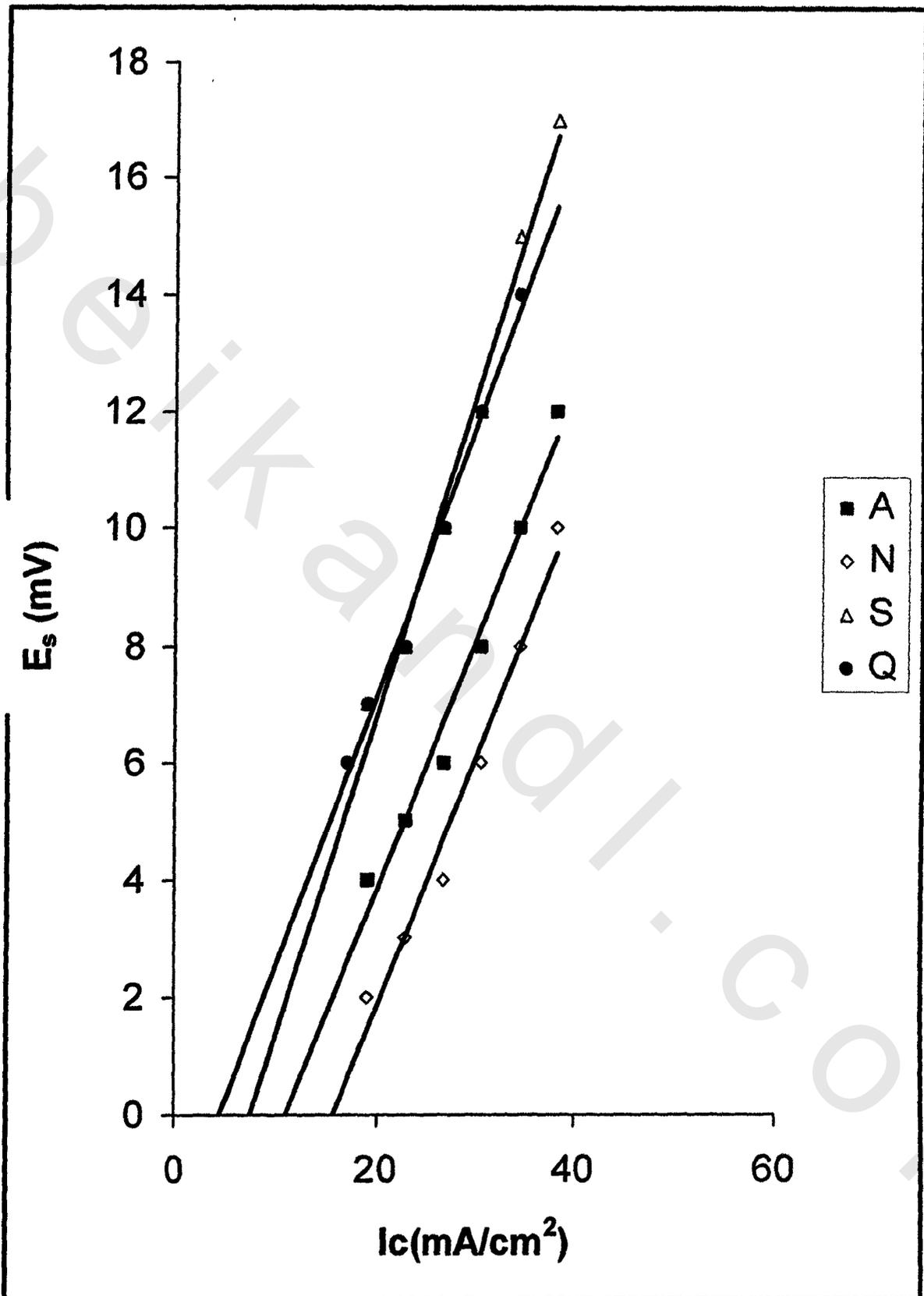
**Fig(86):  $E_s$  values vs. cathodic current density ( $I_c$ ) for L.C.V. steel samples in 0.1 M  $\text{HNO}_3$  at 25 °C in presence of  $8 \times 10^{-5}$  M HEAA**



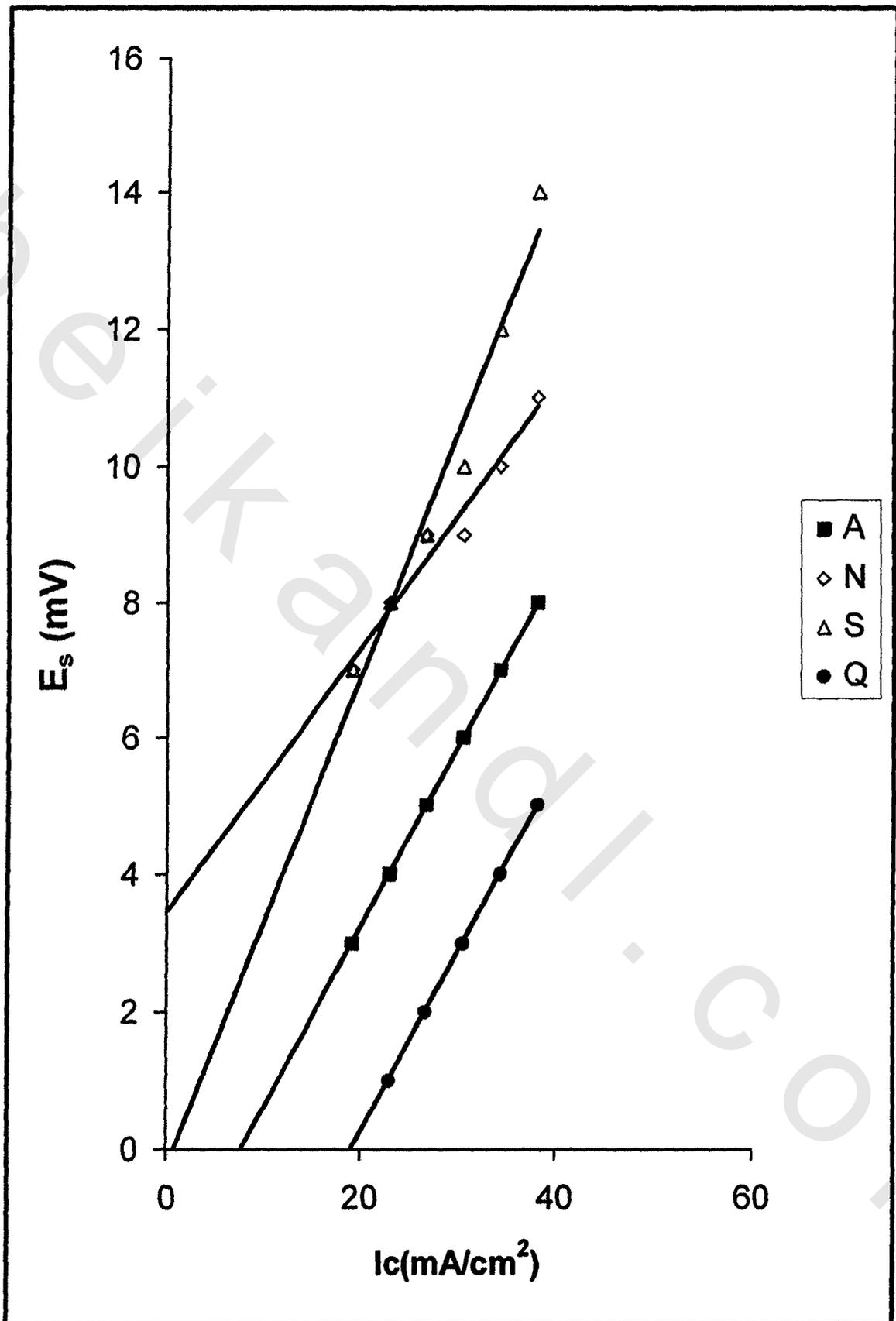
**Fig(87):  $E_s$  values vs. cathodic current density ( $I_c$ ) for L.C.V. steel samples in 0.1 M  $\text{HNO}_3$  at 25 °C in presence of  $10^{-4}$  M HEAA**



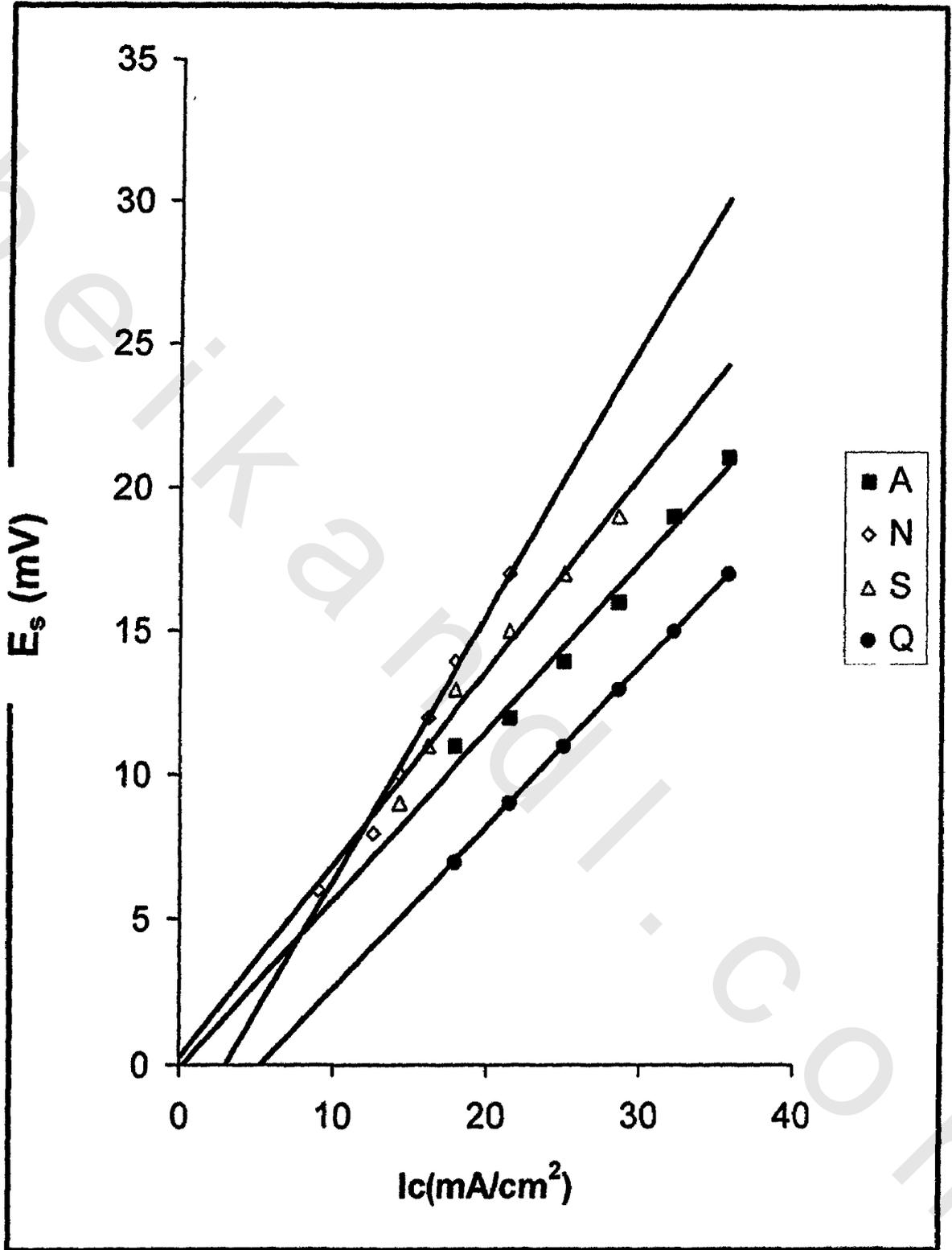
**Fig(88):  $E_s$  values vs. cathodic current density ( $I_c$ ) for L.C.V steel samples in 0.1M HNO<sub>3</sub> at 35 °C**



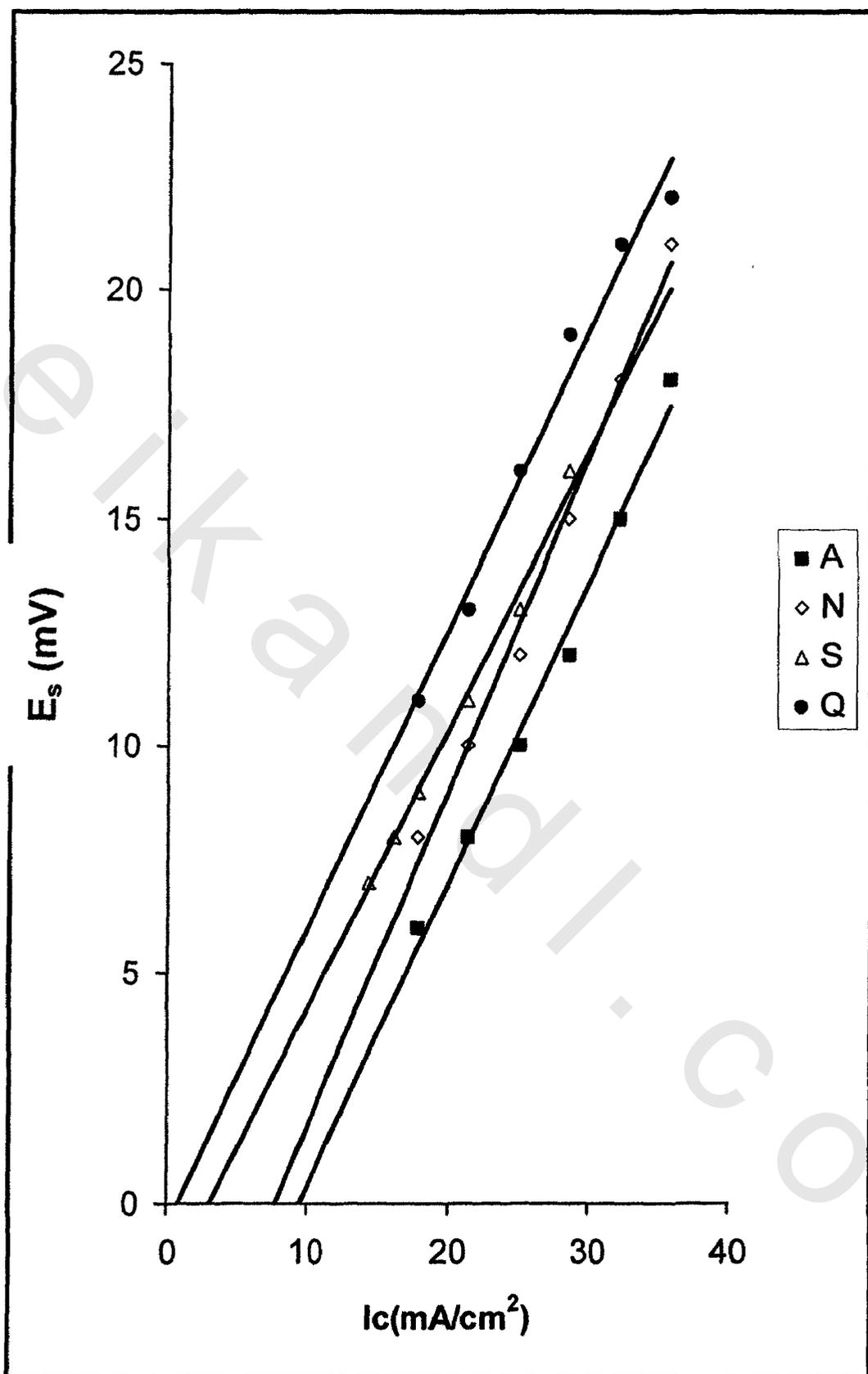
**Fig(89):  $E_s$  values vs. cathodic current density ( $I_c$ ) for L.C.V. steel samples in 0.3 M HNO<sub>3</sub> at 35 °C**



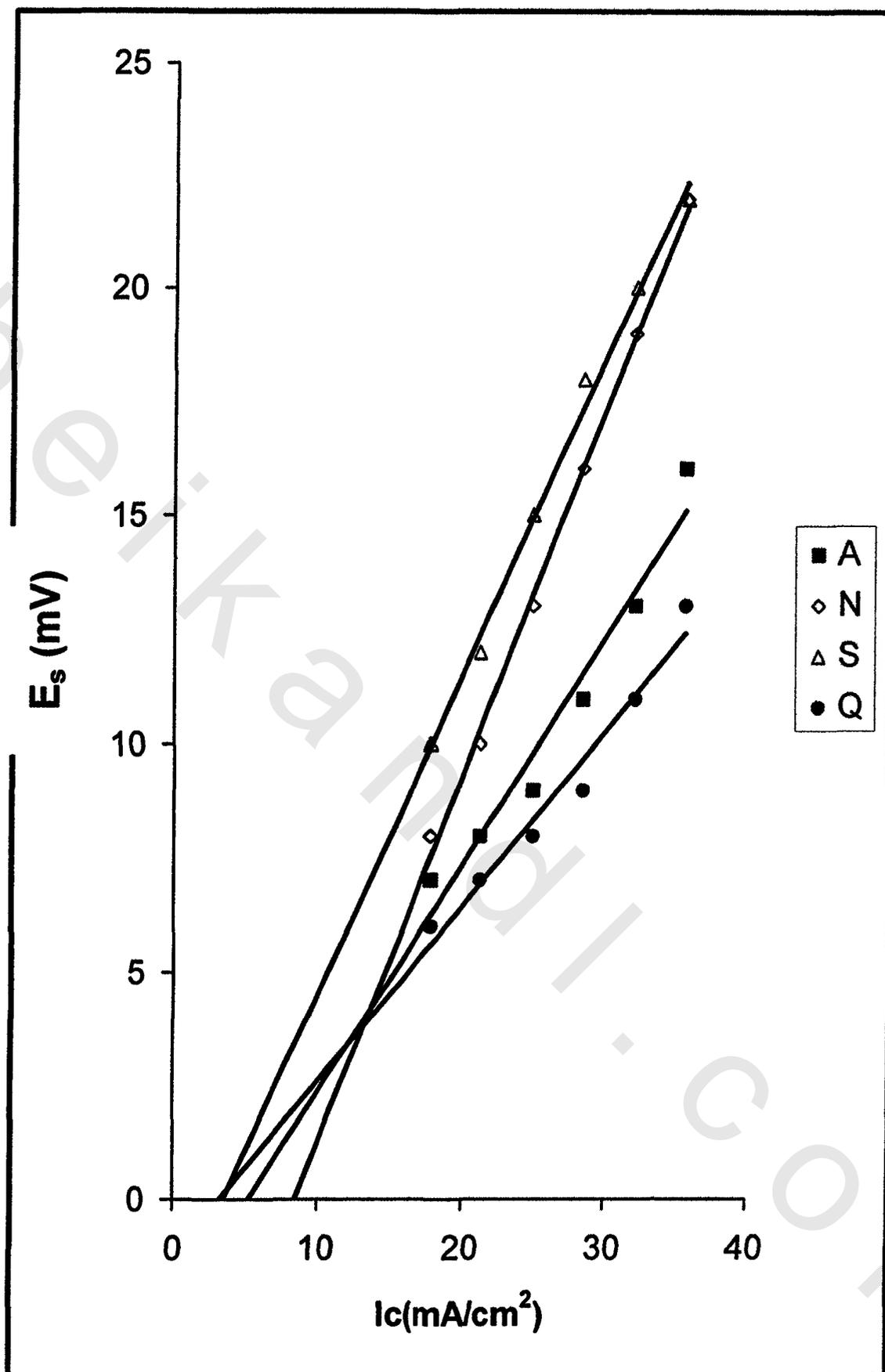
Fig(90):  $E_s$  values vs. cathodic current density ( $I_c$ ) for L.C.V steel samples in 0.5 M  $HNO_3$  at 35 °C



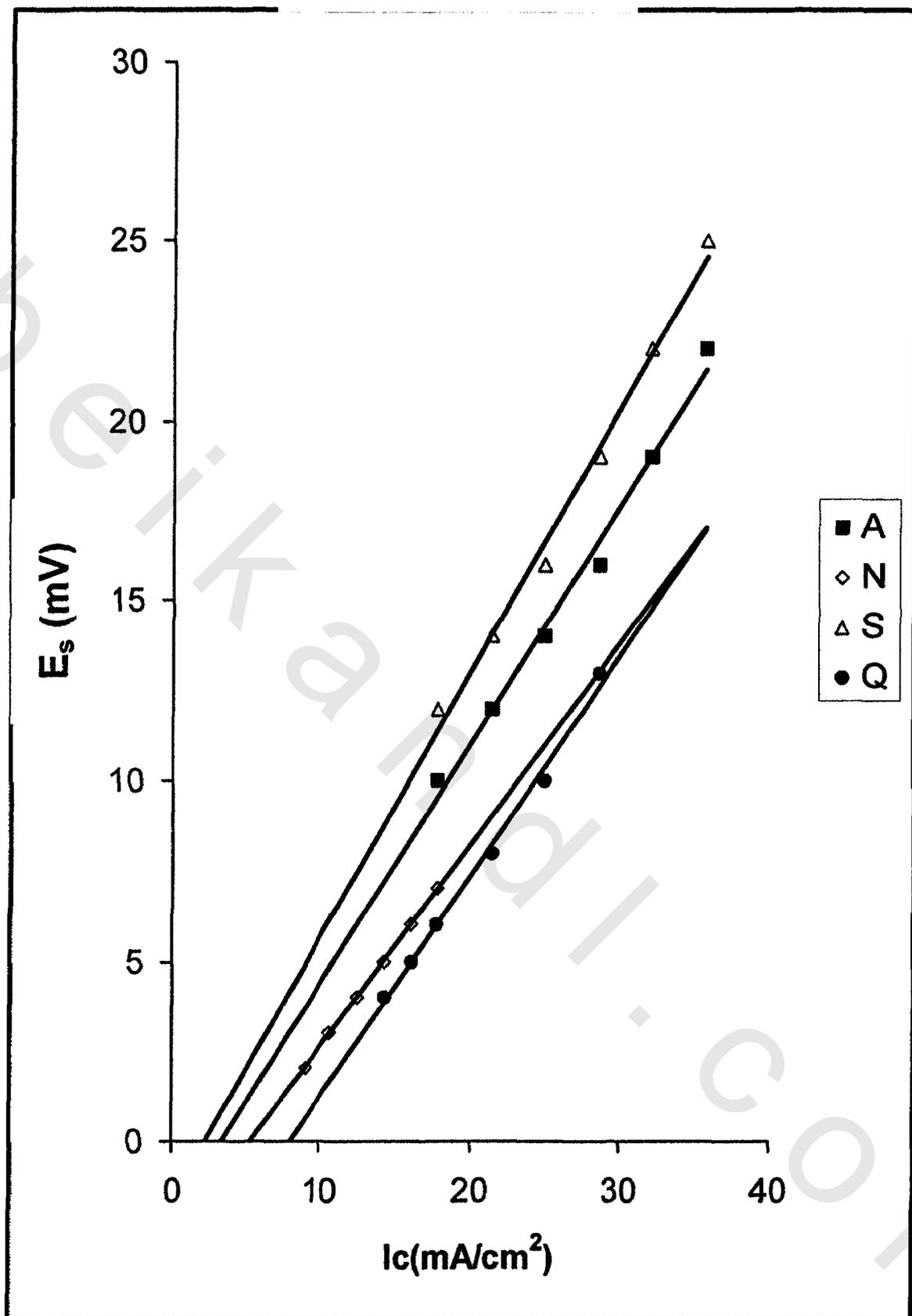
**Fig(91):  $E_s$  values vs. cathodic current density ( $I_c$ ) for L.C.V. steel samples in 0.1M  $HNO_3$  at 35 °C in presence of  $2 \times 10^{-5}M$  HEAA**



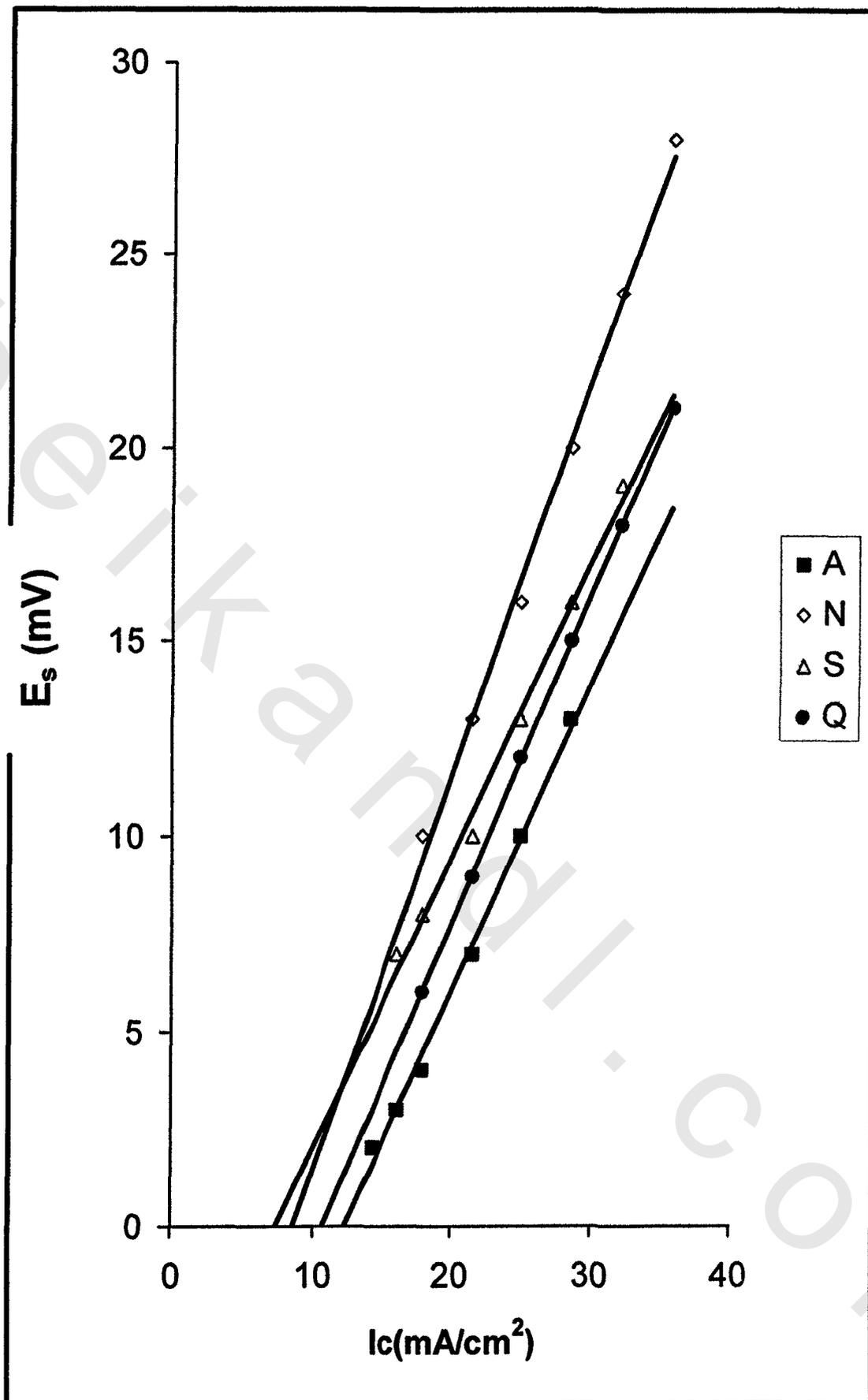
**Fig(92):  $E_s$  values vs. cathodic current density ( $I_c$ ) for L.C.V. steel samples in 0.1M HNO<sub>3</sub> at 35 °C in presence of  $4 \times 10^{-5}$ M HEAA**



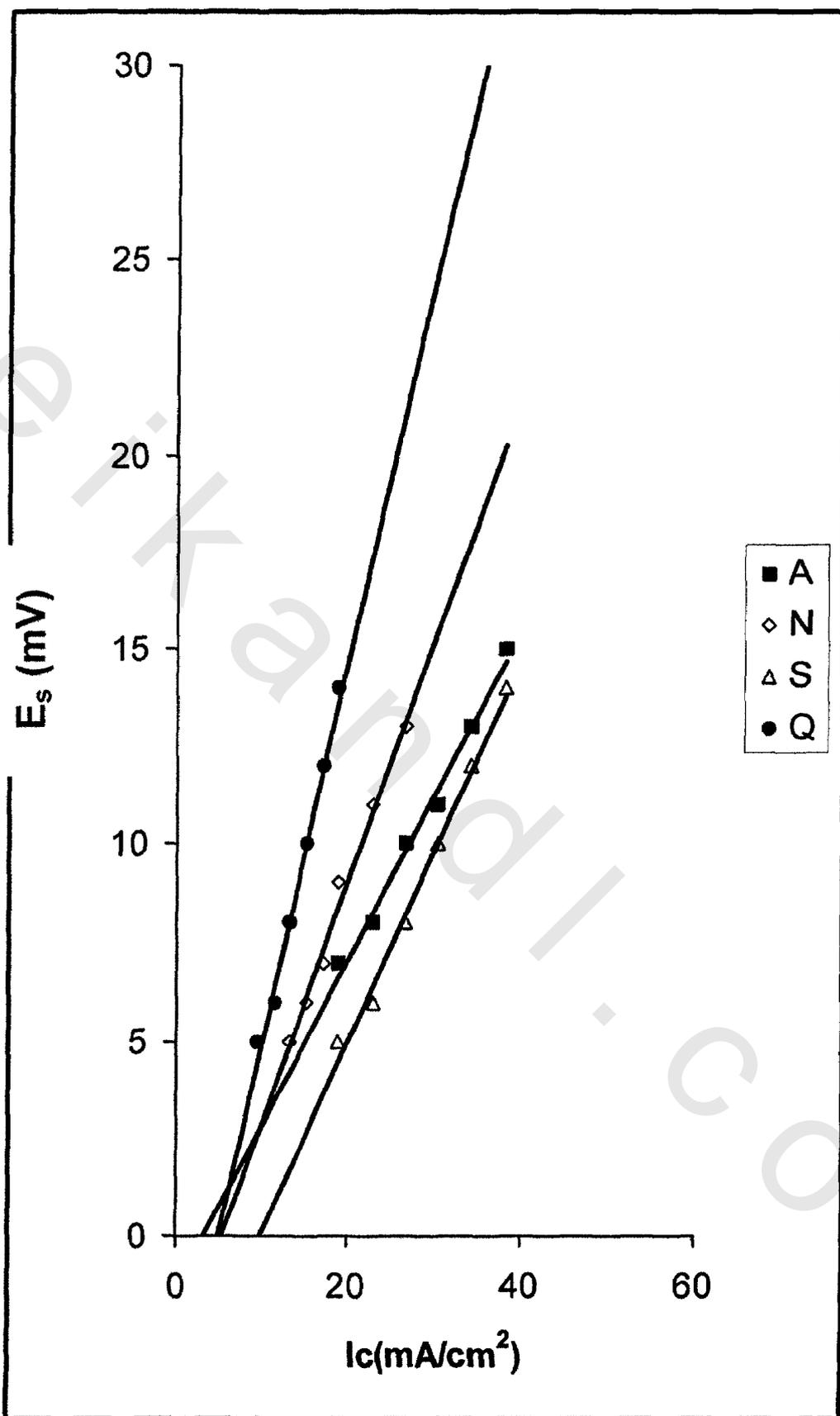
**Fig(93):  $E_s$  values vs. cathodic current density ( $I_c$ ) for L.C.V. steel samples in 0.1M HNO<sub>3</sub> at 35 °C in presence of  $6 \times 10^{-5}$  M HEAA**



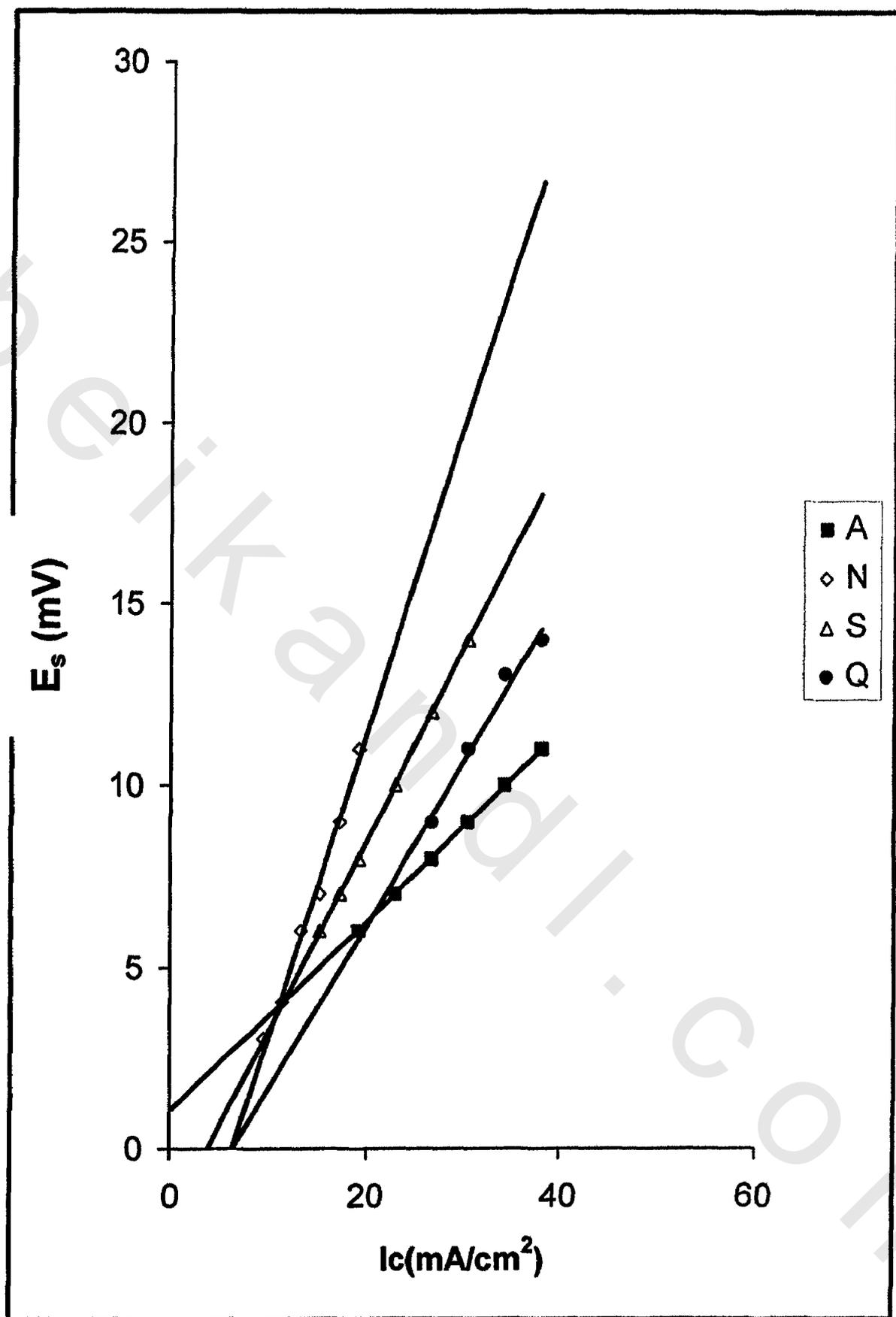
**Fig(94):  $E_s$  values vs. cathodic current density ( $I_c$ ) for L.C.V. steel samples in 0.1M  $HNO_3$  at 35 °C in presence of  $8 \times 10^{-5}M$  HEAA**



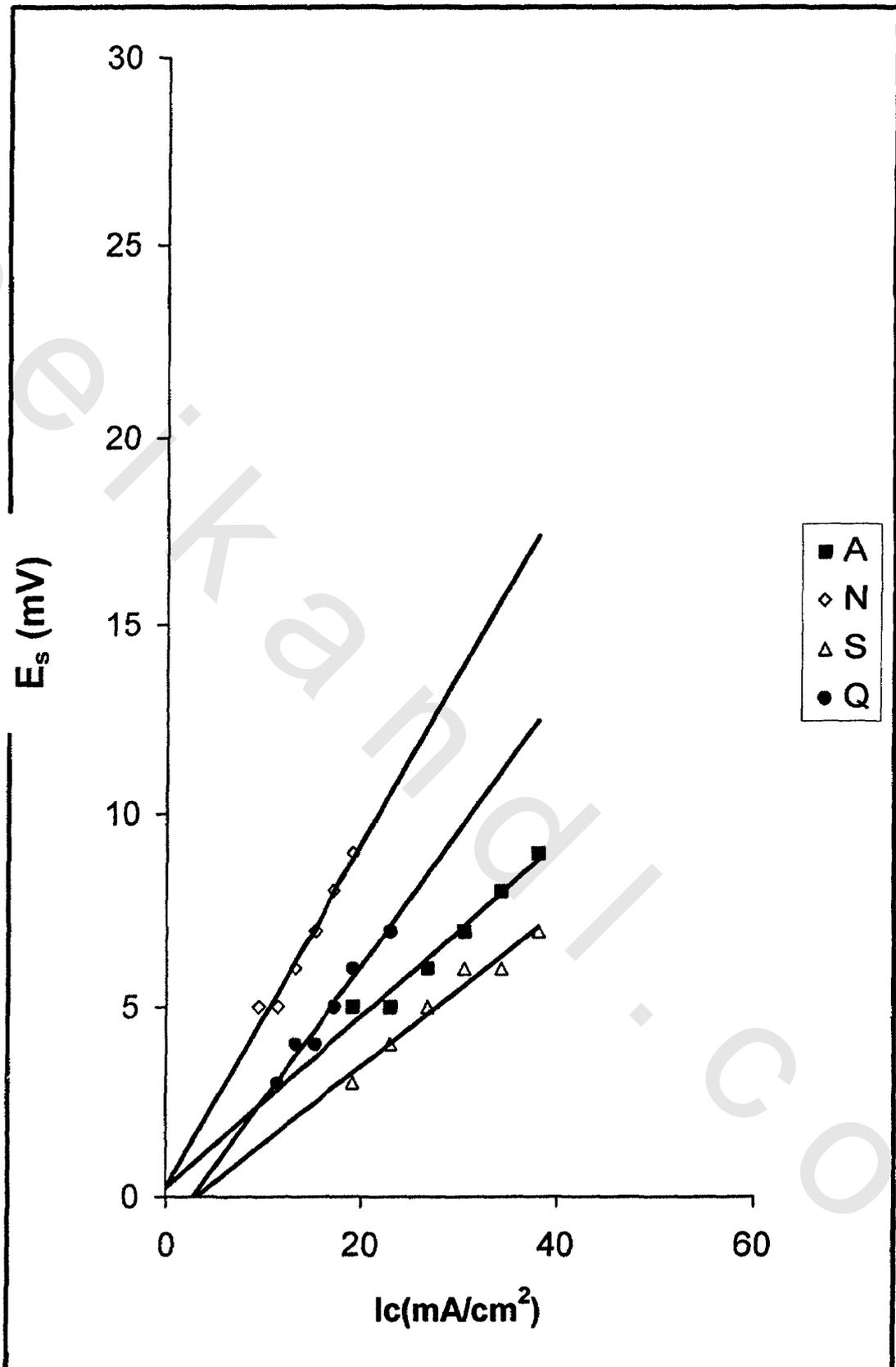
**Fig(95):  $E_s$  values vs. cathodic current density ( $I_c$ ) for L.C.V. steel samples in 0.1M  $HNO_3$  at 35 °C in presence of  $10^{-4}$ M HEAA**



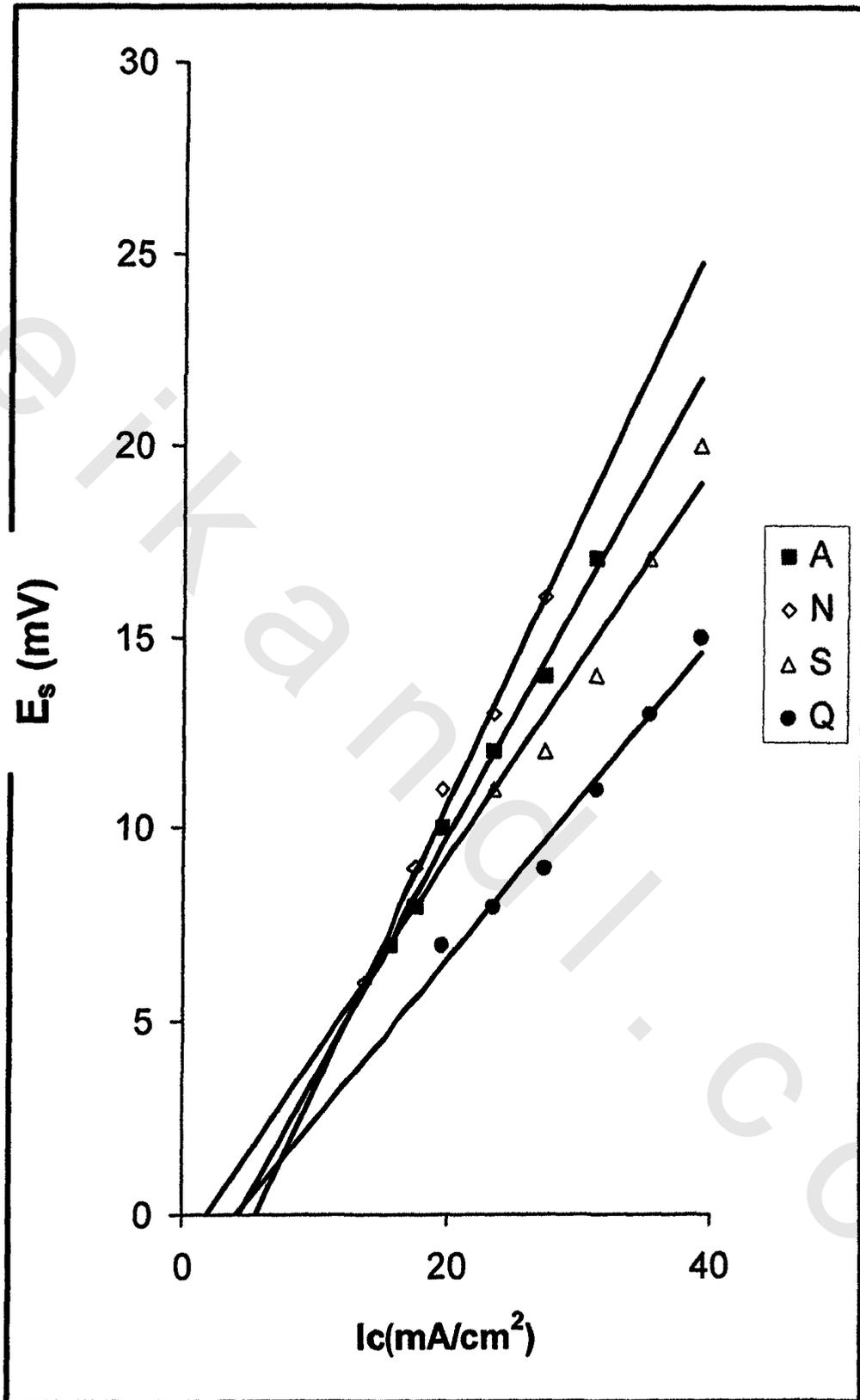
**Fig(96):  $E_s$  values vs. cathodic current density ( $I_c$ ) for L.C.V steel samples in 0.1M HNO<sub>3</sub> at 45 °C**



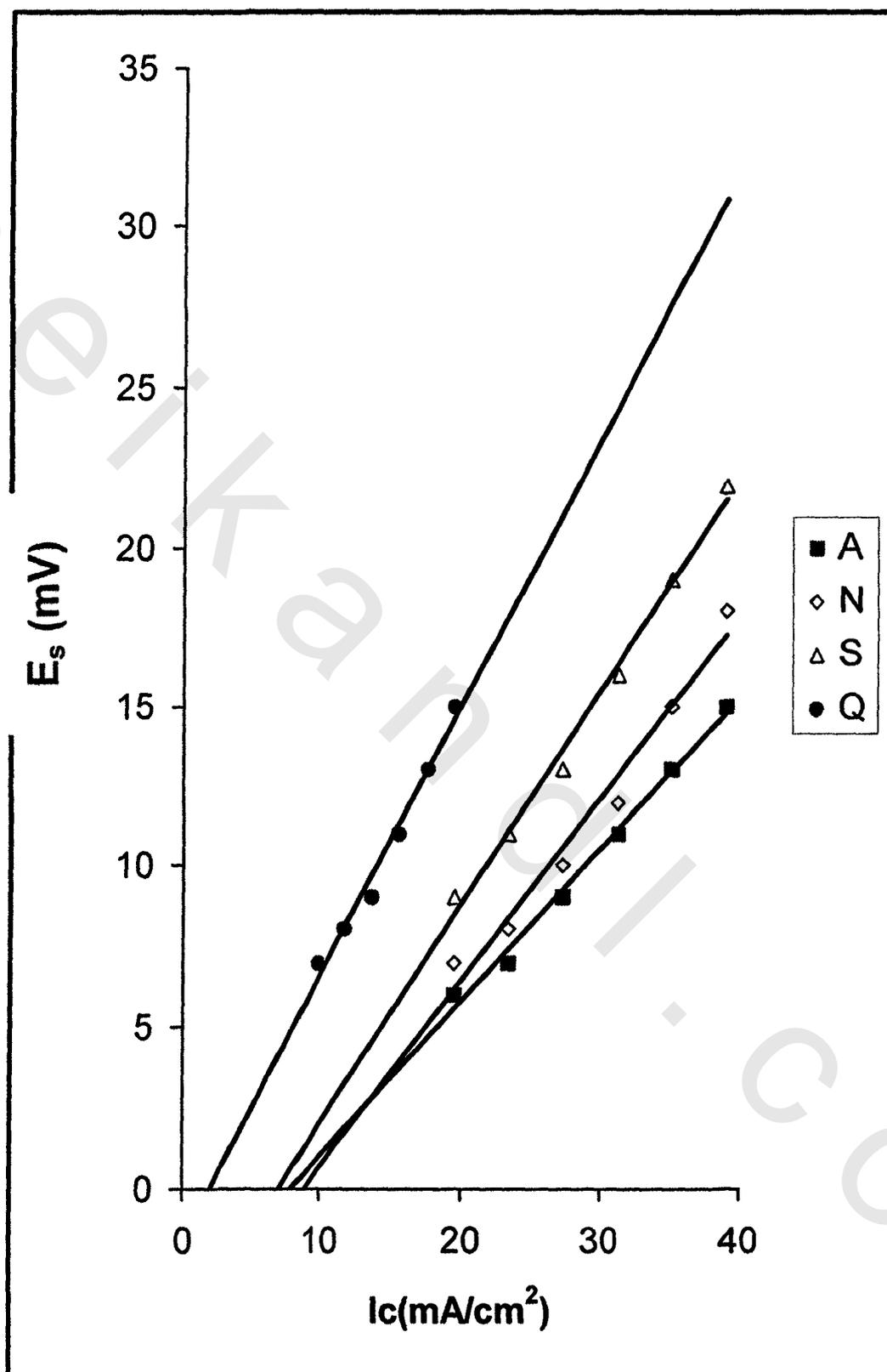
**Fig(97):  $E_s$  values vs. cathodic current density ( $I_c$ ) for L.C.V steel samples in 0.3 M  $\text{HNO}_3$  at 45 °C**



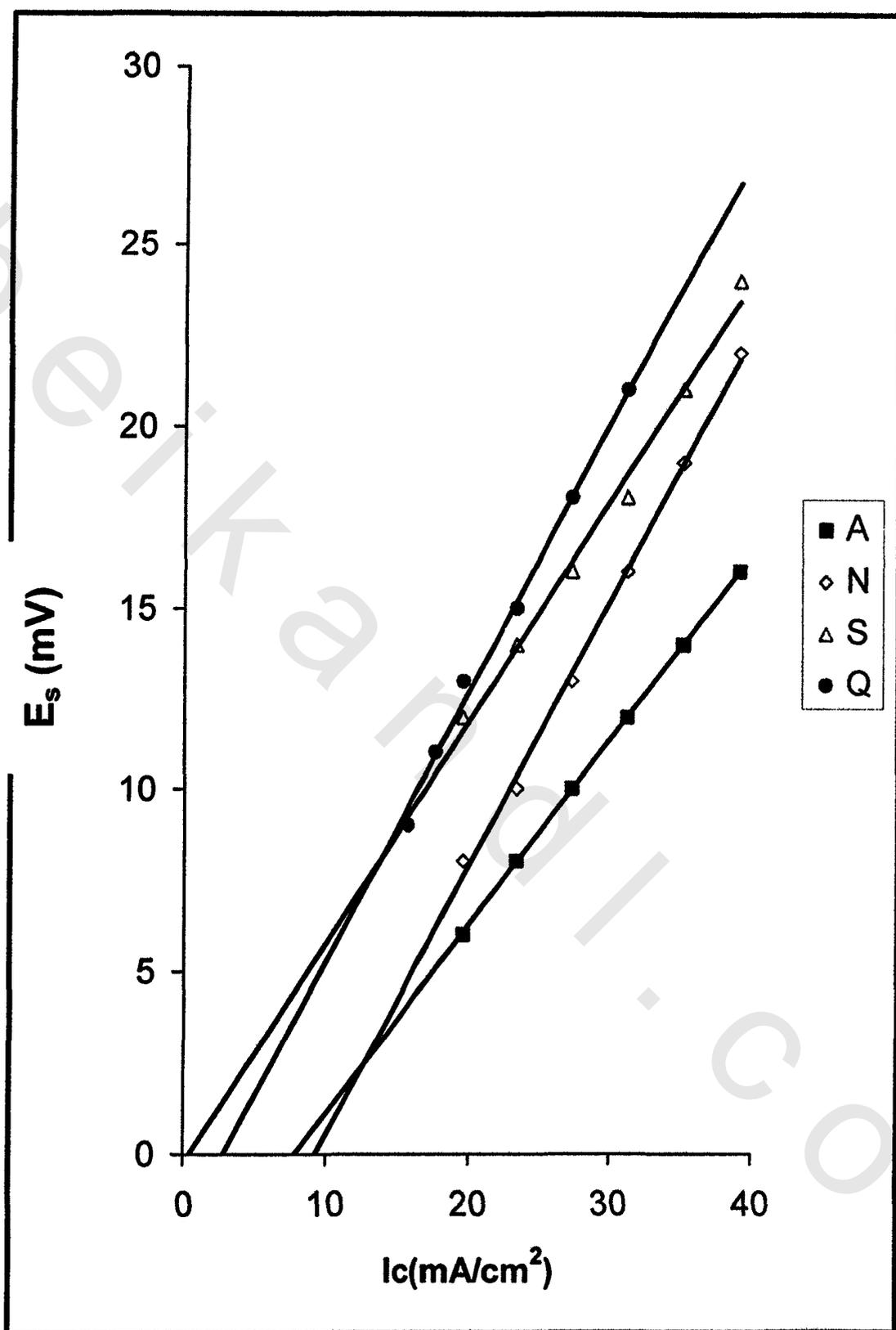
Fig(98):  $E_s$  values vs. cathodic current density ( $I_c$ ) for L.C.V steel samples in 0.5 M  $\text{HNO}_3$  at 45 °C



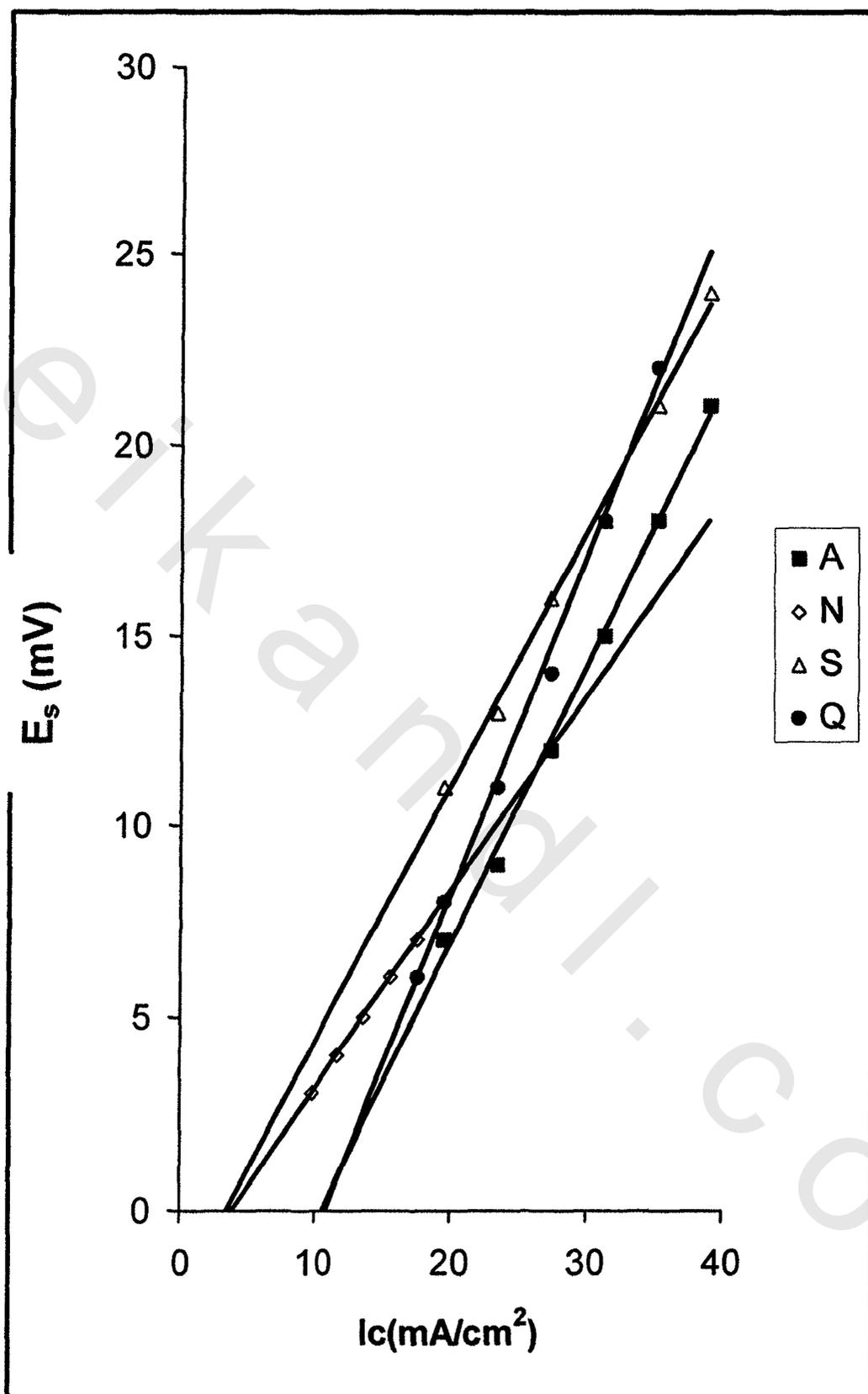
**Fig(99):  $E_s$  values vs. cathodic current density ( $I_c$ ) for L.C.V steel samples in 0.1M HNO<sub>3</sub> at 45 °C in presence of  $2 \times 10^{-5}$ M HEAA**



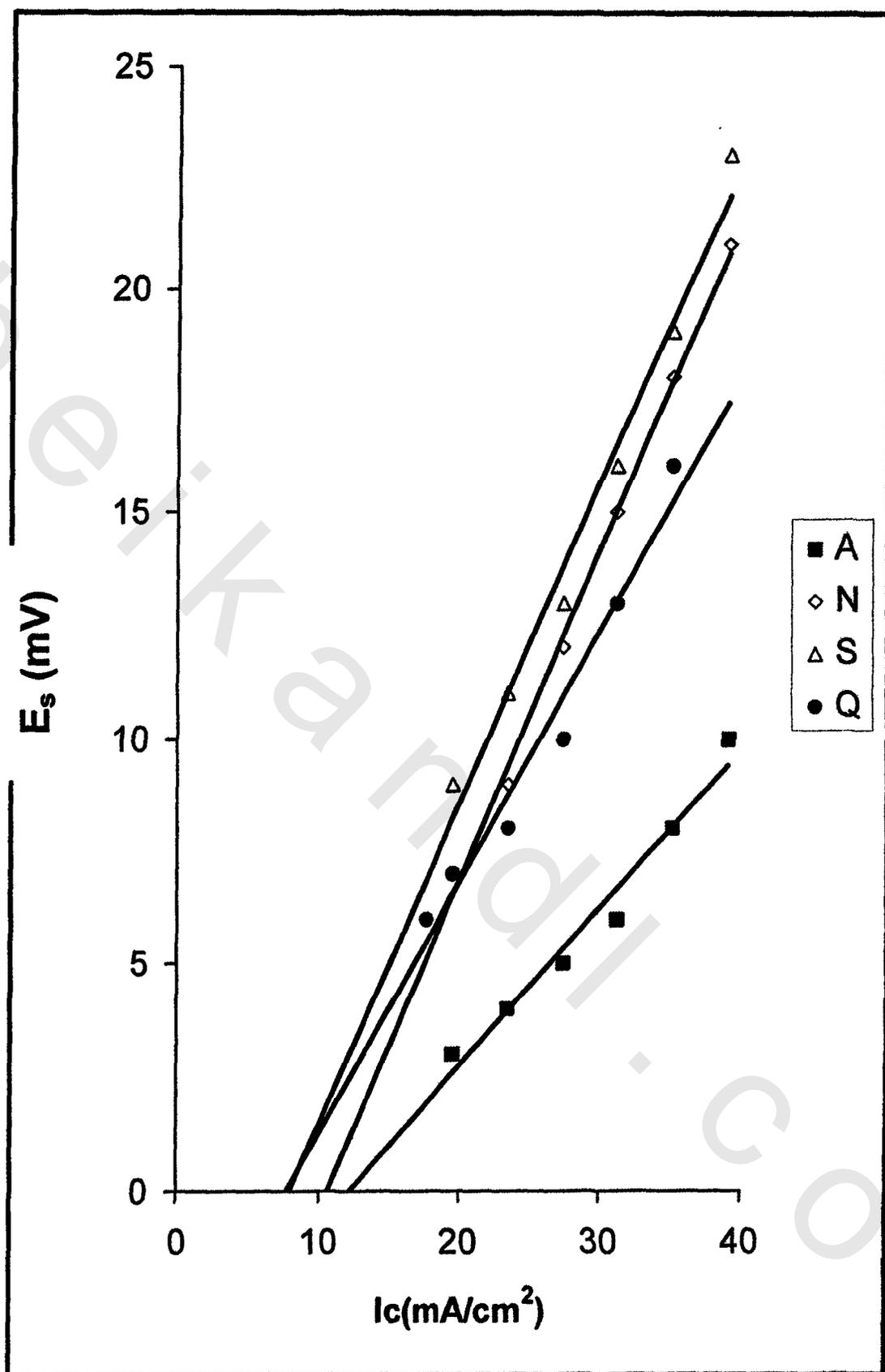
**Fig(100):  $E_s$  values vs. cathodic current density ( $I_c$ ) for L.C.V steel samples in 0.1M  $\text{HNO}_3$  at 45 °C in presence of  $4 \times 10^{-5}$  M HEAA**



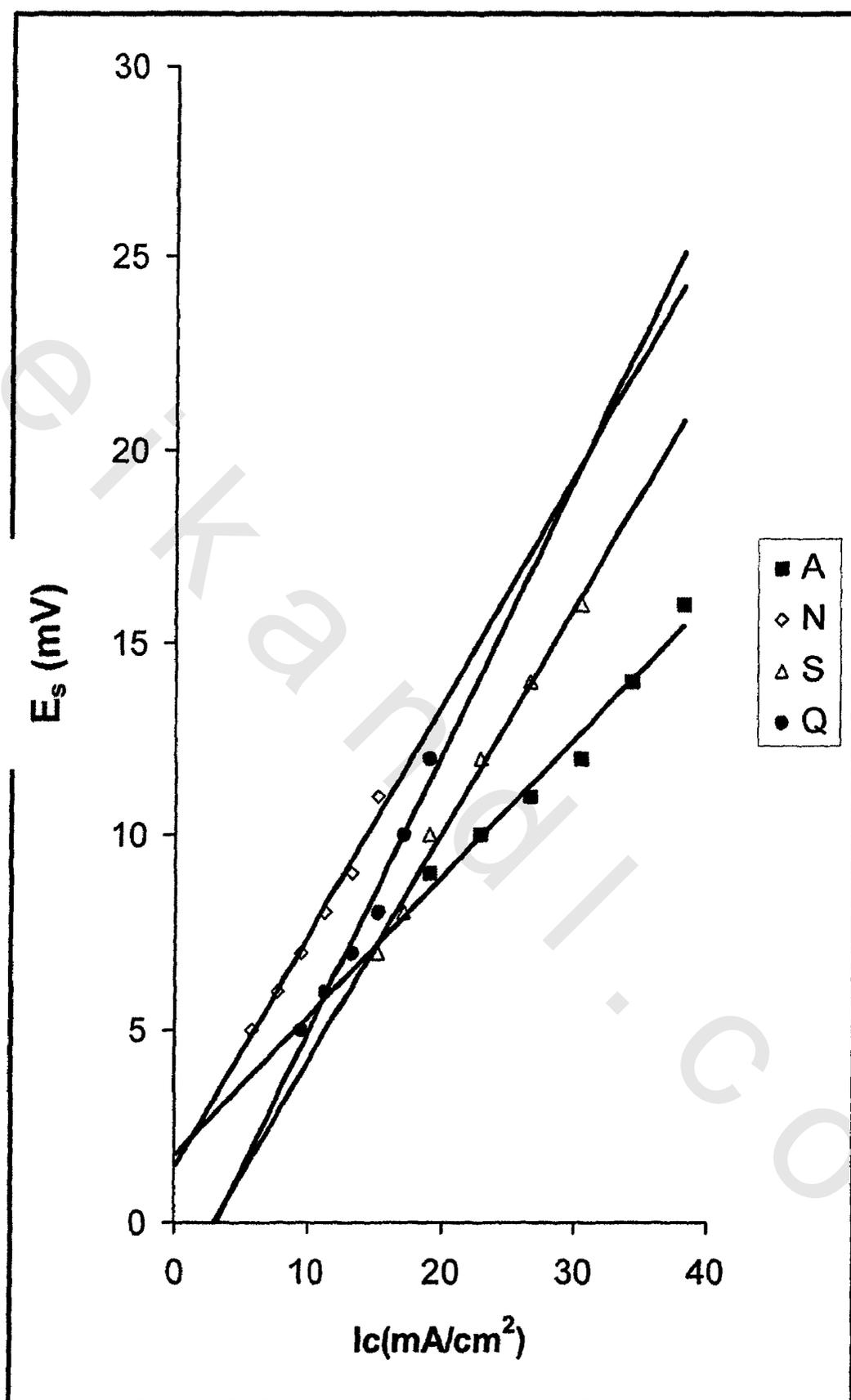
**Fig(101 ):  $E_s$  values vs. cathodic current density ( $I_c$ )for L.C.V. steel samples in 0.1M  $HNO_3$  at 45 °C in presence of  $6 \times 10^{-5}$ M HEAA**



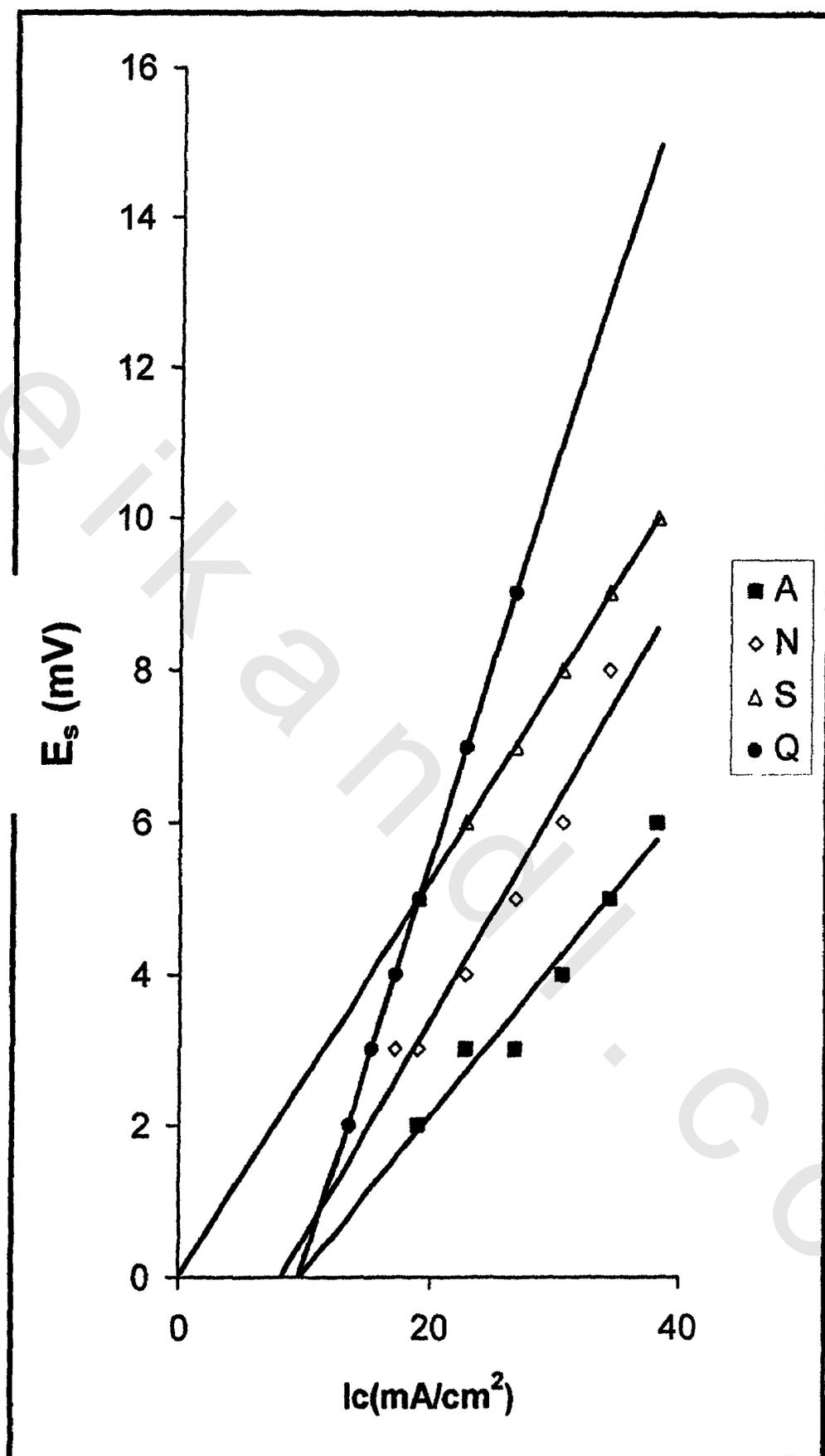
**Fig(102):  $E_s$  values vs. cathodic current density ( $I_c$ ) for L.C.V. steel samples in 0.1M  $HNO_3$  at 45 °C in presence of  $8 \times 10^{-5}$  M HEAA**



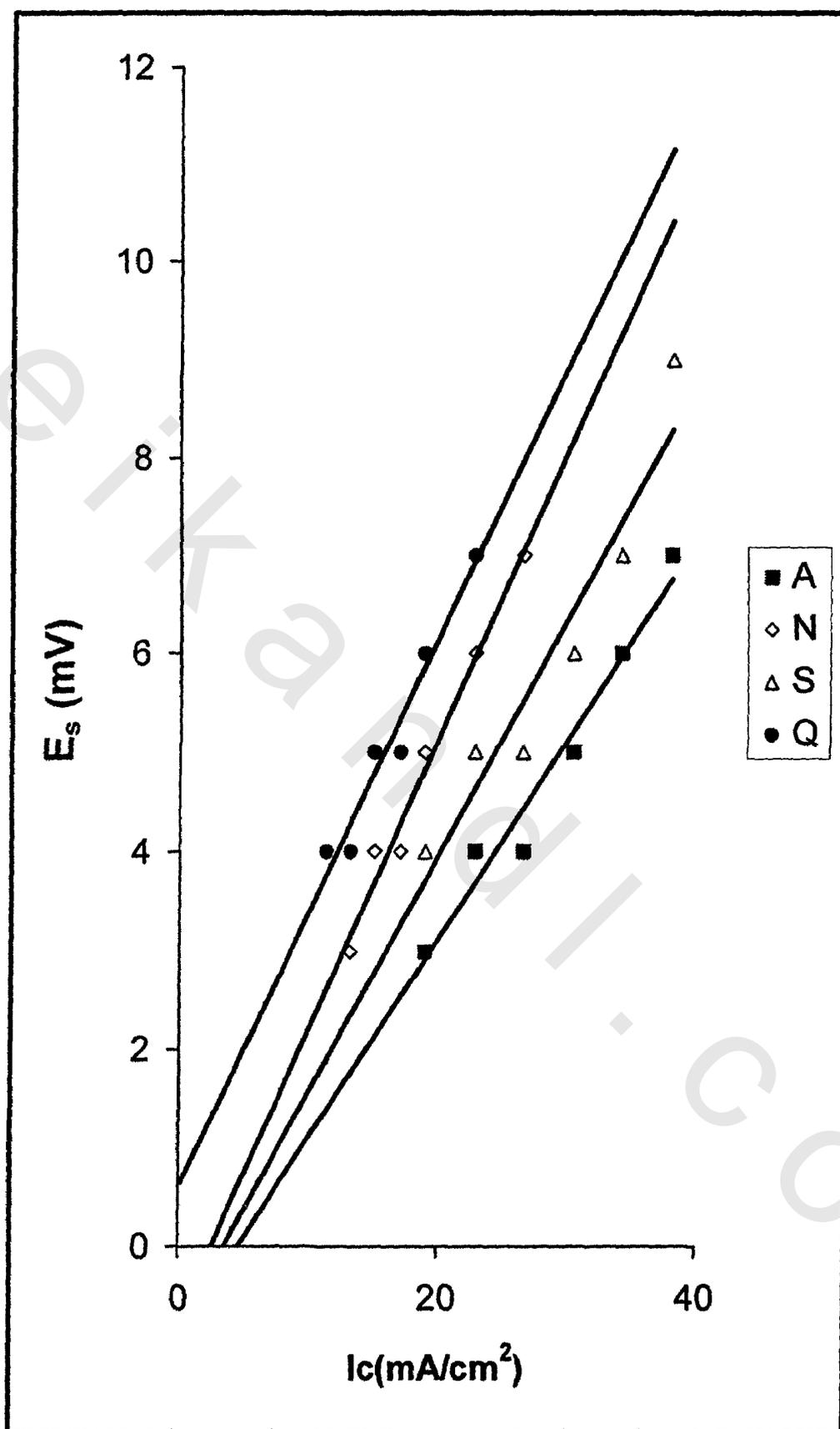
**Fig(103):  $E_s$  values vs. cathodic current density ( $I_c$ ) for L.C.V steel samples in 0.1M  $HNO_3$  at 45 °C in presence of  $10^{-4}$ M HEAA**



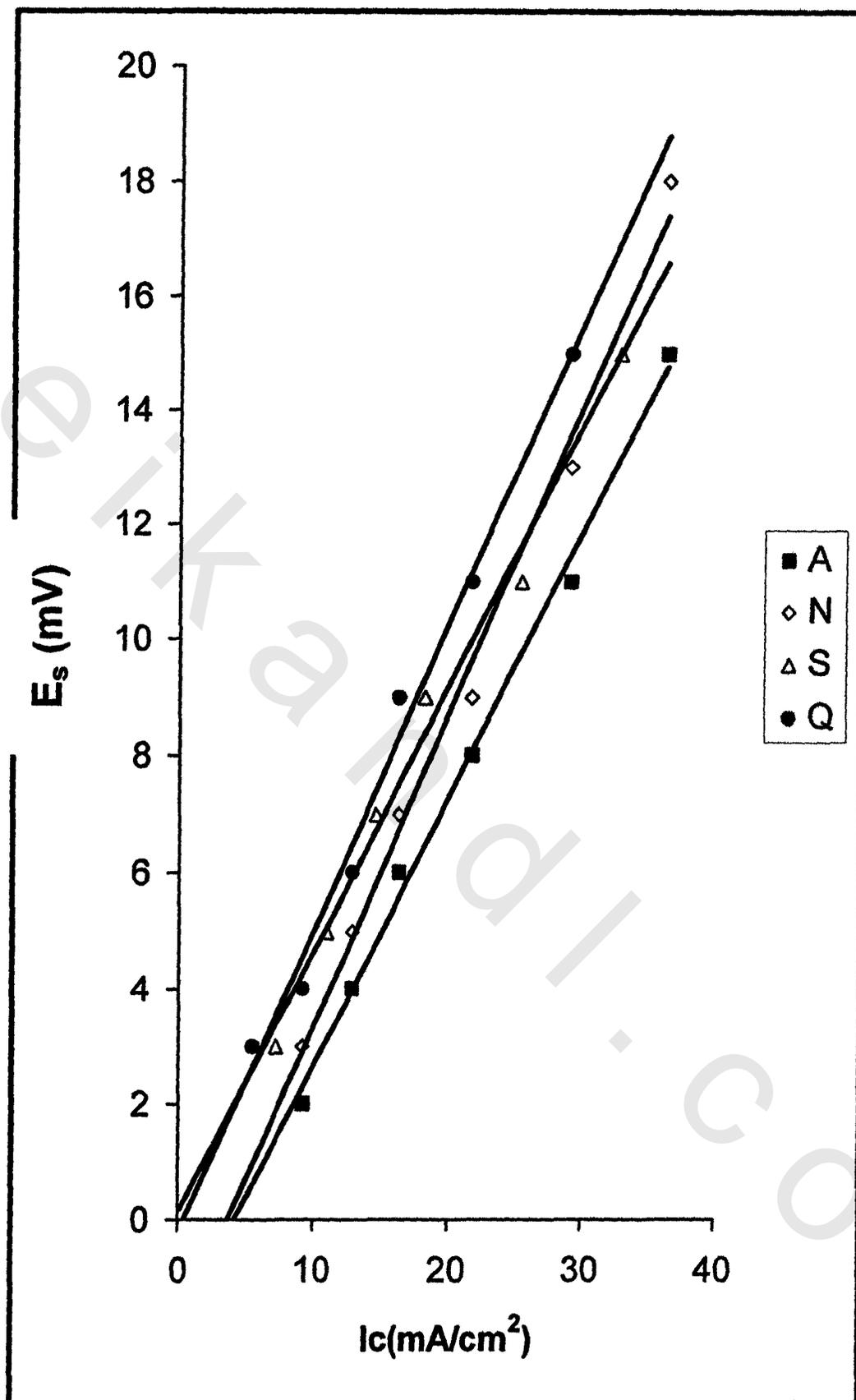
Fig(104):  $E_s$  values vs. cathodic current density ( $I_c$ ) for L.C.V steel samples in 0.1 M  $HNO_3$  at 55 °C



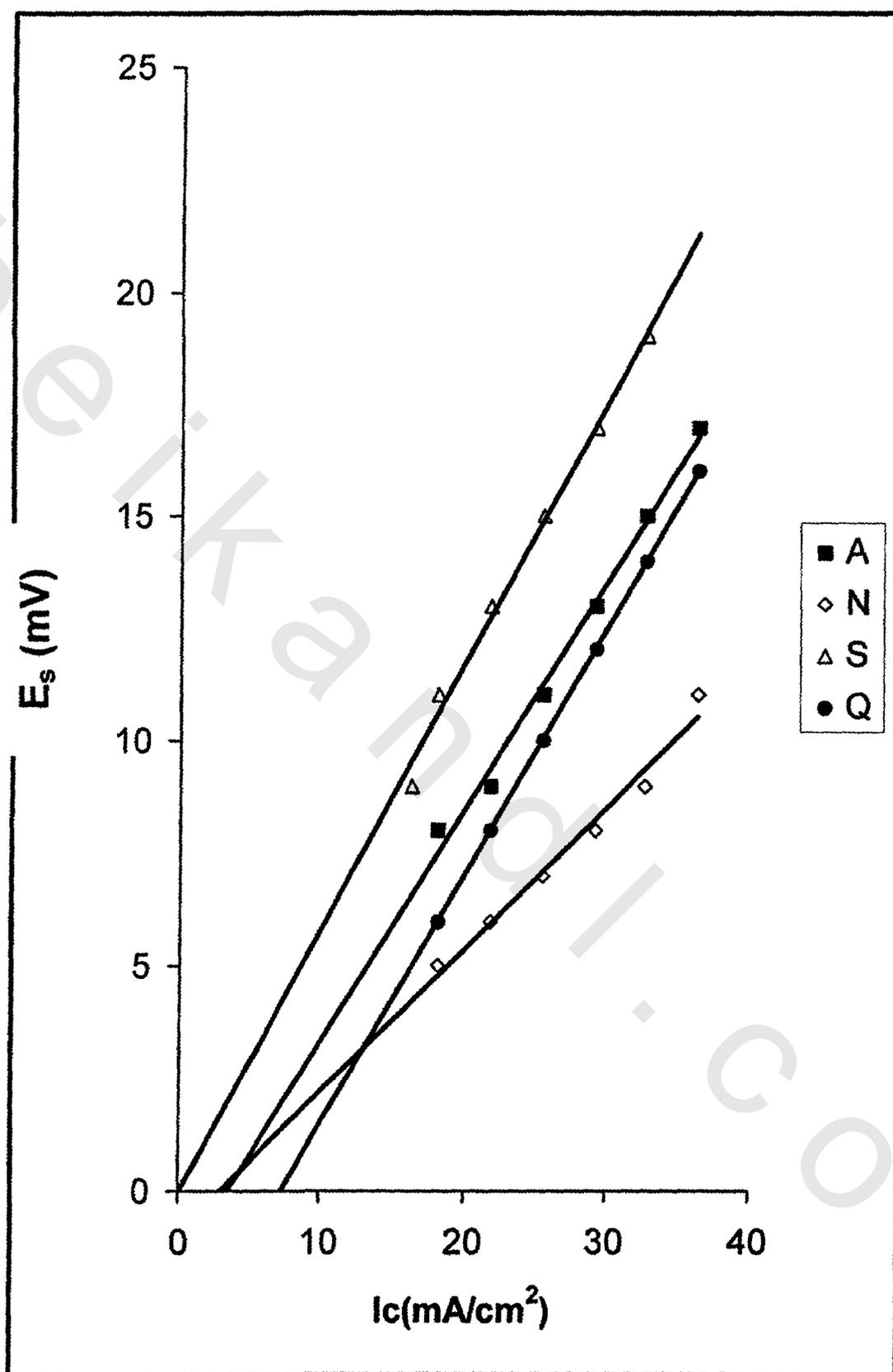
**Fig(105):  $E_s$  values vs. cathodic current density ( $I_c$ ) for L.C.V steel samples in 0.3 M  $HNO_3$  at 55 °C**



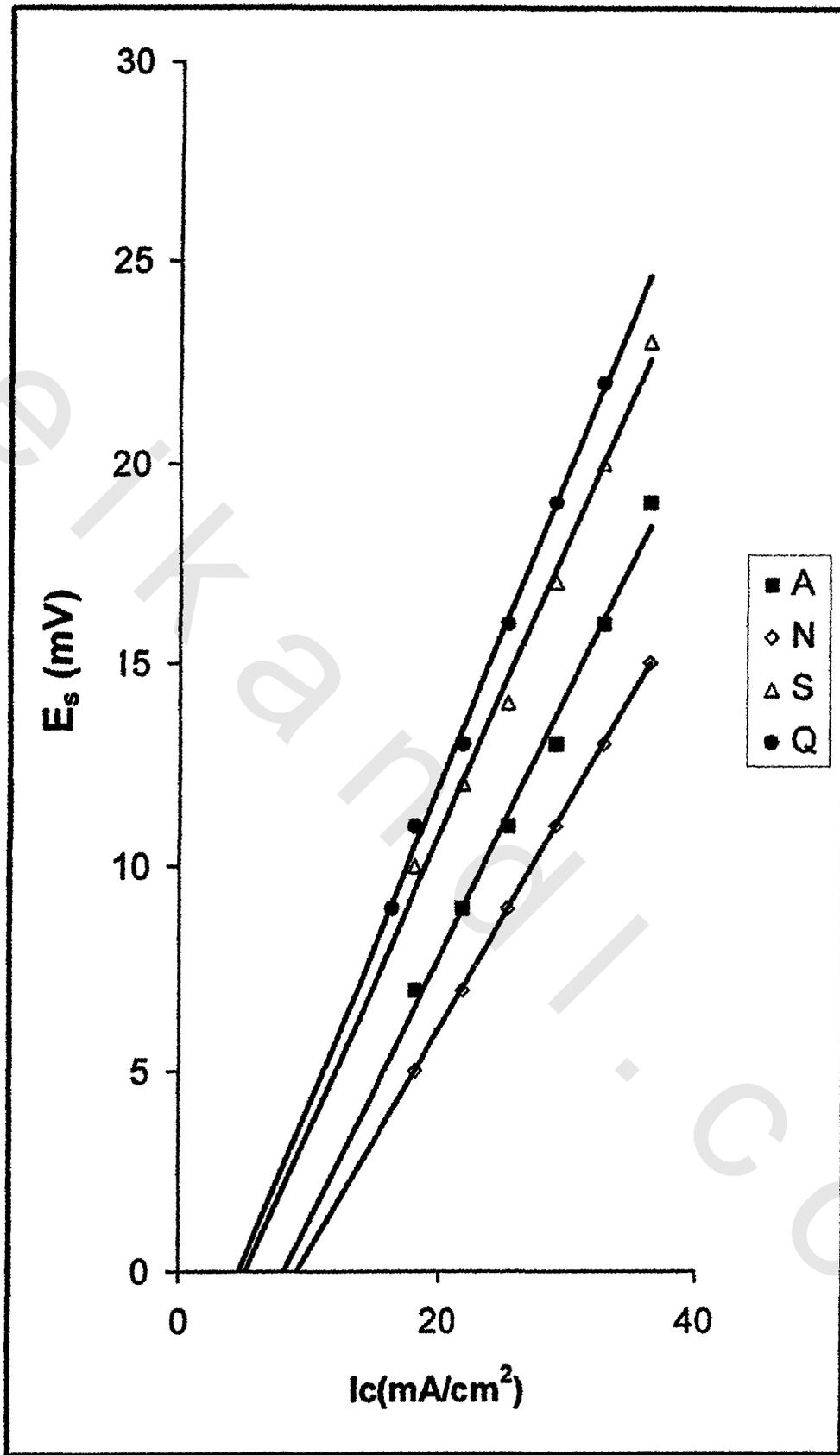
**Fig(106):  $E_s$  values vs. cathodic current density ( $I_c$ ) for L.C.V steel samples in 0.5 M  $HNO_3$  at 55 °C**



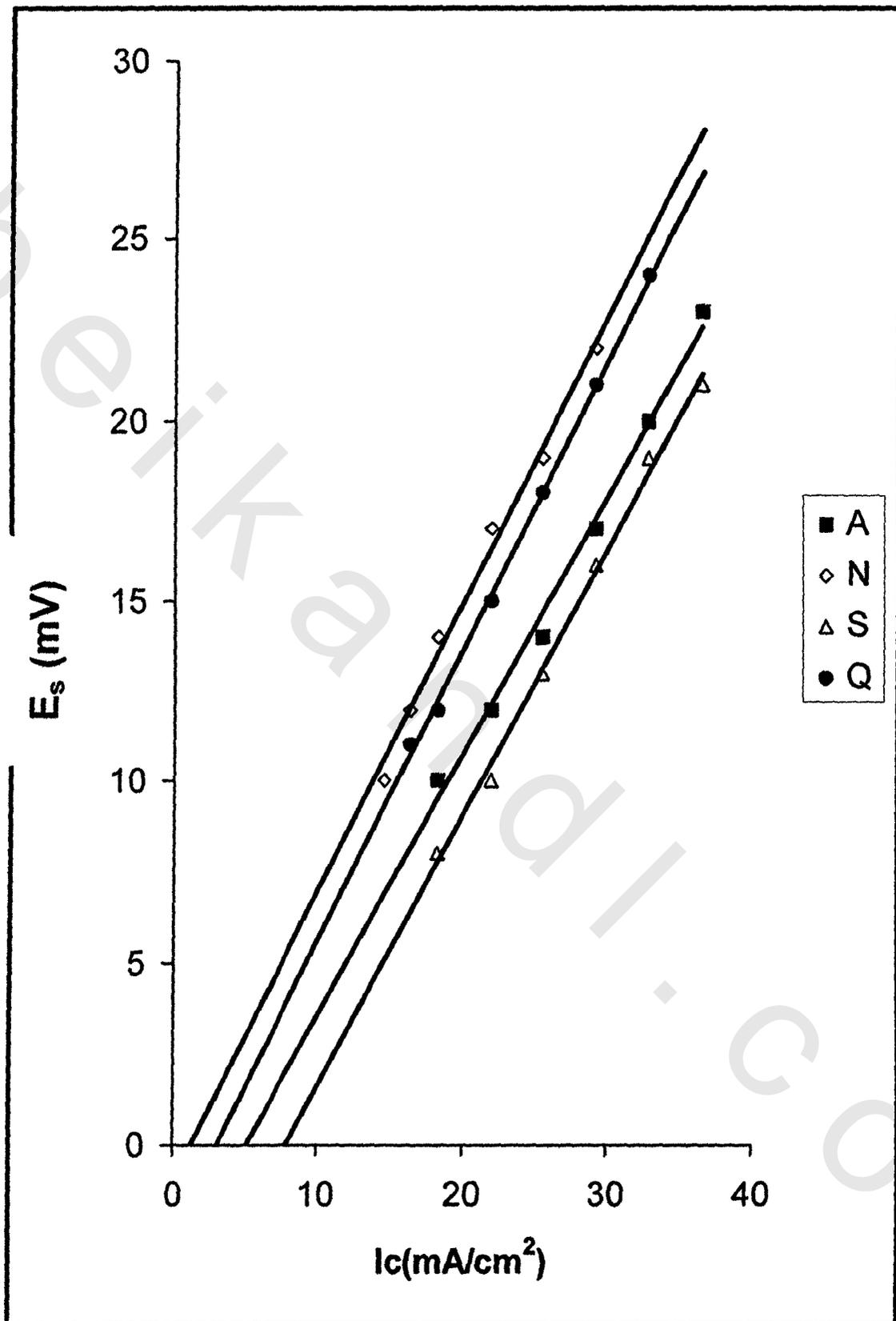
**Fig(107):  $E_s$  values vs. cathodic current density ( $I_c$ ) for L.C.V steel samples in 0.1M  $HNO_3$  at 55 °C in presence of  $2 \times 10^{-5}$  M HEAA**



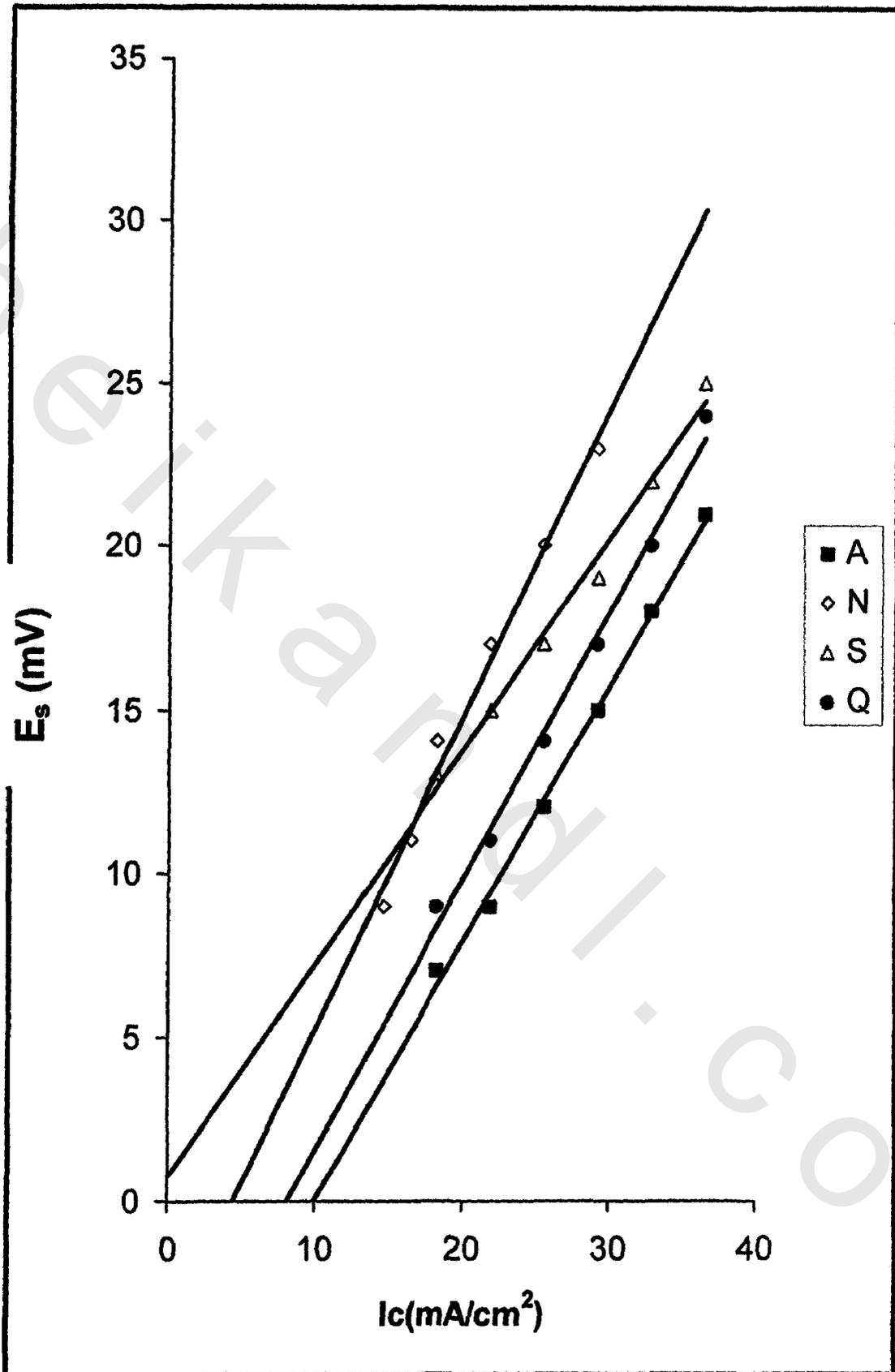
**Fig(108):  $E_s$  values vs. cathodic current density ( $I_c$ ) for L.C.V steel samples in 0.1M HNO<sub>3</sub> at 55 °C in presence of  $4 \times 10^{-5}$ M HEAA**



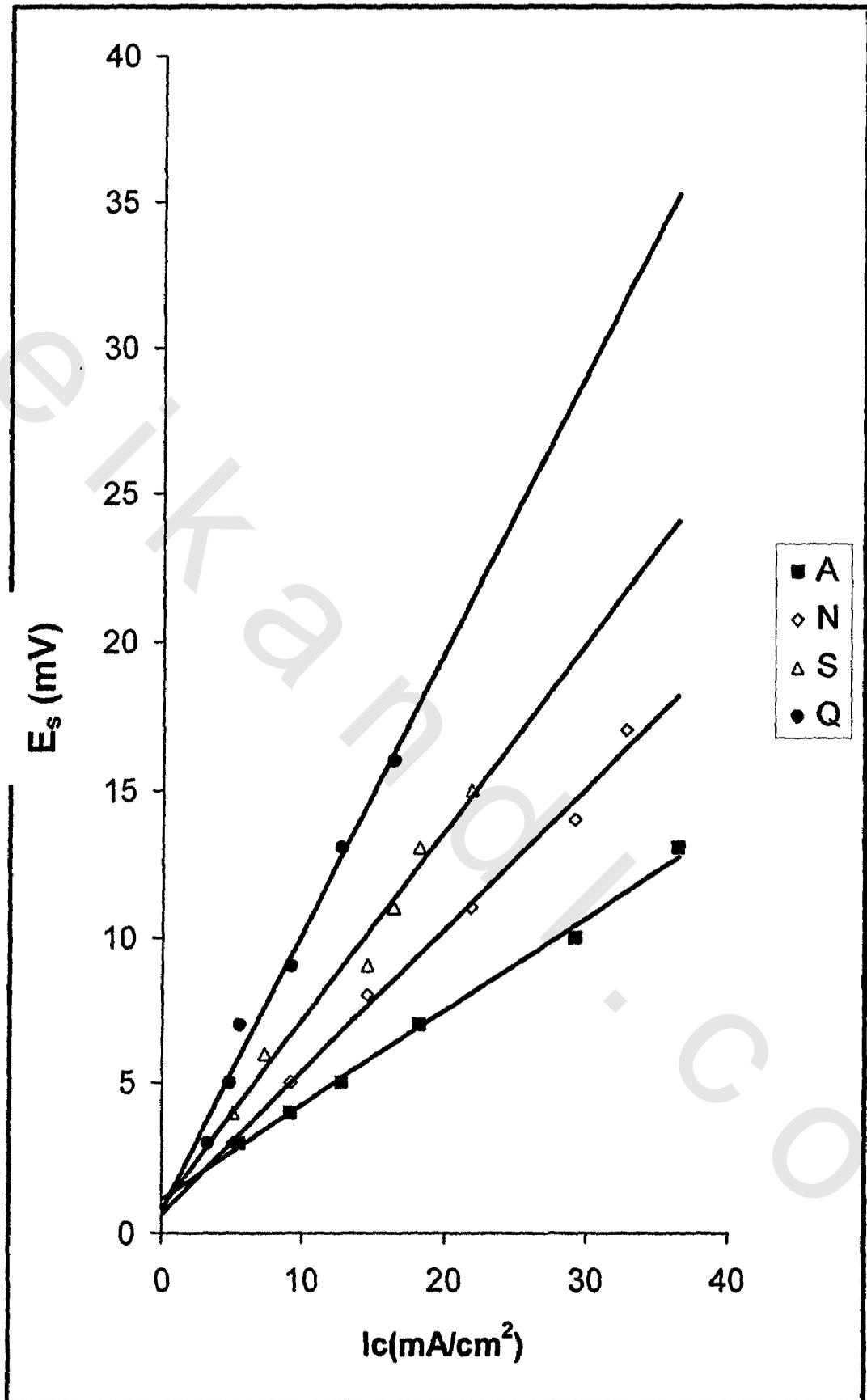
**Fig(109):  $E_s$  values vs. cathodic current density ( $I_c$ ) for L.C.V. steel samples in 0.1M HNO<sub>3</sub> at 55 °C in presence of  $6 \times 10^{-5}$ M HEAA**



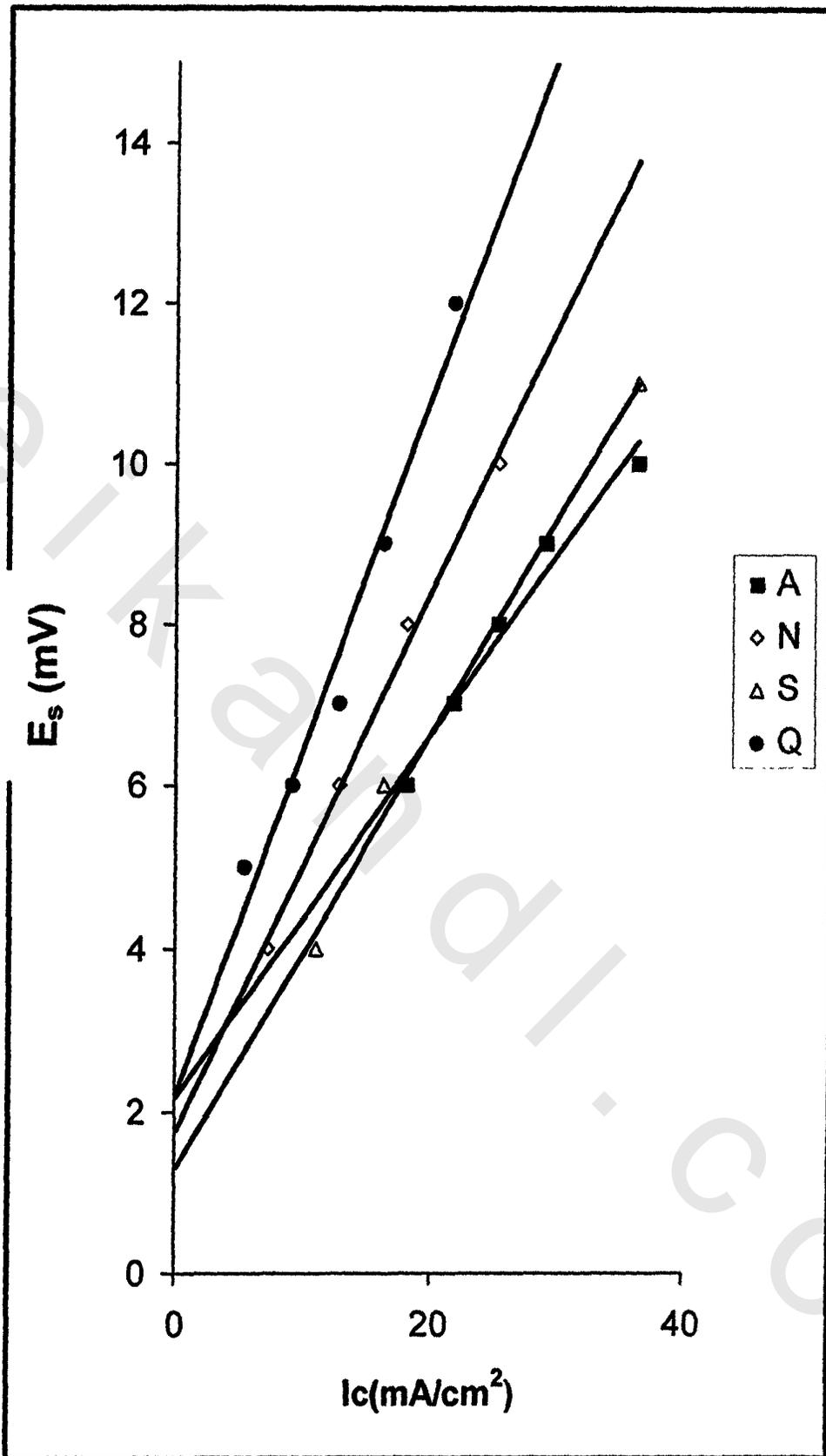
**Fig(110):  $E_s$  values vs. cathodic current density ( $I_c$ ) for L.C.V. steel samples in 0.1M  $HNO_3$  at 55 °C in presence of  $8 \times 10^{-5}$  M HEAA**



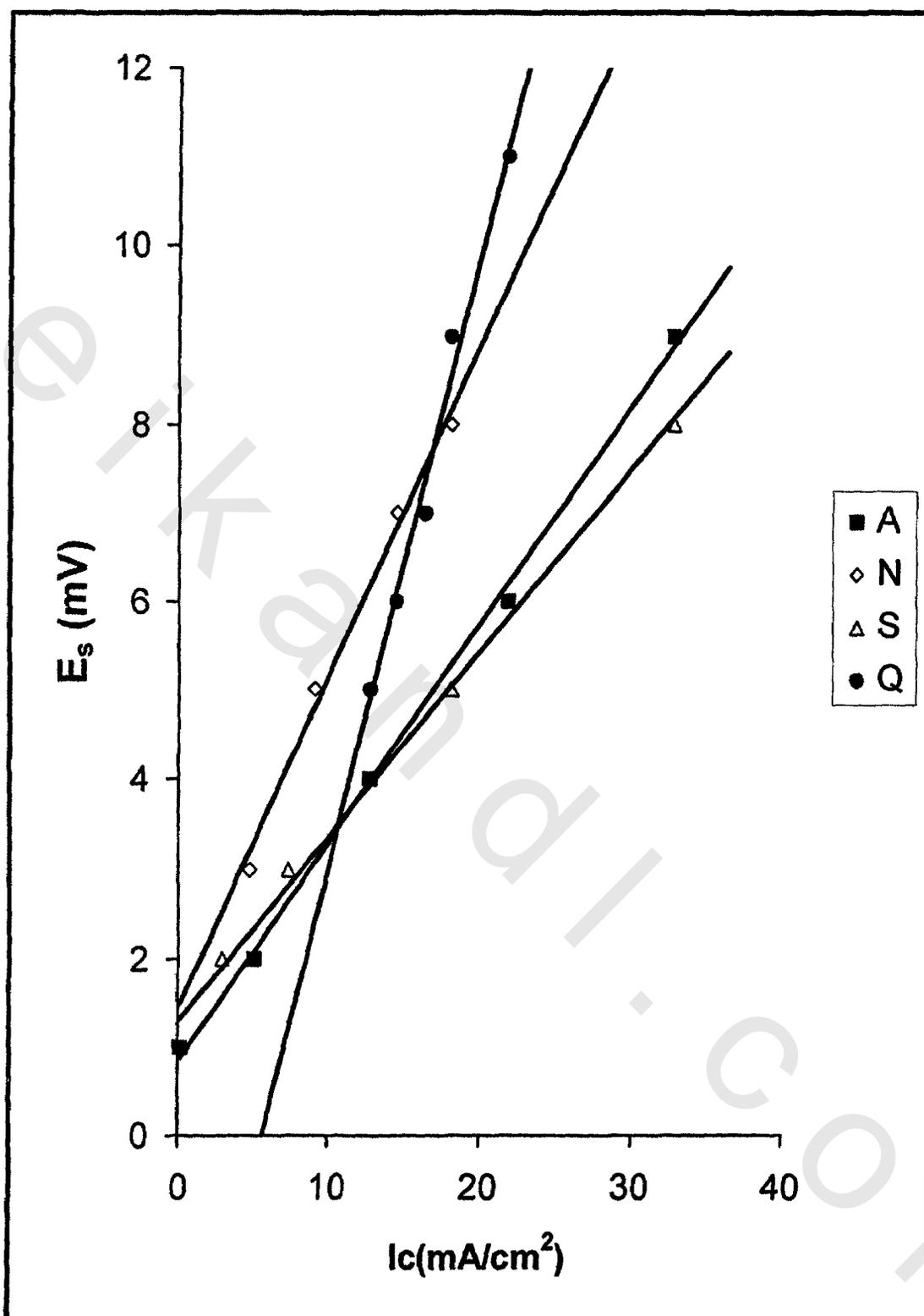
**Fig(111):  $E_s$  values vs. cathodic current density ( $I_c$ ) for L.C.V. steel samples in 0.1M  $HNO_3$  at 55 °C in presence of  $10^{-4}$ M HEAA**



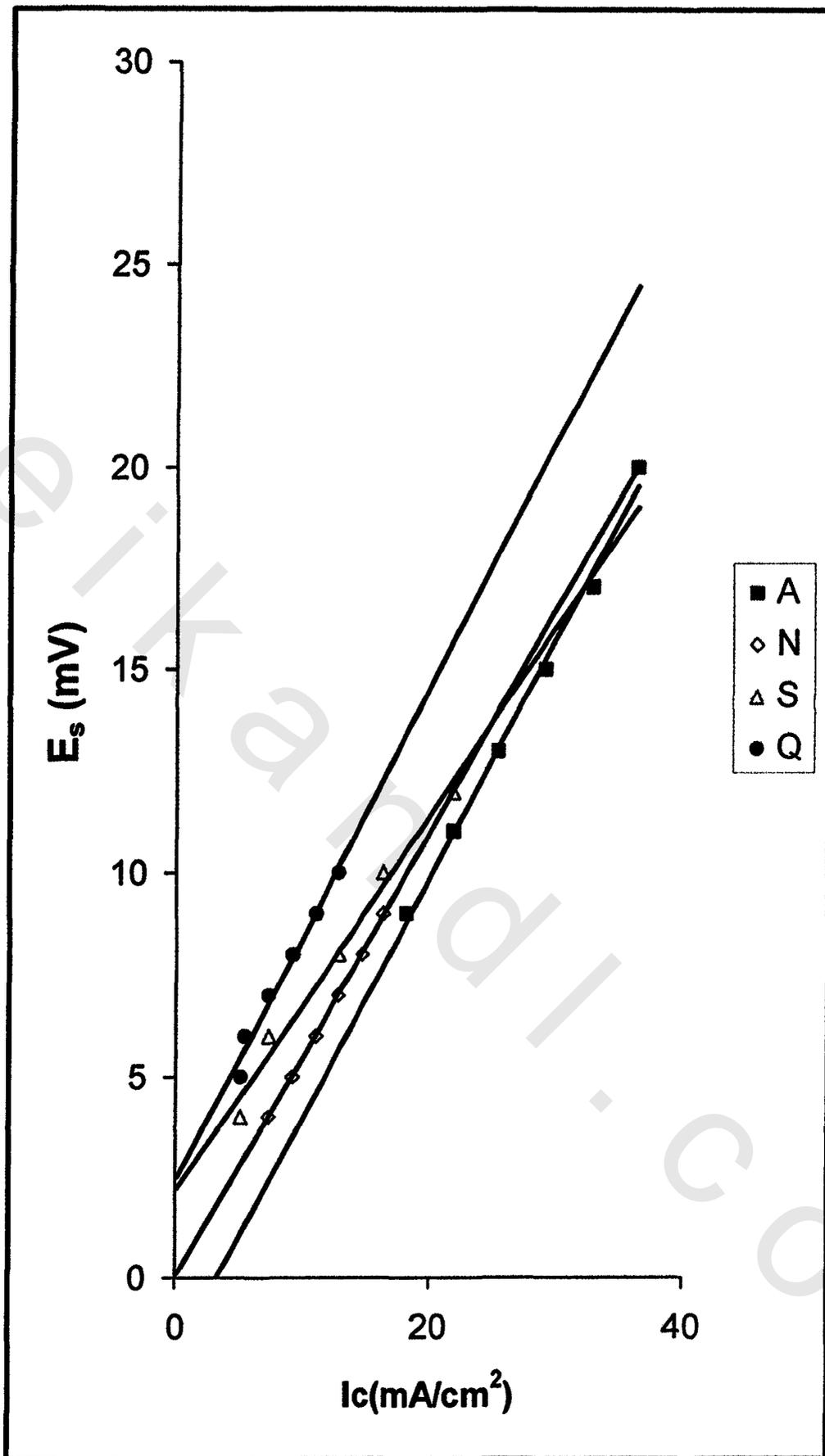
Fig(112):  $E_s$  values vs. cathodic current density ( $I_c$ ) for M.C.V steel samples in 0.1M HNO<sub>3</sub> at 25 °C



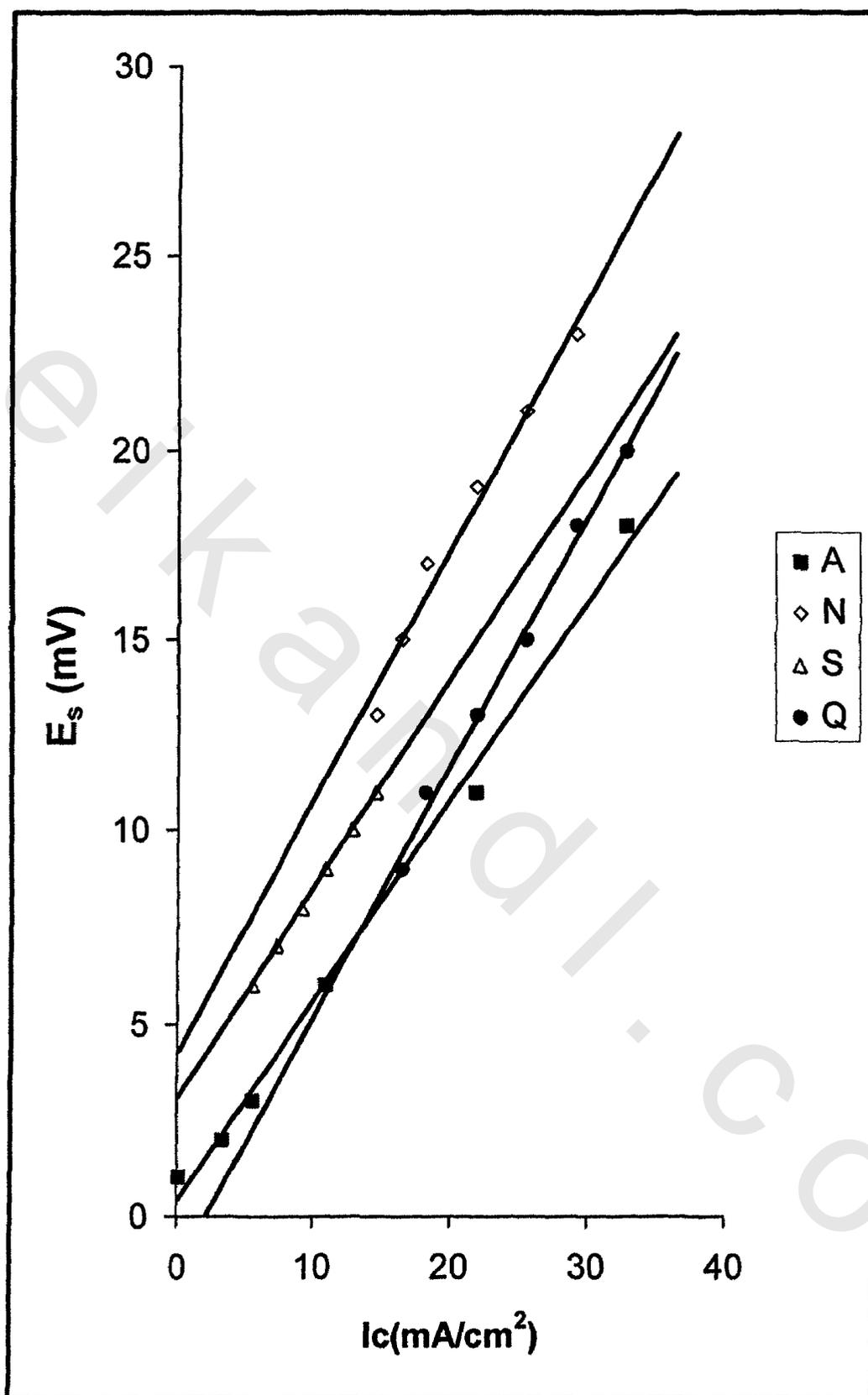
**Fig(113):  $E_s$  values vs. cathodic current density ( $I_c$ ) for M.C.V steel samples in 0.3 M  $HNO_3$  at 25 °C**



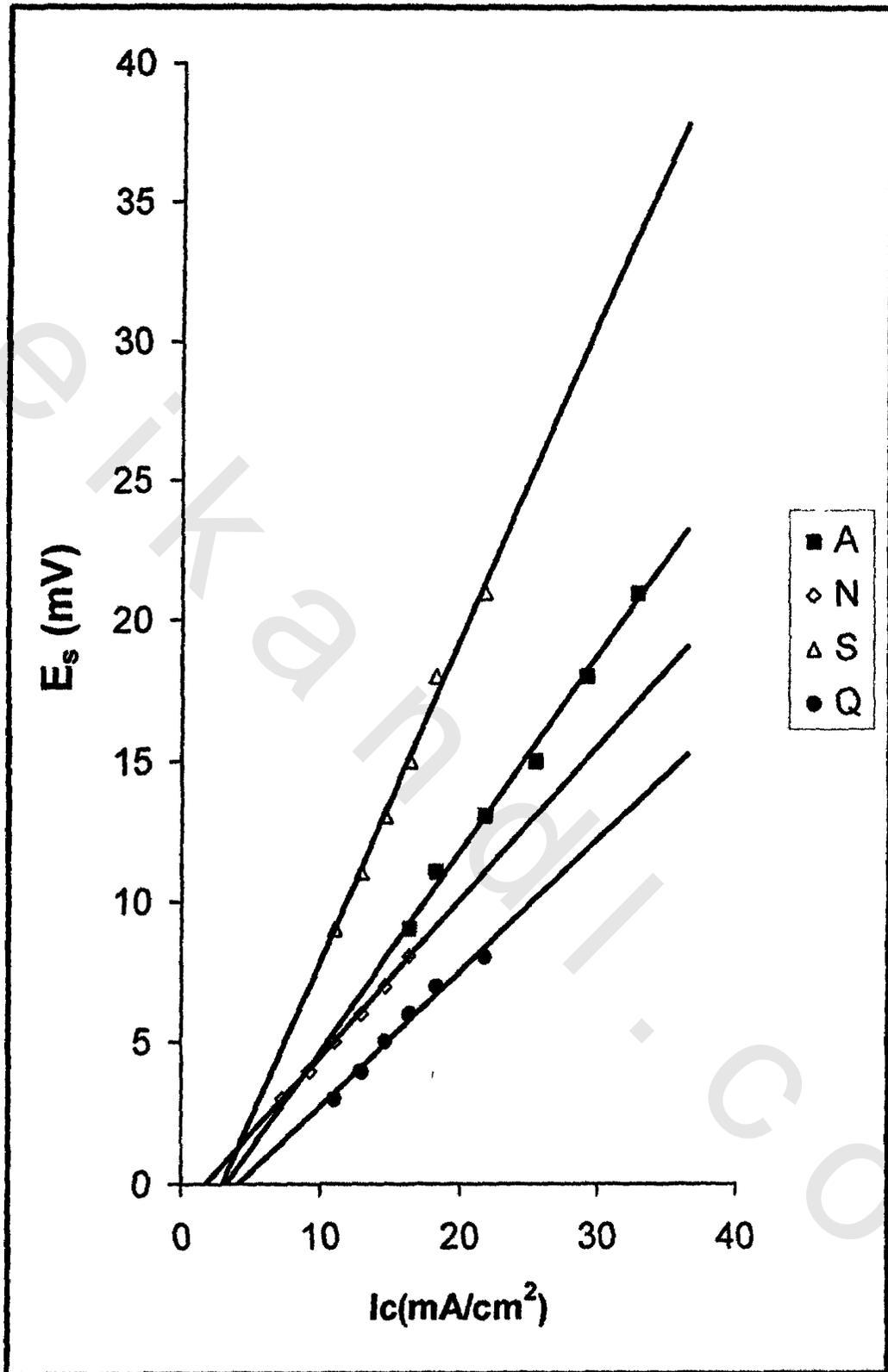
Fig(114):  $E_s$  values vs. cathodic current density ( $I_c$ ) for M.C.V. steel samples in 0.5 M  $HNO_3$  at 25 °C



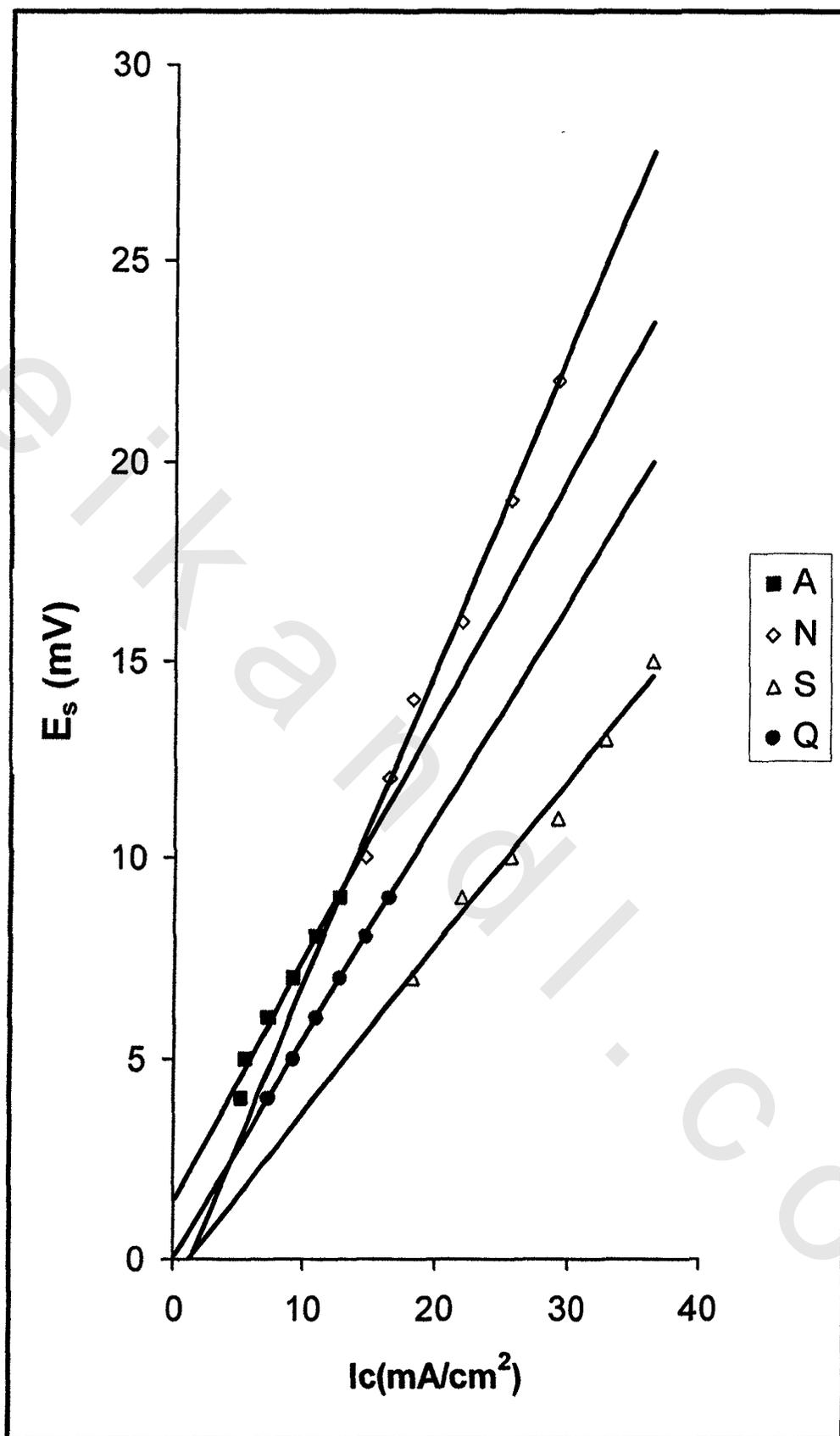
**Fig(115):  $E_s$  values vs. cathodic current density ( $I_c$ ) for M.C.V steel samples in 0.1 M  $HNO_3$  at 25 °C in presence of  $2 \times 10^{-5}$  M HEAA**



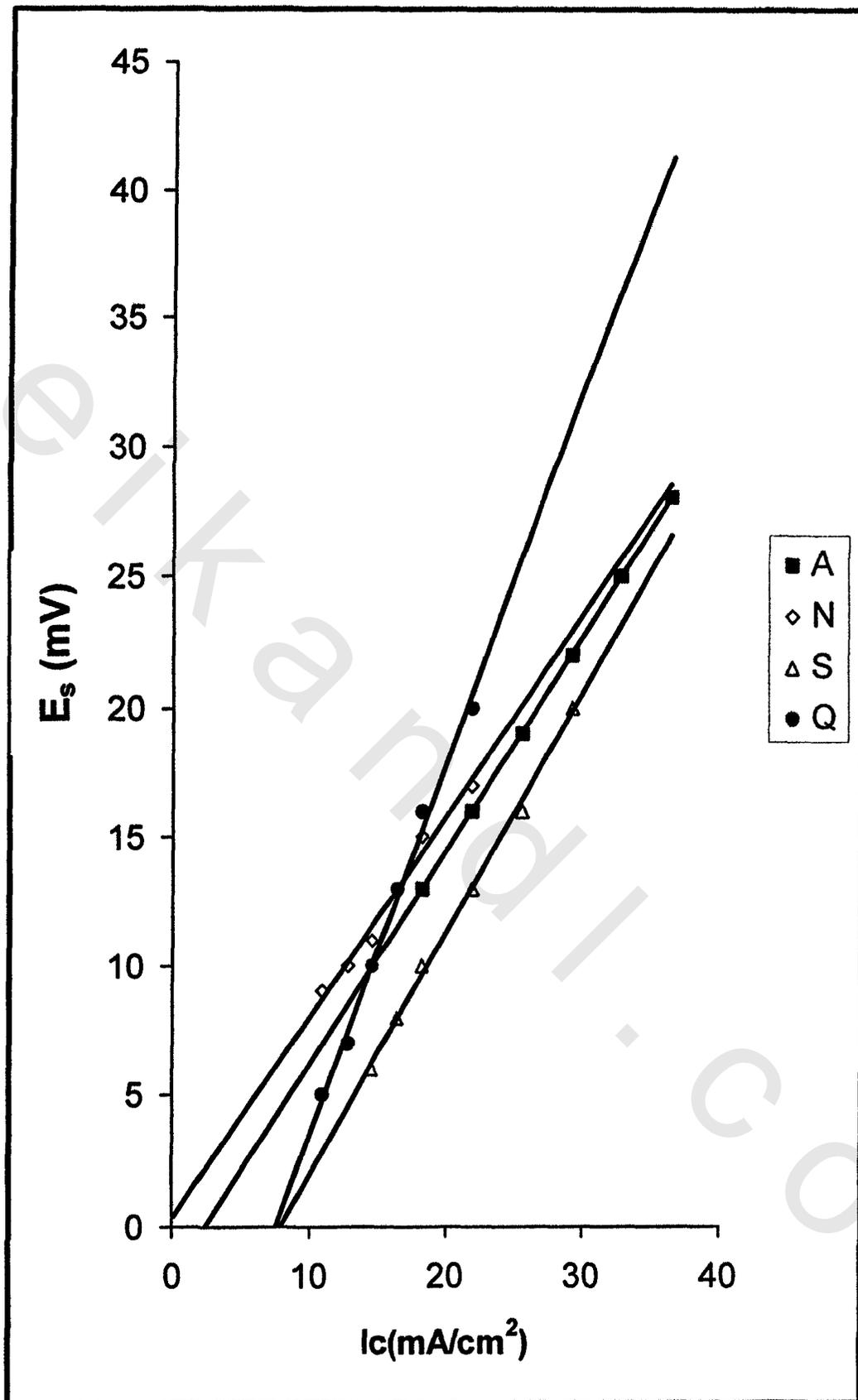
Fig(116):  $E_s$  values vs. cathodic current density ( $I_c$ ) for M.C.V. steel samples in 0.1 M HNO<sub>3</sub> at 25 °C in presence of 4 x 10<sup>-5</sup> M HEAA



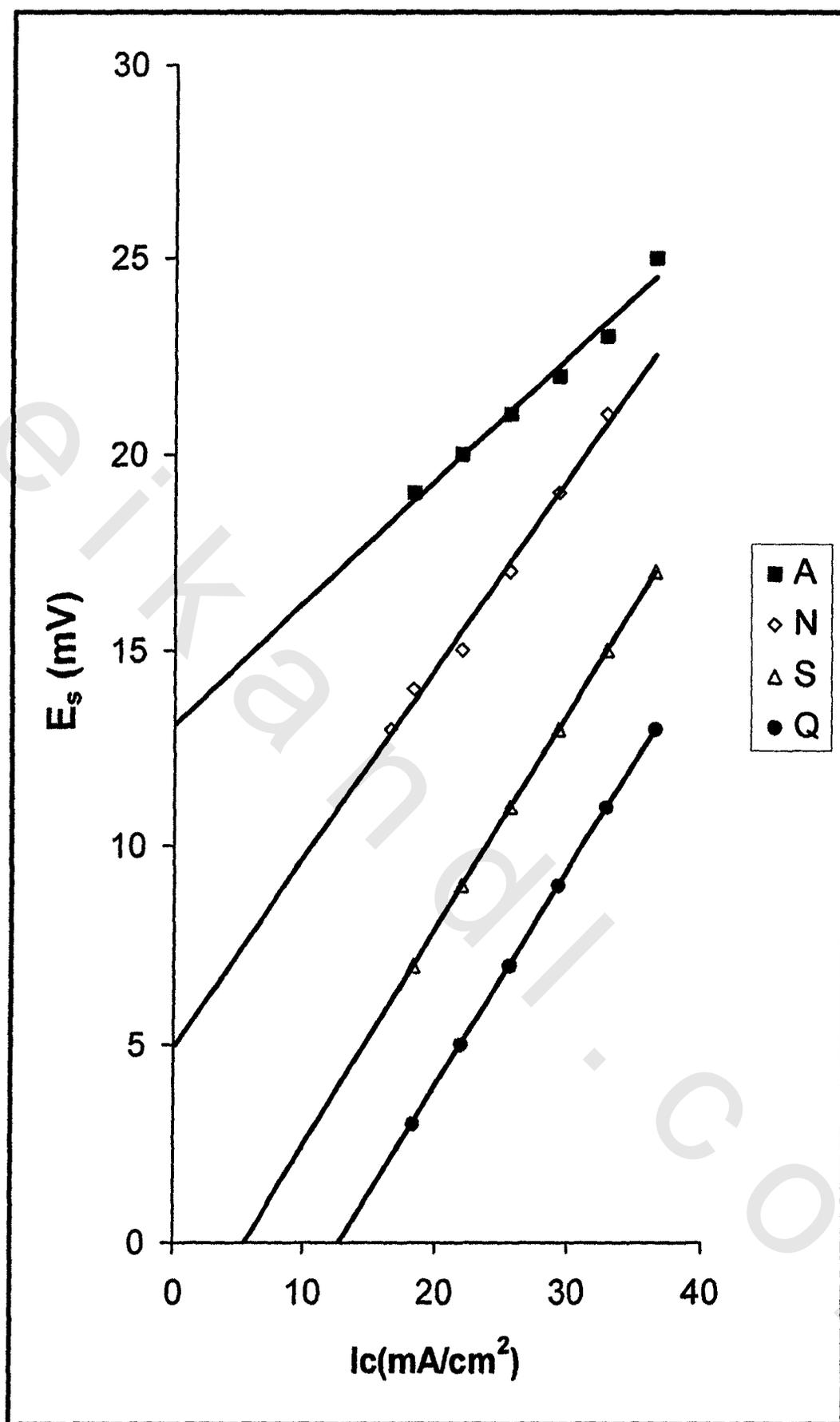
**Fig(117):  $E_s$  values vs. cathodic current density ( $I_c$ ) for M.C.V. steel samples in 0.1 M  $\text{HNO}_3$  at 25 °C in presence of  $6 \times 10^{-5}$  M HEAA**



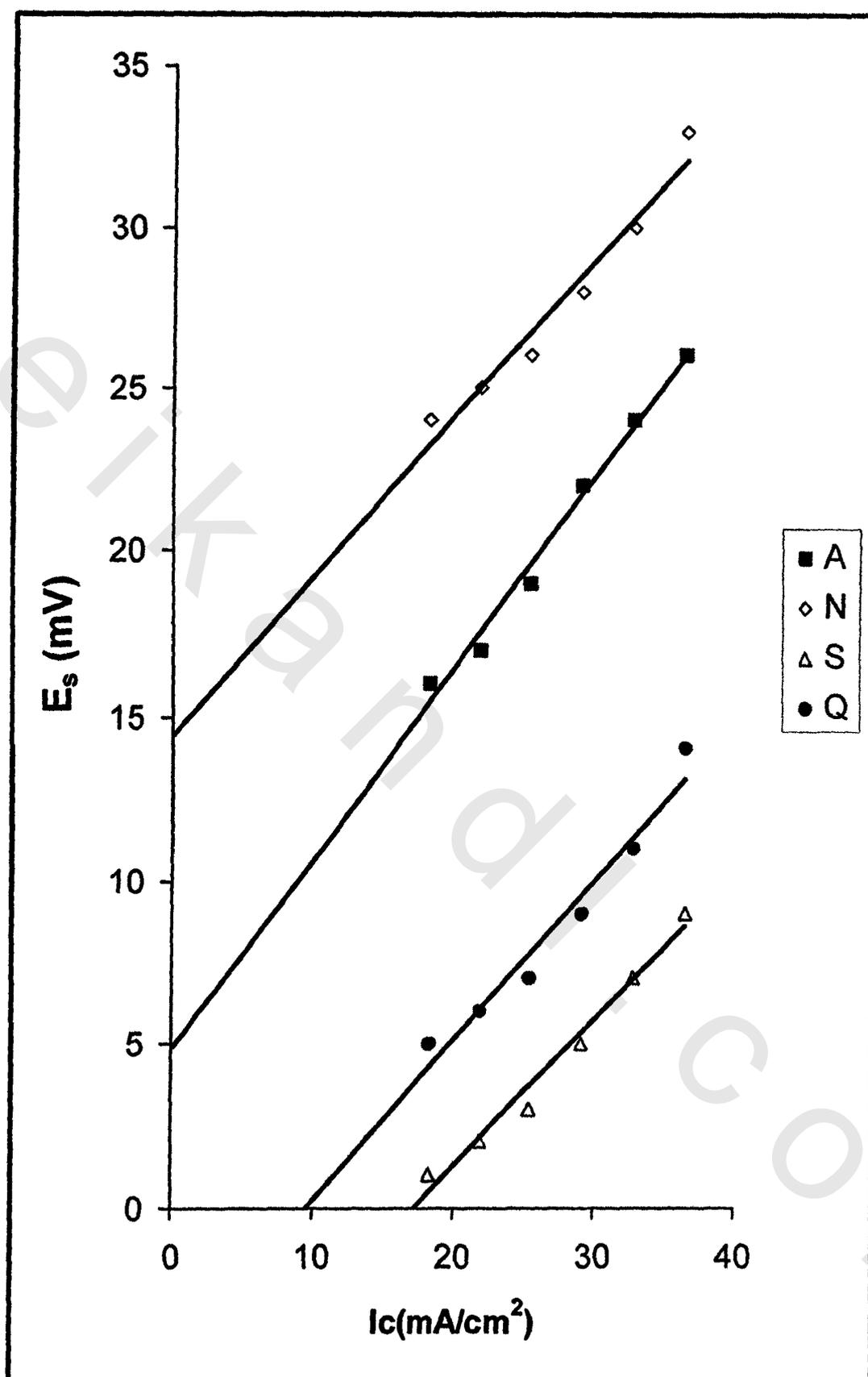
**Fig(118):  $E_s$  values vs. cathodic current density ( $I_c$ ) for M.C.V. steel samples in 0.1 M HNO<sub>3</sub> at 25 °C in presence of  $8 \times 10^{-5}$  M HEAA**



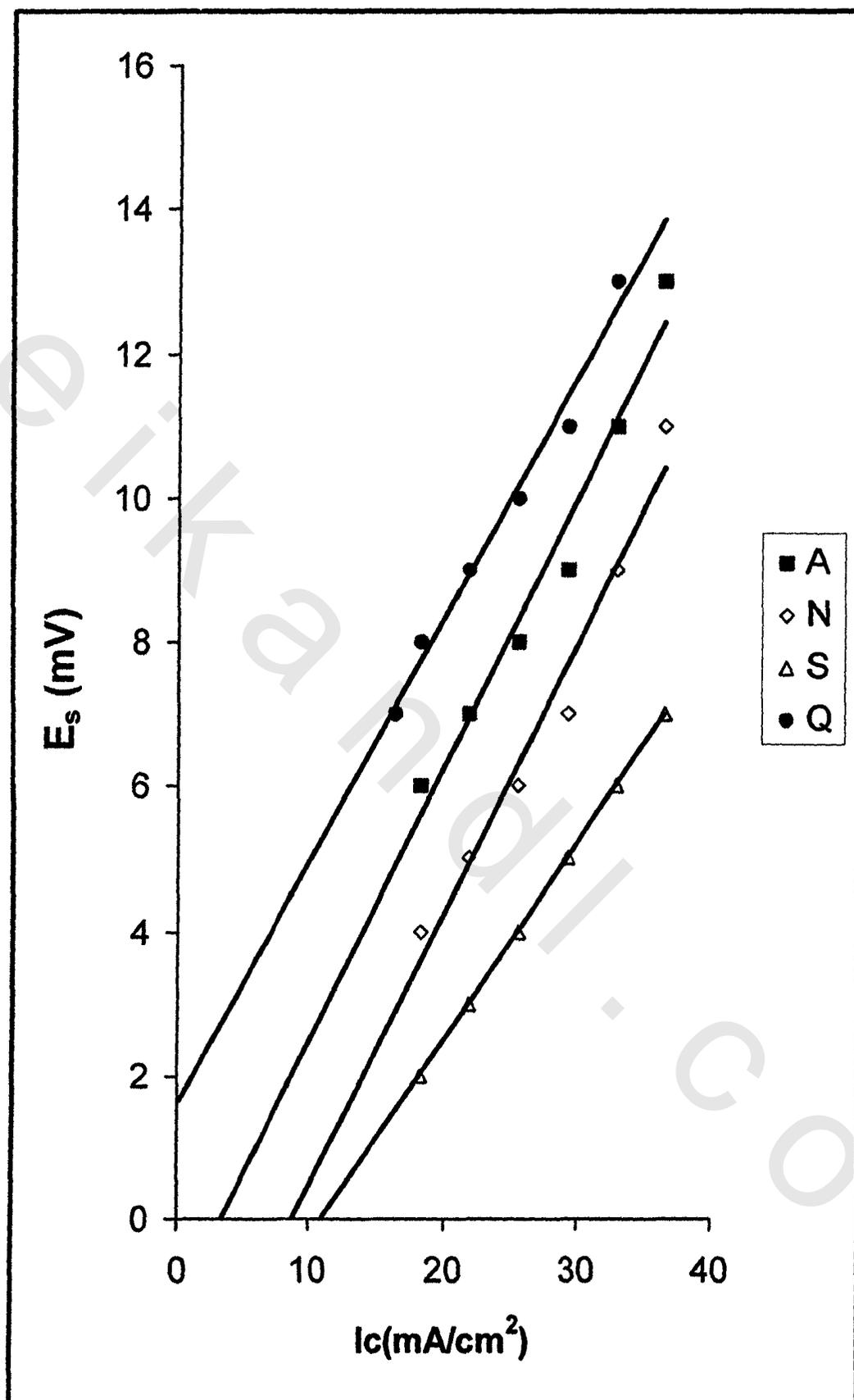
**Fig(119):  $E_s$  values vs. cathodic current density ( $I_c$ ) for M.C.V. steel samples in 0.1 M  $HNO_3$  at 25 °C in presence of  $10^{-4}$  M HEAA**



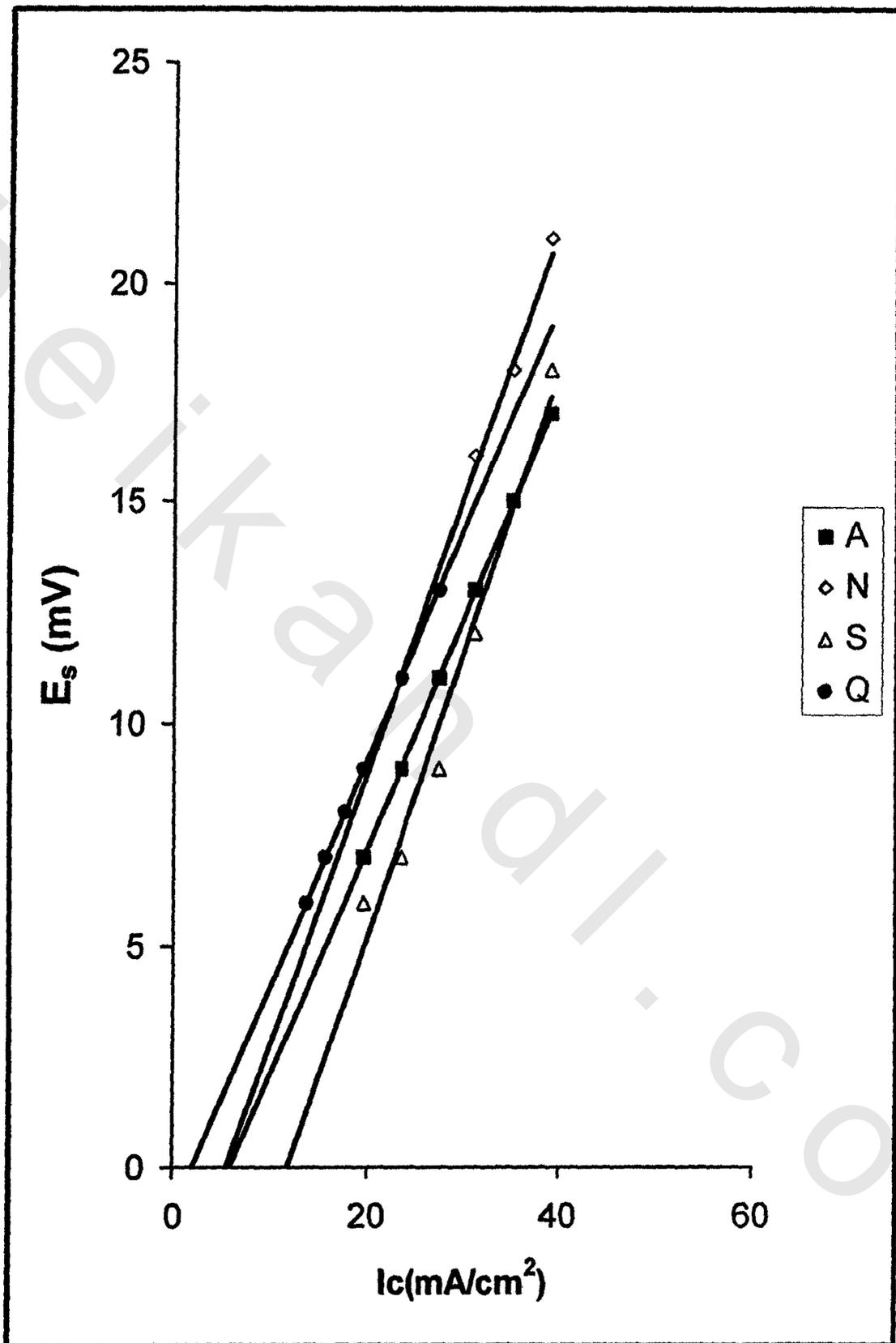
**Fig(120):  $E_s$  values vs. cathodic current density ( $I_c$ ) for M.C.V steel samples in 0.1 M  $HNO_3$  at 35 °C**



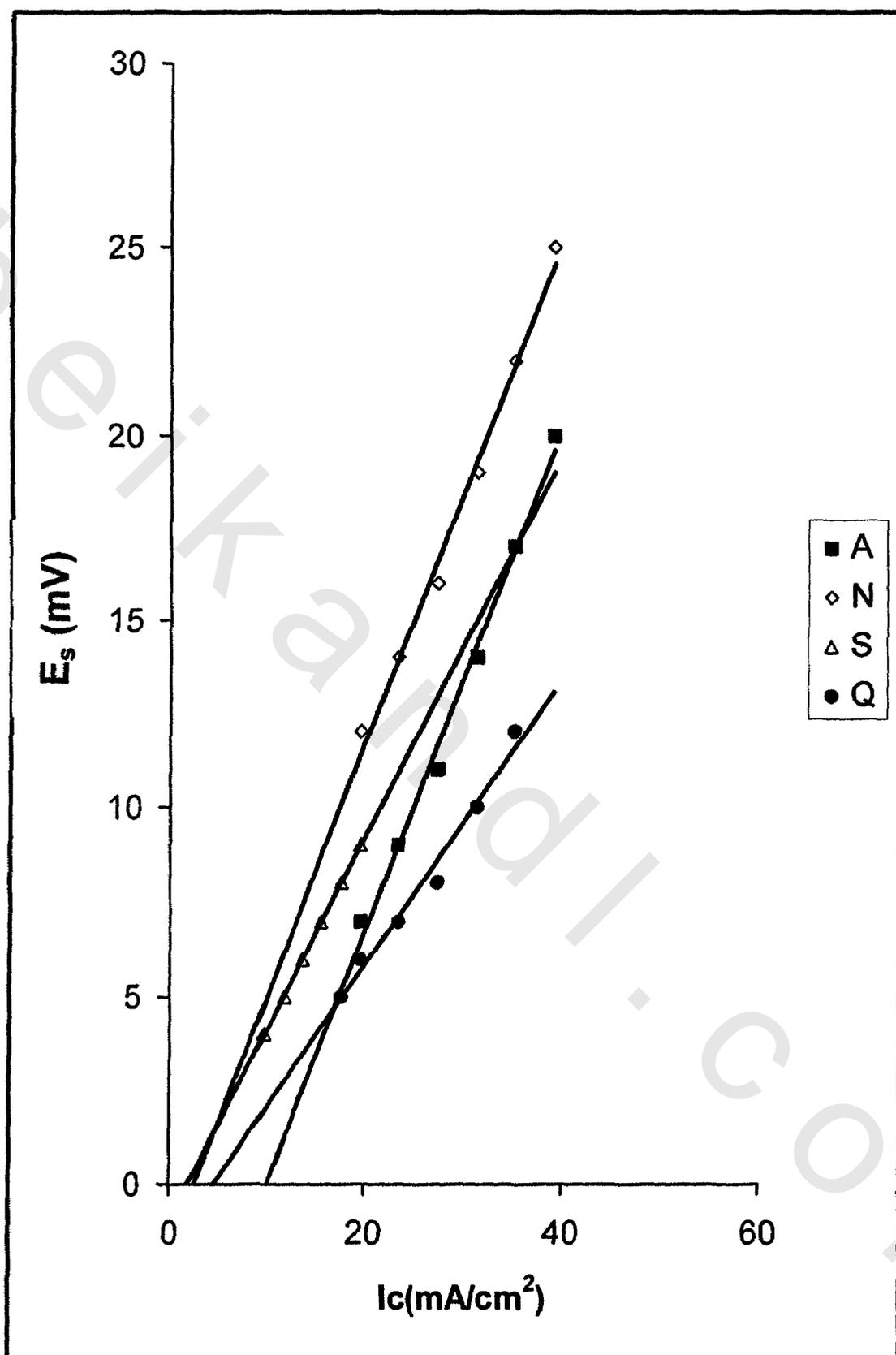
**Fig(121):  $E_s$  values vs. cathodic current density ( $I_c$ ) for M.C.V steel samples in 0.3 M  $HNO_3$  at 35 °C**



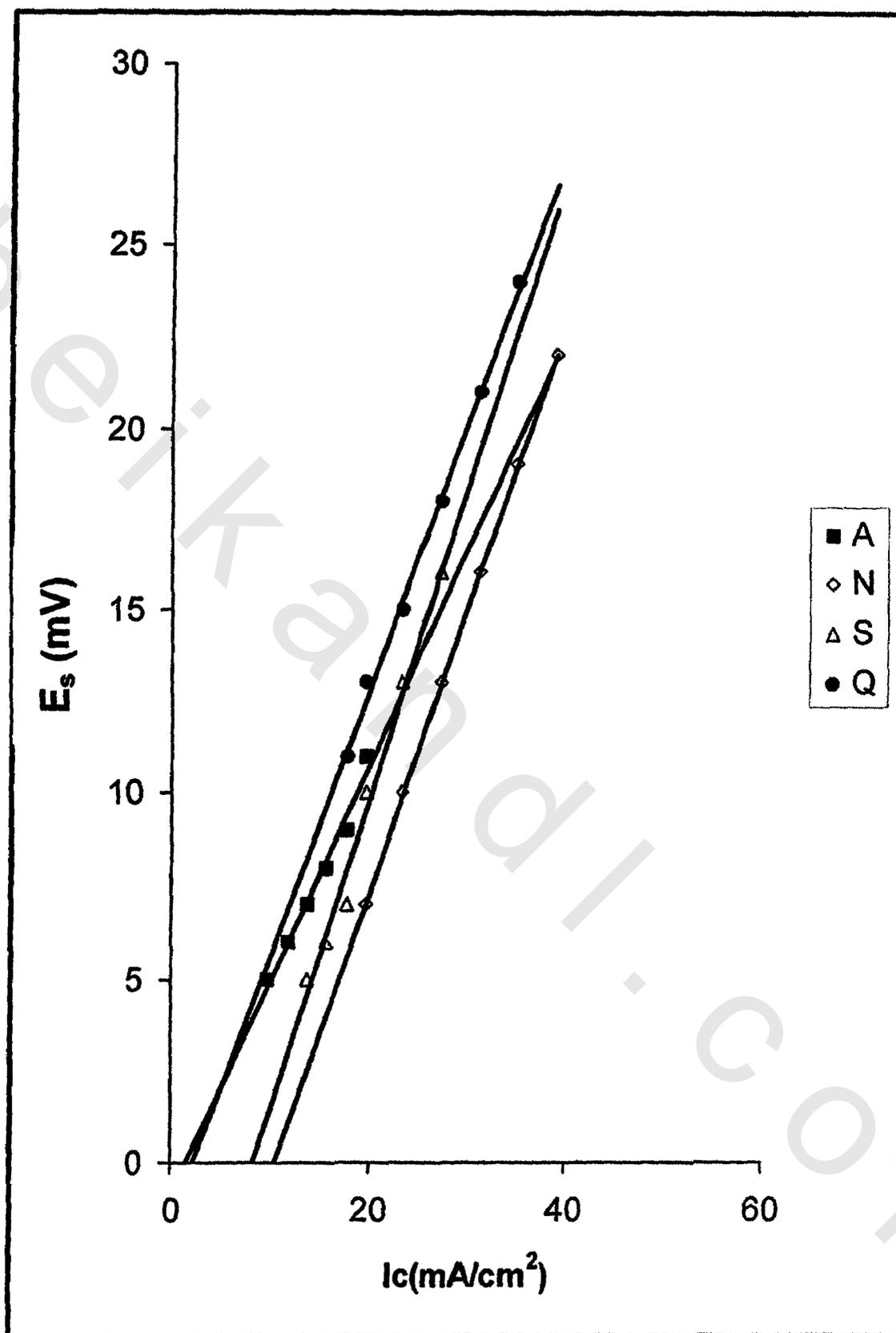
**Fig(122):  $E_s$  values vs. cathodic current density ( $I_c$ ) for M.C.V steel samples in 0.5 M  $HNO_3$  at 35 °C**



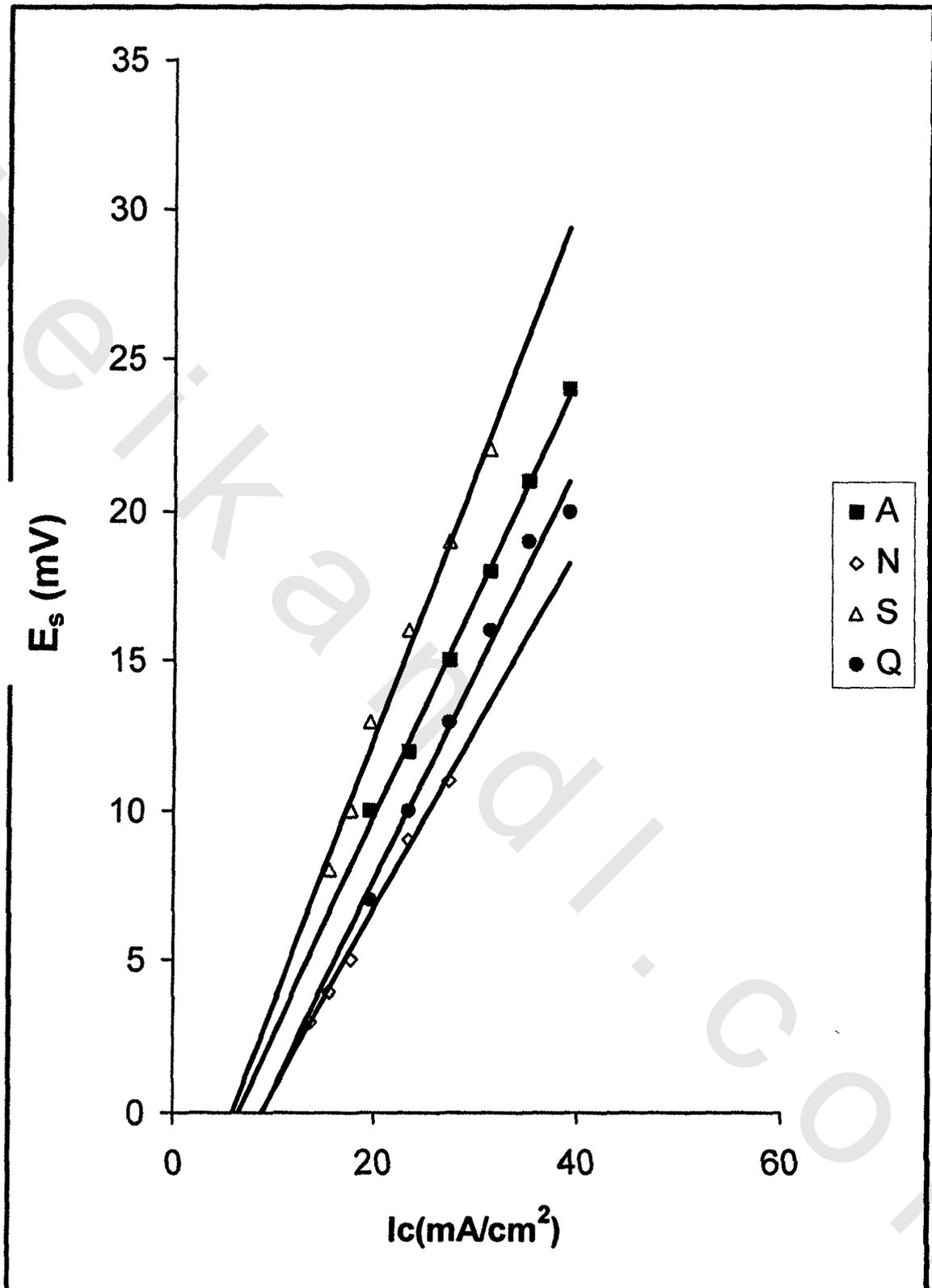
**Fig(123):  $E_s$  values vs. cathodic current density ( $I_c$ ) for M.C.V steel samples in 0.1M  $HNO_3$  at 35 °C in presence of  $2 \times 10^{-5}$  M HEAA**



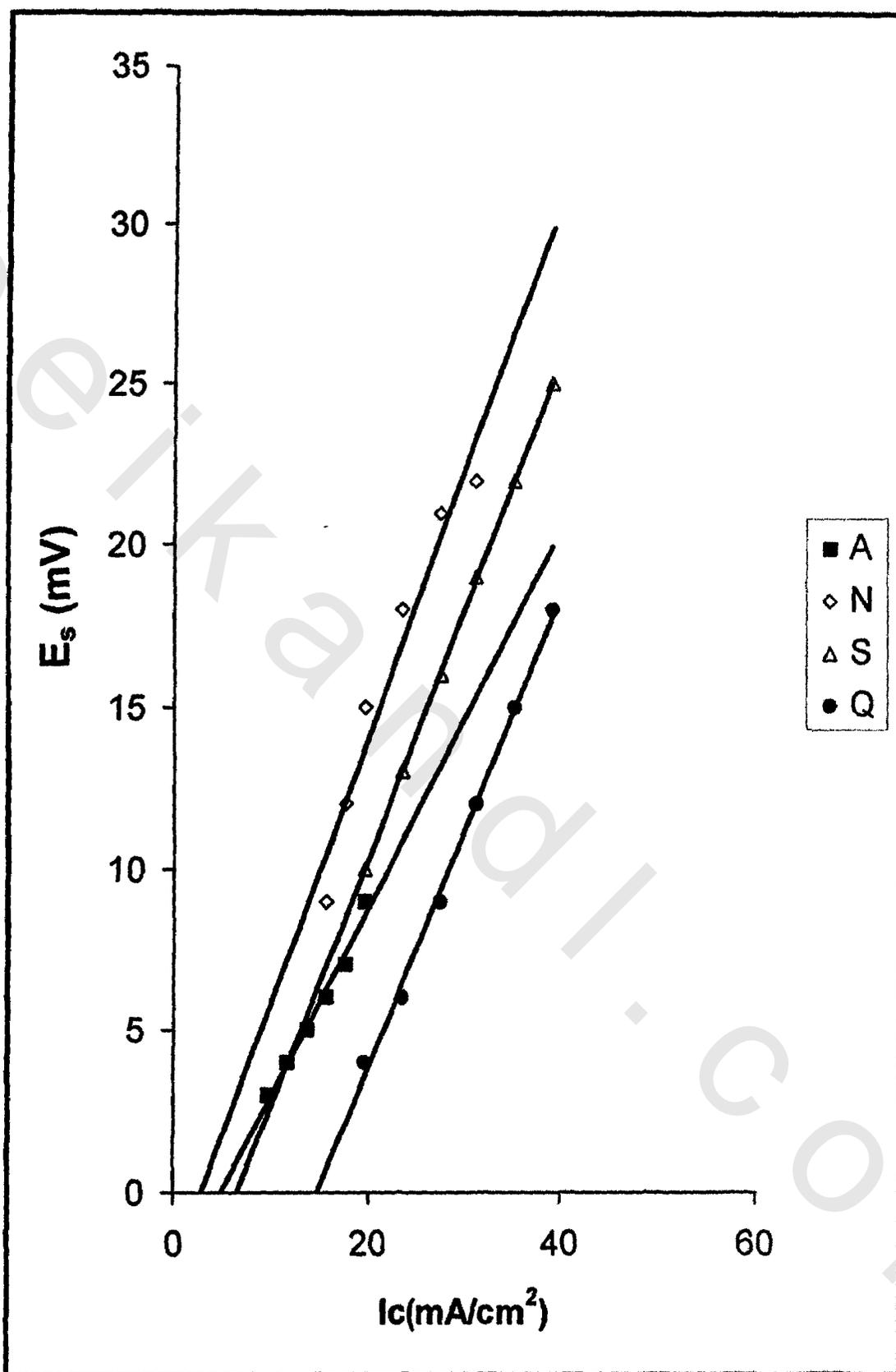
Fig(124):  $E_s$  values vs. cathodic current density ( $I_c$ ) for M.C.V steel samples in 0.1M  $HNO_3$  at 35 °C in presence of  $4 \times 10^{-5}$  M HEAA



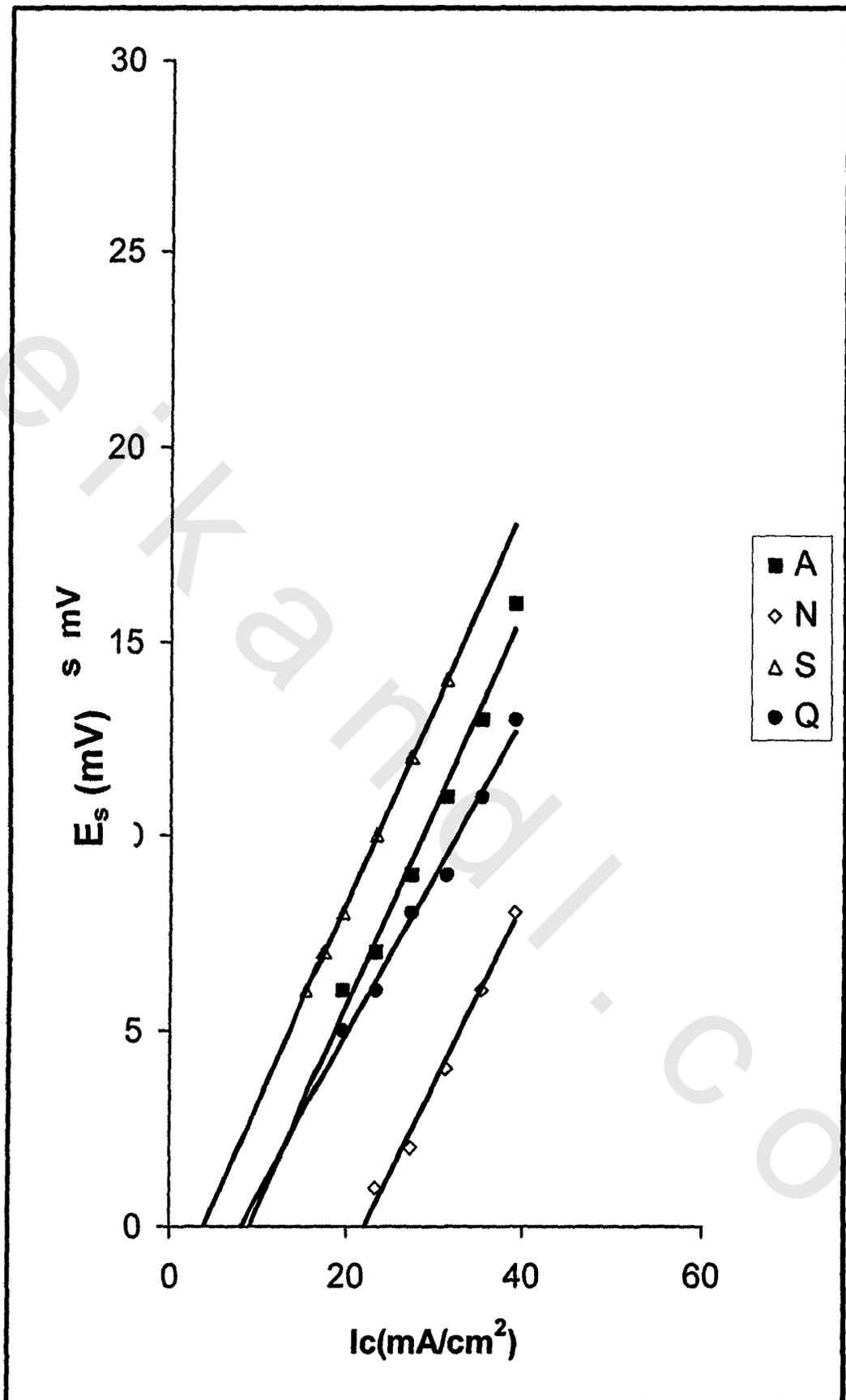
**Fig(125):  $E_s$  values vs. cathodic current density ( $I_c$ ) for M.C.V. steel samples in 0.1M  $HNO_3$  at 35 °C in presence of  $6 \times 10^{-5}$  M HEAA**



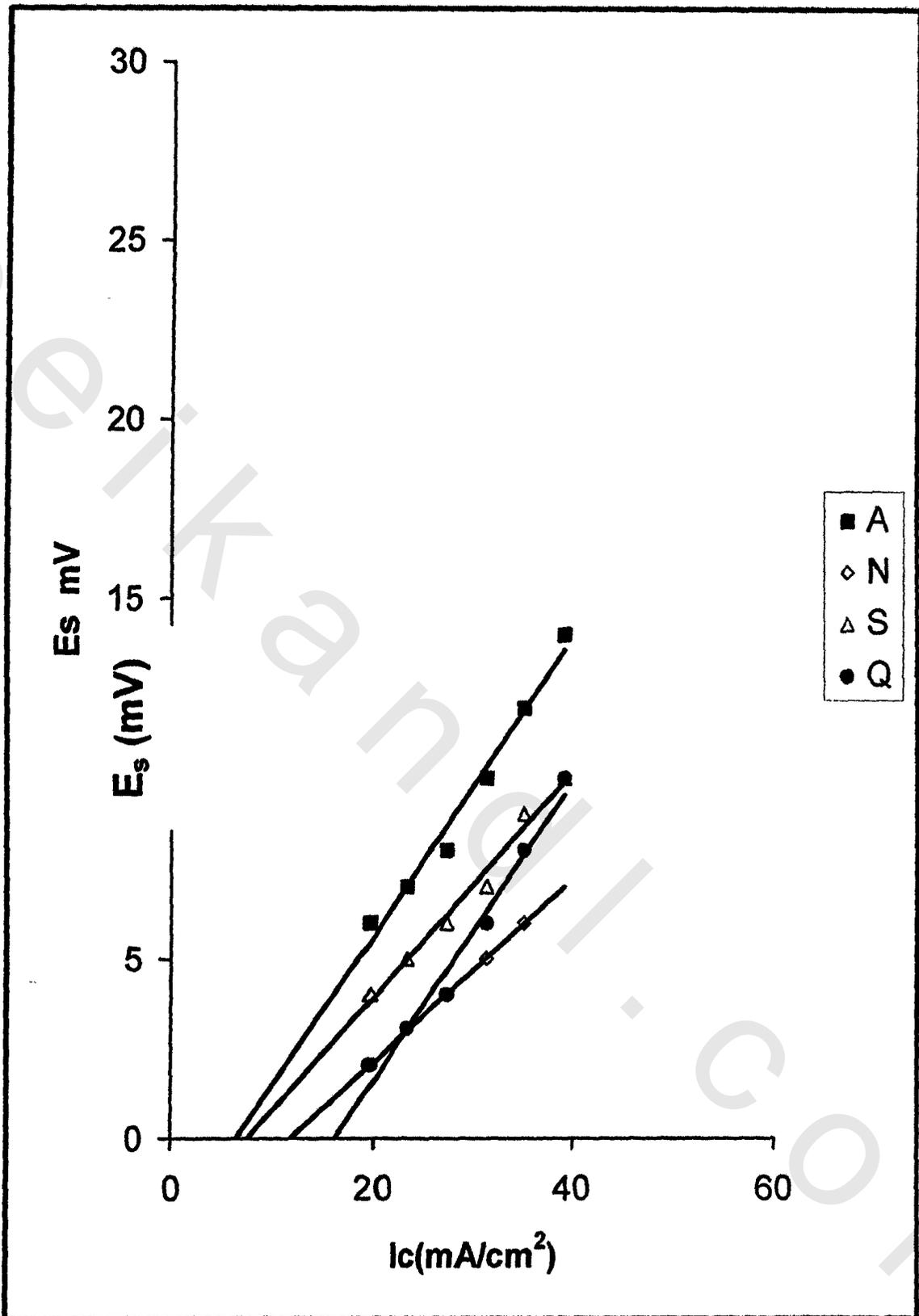
**Fig(126):  $E_s$  values vs. cathodic current density ( $I_c$ ) for M.C.V steel samples in 0.1M HNO<sub>3</sub> at 35 °C in presence of  $8 \times 10^{-5}$  M HEAA**



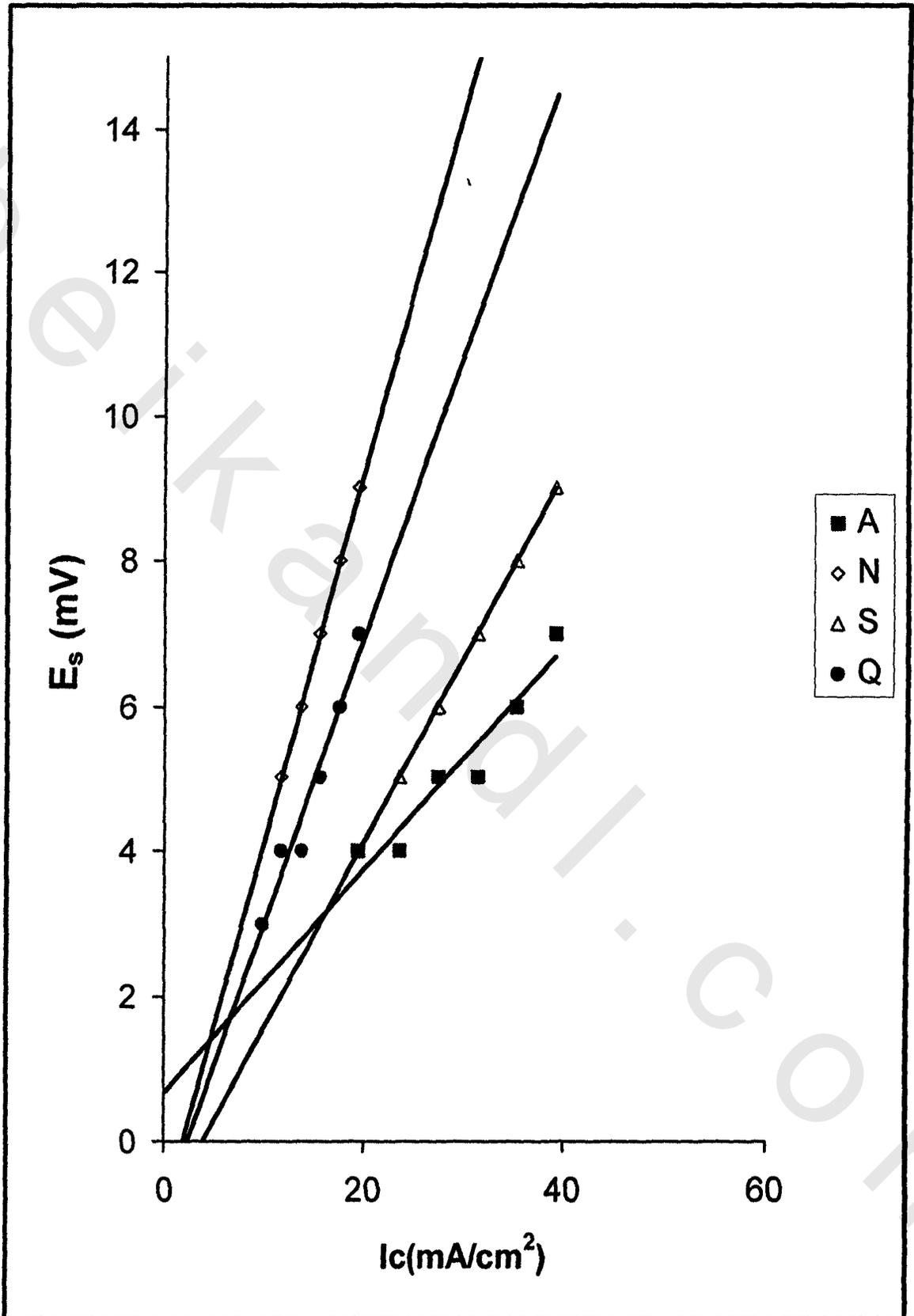
**Fig(127):  $E_s$  values vs. cathodic current density ( $I_c$ ) for M.C.V. steel samples in 0.1M  $\text{HNO}_3$  at 35 °C in presence of  $10^{-4}$  M HEAA**



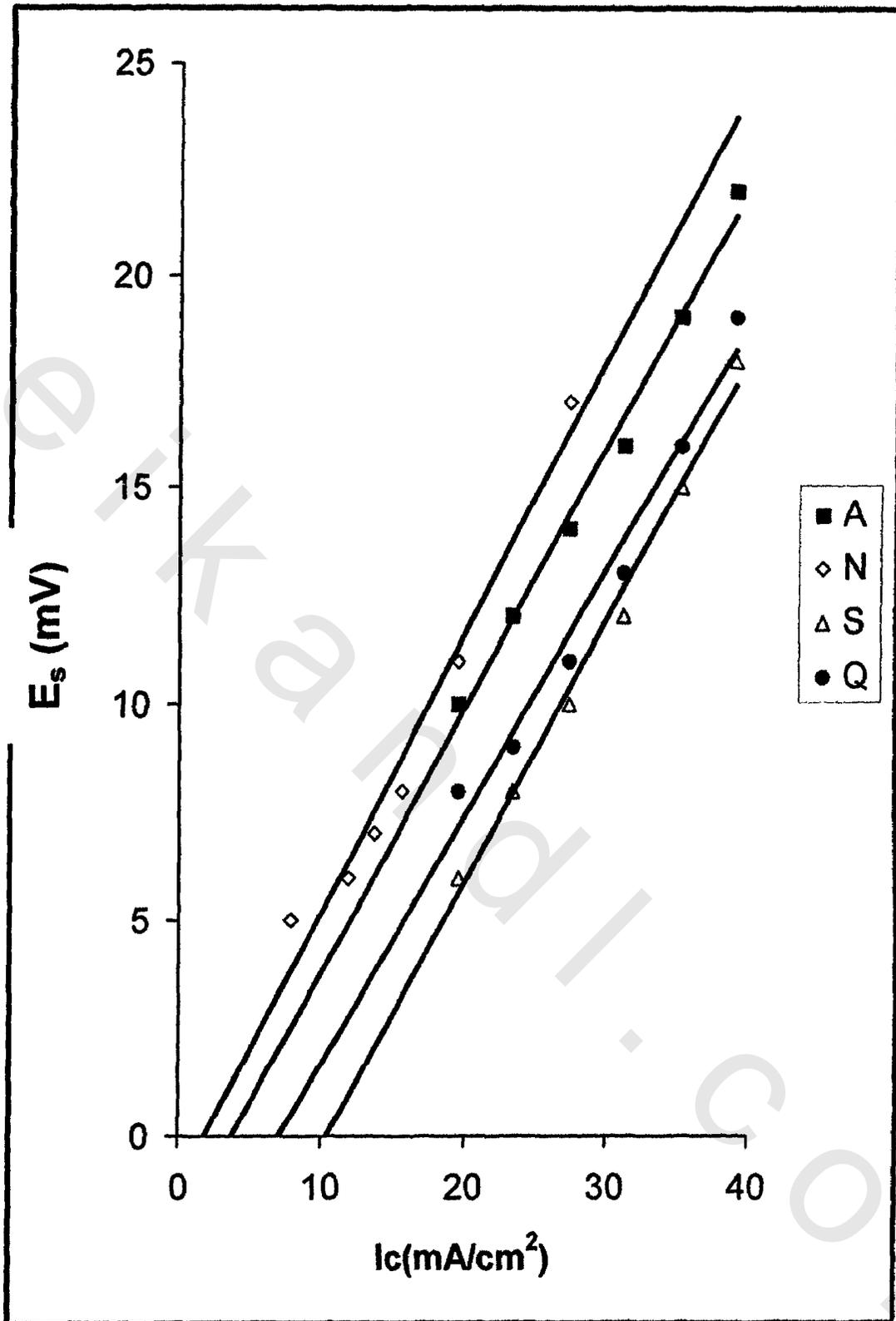
Fig(128):  $E_s$  values vs. cathodic current density ( $I_c$ ) for M.C.V steel samples in 0.1M  $\text{HNO}_3$  at 45°C



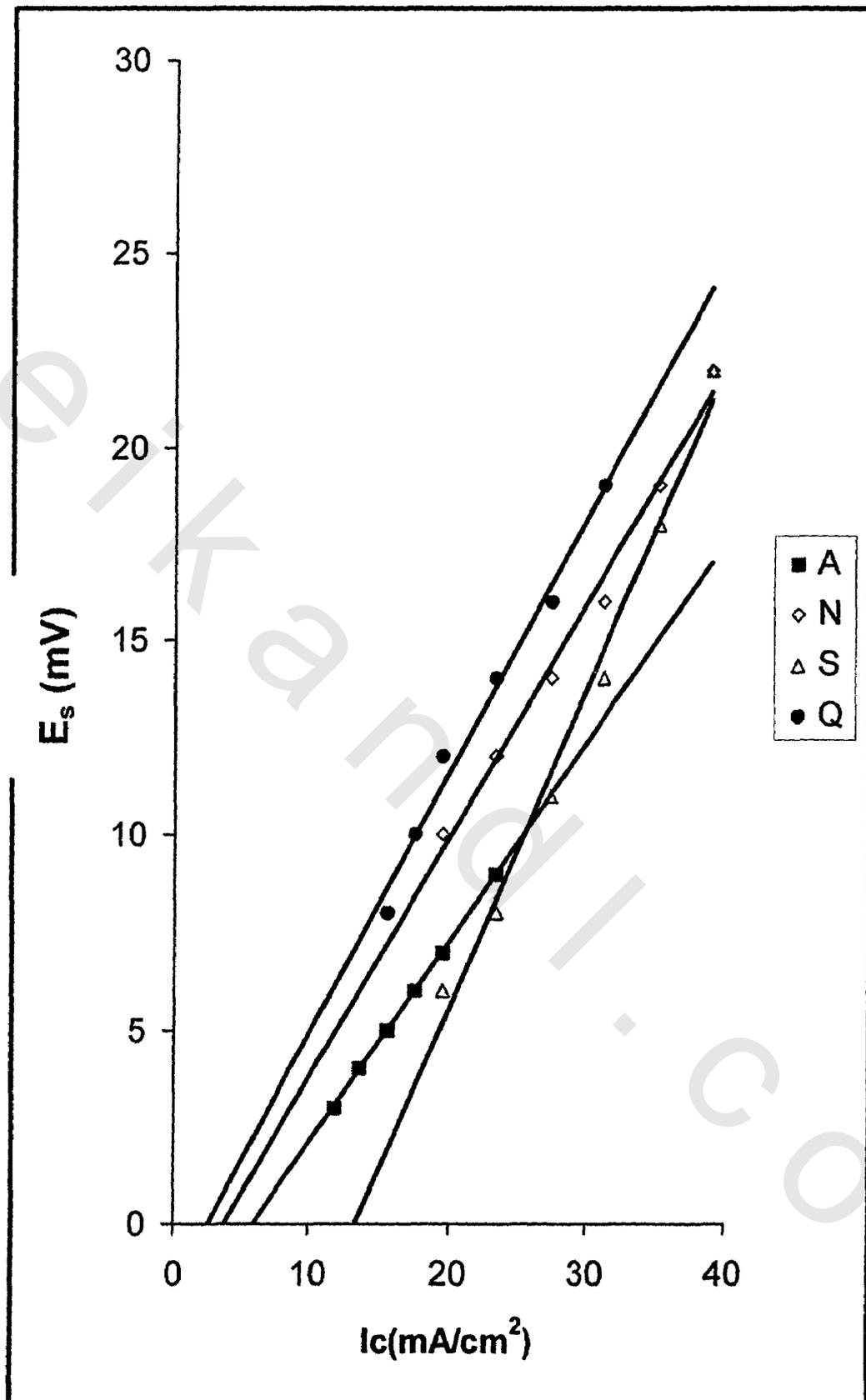
**Fig(129):  $E_s$  values vs. cathodic current density ( $I_c$ ) for M.C.V steel samples in 0.3M HNO<sub>3</sub> at 45 °C**



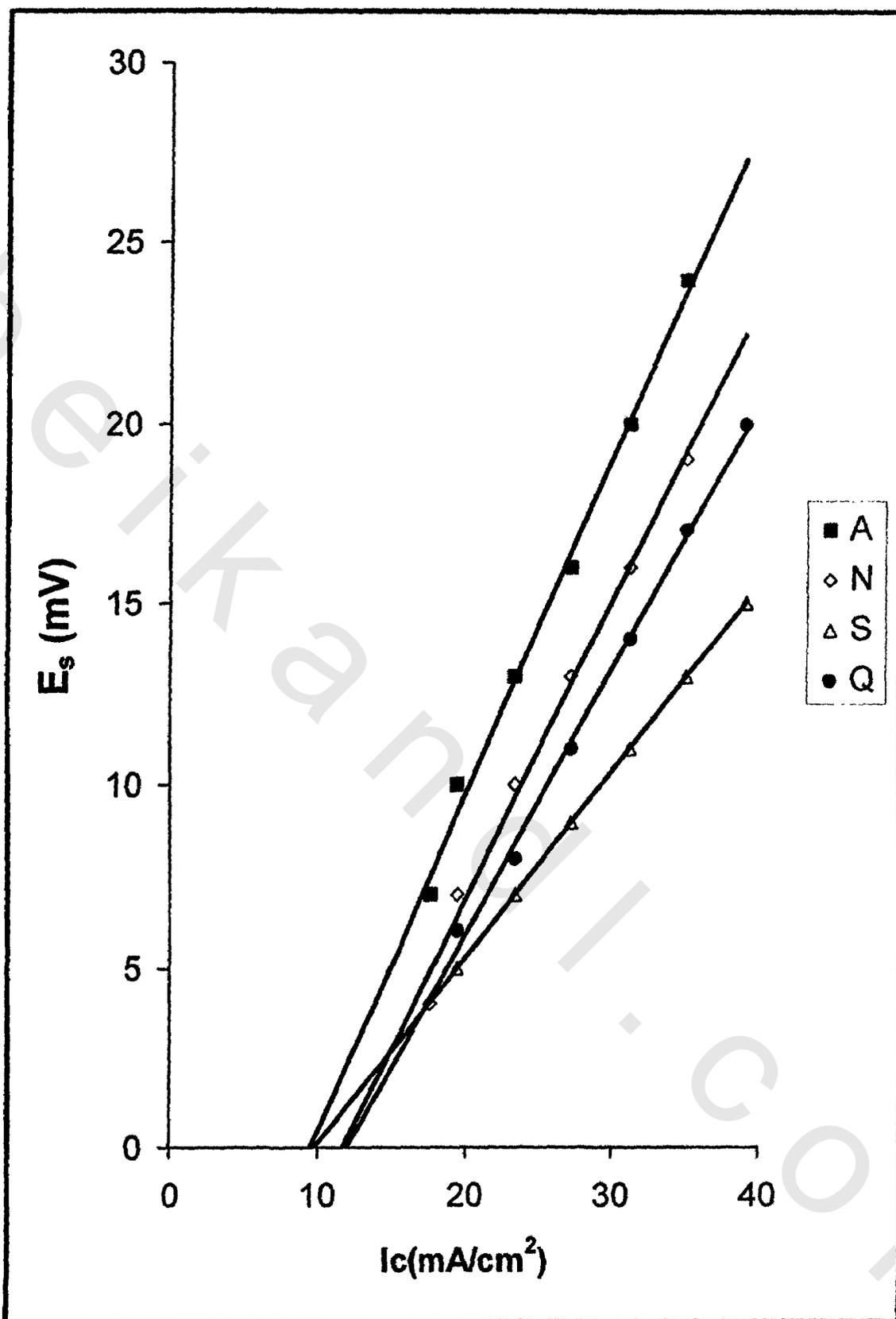
Fig(130):  $E_s$  values vs. cathodic current density ( $I_c$ ) for M.C.V steel samples in 0.5M  $HNO_3$  at 45 °C



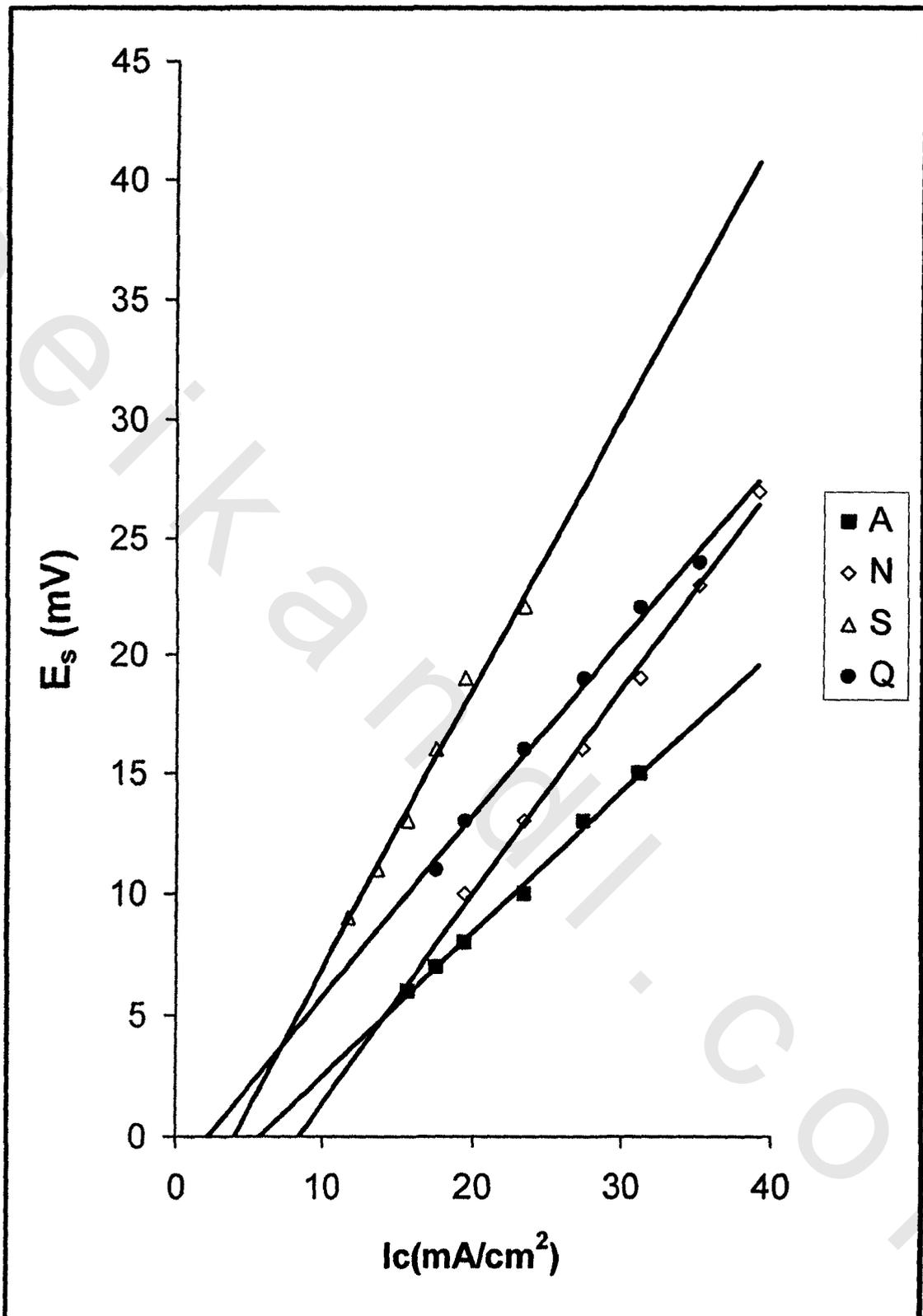
**Fig(131):  $E_s$  values vs. cathodic current density ( $I_c$ ) for M.C.V steel samples in 0.1M  $HNO_3$  at 45 °C in presence of  $2 \times 10^{-5}$  M HEAA**



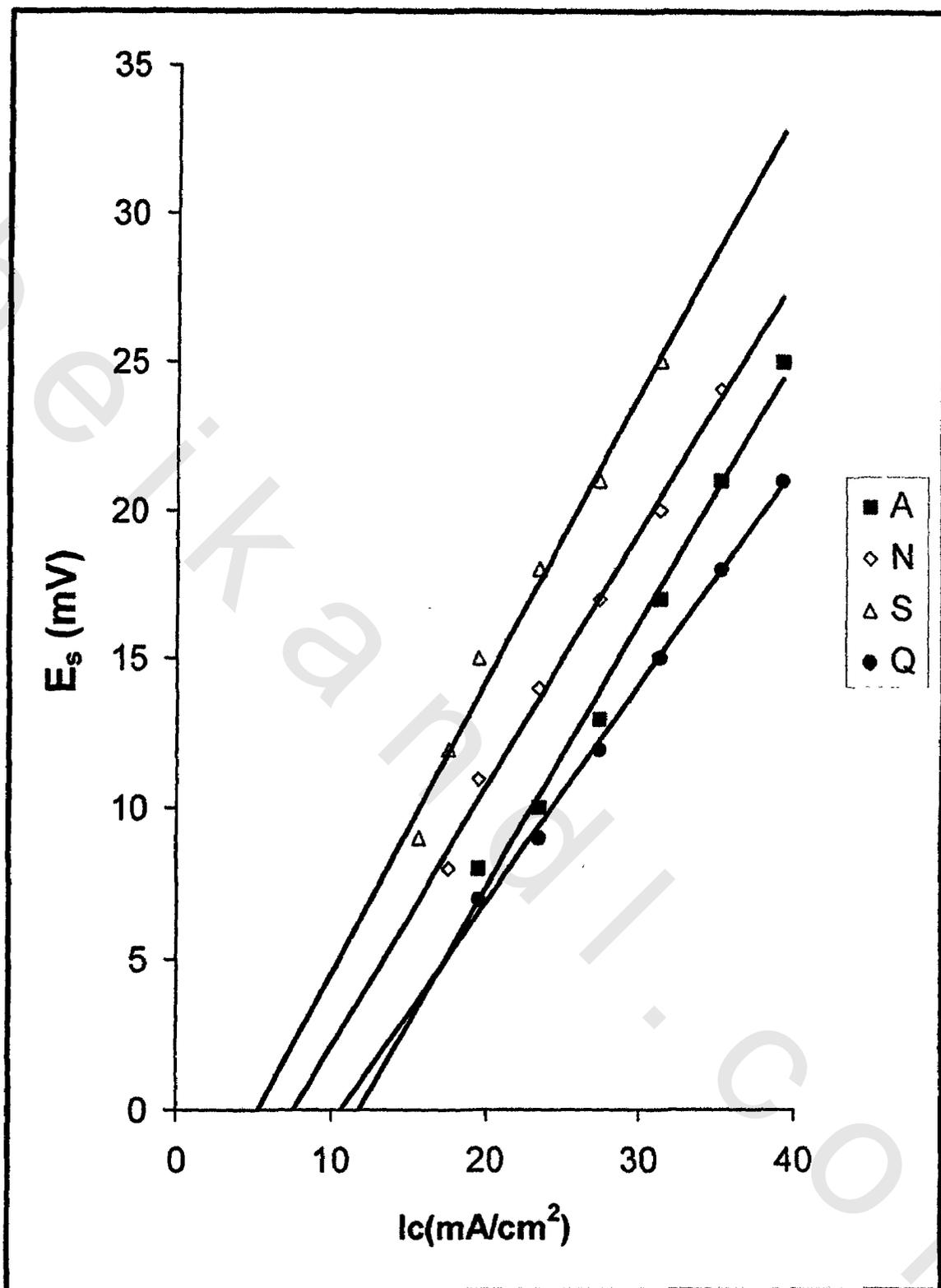
**Fig(132):  $E_s$  values vs. cathodic current density ( $I_c$ ) for M.C.V steel samples in 0.1M  $HNO_3$  at 45 °C in presence of  $4 \times 10^{-5}$  M HEAA**



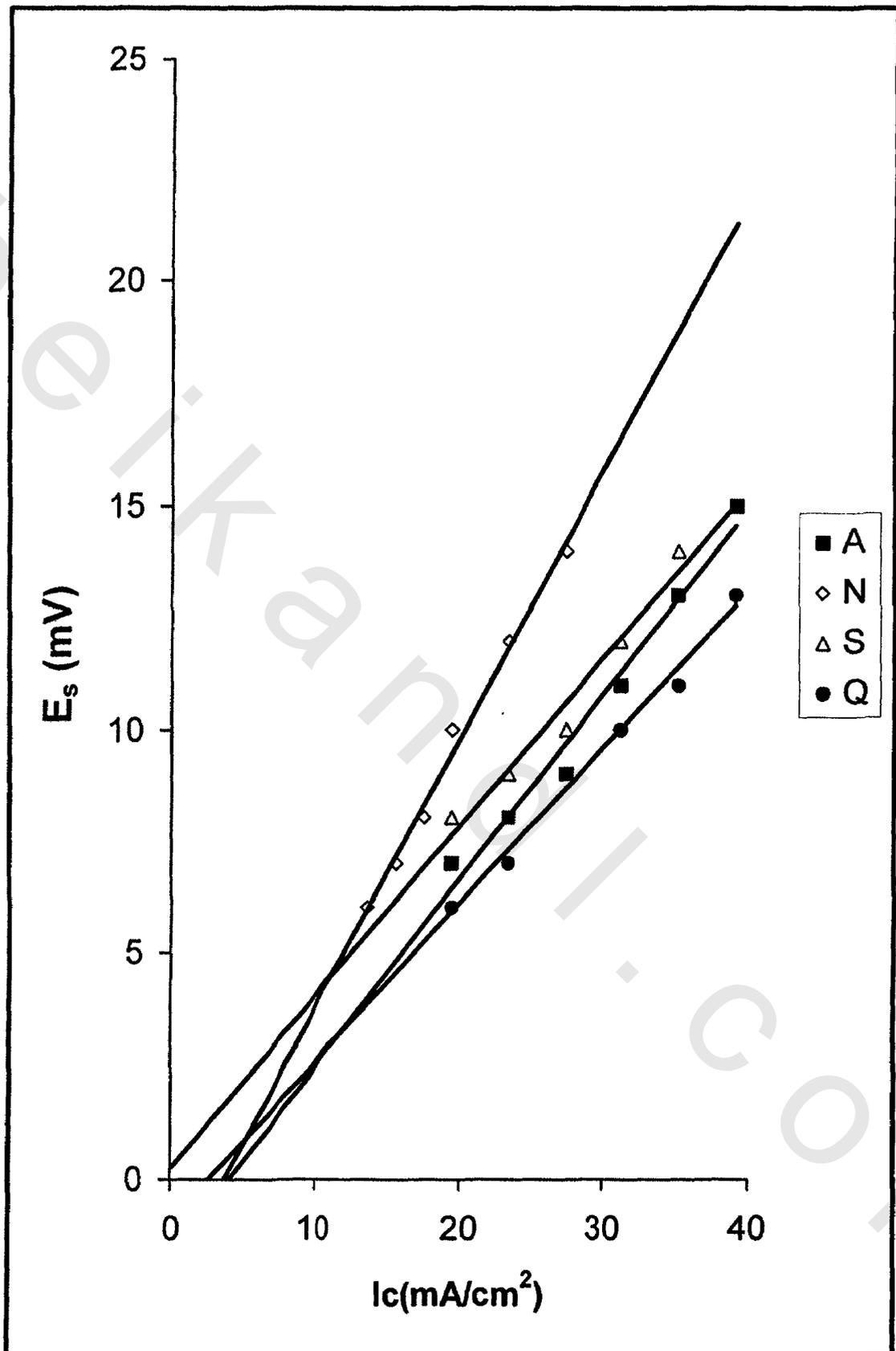
**Fig(133):  $E_s$  values vs. cathodic current density ( $I_c$ ) for M.C.V steel samples in 0.1M HNO<sub>3</sub> at 45 °C in presence of  $6 \times 10^{-5}$  M HEAA**



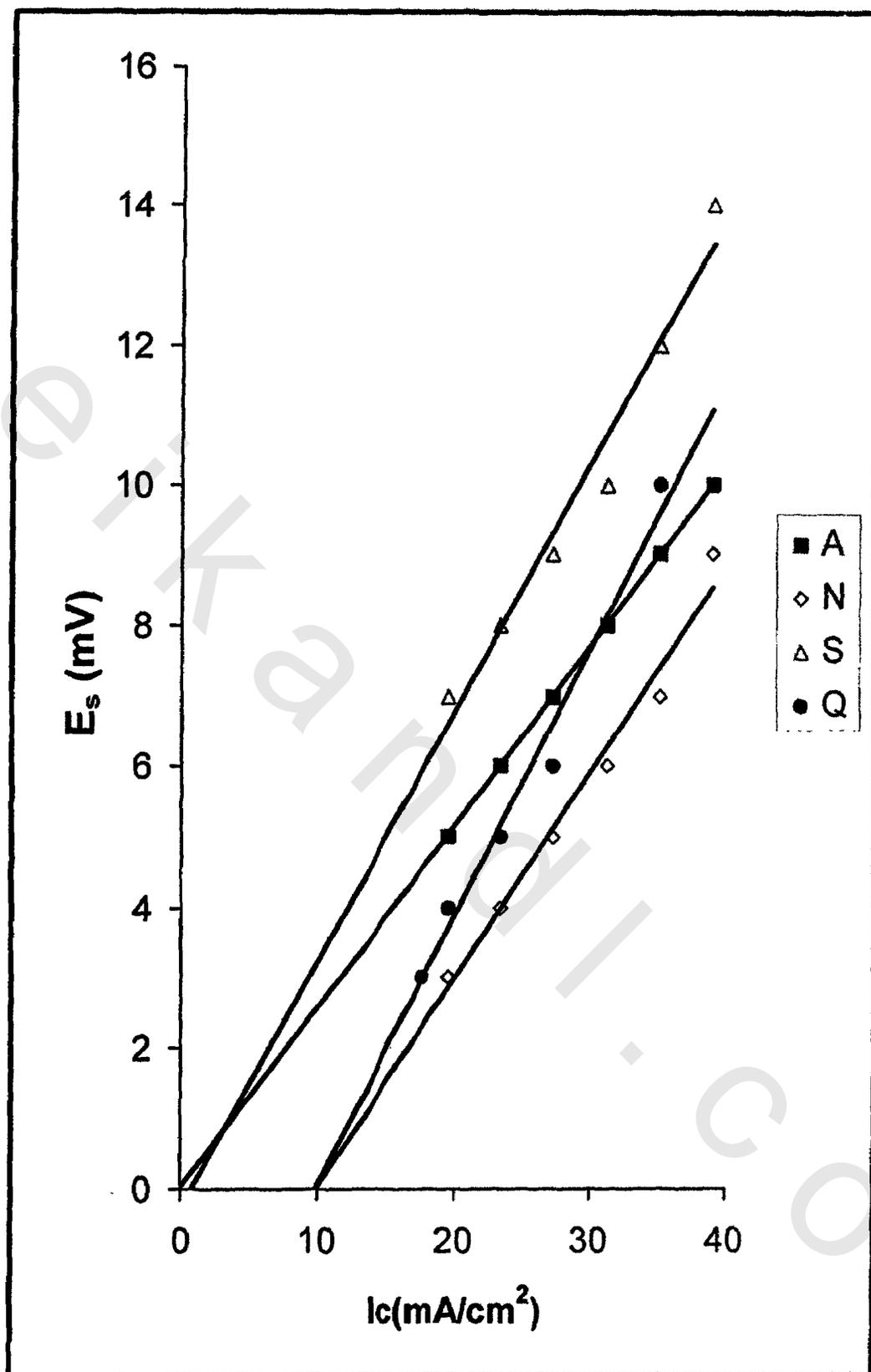
**Fig(134):  $E_s$  values vs. cathodic current density ( $I_c$ ) for M.C.V steel samples in 0.1M  $HNO_3$  at 45 °C in presence of  $8 \times 10^{-5}$  M HEAA**



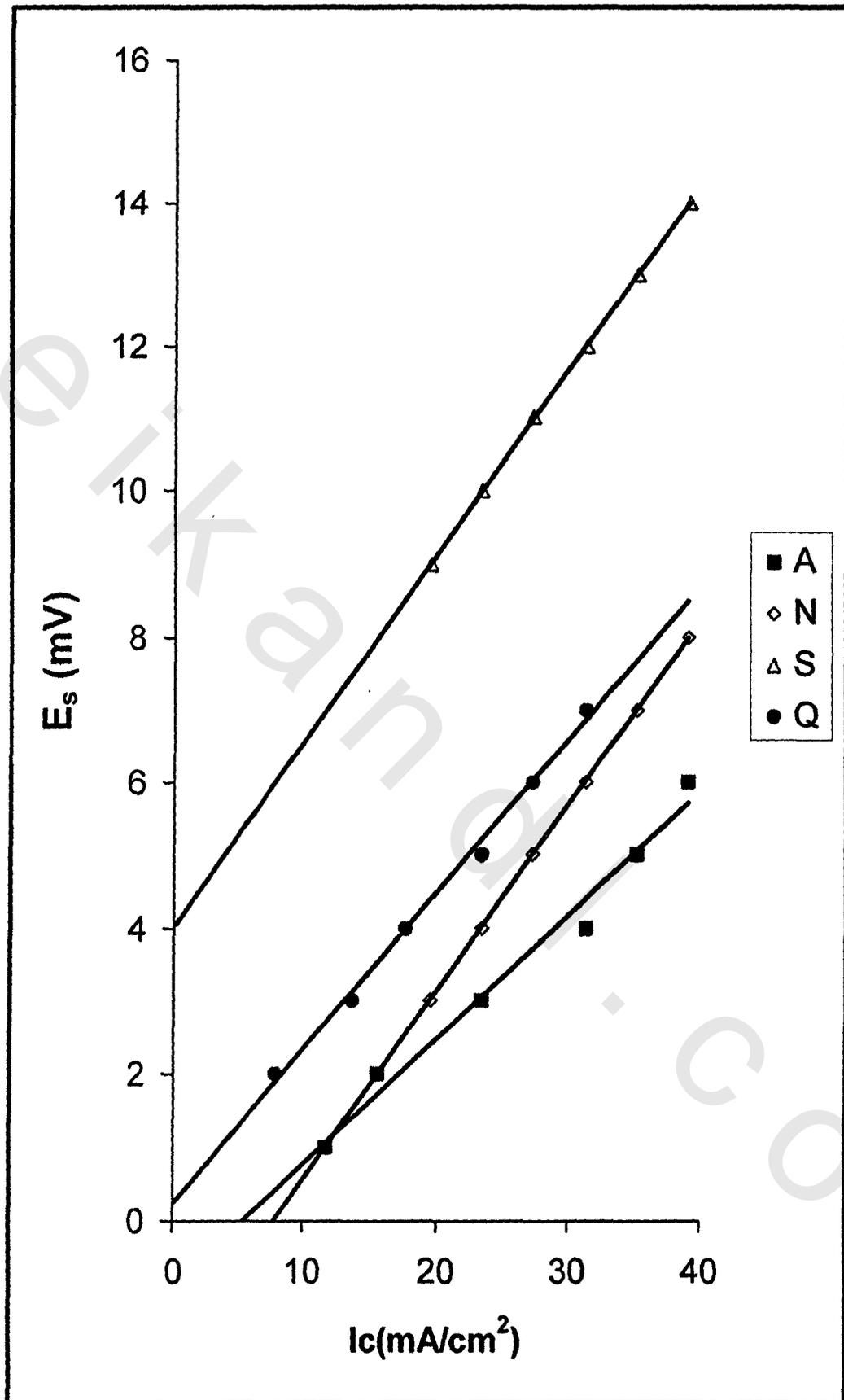
**Fig(135):  $E_s$  values vs. cathodic current density ( $I_c$ ) for M.C.V steel samples in 0.1M  $HNO_3$  at 45 °C in presence of  $10^{-4}$  M HEAA**



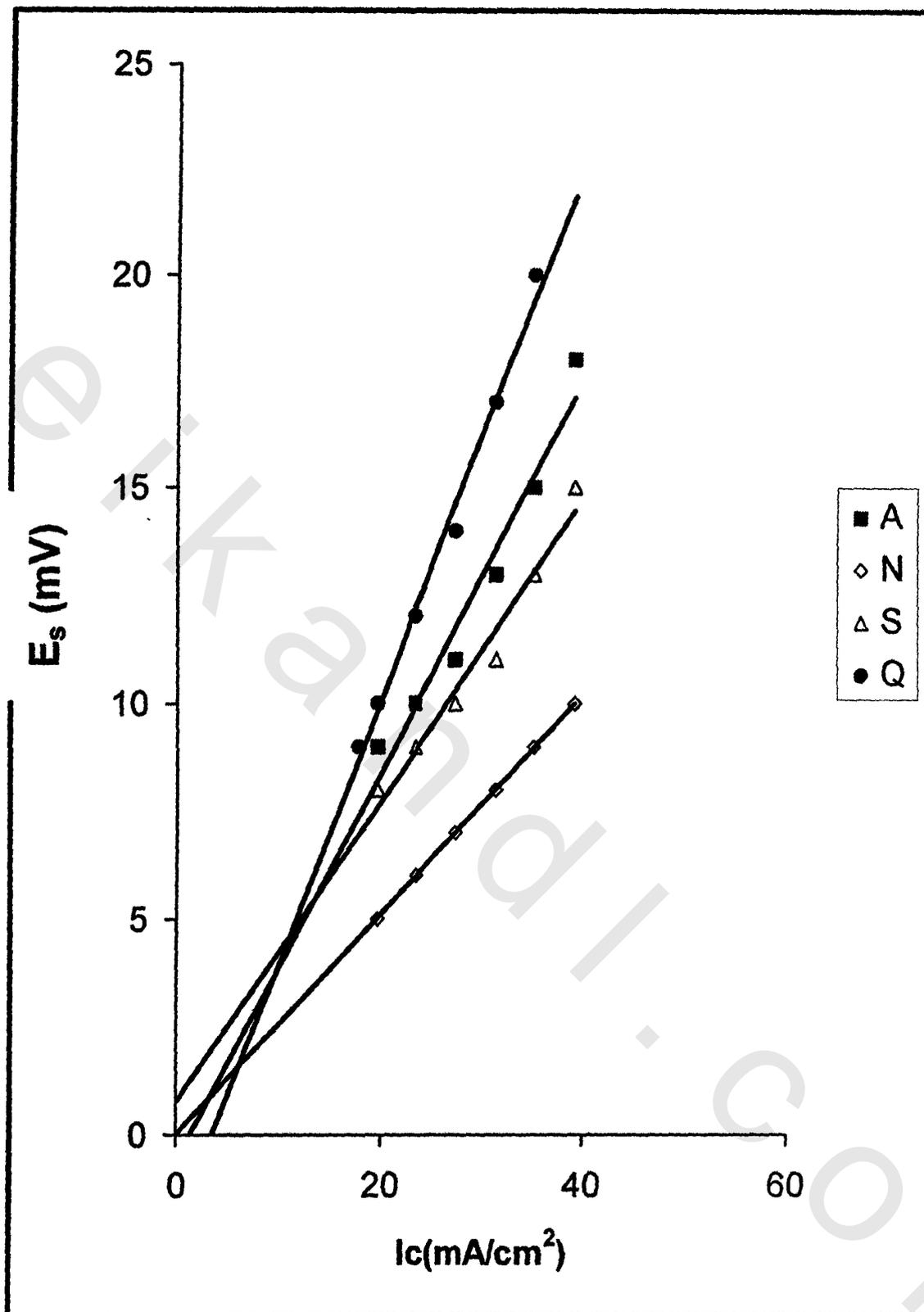
**Fig(136):  $E_s$  values vs. cathodic current density ( $I_c$ ) for M.C.V steel samples in 0.1 M  $HNO_3$  at 55 °C**



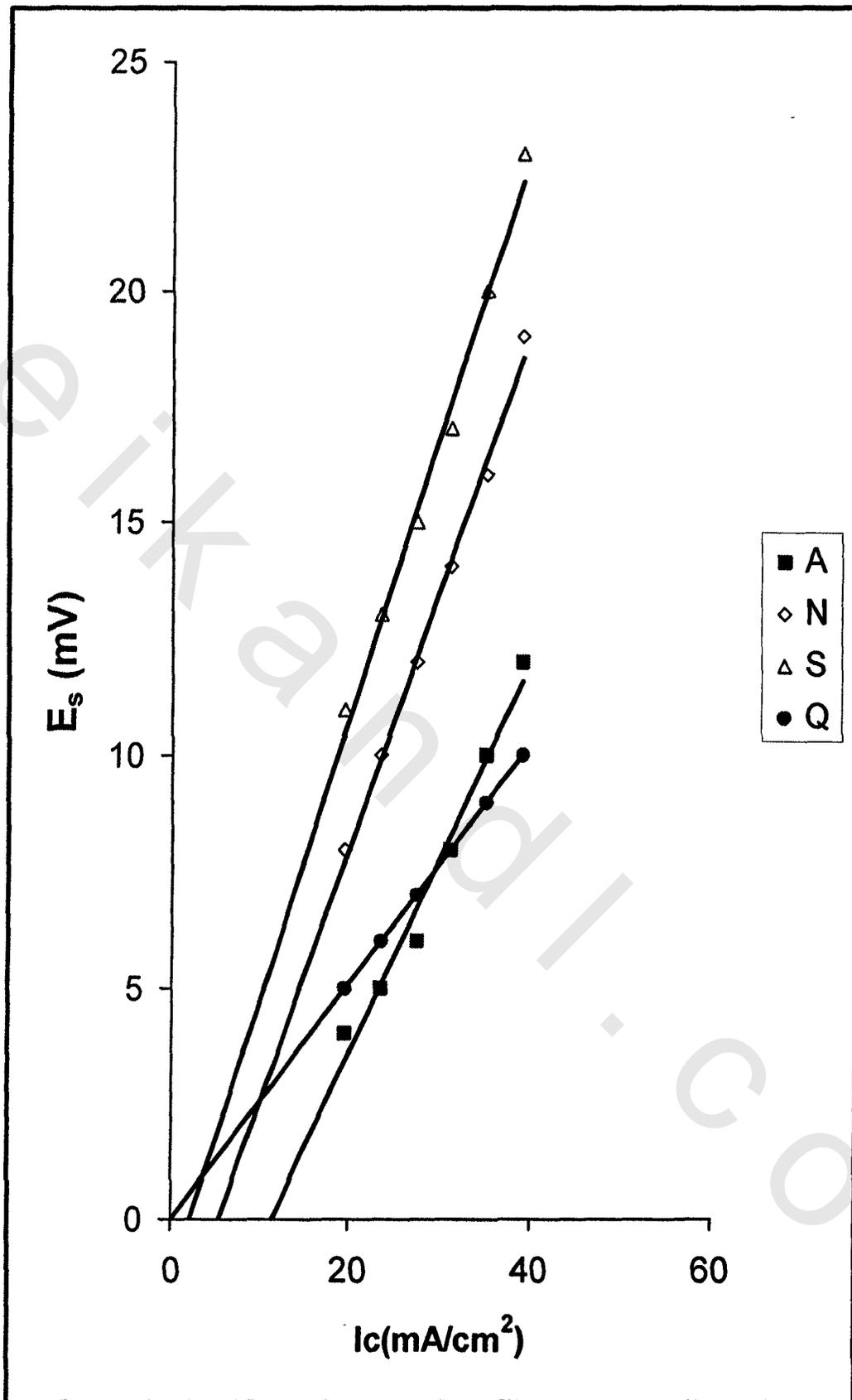
**Fig(137):  $E_s$  values vs. cathodic current density ( $I_c$ ) for M.C.V steel samples in 0.3 M  $\text{HNO}_3$  at 55 °C**



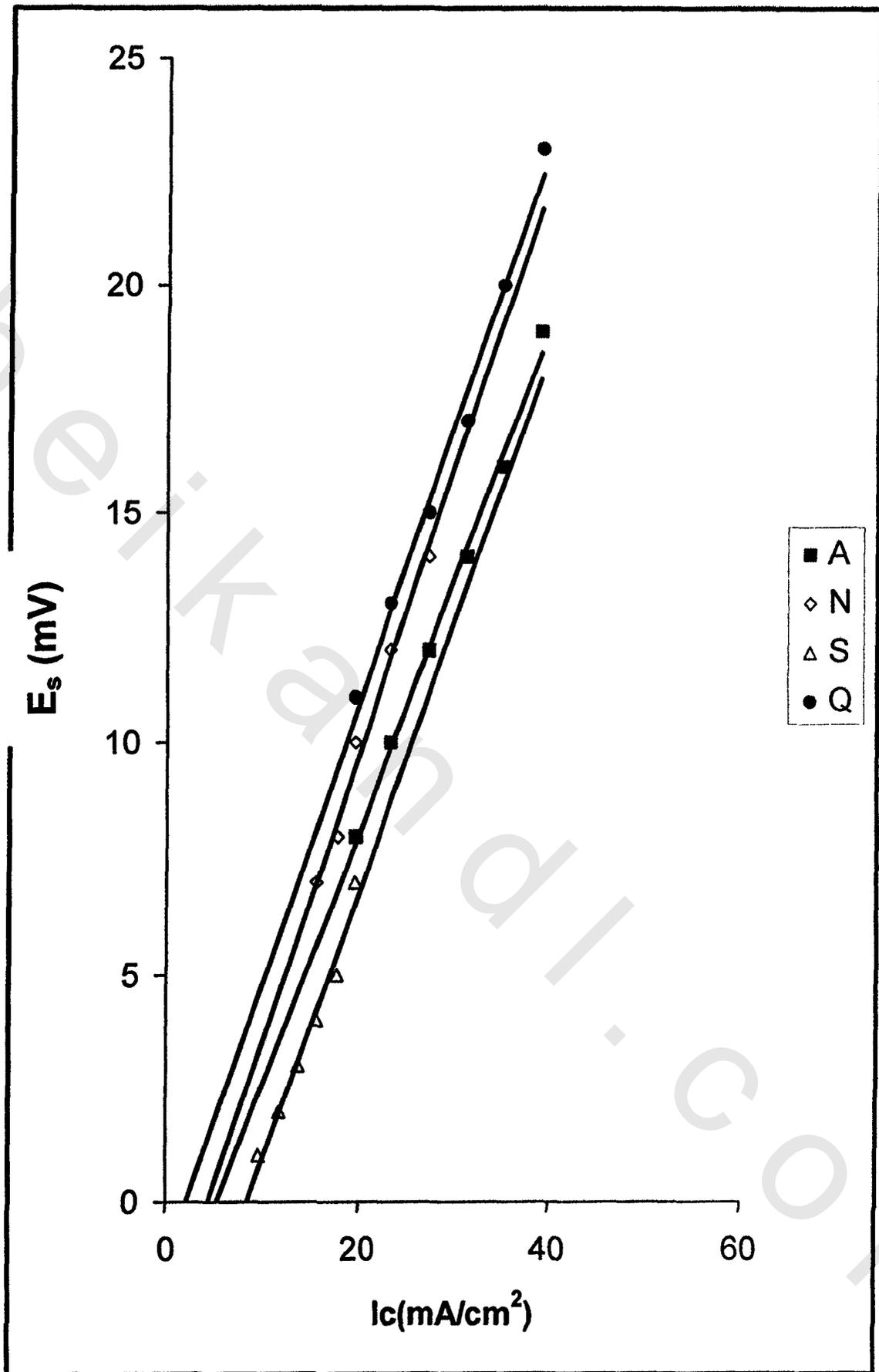
**Fig(138):  $E_s$  values vs. cathodic current density ( $I_c$ ) for M.C.V steel samples in 0.5 M  $HNO_3$  at 55 °C**



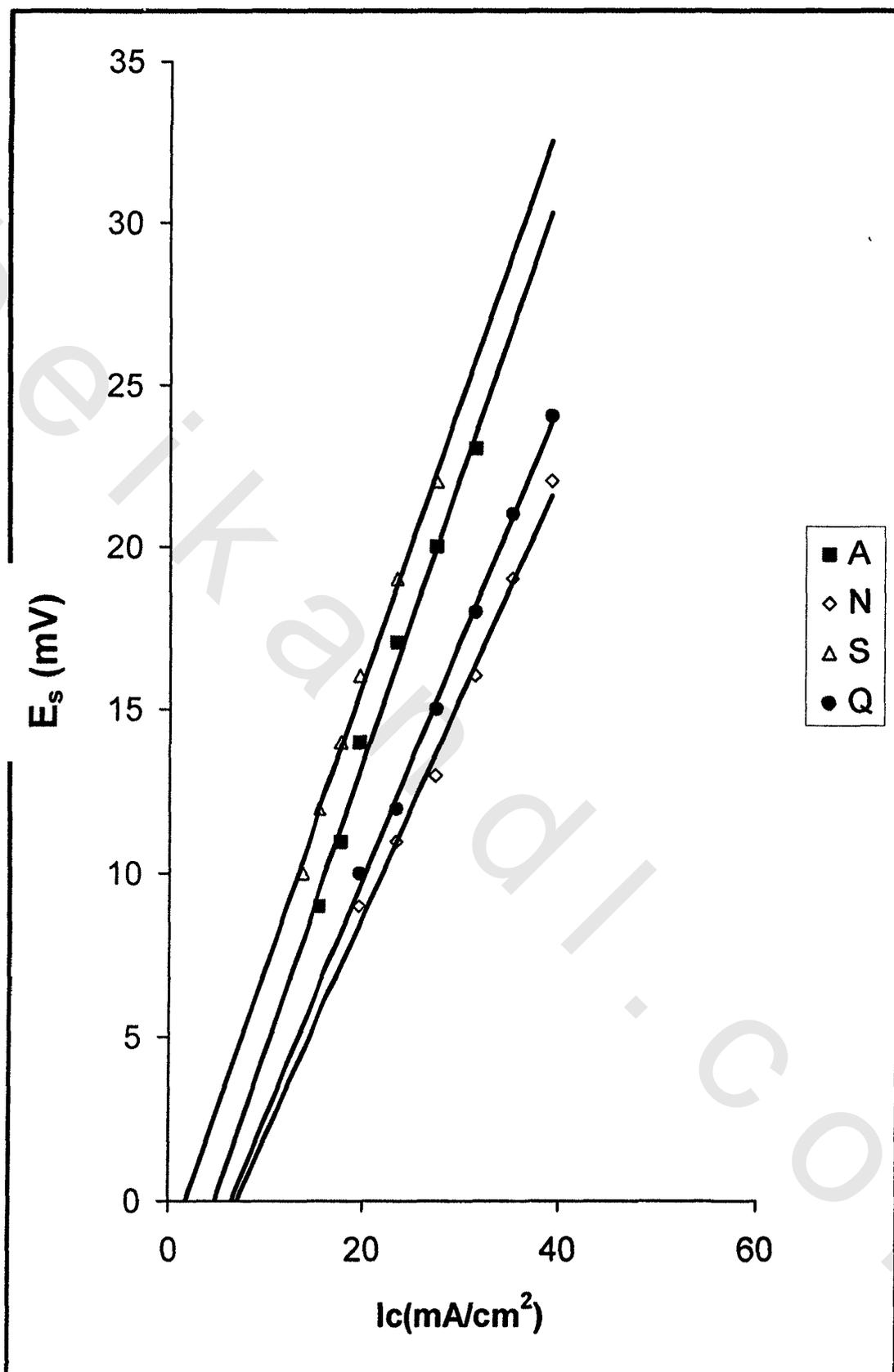
**Fig(139):  $E_s$  values vs. cathodic current density ( $I_c$ ) for M.C.V. steel samples in 0.1M  $HNO_3$  at 55 °C in presence of  $2 \times 10^{-5}$  M HEAA**



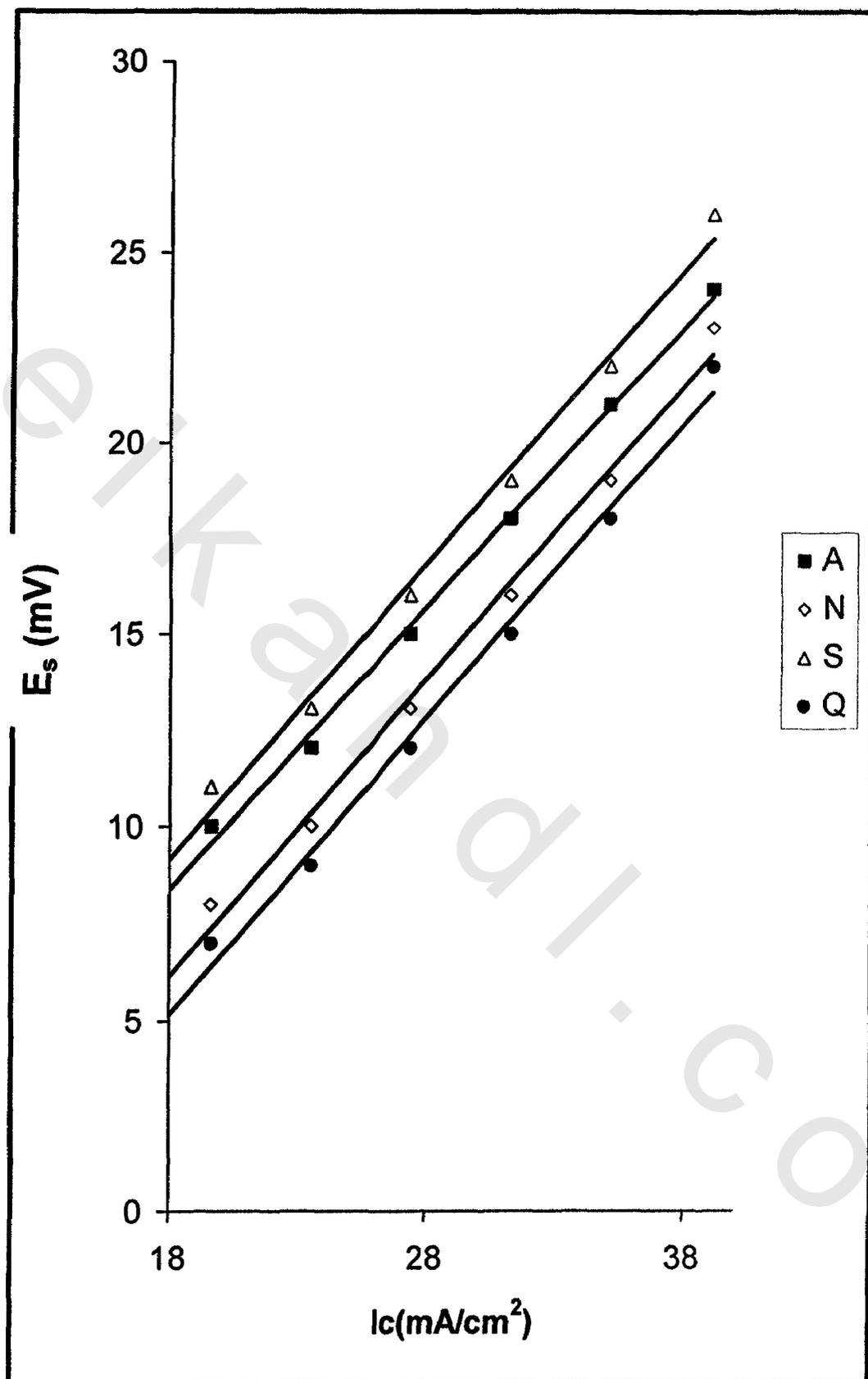
**Fig(140):  $E_s$  values vs. cathodic current density ( $I_c$ ) for M.C.V steel samples in 0.1M  $\text{HNO}_3$  at 55 °C in presence of  $4 \times 10^{-5}$  M HEAA**



**Fig(141):  $E_s$  values vs. cathodic current density ( $I_c$ ) for M.C.V steel samples in 0.1M  $HNO_3$  at 55 °C in presence of  $6 \times 10^{-5}$  M HEAA**



**Fig(142):  $E_s$  values vs. cathodic current density ( $I_c$ ) for M.C.V steel samples in 0.1M  $\text{HNO}_3$  at 55 °C in presence of  $8 \times 10^{-5}$  M HEAA**



**Fig(143):  $E_s$  values vs. cathodic current density ( $I_c$ ) for M.C.V steel samples in 0.1M HNO<sub>3</sub> at 55 °C in presence of 10<sup>-4</sup> M HEAA**

### C) Calculations of the Corrosion rates<sup>(6-13)</sup>

The corrosion rates for all systems, can be determined from the corrosion resistances (it is equal reciprocal of corrosion resistance)<sup>(6-13)</sup>:

$$\text{Corrosion rate} = \frac{1}{\text{Corrosion resistance}} \quad (21)$$

The values of corrosion resistances and corrosion rates for all samples under study are recorded in Tables (2-17).

**Table(2):Corrosion resistance and corrosion rate for L.C.V. steel samples at different concentrations of HNO<sub>3</sub> at 25 °C.**

<b>Sample</b>	<b>[HNO<sub>3</sub>] M</b>	<b>Resistance Ohm</b>	<b>Corr.Rate Ohm<sup>-1</sup></b>
<b>A</b>	<b>0.1</b>	<b>0.51</b>	<b>1.92</b>
	<b>0.3</b>	<b>0.39</b>	<b>2.51</b>
	<b>0.5</b>	<b>0.36</b>	<b>2.75</b>
<b>N</b>	<b>0.1</b>	<b>0.54</b>	<b>1.82</b>
	<b>0.3</b>	<b>0.45</b>	<b>2.18</b>
	<b>0.5</b>	<b>0.35</b>	<b>2.82</b>
<b>S</b>	<b>0.1</b>	<b>0.53</b>	<b>1.85</b>
	<b>0.3</b>	<b>0.42</b>	<b>2.36</b>
	<b>0.5</b>	<b>0.38</b>	<b>2.63</b>
<b>Q</b>	<b>0.1</b>	<b>0.52</b>	<b>1.90</b>
	<b>0.3</b>	<b>0.43</b>	<b>2.27</b>
	<b>0.5</b>	<b>0.41</b>	<b>2.38</b>

**Table(3):Corrosion resistances and corrosion rates for L.C.V steel samples at different concentrations of HNO<sub>3</sub> at 35 °C.**

Sample	[HNO <sub>3</sub> ] M	Resistance Ohm	Corr.Rate Ohm <sup>-1</sup>
A	0.1	0.45	2.19
	0.3	0.34	2.91
	0.5	0.21	4.77
N	0.1	0.44	2.23
	0.3	0.42	2.33
	0.5	0.25	3.92
S	0.1	0.51	1.93
	0.3	0.41	2.42
	0.5	0.37	2.68
Q	0.1	0.47	2.11
	0.3	0.40	2.48
	0.5	0.22	4.45

**Table(4): Corrosion resistances and corrosion rates for L.C.V. steel samples at different concentrations of HNO<sub>3</sub> at 45 °C.**

<b>Sample</b>	<b>[HNO<sub>3</sub>] M</b>	<b>Resistance Ohm</b>	<b>Corr.Rate Ohm<sup>-1</sup></b>
<b>A</b>	<b>0.1</b>	<b>0.38</b>	<b>2.62</b>
	<b>0.3</b>	<b>0.28</b>	<b>3.56</b>
	<b>0.5</b>	<b>0.21</b>	<b>4.58</b>
<b>N</b>	<b>0.1</b>	<b>0.39</b>	<b>2.52</b>
	<b>0.3</b>	<b>0.34</b>	<b>2.88</b>
	<b>0.5</b>	<b>0.16</b>	<b>5.92</b>
<b>S</b>	<b>0.1</b>	<b>0.42</b>	<b>2.32</b>
	<b>0.3</b>	<b>0.32</b>	<b>3.09</b>
	<b>0.5</b>	<b>0.21</b>	<b>4.58</b>
<b>Q</b>	<b>0.1</b>	<b>0.40</b>	<b>2.45</b>
	<b>0.3</b>	<b>0.36</b>	<b>2.70</b>
	<b>0.5</b>	<b>0.18</b>	<b>5.27</b>

**Table(5): Corrosion resistances and corrosion rates for L.C.V. steel samples at different concentrations of HNO<sub>3</sub> at 55 °C.**

Sample	[HNO <sub>3</sub> ] M	Resistance Ohm	Corr.Rate Ohm <sup>-1</sup>
A	0.1	0.42	2.33
	0.3	0.16	5.93
	0.5	0.15	6.35
N	0.1	0.39	2.55
	0.3	0.19	5.07
	0.5	0.18	5.27
S	0.1	0.45	2.18
	0.3	0.27	3.64
	0.5	0.19	5.03
Q	0.1	0.37	2.63
	0.3	0.28	3.54
	0.5	0.17	5.61

**Table(6): Corrosion resistances and corrosion rates for L.C.V. steel samples at different concentrations of HEAA in 0.1 M HNO<sub>3</sub> at 25 °C.**

Sample	[I]X10 <sup>5</sup> M	Resistance Ohm	Corr.Rate Ohm <sup>-1</sup>
A	2	0.69	1.44
	4	0.70	1.42
	6	0.72	1.38
	8	0.78	1.27
	10	0.82	1.21
N	2	0.71	1.40
	4	0.73	1.35
	6	0.80	1.24
	8	0.82	1.21
	10	0.86	1.15
S	2	0.74	1.34
	4	0.76	1.30
	6	0.79	1.25
	8	0.81	1.22
	10	0.85	1.17
Q	2	0.72	1.37
	4	0.73	1.35
	6	0.76	1.30
	8	0.82	1.21
	10	0.83	1.19

**Table(7): Corrosion resistances and corrosion rate for L.C.V. steel samples at different concentrations of HEAA in 0.1 M HNO<sub>3</sub> at 35 °C.**

Sample	[I]X10 <sup>5</sup> M	Resistance Ohm	Corr.Rate Ohm <sup>-1</sup>
A	2	0.53	1.86
	4	0.55	1.82
	6	0.60	1.68
	8	0.63	1.58
	10	0.66	1.49
N	2	0.54	1.82
	4	0.58	1.70
	6	0.62	1.60
	8	0.65	1.52
	10	0.76	1.30
S	2	0.54	1.83
	4	0.60	1.67
	6	0.63	1.58
	8	0.67	1.49
	10	0.71	1.40
Q	2	0.50	1.99
	4	0.57	1.73
	6	0.64	1.53
	8	0.68	1.46
	10	0.71	1.41

**Table( 8 ): Corrosion resistances and corrosion rates for L.C.V. steel samples at different concentrations of HEAA in 0.1 M HNO<sub>3</sub> at 45 °C.**

Sample	[I]X10 <sup>5</sup> M	Resistance Ohm	Corr.Rate Ohm <sup>-1</sup>
A	2	0.44	2.25
	4	0.45	2.18
	6	0.50	1.97
	8	0.67	1.48
	10	0.70	1.42
N	2	0.44	2.25
	4	0.47	2.12
	6	0.60	1.65
	8	0.67	1.47
	10	0.68	1.45
S	2	0.60	1.65
	4	0.63	1.57
	6	0.65	1.52
	8	0.70	1.42
	10	0.71	1.40
Q	2	0.42	2.35
	4	0.44	2.25
	6	0.60	1.64
	8	0.68	1.45
	10	0.70	1.44

**Table( 9 ): Corrosion resistances and corrosion rates for L.C.V steel samples at different concentrations of HEAA in 0.1 M HNO<sub>3</sub> at 55 °C.**

Sample	[I]X10 <sup>5</sup> M	Resistance Ohm	Corr.Rate Ohm <sup>-1</sup>
A	2	0.44	2.25
	4	0.47	2.09
	6	0.57	1.74
	8	0.63	1.57
	10	0.65	1.52
N	2	0.47	2.12
	4	0.51	1.95
	6	0.52	1.88
	8	0.60	1.64
	10	0.63	1.57
S	2	0.46	2.14
	4	0.56	1.78
	6	0.64	1.54
	8	0.66	1.50
	10	0.73	1.35
Q	2	0.48	2.07
	4	0.55	1.80
	6	0.64	1.56
	8	0.68	1.46
	10	0.74	1.33

**Table(10): Corrosion resistances and corrosion rates for M.C.V steel samples at different concentrations of HNO<sub>3</sub> at 25°C**

Sample	[HNO <sub>3</sub> ] M	Resistance Ohm	Corr.Rate Ohm <sup>-1</sup>
A	0.1	0.52	1.92
	0.3	0.46	2.17
	0.5	0.41	2.40
N	0.1	0.57	1.74
	0.3	0.48	2.05
	0.5	0.45	2.18
S	0.1	0.57	1.73
	0.3	0.52	1.90
	0.5	0.44	2.24
Q	0.1	0.66	1.50
	0.3	0.49	2.03
	0.5	0.42	2.35

**Table( 11 ): Corrosion resistances and corrosion rates for M.C.V. steel samples at different concentrations of HNO<sub>3</sub> at 35°C**

<b>Sample</b>	<b>[HNO<sub>3</sub>] M</b>	<b>Resistance Ohm</b>	<b>Corr.Rate Ohm<sup>-1</sup></b>
<b>A</b>	<b>0.1</b>	<b>0.48</b>	<b>2.07</b>
	<b>0.3</b>	<b>0.37</b>	<b>2.66</b>
	<b>0.5</b>	<b>0.23</b>	<b>4.31</b>
<b>N</b>	<b>0.1</b>	<b>0.50</b>	<b>1.99</b>
	<b>0.3</b>	<b>0.43</b>	<b>2.32</b>
	<b>0.5</b>	<b>0.32</b>	<b>3.12</b>
<b>S</b>	<b>0.1</b>	<b>0.48</b>	<b>2.06</b>
	<b>0.3</b>	<b>0.45</b>	<b>2.18</b>
	<b>0.5</b>	<b>0.27</b>	<b>3.60</b>
<b>Q</b>	<b>0.1</b>	<b>0.50</b>	<b>1.96</b>
	<b>0.3</b>	<b>0.37</b>	<b>2.63</b>
	<b>0.5</b>	<b>0.32</b>	<b>3.03</b>

**Table(12 ): Corrosion resistances and corrosion rates for M.C.V steel samples at different concentrations of HNO<sub>3</sub> at 45 °C**

<b>Sample</b>	<b>[HNO<sub>3</sub>] M</b>	<b>Resistance Ohm</b>	<b>Corr.Rate Ohm<sup>-1</sup></b>
<b>A</b>	<b>0.1</b>	<b>0.36</b>	<b>2.74</b>
	<b>0.3</b>	<b>0.32</b>	<b>3.03</b>
	<b>0.5</b>	<b>0.16</b>	<b>6.17</b>
<b>N</b>	<b>0.1</b>	<b>0.46</b>	<b>2.17</b>
	<b>0.3</b>	<b>0.24</b>	<b>4.13</b>
	<b>0.5</b>	<b>0.23</b>	<b>4.31</b>
<b>S</b>	<b>0.1</b>	<b>0.38</b>	<b>2.56</b>
	<b>0.3</b>	<b>0.25</b>	<b>3.90</b>
	<b>0.5</b>	<b>0.22</b>	<b>4.48</b>
<b>Q</b>	<b>0.1</b>	<b>0.35</b>	<b>2.86</b>
	<b>0.3</b>	<b>0.32</b>	<b>3.07</b>
	<b>0.5</b>	<b>0.19</b>	<b>5.21</b>

**Table(13): Corrosion resistances and corrosion rates for M.C.V steel samples at different concentrations of HNO<sub>3</sub> at 55 °C**

<b>Sample</b>	<b>[I]X10<sup>4</sup> M</b>	<b>Resistance Ohm</b>	<b>Corr.Rate Ohm<sup>-1</sup></b>
<b>A</b>	<b>0.1</b>	<b>0.36</b>	<b>2.77</b>
	<b>0.3</b>	<b>0.27</b>	<b>3.59</b>
	<b>0.5</b>	<b>0.16</b>	<b>6.22</b>
<b>N</b>	<b>0.1</b>	<b>0.38</b>	<b>2.58</b>
	<b>0.3</b>	<b>0.22</b>	<b>4.53</b>
	<b>0.5</b>	<b>0.23</b>	<b>4.25</b>
<b>S</b>	<b>0.1</b>	<b>0.40</b>	<b>2.45</b>
	<b>0.3</b>	<b>0.36</b>	<b>2.77</b>
	<b>0.5</b>	<b>0.28</b>	<b>3.49</b>
<b>Q</b>	<b>0.1</b>	<b>0.34</b>	<b>2.89</b>
	<b>0.3</b>	<b>0.25</b>	<b>3.89</b>
	<b>0.5</b>	<b>0.17</b>	<b>5.57</b>

**Table( 14 ): Corrosion resistances and corrosion rates of M.C.V. steel samples at different concentrations of HEAA in 0.1M HNO<sub>3</sub> at 25 °C**

Sample	[I]X10 <sup>5</sup> M	Resistance Ohm	Corr.Rate Ohm <sup>-1</sup>
A	2	0.72	1.38
	4	0.75	1.33
	6	0.79	1.25
	8	0.83	1.21
	10	0.91	1.10
N	2	0.72	1.37
	4	0.79	1.26
	6	0.81	1.23
	8	0.84	1.18
	10	0.94	1.06
S	2	0.73	1.37
	4	0.77	1.30
	6	0.81	1.24
	8	0.86	1.15
	10	0.93	1.07
Q	2	0.74	1.35
	4	0.78	1.28
	6	0.80	1.24
	8	0.85	1.17
	10	0.91	1.10

**Table(15): Corrosion resistances and corrosion rates of M.C.V. steel samples at different concentrations of HEAA in 0.1M HNO<sub>3</sub> at 35 °C**

Sample	[I]X10 <sup>5</sup> M	Resistance Ohm	Corr.Rate Ohm <sup>-1</sup>
A	2	0.52	1.90
	4	0.55	1.82
	6	0.66	1.49
	8	0.71	1.40
	10	0.77	1.29
N	2	0.54	1.84
	4	0.63	1.59
	6	0.64	1.56
	8	0.66	1.51
	10	0.70	1.45
S	2	0.52	1.90
	4	0.63	1.57
	6	0.66	1.50
	8	0.80	1.23
	10	0.84	1.19
Q	2	0.54	1.84
	4	0.60	1.67
	6	0.68	1.45
	8	0.71	1.42
	10	0.73	1.35

**Table(16 ): Corrosion resistances and corrosion rates of M.C.V. steel samples at different concentrations of HEAA in 0.1M HNO<sub>3</sub> at 45 °C**

Sample	[I]X10 <sup>5</sup> M	Resistance Ohm	Corr.Rate Ohm <sup>-1</sup>
A	2	0.57	1.74
	4	0.59	1.70
	6	0.63	1.56
	8	0.67	1.49
	10	0.72	1.38
N	2	0.50	1.98
	4	0.59	1.67
	6	0.63	1.56
	8	0.68	1.45
	10	0.74	1.34
S	2	0.51	1.93
	4	0.56	1.77
	6	0.64	1.53
	8	0.70	1.43
	10	0.78	1.27
Q	2	0.54	1.84
	4	0.57	1.75
	6	0.64	1.55
	8	0.68	1.46
	10	0.71	1.40

**Table(17): Corrosion resistances and corrosion rates of M.C.V. steel samples at different concentrations of HEAA in 0.1M HNO<sub>3</sub> at 55°C**

Sample	[I]X10 <sup>5</sup> M	Resistance Ohm	Corr.Rate Ohm <sup>-1</sup>
A	2	0.46	2.17
	4	0.54	1.82
	6	0.59	1.68
	8	0.63	1.56
	10	0.67	1.49
N	2	0.47	2.11
	4	0.49	2.05
	6	0.52	1.89
	8	0.63	1.58
	10	0.66	1.54
S	2	0.46	2.14
	4	0.57	1.73
	6	0.61	1.64
	8	0.70	1.43
	10	0.76	1.31
Q	2	0.46	2.14
	4	0.60	1.64
	6	0.63	1.57
	8	0.68	1.45
	10	0.71	1.40