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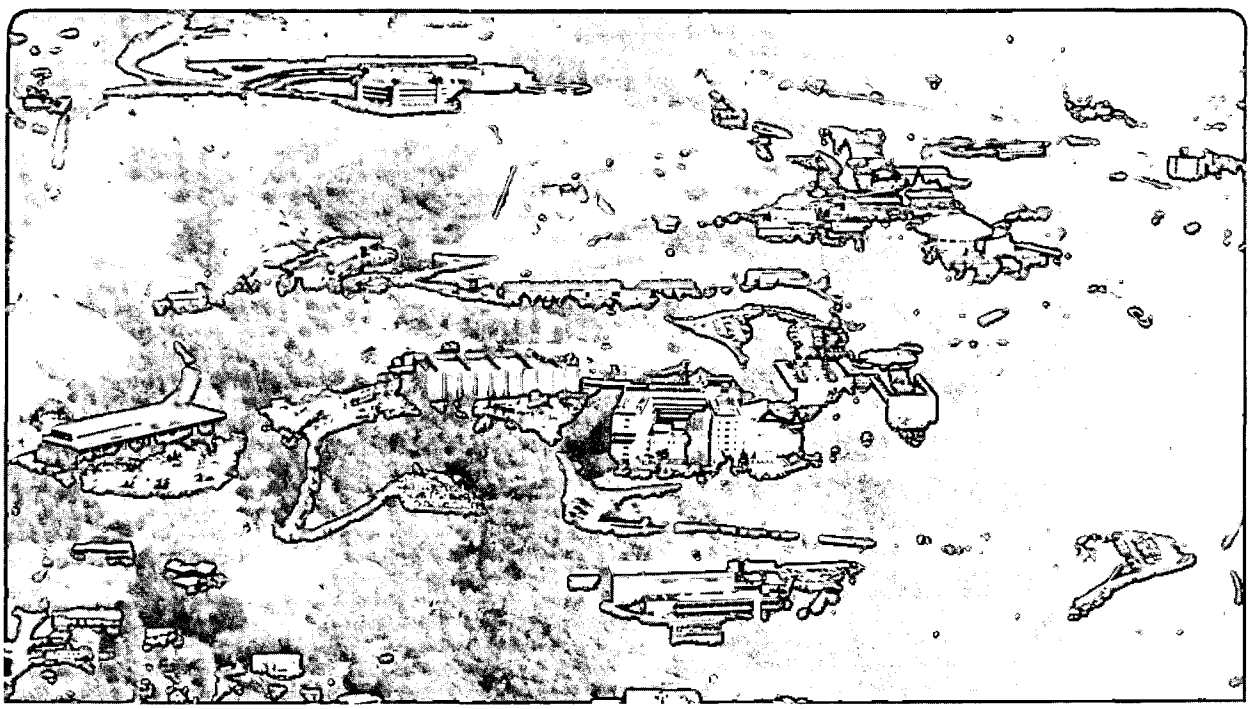

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DISCLAIMER

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	ESO 510	M4904	1 OF 2

AUTHOR	DEPARTMENT	LOCATION	DATE
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PROGRAM — PROJECT — JOB

ESCAR REFRIGERATION SYSTEM

PBL

TITLE

CHARCOAL ADSORBANT DESIGN

OBJECTIVE:

Design a charcoal adsorber to purify helium flow with a pressure drop less than 0.7 ÷ 0.8 psi. Estimate approximate operating time between successive regenerations.

GIVEN:

3,000 SCFM of dry helium gas at 18-20 atm, assumed: 1 ppm of oil.
Pressure vessel diameter - 36"
Bed depth 20" ÷ 25"
Thus linear velocity $V = \frac{3000}{20} \Big/ \pi \left(\frac{18}{12}\right)^2 = 21.22 \ \frac{ft.}{min}$

In this work we analyse the possibility of using theoretical equations for purpose of design.

INTRODUCTION:

The charcoal adsorber performs a similar job to the fiberglas filter, which is the removal of oil particles from helium flow, but uses different physical phenomena: adsorption. The physical ruggedness, chemical stability and permanence of the adsorbing surfaces are important factors from a theoretical approach to the problem.

From the engineering point of view distribution of the adsorbent, hardness, mesh size, pressure drop, adsorptive capacity per unit weight, none of which are closely related to the theoretical aspects of adsorption, are much more important. Essence of the theoretical equations used for calculations is that the break-through concentration is a function of the number of transfer units N_{pore} and through - put parameter Z (Eq. 3). Separately N is related to rate factors and residence time (T) and Z to capacity factors for the solid and the fluid.

Empirical relation (Ref. 1 Eq. 16-111, 16-112):

$$X = 0.557\left[N_{pore,\,F}\ (Z-1) + 1.15\right] - 0.0774\left[N_{pore,\,F}(Z-1) + 1.15\right]^2 \quad (1)$$

with

$$N_{pore,\,F} = \frac{60 \cdot D_{pore} \cdot \mathcal{V}}{F \cdot d_p^2} \quad (2)$$ where

D_{pore} - solid phase diffusivity (pore diffusion);

$\mathcal{V}$ - volume of contractor (bed volume);
f - volumetric flow rate of fluid phase;
d_p - effective spherical diameter of sorbent particle;
x - dimensionless fluid-phase concentration
z - through-put parameter

Consequently (ref. 1 Eq. 16-96)

$$Z = \frac{Co\,(V - v\epsilon}{Q \cdot \rho_b \cdot v} = \frac{V - v\epsilon}{D_\Sigma \epsilon v} = \frac{T}{D_\Sigma \epsilon v/F} \quad (3), \text{ where}$$

Co - total concentration of solutes in fluid phase;
Q - total concentration of solutes in solid phase;
D_Σ - distribution ratio for binary ion exchange;
T - time;
F - volumetric flow rate of fluid phase

Our problem (to calculate on-stream time) corresponds to the example given in Ref. (p. 16-37) which is for high concentration sugar solution. Computation steps were made in the same order.

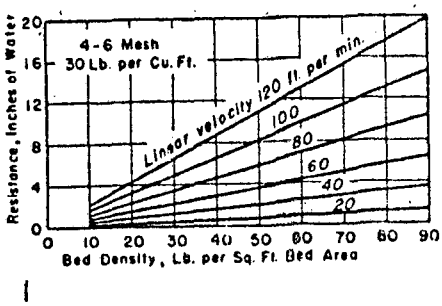
Solution of Eq. (1.) for X = 0 gives a negative number for Z.

Since Z (from Eq. 3) is number of void volumes that have passed through the column, divided by distribution ratio which can not be negative during the adsorbtion process, this solution is invalid.

Further study of the theory of adsorbtion shows that X = 0 and X = 1 are the limits of validity for all of these empirical equations.

PRESSURE DROP:

The problem of pressure drop calculation is much simpler as seen from diagram 1, 2, 3 (Ref. 2) below. Pressure drop through charcoal bed does not exceed 0.6 inches of water (~0.014 psi.), for a large range of bed density (bed depth) and any available mesh size of charcoal.



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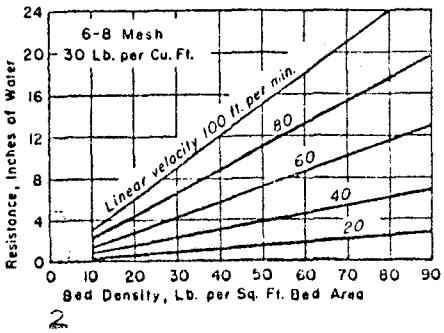

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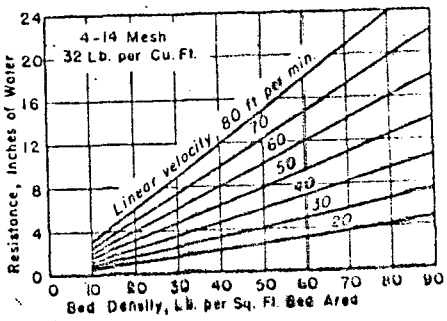

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SUMMARY:

One can't determine precisely the one-stream time by available equations. This must be confirmed by operating experience.

If longer service time is needed the bed depth can be increased without significant increase in pressure drop.

References:
1. Chemical Engineers' Handbook, 1953, Fourth Edition
2. Chemical Engineers' Handbook, 1950, Third Edition
3. Adsorption, Mantell, 1951

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