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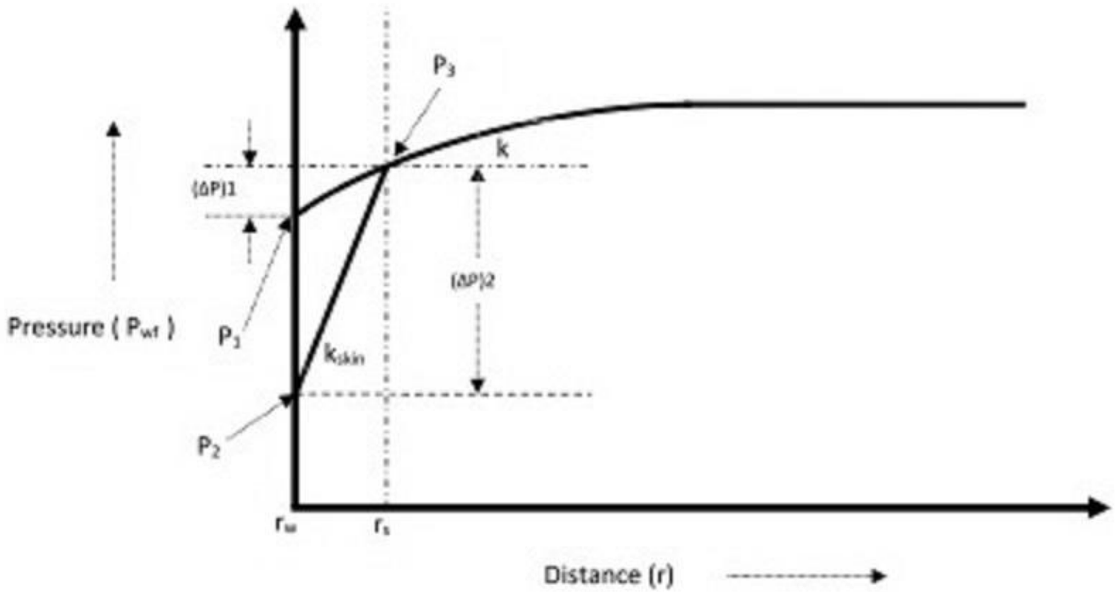
8:30 Am

Hawkins (1956), suggested that the permeability in the skin zone, i.e., k_{skin}, is uniform and the pressure drop across the zone can be approximated by **Darcy's** equation. **Hawkins** proposed the following approach as shown in below figure:

$$\Delta p_{skin} = [\Delta p \text{ in skin zone due to } k_{skin} - \Delta p \text{ in skin zone due to } k]$$



$$\Delta P\, s. = (\Delta P_2 - \Delta P_1) = (P_3 - P_2) - (P_3 - P_1) \ldots\ldots (1)$$

or

$$\Delta P\, s. = (P_1 - P_2) \ldots\ldots (2)$$

<u>Where:</u>

ΔP_2 = pressure drop in the altered zone around the well bore (r_s, k_{skin}).

ΔP_1 = pressure drop in the undamaged zone (r_s, k).

Apply **Darcy's law** for radial-steady state flow with field units.

$$Q = 7.08 * 10^{-3} \frac{k * h * (P \quad - P \quad)}{\mu o * B \; * \ln(r_e / r_w)}$$

p_{wf} = flowing bottom hole (well bore) pressure, psi.

$$\Delta P_1 = 141.2\ \frac{Q_o\ \mu_o\ B_o \ln(r_s/r_w)}{kh} \qquad \text{.........(3)}$$

$$\Delta P_2 = 141.2\ \frac{Q_o\ \mu_o\ B_o \ln(r_s/r_w)}{k_{skin}h} \qquad \text{.........(4)}$$

Substitute Eq. (3) & (4) in Eq. (1)

$$\Delta P\,s. \quad = (\Delta P_2 - \Delta P_1) = (P_3 - P_2) - (P_3 - P_1) \ldots\ldots\ldots(1)$$

$$\Delta P_{skin} = 141.2\ Q_o\ \mu_o\ B_o \ln(r_s/r_w) / k_{skin}h \ - 141.2\ Q_o\ \mu_o\ B_o \ln(r_s/r_w) / kh$$

$$\Delta P_{skin} = 141.2\ \frac{Q_o\ \mu_o\ B_o}{kh}\ \left[\frac{(k - k_{skin})}{k_{skin}}\ \ln\left(\frac{r_s}{r_w}\right) \right] \ \ldots\ldots(5)$$

Van Everdingen defined ΔP_{skin} as:-

$$(\Delta P_{skin})_{fm} = 141.2\ \frac{Q_o\ \mu_o\ B_o}{kh}\ (S_{fm}) \quad \ldots\ldots(6)$$

Solving for S_{fm} equalizing Eqs. (5) & (6).

$$S_{fm} = \left[\frac{(k - k_{skin})}{k_{skin}} \ln\left(\frac{r_s}{r_w}\right) \right] \quad \ldots\ldots.(7)$$

Re-exam Eq. (7)

Case-1 $\quad k = k_a \quad$ No damage, No stimulation
$S_{fm} = 0$, $\Delta P_{skin} = 0$

Case-2 $\quad k > k_a \quad$ Damage
$S_{fm} = +ve$, $\Delta P_{skin} = +ve$ increase total pressure drop when produce with constant rate.

Case-3 $\quad k < k_a \quad$ Stimulation
$S_{fm} = -ve$, $\Delta P_{skin} = -ve$ decrease total pressure drop when produce with constant rate.

Completion Efficiency

S_{pp} = skin factor due to partial penetration of the formation.

The skin factor S_{pp}, is affected by perforations in only a portion of the total formation thickness (effect of incompletely perforated interval). This factor causes an additional pressure drop near the well. The purpose from partial penetration of the formation is avoided water and gas coning.

S_{pp} is depended on penetration ratio ($b = h_p / h_t$) and (h_t/r_w). Where, h_t is the total formation thickness, h_p is height of the perforated interval, and r_w is well-bore radius. As shown in figure - 20 .

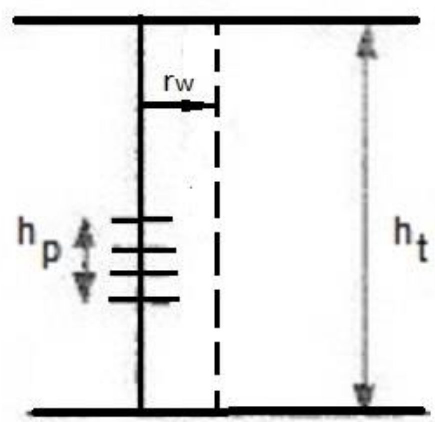


Figure – 20: partial penetration of formation by a well.

S_{pp} value is determined by figure – 21:by use value of b and (h_t/r_w).

S_{pp} is always +ve.

Also:

$$(\Delta P_{skin})_{pp} = 141.2 \frac{Q_o \mu_o B_o (S_{pp})}{Kh}$$

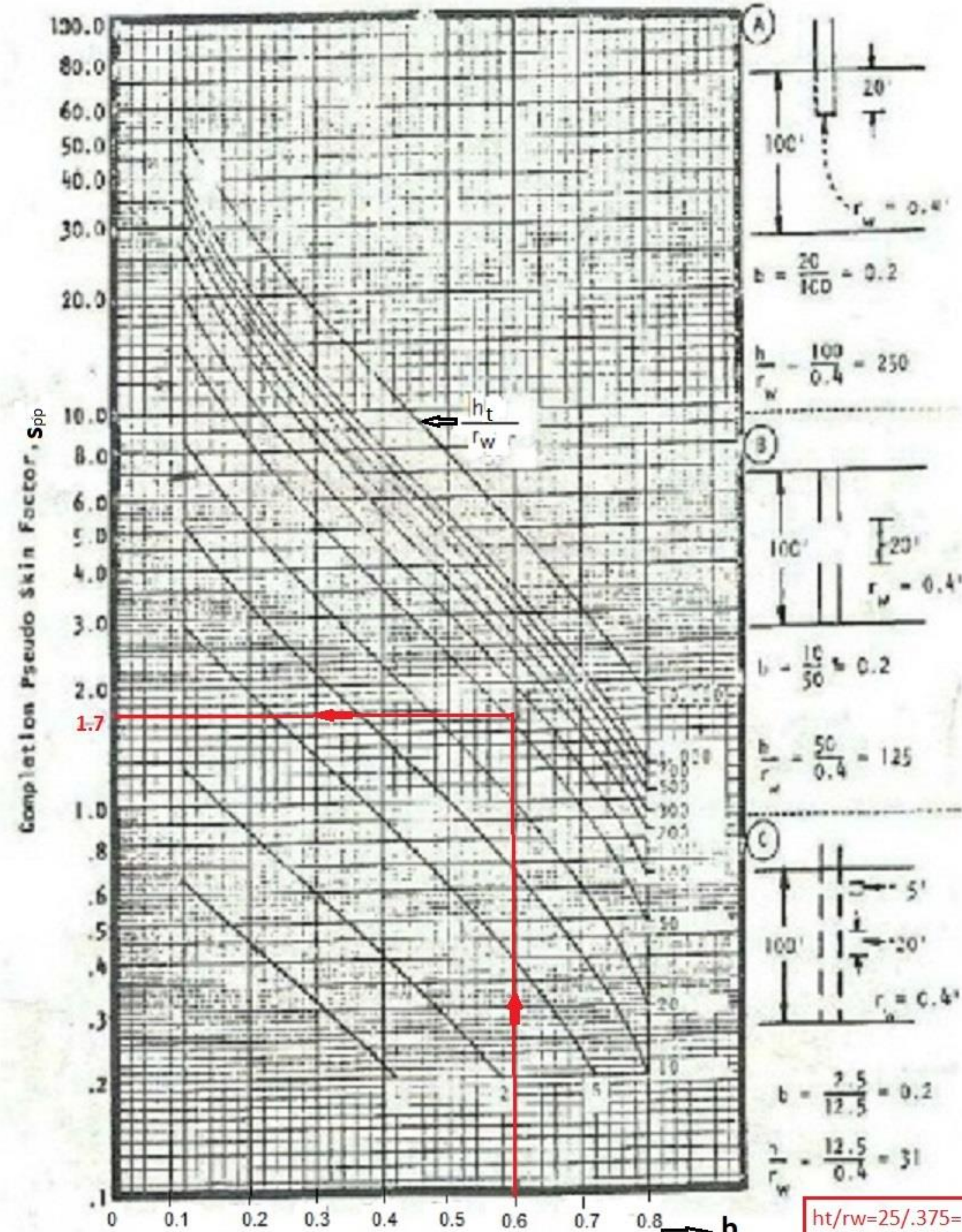


Figure – 21 skin factor due to partial penetration of the formation, S_{pp}.

ht/rw=25/.375= 66.67
hp/ht=15/25= 0.6

S_c = skin factor due to completion configuration.

Skin factor due to completion configuration is determined by use figure (22), (23), and figure (24) and the following data.

1- Perforating techniques (Bullet guns, Jet guns, Hydraulic perforator), and formation compressive strength. Used to determine formation penetration (distance of bullet penetrate the formation).

2- Perforation phase.

3- Area of perforated interval.

4- Perforation density, (number of perforation per foot of perforated interval).

$(S_c)_{chart}$ is corrected according to perforated zone, by: .

$(S_c)_{cor} = (S_c)_{chart} \ (h_t / h_p)$

Also:

$$(\Delta P_{skin})_c = 141.2 \frac{Q_o \mu_o B_o}{kh} (S_c)_{cor}$$

or

$$(\Delta P_{skin})_c = 141.2 \frac{Q_o \mu_o B_o}{kh_p} (S_c)_{chart}$$

So: $$St = S_{fm} + S_c + S_{pp}$$

$$(\Delta P_{skin})_{total} = (\Delta P_{skin})_{Sfm} + (\Delta P_{skin})_{spp} + (\Delta P_{skin})_{Sc}$$

$$(\Delta P_{skin})_{total} = 141.2 \frac{Q_o \mu_o B_o}{kh} (S_t)$$

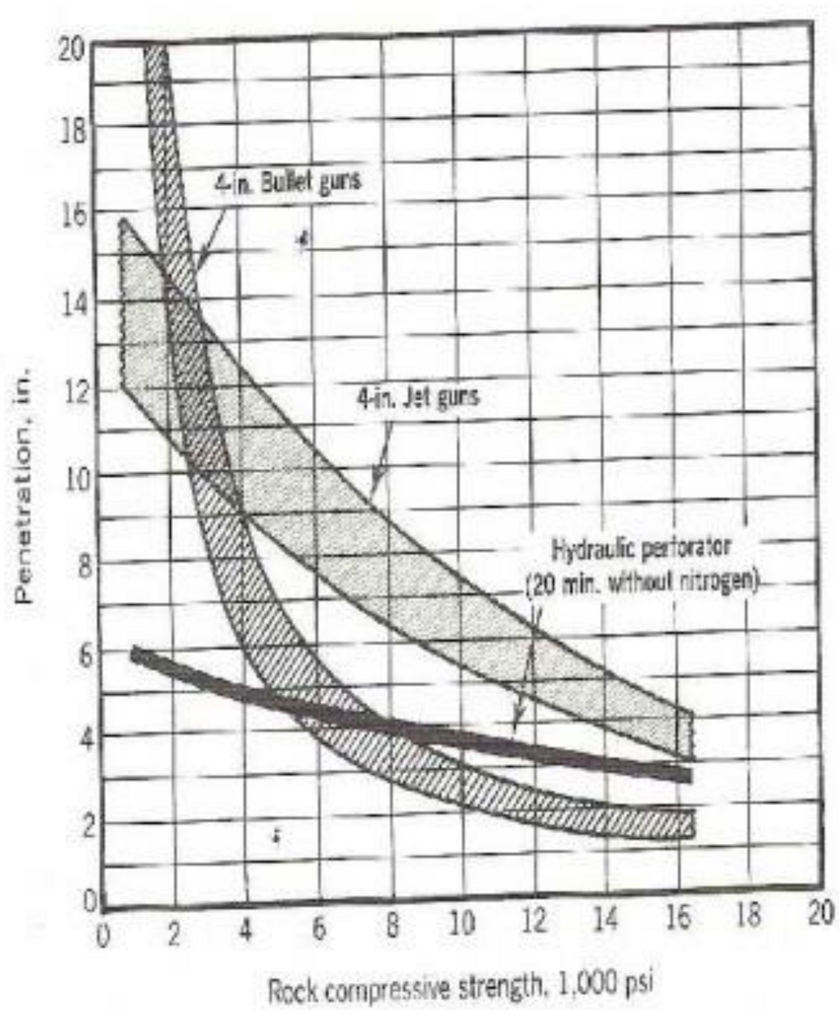

4-in. Bullet guns
4-in. Jet guns
Hydraulic perforator
(20 min. without nitrogen)
Penetration, in.
Rock compressive strength, 1,000 psi
0
2
4
6
8
10
12
14
16
18
20

Figure - **22**

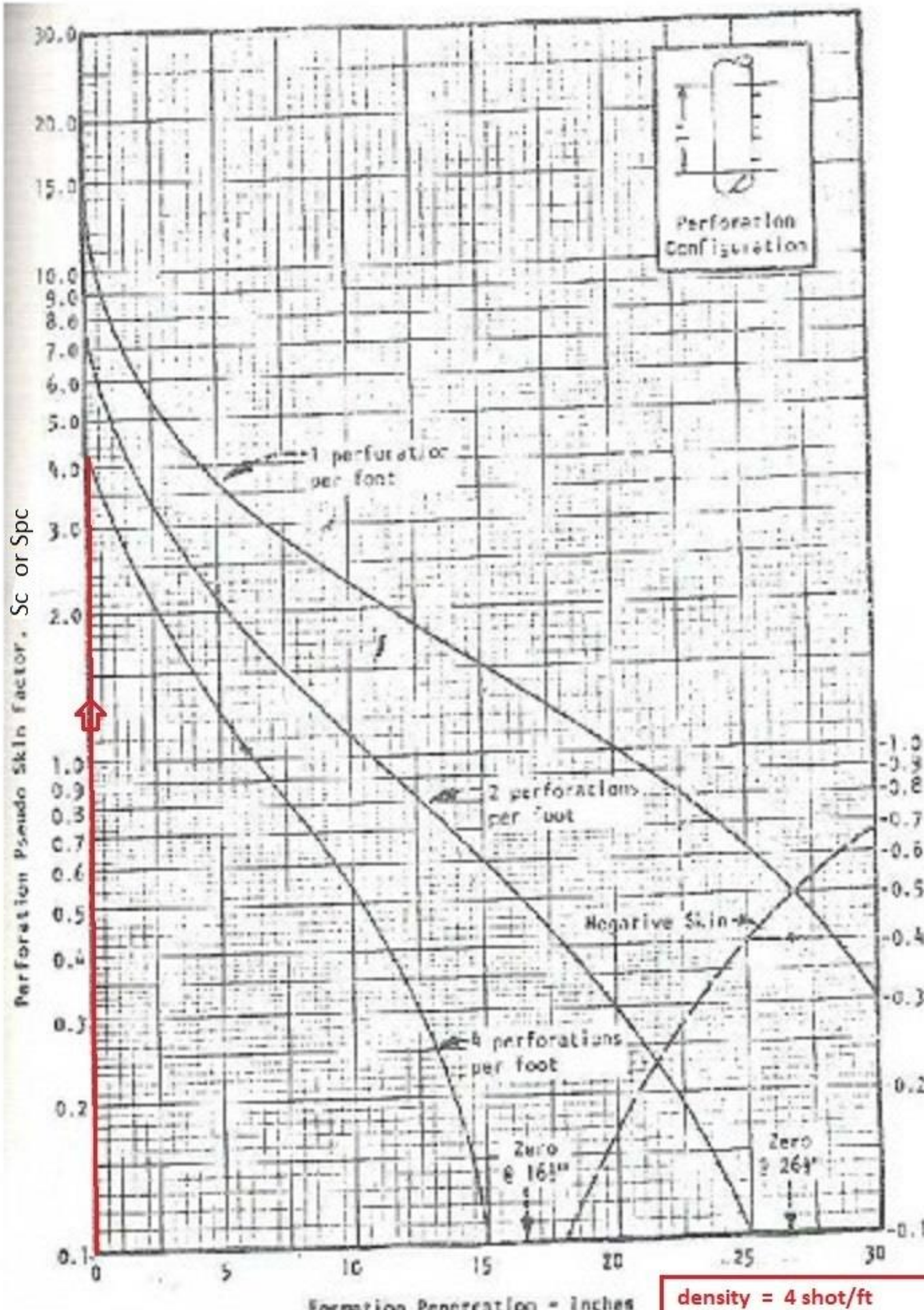
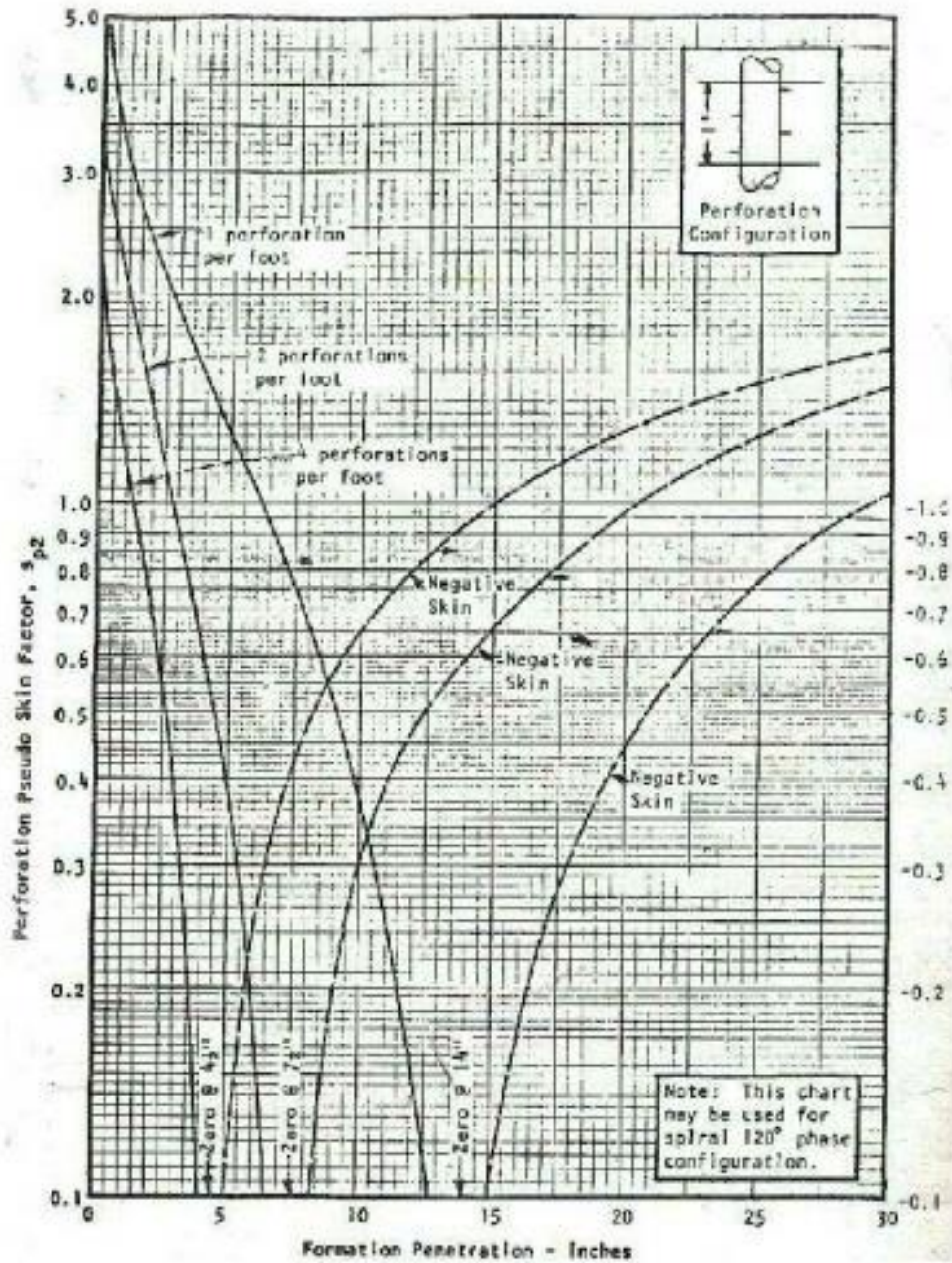


Figure - 23

density = 4 shot/ft
angle of porforation = 0
formation penetration = 0



5.0
4.0
3.0
2.0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Perforation Pseudo Skin Factor, s_{p2}
1 perforation per foot
2 perforations per foot
4 perforations per foot
Perforation Configuration
Negative Skin
Negative Skin
Negative Skin
Zero @ 4½"
Zero @ 7½"
Zero @ 14"
Note: This chart may be used for spiral 120° phase configuration.
0
5
10
15
20
25
30
Formation Penetration - Inches
-0.9
-0.8
-0.7
-0.6
-0.5
-0.4
-0.3
-0.2
-0.1

Figure - 24