MODEL FOR DETECTION OF GAS LOSS BY LEAKAGE FROM THE GAS STORAGE RESERVOIR

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ABSTRACT

Determination of the amount of gas loss by leakage from the underground gas storage reservoir developed in an oil depleted reservoir is presented in this paper. Reservoir fluid data obtained from an oil depleted reservoir located onshore oil field, Nigeria was used for the purpose. Two approaches were used which include; (1) pressure-volume relationship where pressure was varied for ten cases to establish new volume of gas (2) Microsoft Visual Basic computer program was also applied to obtain the change in content of the gas reservoir whenever the pressure changes. It was confirmed that for gas to leak off from the storage reservoir for any reason, the reservoir pressure must decline.

Keywords: Leakage, underground, pressure, storage, volume, reservoir

INTRODUCTION

In depleted oil or gas reservoir storage or in aquifer storage the presence of a suitable cap rock is of paramount importance for the retention of natural gas within the structural boundaries of the reservoir. The cap rock that constitutes the overburden to a natural petroleum reservoir obviously does possess proved integrity to retain the gas at least up to discovery pressure (Tek et al., 1966).

During the primary production period of a gas field especially older gas fields, the operator usually is not aware of any gas loss from the reservoir, such as loss to shallow or deeper formations by means of well bore communication gas vented from surface production equipment, or gas lost by leaks in such equipment. Though the operator may be aware of these losses, a reasonable accurate accounting is rarely attainable. However, in gas storage operations, losses can be experienced from usual causes encountered during primary production as well as from other causes. Verification of gas inventory by the operator of storage field is necessary in order to maintain storage field performance and it is also necessitated by cost considerations. Consequently, the operators of storage fields routinely gather reservoir performance data to verify that gas injected into the field is indeed within the reservoir. If there are losses, the operator should be able to determine the magnitude of such loss.

Most gas storage fields were originally, gas fields, oil fields or aquifers that were converted to gas storage after depletion of native gas or oil reserves. Many of these fields were bounded down structure by water. The production of native gas or oil allowed water to expand into the reservoirs reducing the pressure in the surrounding aquifer in the vicinity of the field. To inject into these reservoirs, a volume of storage gas equal to that produced from the field during primary production, reservoir space voided by primary production and now occupied by encroached water must be regained during gas injection by the movement of water back into the aquifer. Bypassing of encroached water and movement of gas beyond the original gas/water contact has been observed during gas injection in numerous gas storage fields. This

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is because the aquifer pressure has been reduced by primary production and gas flow through the paths of least resistance (Mayfield, 1981).

This research paper is geared towards analyzing the possible causes of gas leakages/loss from the storage reservoir and also the methods of detecting the loss and quantity when occur.

The leakage or spill of gas from the storage systems may be due to:

1. Exceeding the threshold pressure of the cap rock
2. Mechanically fracturing the cap rock because of excessive overpressure
3. By having "overpressure" of excessive extent or duration to cause water to be pushed beyond the seal of structural closures
4. By fractures extending through and across the cap, induced during drilling or formation stimulation
5. By poor bonding of the cement between casing and hole
6. By existing permeable faults or incipient fractures in the native formation.

According to Glenn et al., (1979), if known volumes of injected storage gas per psi do not reproduce the historical pattern of injection and withdrawal pressures with time, the storage reservoir is therefore not functioning properly and there might be leakage.

METHODOLOGY

In this work, the determination of the amount of gas loss from the reservoir is given two approaches: (1) Determination of amount of gas loss using the Pressure-Volume relationship, and (2) Determination of amount of gas loss using Microsoft Visual Basic Program which was developed with the leakage equation as given below in eq 2.1a.

Determination of the Amount of Gas Loss by Leakage from the Gas Storage Reservoir

According to Katz and Tek, (1981), a system of observation wells permits measurements to verify if the injected gas is confined to the designated area and has not migrated away. Each year, the gas storage operating team must assure the management (investors) that the inventory of the net stored gas resides in the reservoir in communication with the wellbores. Closed pressure measurements for a period of 3 to 15 days or more are used for all wells, usually when at maximum and minimum storage pressures.

The pressure content data relates the measured change in inventory to the initial content as shown in equation 2.1 (Katz and Tek, 1981).

$$\text{Initial content} = \frac{\text{Change in content}}{(P_1/Z_1) - (P_2/Z_2)} \frac{P}{Z} \qquad 2.1$$

$$\text{Amt of Leakage, } Q = \left[\frac{P_1}{Z_1} - \frac{P_2}{Z_2}\right] * \frac{V_1 Z_1}{P_1} \qquad 2.1a$$

Initial content (volume), V_1 in Eq 2.1 represents maximum storage capacity of depleted reservoir, and is estimated using eq 2.2 below: (Anyadiegwu, 2011)

$$V_{inj} = 5.615[N_p B_o/B_{gi} + N_p(R_p - R_s)] \qquad 2.2$$

Where N_p = cumulative oil production, B_o = oil formation volume factor, B_{gi} = initial gas formation volume factor, R_p = gas-oil ratio, R_s = gas solubility

Pressure was varied for several cases to obtain new Z-factors (Z_1 and Z_2) in each case, using the Z-factor chart as shown in Figure 2.1 (Katz and Lee, 1990).

A Microsoft Visual Basic Program was developed using equation 2.1, and was used to obtain the amount of gas loss from the depleted storage reservoirs at different pressure drops.

The sample of the Microsoft visual basic program for the determination of amount of gas loss from reservoirs is as shown in Figure 2.2

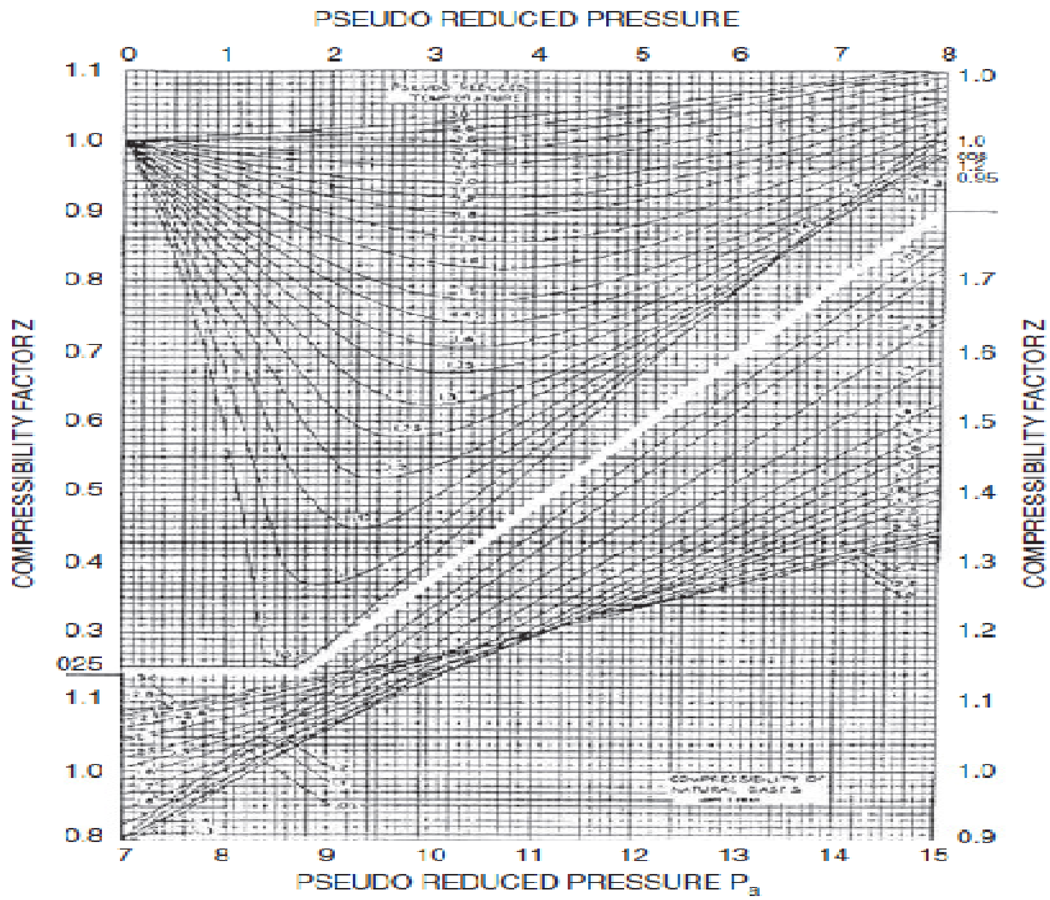

Figure 2.1 Compressibility of natural gas as a function of reduced temperature and pressure, standing and Katz, (1942)

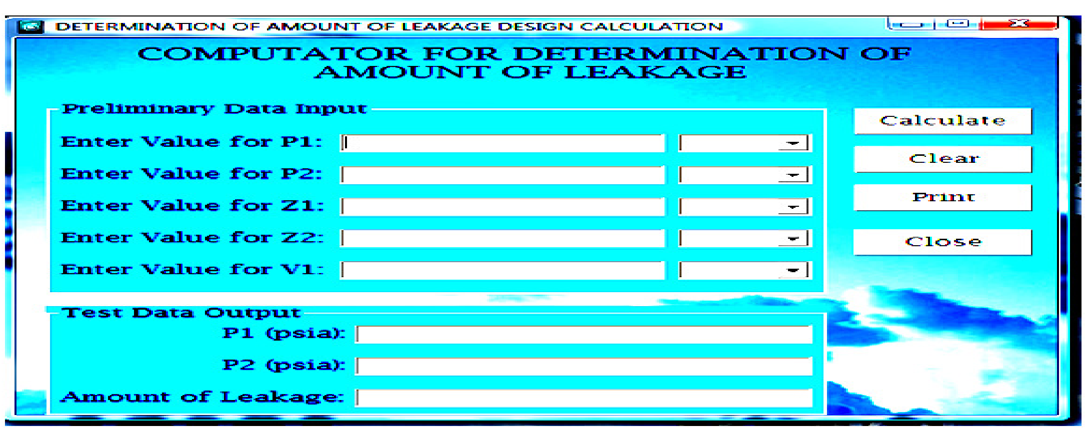

Figure 2.2. Program computator for determination of amount of gas loss at given pressure drop (Anyadiegwu, 2012)

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RESULTS

Determination of Amount of Gas Loss Using Pressure-Volume Relationship at Different Pressure Drops

The reservoir and fluid data for this work were obtained from a depleted oil reservoir in an oilfield onshore location, Nigeria. These include: reservoir temperature, 216^0F, Solution-gas specific gravity, 0.89, Oil API gravity, 26 ^{0}API, Cumulative oil produced, N_p, 0.5825 MMstb, Initial oil formation volume factor, B_{oi}, 1.405.

If the reservoir pressure drops from 3955 psig to 3900 psig, the initial volume, V_1 is the volume of gas injected at 3955 psig which was earlier calculated. Its value is given as 8.8Bscf, Z_1 and Z_2 are 0.86 and 0.857 respectively

The initial pressure, P_1 converted to psia is 3955psig + 14.7 = 3969.7psia, the final pressure, P_2 = 3900 + 14.7 = 3914.7psia

The amount of leaked gas is estimated with eqn 2.1 as:

Amount of Leakage = [3969.7/0.86 – 3914.7/0.857]*8.8Bscf * 0.86/3969.7

= 91.5MMscf

If the reservoir pressure drops from 3900 psig to 3782 psig (3796.7psia), the initial volume, V_1 is 8.71 Bscf, Z_1 and Z_2 are 0.857 and 0.85 respectively. The amount of leaked gas is estimated with eqn 2.1 as:

Amount of Leakage = [3914.7/0.857 – 3796.7/0.85]*8.7Bscf*0.857/3914.7

= 192.94MMscf

If the reservoir pressure drops from 3782 psig to 3534 psig (3548.7psia), the initial volume, V_1 is 8.52Bscf, Z_1 and Z_2 are 0.85 and 0.84 respectively. The amount of leaked gas is estimated with eqn 2.1 as:

Amount of Leakage = [3796.7/0.85 – 3548.7/0.84]*8.5Bscf * 0.85/3796.7

= 461.48MMscf

If the reservoir pressure drops from 3534 psig to 3350 psig (3364.7psia), the initial volume, V_1 is 8.05Bscf, Z_1 and Z_2 are 0.84 and 0.82 respectively. The amount of leaked gas is estimated with eqn 2.1 as:

Amount of Leakage = [3548.7/0.85 – 3364.7/0.82]*8.05Bscf * 0.84/3548.7

= 231.347MMscf

If the reservoir pressure drops from 3350 psig to 3288 psig (3302.7psia), the initial volume, V_1 is 7.82Bscf, Z_1 and Z_2 are 0.82 and 0.816 respectively. The amount of leaked gas is estimated with eqn 2.1 as:

Amount of Leakage = [3364.7/0.82 – 3302.7/0.816]*7.82Bscf * 0.82/3364.7

= 106.5057MMscf

If the reservoir pressure drops from 3288 psig to 3212 psig (3226.7psia), the initial volume, V_1 is 7.72Bscf, Z_1 and Z_2 are 0.816 and 0.813 respectively. The amount of leaked gas is estimated with eqn 2.1 as:

Amount of Leakage = [3302.7/0.816 – 3226.7/0.813]*7.72Bcf * 0.816/3302.7

= 149.7429MMscf

If the reservoir pressure drops from 3212 psig to 3199 psig (3213.7psia), the initial volume, V_1 is 7.57Bscf, Z_1 and Z_2 are 0.813 and 0.81 respectively. The amount of leaked gas is estimated with eqn 2.1 as:

Amount of Leakage = [3226.7/0.813 – 3213.7/0.81]*7.57Bcf * 0.813/3226.7

= *2.5733MMscf*

If the reservoir pressure drops from 3199 psig to 2922 psig (2936.7psia), the initial volume, V_1 is 7.56Bscf, Z_1 and Z_2 are 0.81 and 0.78 respectively. The amount of leaked gas is estimated with eqn 2.1 as:

Amount of Leakage = [3213.7/0.81 – 2936.7/0.78]*7.56Bscf * 0.81/3213.7

= *386.1132MMscf*

If the reservoir pressure drops from 2922 psig to 2881 psig (2895.7psia), the initial volume, V_1 is 7.18Bscf, Z_1 and Z_2 are 0.78 and 0.772 respectively. The amount of leaked gas is estimated with eqn 2.1 as:

Amount of Leakage = [2936.7/0.78 – 2895.7/0.772]*7.18Bscf * 0.78/2936.7

= *26.86798MMscf*

Determination of Amount of Leakage Using Microsoft Visual Basic Program

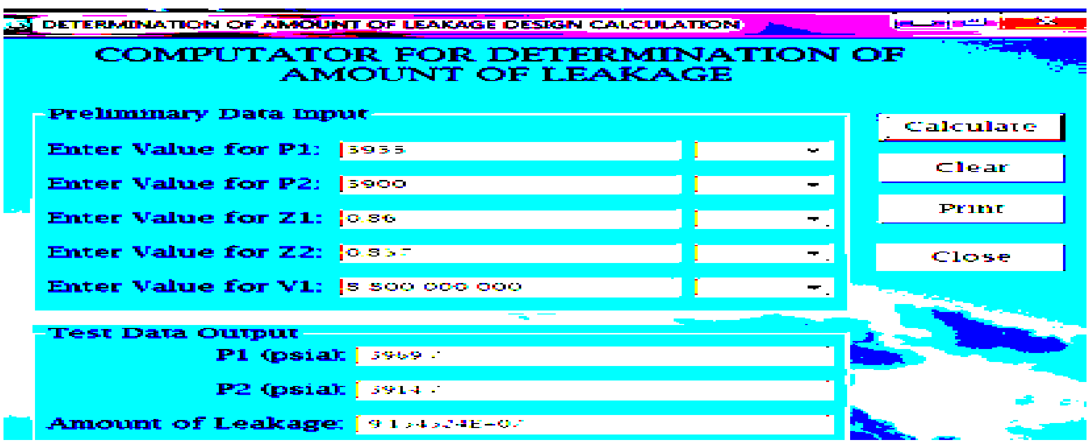

Figure 3.1 Amount of Gas Loss at a Pressure Drop from 3955psig to 3900psig

Amount of gas losses at various pressure drops in the reservoir are given in Table 3.1, as computed using Figure 3.1, which was used to plot a chart of amount of gas loss against pressure drop as shown in Figure 3.2

Table 3.1 (Part-I). Amount of Gas Losses at Various Pressure Drops of the Storage Reservoir

P, Psig	*P, Psia*	*Pressure Drop, psig*	*Pressure Drop, psia*	*Z*	*Vol of gas, Bscf*	*Leakage, MMscf*
3955	3969.7	-	-	0.86	8.8	-
3900	3914.7	55	69.7	0.857	8.71	91.5
3782	3796.7	118	132.7	0.85	8.52	192.94
3534	3548.7	248	262.7	0.84	8.05	461.48
3350	3364.7	184	198.7	0.82	7.82	231.347

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Table 3.1 (Part-II). Amount of Gas Losses at Various Pressure Drops of the Storage Reservoir

P, Psig	*P, Psia*	*Pressure Drop, psig*	*Pressure Drop, psia*	*Z*	*Vol of gas, Bscf*	*Leakage, MMscf*
3288	3302.7	62	76.7	0.816	7.72	106.5057
3212	3226.7	76	90.7	0.813	7.57	149.7429
3199	3213.7	13	27.7	0.81	7.56	2.5733
2922	2936.7	277	291.7	0.78	7.18	386.1132
2881	2895.7	41	55.7	0.772	7.15	26.86798

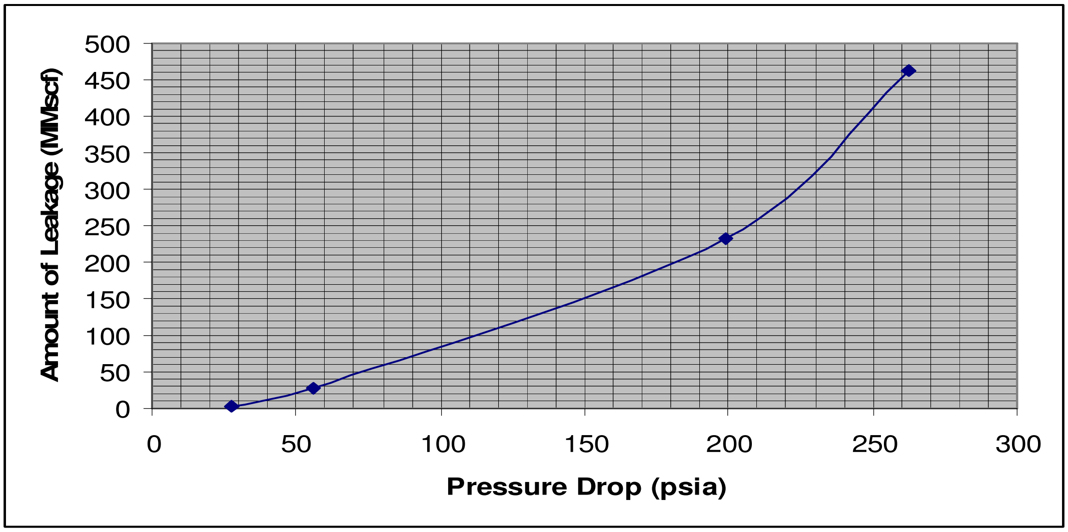

Figure 3.2. Plot of Amount of Gas Losses against Pressure Drops for the Storage Reservoir

CONCLUSION

At the end of this work, it is established that it is possible to detect gas loss/leakage from the storage reservoir, moreso the actual quantity of gas that leaks off.

The gas storage operators can effectively monitor of the storage system for proper planning and decision making.

The malfunctioning of the storage system can easily be detected for proper re-working.

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NOMENCLATURE

B_{gi} = Original gas volume factor (scf/bbI)

B_g = Formation volume factor of the evolved solution gas (scf/bbI)

B_o = Oil formation volume factor at depletion pressure, P_{ab} (rb/stb)

Bscf = Billion standard cubic feet

MMscf = Million standard cubic feet

N = Original oil in place

N_p = Cumulative stock tank barrels of oil produced (stb)

psi = pounds per square inch

psia = pounds per square inch atmosphere

psia = pounds per square inch gauge

P_1= The maximum storage pressure

P_2 = Decreased storage pressure

R_p = Cumulative produced GOR (scf)

R_s = Solution gas oil ratio at abandonment (depletion) pressure (scf/stb)

V_i = Initial volume

V_{inj} = Volume of gas to be injected (scf)

V_{total} = Total storage capacity

Z_1 = Compressibility factor at pressure, P_1 and reservoir temperature

Z_2 = Compressibility factor at pressure P_2 and reservoir temperature