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Highlights

Storage of Natural Gas

Assessment of Prescribing Practices

Discovering Thoughts, Inventing Future

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Underground Storage of Natural Gas in Hydrate State: Primary Injection Stage

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E. A. Bondarev [α], I. I. Rozhin [σ], V. V. Popov [ρ] & K. K. Argunova [ω]

Abstract- The paper is devoted to simulation of the initial stage of natural gas hydrate underground storage: gas injection into aquifer just below permafrost rocks. It is based on the mathematical model of multiphase non-isothermal real gas and water flow in porous media. The model takes into account the transformation of gas and water into hydrate at certain temperature which depends on gas flow pressure. The dynamics of hydrate and water saturation as well as the pressure and temperature fields in a reservoir with given porosity, permeability and initial values of pressure, temperature and water saturation have been studied. An implicit finite-difference scheme is used to approximate the original boundary-value problem. The finite-difference equations have been solved using simple iteration and sweeping algorithms. Several examples of calculations corresponding to real cases are given. Calculations have revealed that the final result strongly depends on the combination of porosity and permeability of a reservoir.

Keywords: permafrost, underground storage, natural gas, hydrate formation, mathematical modeling.

I. Introduction

Nowadays underground gas storages are built in the depleted gas reservoirs or aquifers situated near gas pipelines or large centers of gas consumption. Along with the peak-shaving storages, they are used to meet load variations, that is, gas is injected into storage during periods of low demand and is withdrawn during periods of peak one, which is especially important for the Northern regions where they can be used as distinctive accumulators of natural gas.

One of the alternatives to common gas storages would be those of hydrates compounds formed when natural gas is injected into porous reservoirs under certain thermodynamic conditions (at specific temperature – pressure relations controlled by the gas composition). Subpermafrost aquifers in the areas of continuous permafrost act readily as such reservoirs. For example, in Central Yakutia, they can occur directly beneath the permafrost base at depths of 500-600 m [*Balobaev et al., 2003*], with permeability ranging between10^{-12} and 10^{-14} m^2.

In [*Duchkov et al., 2009*] it is shown that carbon dioxide sequestration in the subpermafrost horizons is possible through CO_2 injections into reservoirs located beneath the carbon dioxide hydrate stability zone. Major advantages of this method consist in greater compactness and stability of the repository, given that gas in a solid state occupies a considerably smaller volume versus its being in free state at equal temperature and pressure, and that during gas transition into the hydrate state all free reservoir water becomes bound. The already known method of natural gas hydrate storage consists of hydrate formation in special aboveground tanks, analogous to liquefied gas storages.

In the paper [*Bondarev et al, 2015*] conceptual possibility of natural gas underground storage in hydrate state was proved via mathematical modeling of gas injection into water saturated reservoir at shallow depths corresponding to the permafrost base in the central part of Eastern Siberia. Gas injection time was limited to 10 days. The model takes into account key physical features of the process: real gas properties, Joule-Thomson effect, simultaneous flow of water–gas mixture, and mass transfer between gas, water and hydrate. Here the authors extend time of gas injection up to 100 days, which corresponds to real period of lower gas consumption during the summer.

II. Problem Formulation

To assess the concept of storing natural gas occurring in hydrate state consider a standard axisymmetric problem of gas injection into a horizontal aquifer, with impermeable and thermally insulated top and bottom, through a single well. Let us assume that gas flows in the reservoir initially saturated with water. Porous matrix is considered rigid, gas is only in the gaseous/hydrate state, whereas water – only in the liquid/hydrate states, that is neither ice nor vapor are formed.

In [*Bondarev et al., 2009*] it was shown that, the role of thermal conductivity is negligible versus forced convection in overall heat transfer balance and, therefore, the heat conductivity term in the energy equation is set to zero. Then, in the frame of multiphase flow mechanics [*Bondarev et al., 1976; Basniyev et al., 1986*] and subject to the generalized Darcy's law, the

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energy equation in cylindrical coordinates takes the following form:

$$(\rho c)_e \frac{\partial T}{\partial t} - mq\rho_h \frac{\partial \nu}{\partial t} - m(1-\nu-\sigma)\left(1+\frac{T}{z}\frac{\partial z}{\partial T}\right)\frac{\partial p}{\partial t} -$$

$$-k(1-\nu)\left(\rho_w c_w \frac{f_w}{\mu_w} + \rho_g c_g \frac{f_g}{\mu_g}\right)\frac{\partial p}{\partial r}\frac{\partial T}{\partial r} +$$

$$+k(1-\nu)\rho_g c_g \frac{f_g}{\mu_g}\frac{RT^2}{c_p p}\frac{\partial z}{\partial T}\left(\frac{\partial p}{\partial r}\right)^2 = 0, \qquad (1)$$

where $(\rho c)_e = (1-m)\rho_s c_s + m(1-\nu-\sigma)\rho_g c_g + m\nu\rho_h c_h + +m\sigma\rho_w c_w$ – is effective value of specific volume heat capacity of porous medium saturated with gas, hydrate and water.

The equations of gas and water filtration are to be written down in these same coordinates:

$$m\frac{\partial}{\partial t}\left((1-\nu-\sigma)\frac{p}{zT}\right) =$$

$$= \frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{k(1-\nu)f_g}{\mu_g}\frac{p}{zT}\frac{\partial p}{\partial r}\right) - m\rho_h \varepsilon R\frac{\partial \nu}{\partial t}, \qquad (2)$$

$$m\frac{\partial \sigma}{\partial t} = \frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{k(1-\nu)f_w}{\mu_w}\frac{\partial p}{\partial r}\right) - m(1-\varepsilon)\frac{\rho_h}{\rho_w}\frac{\partial \nu}{\partial t}. \qquad (3)$$

Here and elsewhere the following notations are used: c –specific heat capacity; f –relative permeability; k –absolute permeability; m –porosity; p –pressure; q –latent heat of "hydrate–gas+water" phase change; R –gas constant; r –space coordinate; r_b –well radius; r_k –external boundary radius; T – temperature; t –time; z –gas compressibility function; ε –gas content per hydrate unit volume; μ –dynamic viscosity; ρ –density; σ –water saturation; ν –hydrate saturation. The lower indices g, h, s, w, 0 stand for gas, hydrate, solid matrix, water and reference state, respectively.

To find a single-valued of the (1) - (3) set, initial and boundary conditions should be formulated. Constant values of pressure, temperature, hydrate saturation and water content have been chosen as initial conditions:

$$p(r,0)=p_0,\ T(r,0)=T_0,\ \nu(r,0)=\nu_0,\ \sigma(r,0)=\sigma_0 \qquad (4)$$

At gas injection point (bottom hole), the following conditions are set:
constant temperature

$$T(r_b,t)=T_b \qquad (5)$$

and bottom hole gas pressure

$$p(r_b,t)=p_b(t), \qquad (6)$$

or its volume flow rate (modified to normal physical conditions)

$$2\pi r_b H \frac{\rho_g}{\rho_n}\frac{k(1-\nu)f_g}{\mu_g}\frac{\partial p(r_b,t)}{\partial r} = -Q, \qquad (7)$$

where H – reservoir thickness; ρ_n – gas density at $p_n = 101325$ Pa and $T_n = 273.15$ K.

Instead of impermeability condition at reservoir boundary used in [*Bondarev et al, 2015*] here the possibility of water flow outside storage boundary is stated

$$-\frac{\partial p(r_k,t)}{\partial r} = \frac{f_w(p(r_k,t)-p_0)}{r_k \ln(r_{out}/r_k)}. \qquad (8)$$

where r_{out} – radial distance of hydrodynamic influence.
Equations of the problem are closed by:

1) The relations for gas and water relative permeabilities [*Charnyi, 1963*]

$$f_g(\sigma) = \begin{cases} \left(1-\dfrac{\sigma}{0.9}\right)^{3.5}(1+3\sigma),\ 0\le\sigma<0.9 \\ 0,\ \sigma\ge 0.9 \end{cases}; \qquad (9)$$

$$f_w(\sigma) = \begin{cases} \left(\dfrac{\sigma-0.2}{0.8}\right)^{3.5},\ 0.2<\sigma\le 1 \\ 0,\ 0\le\sigma\le 0.2 \end{cases}; \qquad (10)$$

2) The gas-hydrate–water thermodynamic equilibrium condition

$$T = \alpha_1 \ln p + \alpha_2, \qquad (11)$$

where α_1, α_2 – empirical constants determined through experimental data or calculated for gas of a given composition, on the basis of methods described in [*Istomin and Kvon, 2004; Sloan and Koh, 2008*];

3) Equation of state for real gas

$$\rho_g = p/zRT, \qquad (12)$$

where dependent on pressure and temperature gas compressibility function is approximated by the Latonov–Gurevich empirical equation [*Latonov and Gurevich, 1969*]:

$$z = (0.17376\ln(T/T_c)+0.73)^{p/p_c} + 0.1p/p_c.$$

Critical parameters of natural gas are determined according to its composition by the Kay's Rule (for non-ideal gas mixtures) [*Kay, 1936*]:

$$p_c = \sum_{i=1}^{n} y_i p_{ci},\ T_c = \sum_{i=1}^{n} y_i T_{ci},$$

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where p_{ci}, T_{ci}, y_i – are critical pressure and temperature and molar fraction of the i-th component of natural gas.

The method of finite differences is applied to solve the problem (1) - (12). Here with the original equations, boundary and initial conditions are replaced by their mesh analogues [*Bondarev et al, 2009*], whereas the proposed by [*Vasiliev et al., 2000; Bondarev and Popov, 2002*] algorithm for implementation of simple iterations method was applied for solving the corresponding system of algebraic equations at each time step.

III. Numerical Implementation of the Model and its Algorithm

To solve the initial value problem (1)-(12), replace $p(r_i, t_j) = p_i^j$, $T(r_i, t_j) = T_i^j$, $\nu(r_i, t_j) = \nu_i^j$ and $\sigma(r_i, t_j) = \sigma_i^j$ with numerical analogues in the space-time mesh points we approximate equations (1)-(8) by purely implicit absolutely stable difference scheme:

$$(\rho c)_{e,i}\frac{T_i^j - T_i^{j-1}}{\tau} - mq\rho_h\frac{\nu_i^j - \nu_i^{j-1}}{\tau} - m\left(1-\nu_i^j-\sigma_i^j\right)\times$$

$$\times\left(1+\frac{T_i^j}{z_i^j}\left(\frac{\partial z}{\partial T}\right)_i^j\right)\frac{p_i^j - p_i^{j-1}}{\tau_n} = k\left(1-\nu_i^j\right)\times$$

$$\times\left(\rho_w\frac{c_w f_{w,i}}{\mu_w} + \frac{p_i^j}{z_i^j RT_i^j}\frac{c_g f_{g,i}}{\mu_g}\right)\frac{p_{i+1}^j - p_i^j}{h_{i+1}}\frac{T_{i+1}^j - T_i^j}{h_{i+1}} -$$

$$-\frac{k\left(1-\nu_i^j\right)f_{g,i}}{\mu_g}\frac{T_i^j}{z_i^j}\left(\frac{\partial z}{\partial T}\right)_i^j\left(\frac{p_{i+1}^j - p_i^j}{h_{i+1}}\right)^2,$$

$$i=\overline{1, n-1},\quad j>0; \tag{13}$$

$$m\left(\left(1-\nu_i^j-\sigma_i^j\right)\frac{p_i^j}{z_i^j T_i^j} - \left(1-\nu_i^{j-1}-\sigma_i^{j-1}\right)\frac{p_i^{j-1}}{z_i^{j-1}T_i^{j-1}}\right)\times$$

$$\times\frac{\hbar_i r_i}{\tau} + m\rho_h \varepsilon R\frac{\nu_i^j - \nu_i^{j-1}}{\tau}\hbar_i r_i =$$

$$=\left(r\frac{k(1-\nu)f_g}{\mu_g}\frac{p}{zT}\right)_{i+1/2}^j\frac{p_{i+1}^j - p_i^j}{h_{i+1}} -$$

$$-\left(r\frac{k(1-\nu)f_g}{\mu_g}\frac{p}{zT}\right)_{i-1/2}^j\frac{p_i^j - p_{i-1}^j}{h_i},\quad i=\overline{1, n-1}; \tag{14}$$

$$m\frac{\sigma_i^j - \sigma_i^{j-1}}{\tau}\hbar_i r_i + m(1-\varepsilon)\frac{\rho_h}{\rho_w}\frac{\nu_i^j - \nu_i^{j-1}}{\tau}\hbar_i r_i =$$

$$=\left(r\frac{k(1-\nu)f_w}{\mu_w}\right)_{i+1/2}^j\frac{p_{i+1}^j - p_i^j}{h_{i+1}} -$$

$$-\left(r\frac{k(1-\nu)f_w}{\mu_w}\right)_{i-1/2}^j\frac{p_i^j - p_{i-1}^j}{h_i},\quad i=\overline{1, n-1},\quad j>0; \tag{15}$$

$$p_i^0 = p_0,\ T_i^0 = T_0,\ \nu_i^0 = \nu_0,\ \sigma_i^0 = \sigma_0,\ i=\overline{0, n}; \tag{16}$$

$$T_0^j = T_b,\quad j>0; \tag{17}$$

$p_0^j = p_b$ or

$$2\pi r_b H\frac{p_0^j}{z_0^j RT_0^j}\frac{k\left(1-\nu_0^j\right)f_{g,0}}{\rho_n \mu_g}\frac{p_1^j - p_0^j}{h_1} = -Q,\quad j>0; \tag{18}$$

where τ is a constant step of time mesh $\overline{\omega}_\tau = \left\{t_j = j\cdot\tau,\ j=\overline{0, J}\right\}$; h_i is a constant step of radial mesh $\overline{\omega}_h = \left\{r_{i+1} = r_i + h_{i+1},\ h_{i+1} = (r_k - r_b)/n,\ i=\overline{0, n-1};\ r_0 = r_b,\ h_0 = 0\right\}$; and $\hbar_i = (h_i + h_{i+1})/2$ is a step of flow mesh.

In the finite-difference form, the right-hand side boundary condition is written with a first order approximation:

$$-\frac{p_n^j - p_{n-1}^j}{h_n} = \frac{f_{w,n}\left(p_n^j - p_0\right)}{r_k \ln\left(r_{out}/r_k\right)} \tag{19}$$

To solve the set of non-linear algebraic equations (13) - (19) one can use the following implementation algorithm of simple iteration method at each time step. First, using (13), we exclude the expression $\left(\nu_i^j - \nu_i^{j-1}\right)/\tau$ from (14), replacing at the same time each and every T_i^j with $\alpha_1 \ln p_i^j + \alpha_2$. In the resulting equation, the discrete analogue of time temperature derivative is replaced with the finite-difference analogue of time pressure derivative. The follow-up algorithm involves the following operations as to:

1. Give initial value of the iterations counter $s=0$ and initial approximations of the of pressure, temperature, water and hydrate saturations distributions equal to their corresponding values on the lower time step:

$$\overset{s}{p}_i = p_i^{j-1},\ \overset{s}{T}_i = T_i^{j-1},\ \overset{s}{\nu}_i = \nu_i^{j-1},\ \overset{s}{\sigma}_i = \sigma_i^{j-1},\ i=\overline{0, n}.$$

2. Increase an iterations counter by one unit and then multiply the equation (15) by $p_i^j/\left(z_i^j T_i^j\right)$ and sum it up with equation (14). The resulting equation is solved by the stream sweeping method for calculating the pressure distribution $\overset{s}{p}_i,\ i=\overline{0, n}$.

3. Beginning from the left-hand side ($i=0$),for all $\overset{s}{\sigma}_i > 0$ the distribution of hydrate saturation $\overset{s}{\nu}_i$, is obtained from equation (13), while the temperature distribution resulted from the three-phase hydrate-gas-water equilibrium $\overset{s}{T}_i = \alpha_1 \ln \overset{s}{p}_i + \alpha_2,\ i=\overline{0,n}$. In case of $\overset{s}{\sigma}_i = 0$ the equation (13) instantly gives the temperature distribution $\overset{s}{T}_i$.
4. Water saturation distribution $\overset{s}{\sigma}_i$, is derived from equation (15). The calculations also start from the left-hand side.
5. Steps 2 - 4 are repeated until the specified accuracy is reached. If iteration convergence conditions are satisfied, then proceed to the next time step.

IV. Results of Computational Experiment

The effects of porosity and permeability of the aquifer and gas injection rate on the dynamics of the fields of temperature, pressure, water and hydrate saturation were studied in computational experiment. Other initial parameters were the following:

$\rho_w = 1000$ kg/m^3, $\rho_s = 2650$ kg/m^3, $\rho_h = 920$ kg/m^3,
$c_w = 4200$ J/(kg·K), $c_s = 700$ J/(kg·K),
$c_h = 3210$ J/(kg·K), $c_g = 2093$ J/(kg·K),
$q = 510000$ J/kg, $\varepsilon = 0.147$, $\mu_w = 1.8\cdot10^{-3}$ Pa·s,
$\mu_g = 1.3\cdot10^{-5}$ Pa·s, $p_0 = 3.0\cdot10^{6}$ Pa, $T_0 = 274.15$ K,
$T_w = 279.15$ K, $H = 10$ m, $r_b = 0.1$ m, $r_k = 300.1$ m,
$r_{out} = 1000.1$ m, $n = 3000$, $\tau = 100$ s.

Gas constant, critical pressure and temperature, and empirical coefficients in equation (11) were calculated according to the composition of the injected natural gas. It corresponds to the Sredne-Botuobinskoye field in the Republic of Sakha (Yakutia): $CH_4 - 85.90$, $C_2H_6 - 7.32$, $C_3H_8 - 2.24$, $iC_4H_{10} - 0.26$, $nC_4H_{10} - 0.68$, $iC_5H_{12} - 0.17$, $nC_5H_{12} - 0.24$, $C_6H_{14} - 0.08$, $CO_2 - 0.05$, $N_2 - 2.64$, $H_2 - 0.14$, $He - 0.28$ (volume percents); $R = 445.6$ J/(kg·K), $p_c = 4.555$ MPa, $T_c = 204.134$ K, $\alpha_1 = 7.82$ K, $\alpha_2 = 166.64$ K. The field was chosen primarily due to the fact that the experimental data on the equilibrium conditions of hydrate formation are available for its gas, and they were used to calculate empirical coefficients of relation (11).

The computational experiment was carried out to evaluate the role of gas injection flow rate (1 m^3/s and 5 m^3/s) and the different combinations of porosity and permeability of a reservoir (1 – $m = 0.15$, $k = 8\cdot10^{-13}$ m^2; 2 – $m = 0.15$, $k = 8\cdot10^{-14}$ m^2; 3 – $m = 0.4$, $k = 8\cdot10^{-13}$ m^2; 4 – $m = 0.4$, $k = 8\cdot10^{-14}$ m^2) in dynamics of hydrate and water saturation fields as well as temperature and pressure ones. Initially the aquifer does not contain hydrates and its water saturation equals 0.9. The most essential results of calculations can be seen at Fig. 1 - 11. Their analysis leads to the following conclusions.

At first, consider dynamics of gas temperature fields because of its determinative role in hydrate formation.

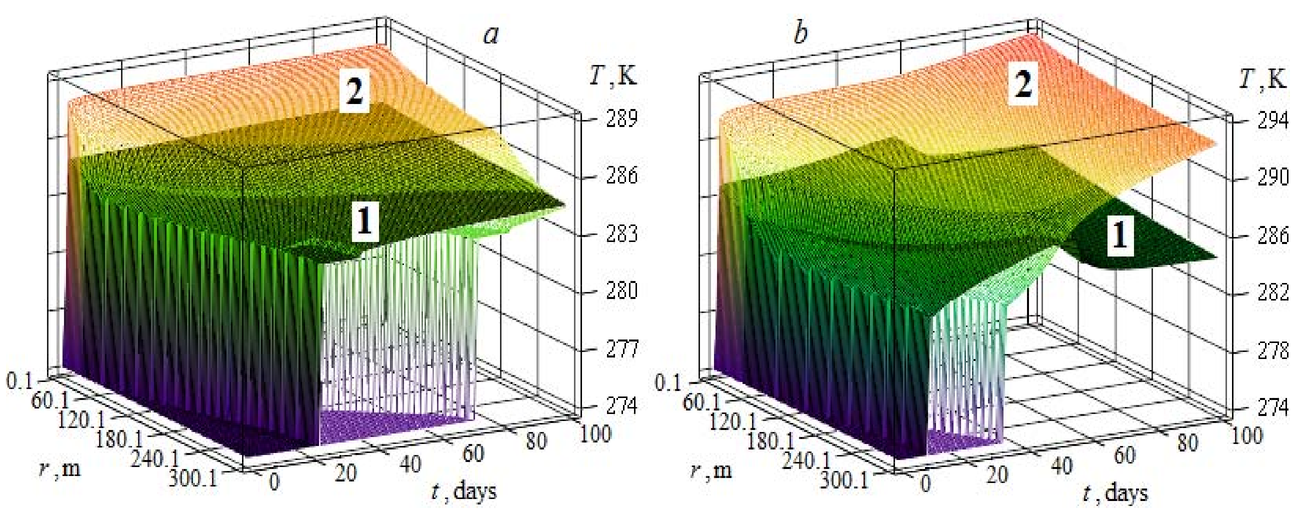

Fig. 1: Dynamics of temperature fields:*a* – mass flow rate equals 1 m^3/s; *b* – mass flow rate equals 5 m^3/s (figures at the surfaces correspond to combinations of porosity and permeability)

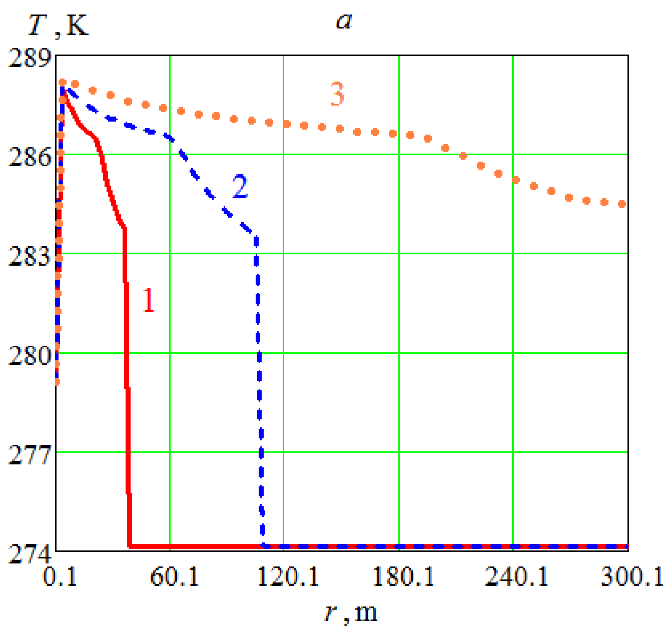

Fig. 2: Temperature distribution in reservoir: *a* – mass flow rate equals 1 m^3/s; *b* – mass flow rate equals 5 m^3/s (1 – t = 1.25 days, 2 – t = 10 days, 3 – t = 100 days)

It is seen from Figures 1 - 3 (Fig. 2 and Fig. 3 correspond to lower permeability) that over a relatively short time interval (several hours) temperature goes up significantly: at high flow rate – about 20 degrees, and about 15 degrees – at low flow rate (cf. curves 1 in Fig. 3*a* and Fig. 3*b*). After 10 days of gas injection, temperature front reaches 110 m and 160 m distances and in 70 and 35 days – reservoir boundary, for low and high injection rate, correspondingly (curves 2 in Fig. 2*a*, 2*b* and curves 3 in Fig. 3*a*, 3*b*). At the end of gas injection for high flow rate the temperature is almost leveled throughout the reservoir (curve 3 in Fig. 2*b*). Figure 1 illustrates all these features and demonstrates an influence of permeability on velocity of temperature front and on temperature dynamics and distribution (cf. surfaces 1 and 2 which correspond to permeability $k = 8 \cdot 10^{-13}$ m^2 and $k = 8 \cdot 10^{-14}$ m^2, correspondingly, with porosity being equal to 0.15).

Permeability value is crucial for pressure dynamics and distribution in the storage (cf. surfaces 1 and 2 in Fig. 4).

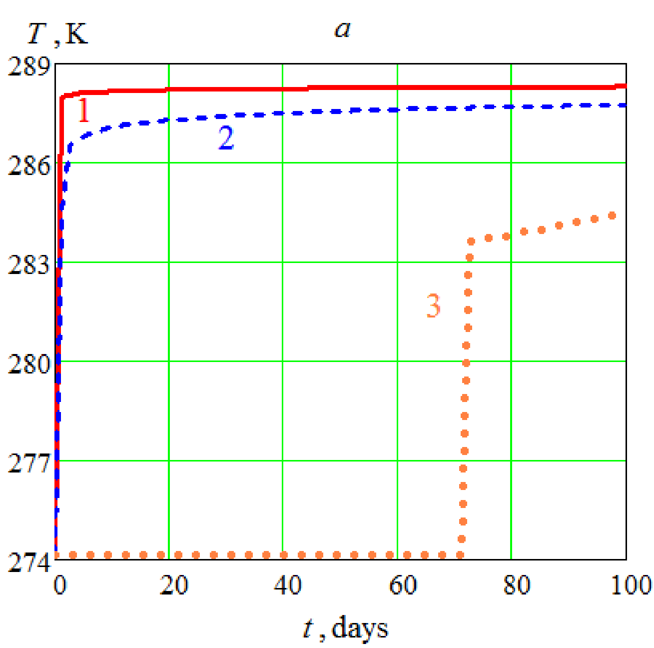

Fig. 3: Temperature dynamics: *a* – mass flow rate equals 1 m^3/s; *b* - mass flow rate equals 5 m^3/s (1 – r = 3.1 m, 2 – r = 30.1 m, 3 – r = 300.1 m)

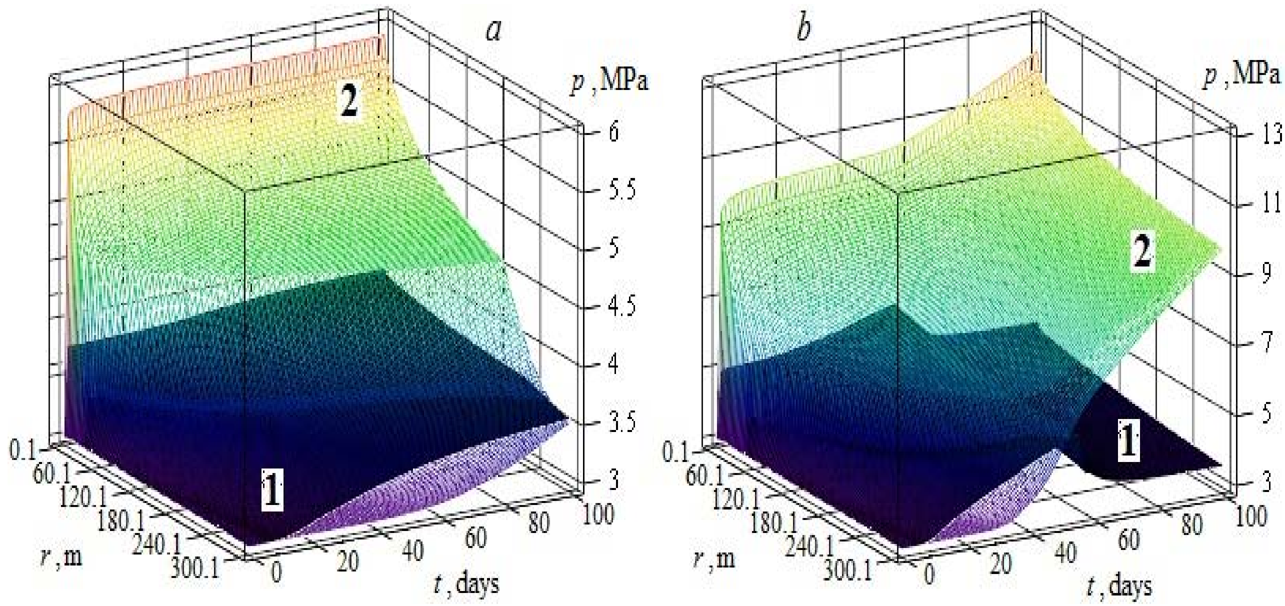

Fig. 4: Dynamics of gas pressure: *a* – mass flow rate equals 1 m^3/s; *b* – mass flow rate equals 5 m^3/s (figures at the surfaces correspond to combinations of porosity and permeability)

Near gas well it is growing with the same speed as temperature but at low flow rate it almost reaches its limit of 6 MPa (curve 3 in Fig. 6), while for high flow rate it is growing progressively (curves 1 and 2 in Fig. 6). Pressure growth at high flow rate is twice as much as at low one (cf. Fig. 4*a* and Fig. 4*b* as well as Fig. 5*a* and Fig. 5*b*). For some geological conditions, such high pressure may lead rock fractures.

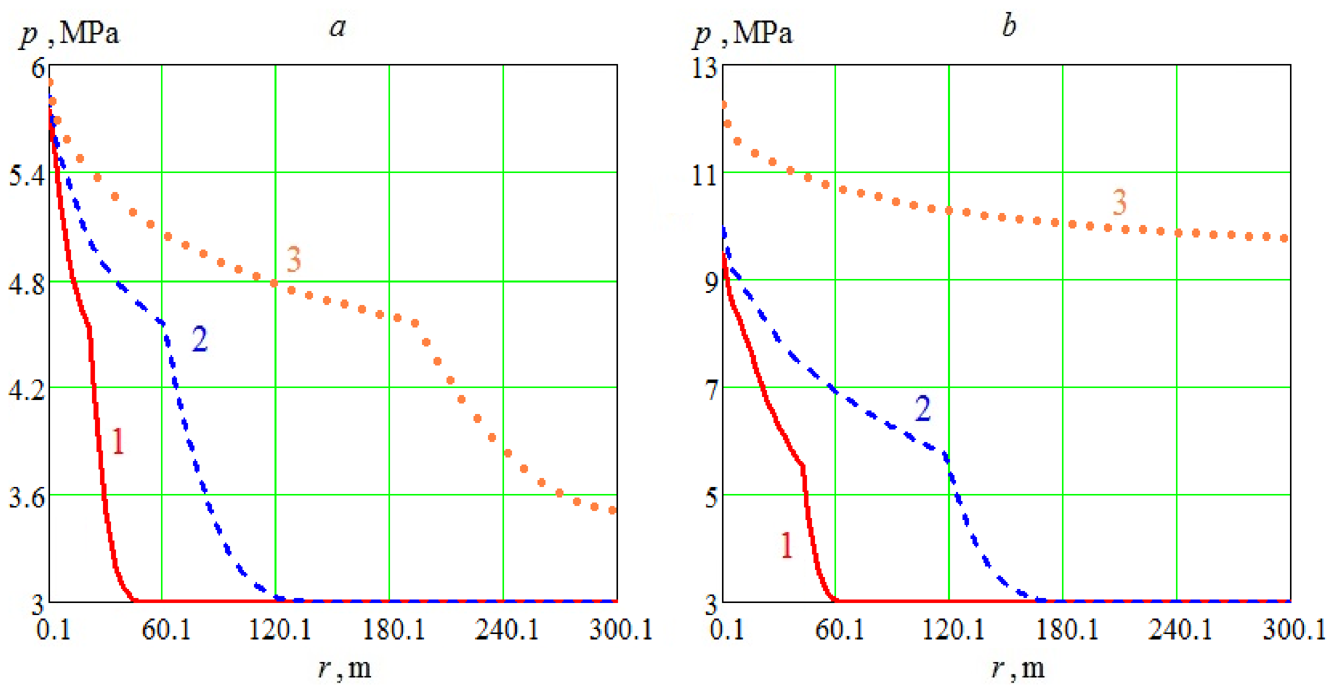

Fig. 5: Pressure distribution in reservoir:*a* – mass flow rate equals 1 m^3/s; *b* – mass flow rate equals 5 m^3/s (1 – t = 1.25 days, 2 – t = 10 days, 3 – t = 100 days)

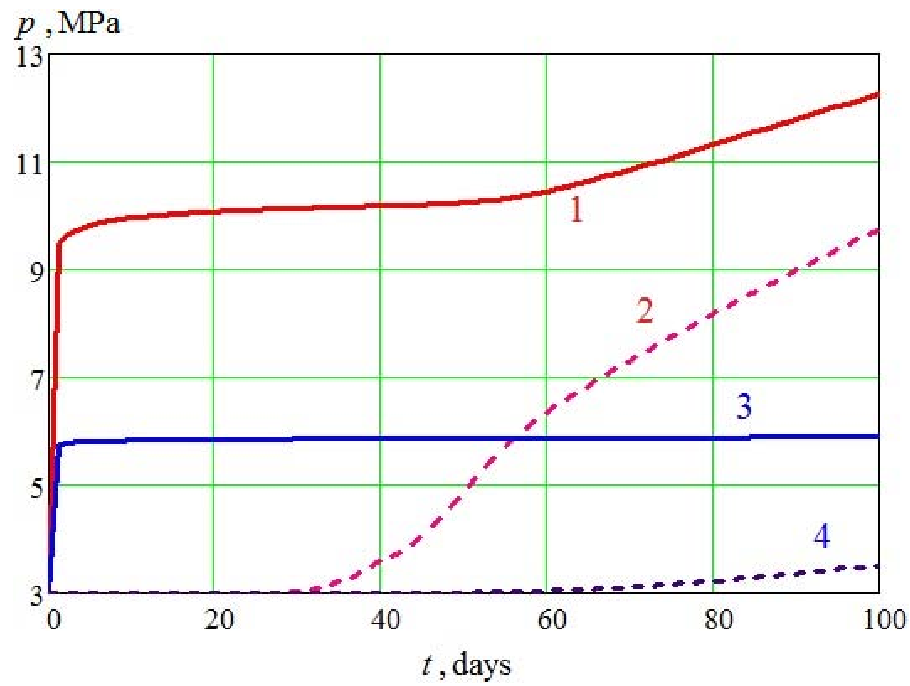

Fig. 6: Pressure dynamics: 1 and 2 – mass flow rate equals 5 m^3/s; 3 and 4 – mass flow rate equals 1 m^3/s (solid lines – r = 0.1 m, dashed lines – r = 300.1 m)

Now consider the influence of dynamics of pressure and temperature fields on water displacement and hydrate formation in the storage. Here we limit the analyses to the case of low permeability because it corresponds to higher temperature and pressure values as can be seen from Fig. 1 and Fig. 4, which may lead to *a priory* unpredictable dynamics of hydrate formation.

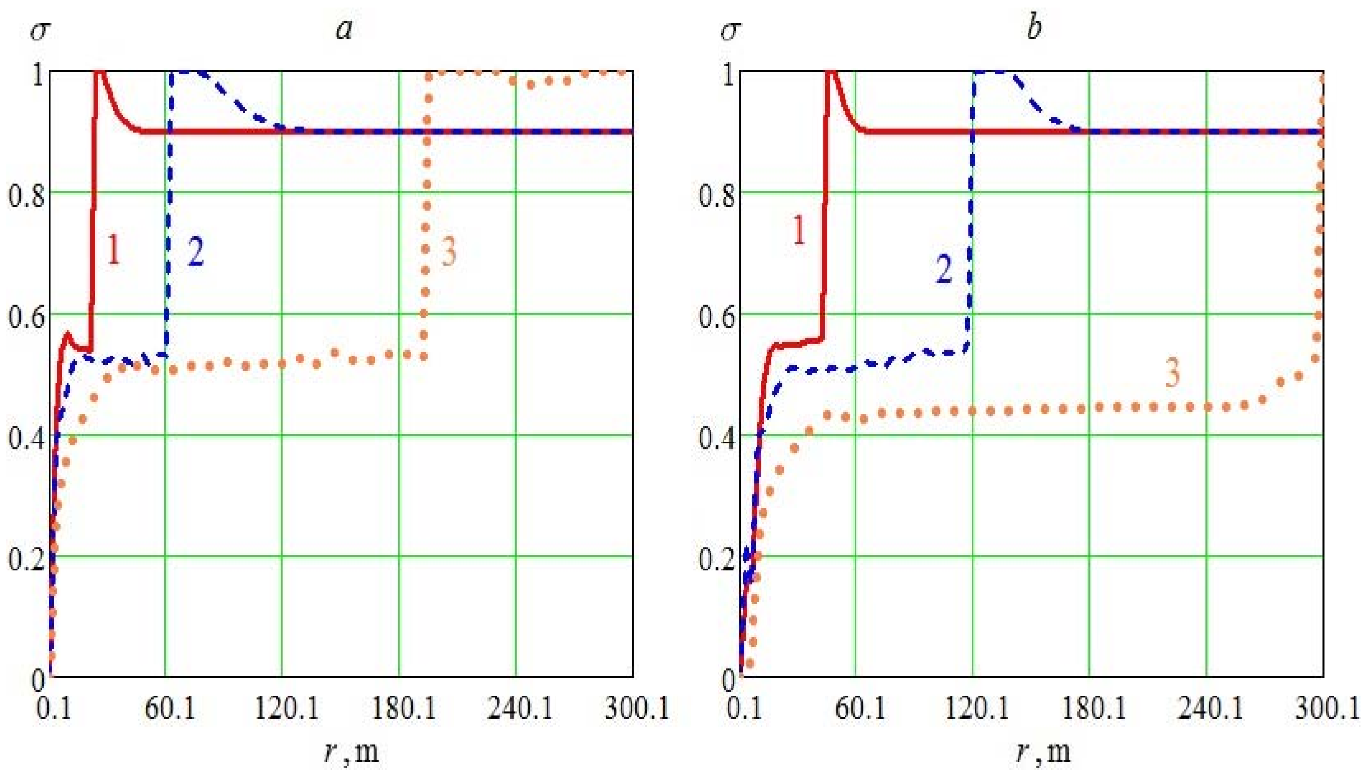

Fig. 7: Water saturation distribution in reservoir:*a* – mass flow rate equals 1 m^3/s; *b* – mass flow rate equals 5 m^3/s (1 – t = 1.25 days, 2 – t = 10 days, 3 – t = 100 days)

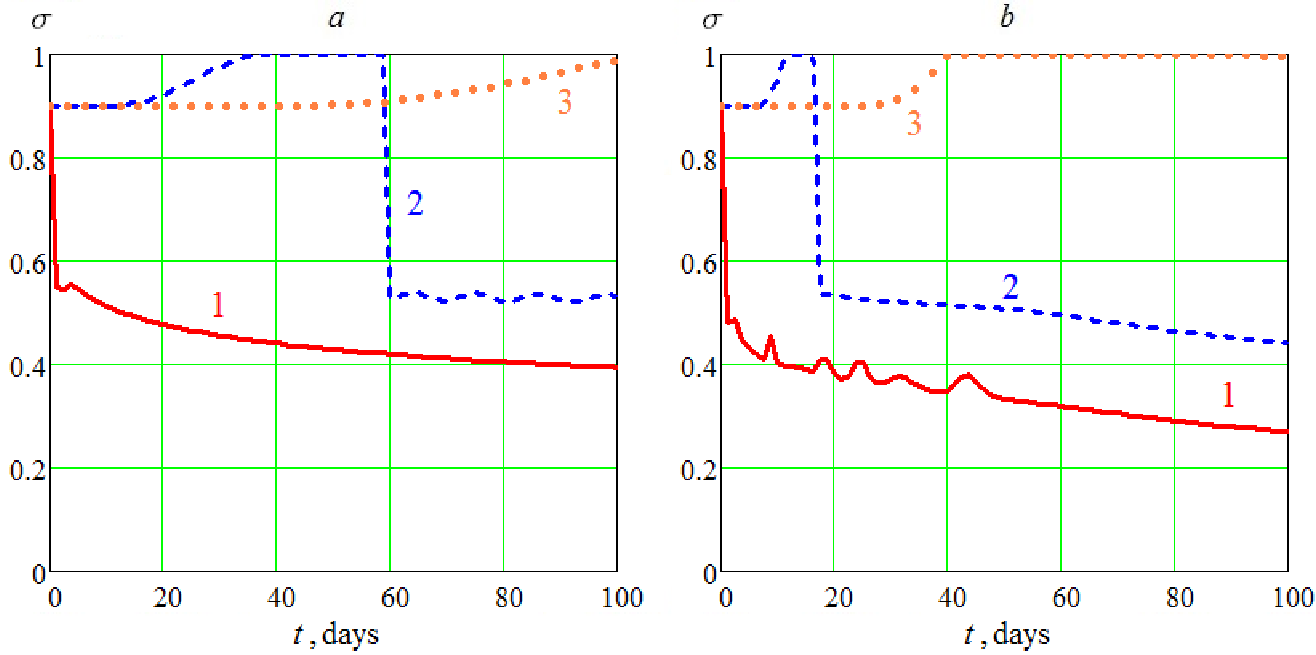

Fig. 8: Water saturation dynamics: *a* – mass flow rate equals 1 m^3/s; *b* – mass flow rate equals 5 m^3/s (1 – r = 12.4 m, 2 – r = 150.1 m, 3 – r = 300.1 m)

Comparison of curves 1 and 2 in Fig. 2 and in Fig. 7 shows that velocity of water saturation front is significantly lower than that of the temperature front. At Fig. 7 and Fig. 8 it is clearly seen that water saturation distribution is in qualitative agreement with the solution of Buckley-Leverett problem [*Charnyi, 1963*]. The effect of hydrate formation, i.e. transition of water into the immobile phase, is manifested in non-monotonic water distribution behind the front and in the fact that water saturation before the front is always lower than 1 (curves 2 in Fig. 8). Naturally, velocity of front propagation is strongly dependent on rate of gas injection. However, in accordance with the theory of two-phase flow in porous media [*Charnyi, 1963*] gas injection cannot displaces all reservoir water (see curve 3 in Fig. 7*b*).

Calculations of hydrate formation show the complicated influence of such competitive factors as reservoir conditions and technology of gas injection.

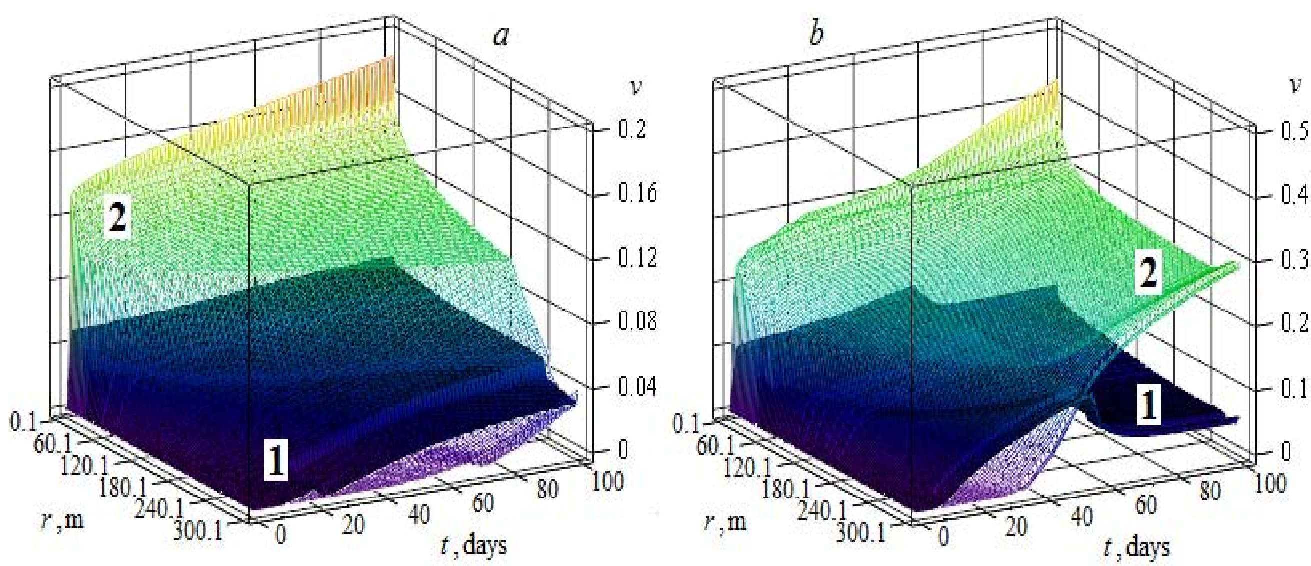

Fig. 9: Dynamics of hydrate saturation: *a* – mass flow rate equals 1 m^3/s; *b* – mass flow rate equals 5 m^3/s (figures at the surfaces correspond to combinations of porosity and permeability)

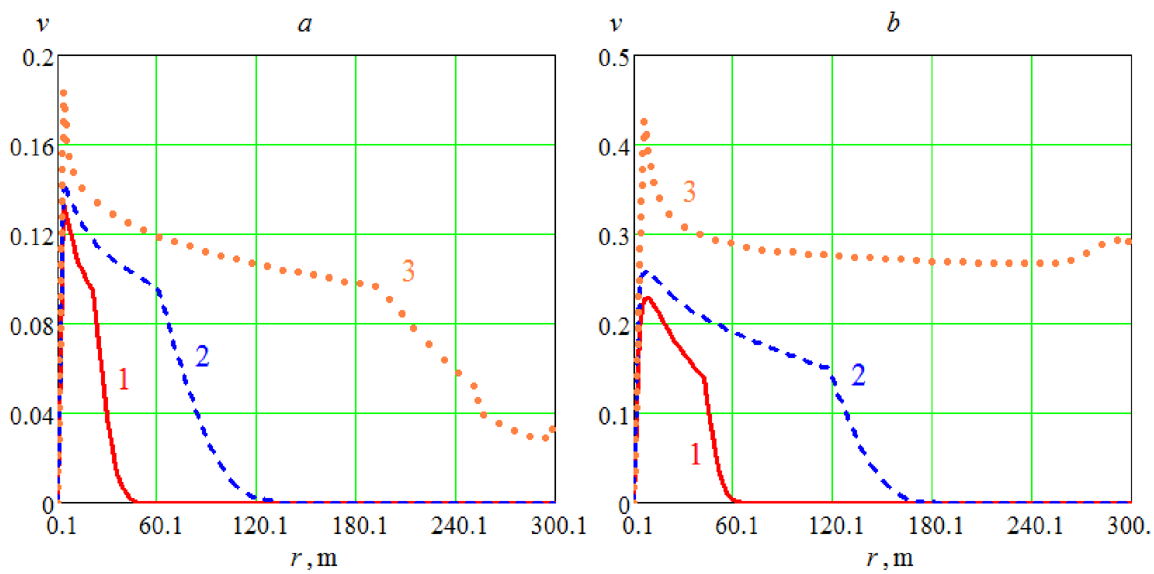

Fig.10: Hydrate saturation distribution in reservoir: *a*– mass flow rate equals 1 m^3/s; *b* – mass flow rate equals 5 m^3/s (1 – t = 1.25 days, 2 – t = 10 days, 3 – t = 100 days)

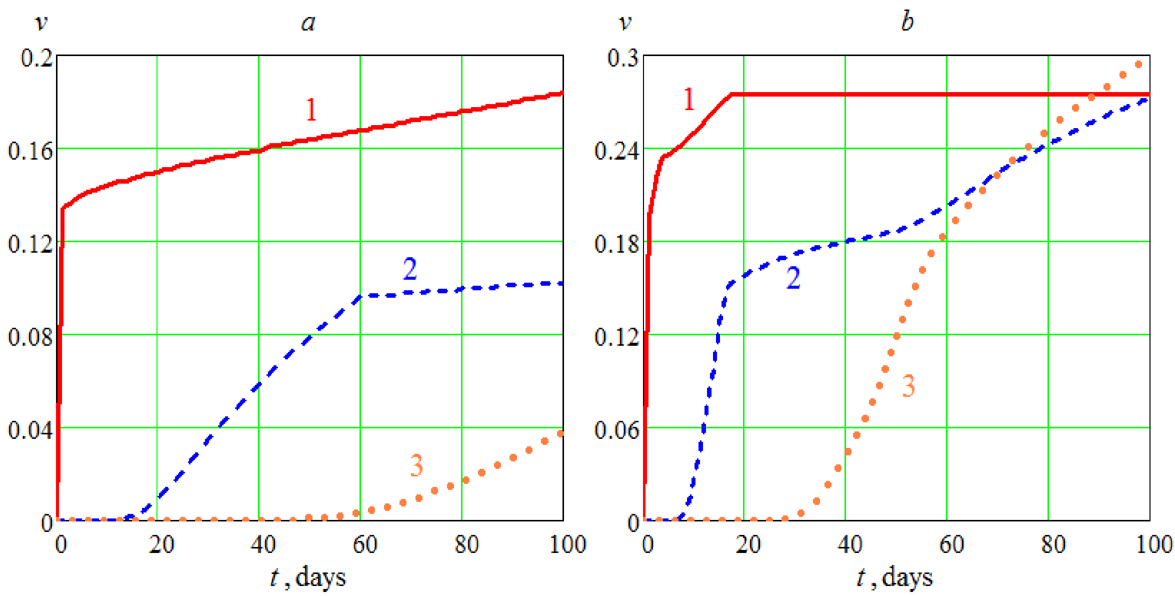

Fig. 11: Hydrate saturation dynamics: *a* – mass flow rate equals 1 m^3/s; *b* - mass flow rate equals 5 m^3/s (1 – r = 12.4 m, 2 – r = 150.1 m, 3 – r = 300.1 m)

First of all, it is seen that higher rate of injection is more favorable for hydrate formation in a reservoir with lower permeability (cf. surfaces 2 in Fig 9*a* and in Fig. 9*b*). It is clear from the fact that high pressure is favorable for hydrate formation. The statement is also supported by comparison of curves 3 in Fig. 10*a* and Fig. 10*b*. Promising is the growth of hydrate saturation at the reservoir boundary with time (curve 3 in Fig. 11*b*).

V. Conclusion

The results of computational experiment show that underground gas hydrate storage development in the subpermafrost aquifers requires a careful analysis of the reservoir geological characteristics and well test data. Specifically, reservoirs with porosity less than 0.2 should be preferred because it ensures a uniform filling of the storage by hydrate. Permeability higher than 10^{-14} m^2 is advantageous to prevent development of excessive pressure at high rate of gas injection, which may result in loss of sealing properties of the reservoir top and bottom.

Additional research is needed to estimate thermal interaction of gas storages with the surrounding rocks and hydrate formation after an injection period.

The results of numerical experiment and proposed mathematical model can be used in the development of scientific bases substantiation of and a basis for technologies of underground hydrate storage of natural gas, as well as toxic gases.

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Optimization of the use of Betterave (*Beta Vulgaris*) for the Production of Green Energy

By Yannibock Hulda, Aboubakar, Njintang Y. N & Mbofung CMF
University of Maroua

Abstract- This work aimed to conduct optimization method of ethanol production from using beet. To attain this objective, we propose to produce the distillation energy through biogas, and fertilizer for the culture of beet. We carried out some tests by using samples of red beets. These samples were subjected to fermentation, distillation with Vigreux column and methanization. The red beet was, a grinder, juice extractor, fermenters, fresh yeast, water, distillation device with a Vigreux column, two batch digesters, a balance and graduated containers. During the tests 376 mL of ethanol, 31 L of biogas and fertilizer evaluated at 1 KWh were obtained. The energy efficiency of production with this method stood at 58, 54 %. This discovery could be a solution to energy problems of many regions, an alternative to fossil energy while being a source of fertilizer. The proposed system does not reject waste: the carbon cycle and even that of nitrogen is closed. It is less costly and easy to put in place. He is environment friendly and has a good energetic performance.

Keywords: beet, fermentation, distillation, biogas, ethanol, fertilizer.

GJSFR-I Classification: FOR Code: 850499

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Strictly as per the compliance and regulations of:

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Yannibock Hulda [α], Aboubakar [σ], Njintang Y. N [ρ] & Mbofung CMF [ω]

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Keywords: beet, fermentation, distillation, biogas, ethanol, fertilizer.

I. Introduction

For centuries economic development and technological advances have always been based on energy. Jean-Marie Boudaire, in his 2011 book on energy, talks about energy as being at the center of the three major issues that will shape the first decades of the next century. It is therefore crucial for a region or country concerned about its development to give capital importance to energy. However, the abusive or clumsy use of the latter leads to harmful consequences that can destroy human life in the long term (climate change, air pollution, diseases ...) (Cned, 2009). It is therefore necessary to produce energy, but it is equally important to think about how to produce it and how to use it. It is in this context that the development of renewable energies takes place. Renewable energy can be defined as a source of energy that is renewed rapidly enough to be considered inexhaustible on a human scale; Renewable energies come from regular or constant natural phenomena caused by the stars, mainly the sun, but also the moon and the earth (Marwan, 2009, Claudine, C., 2014). They can be classified into six main types: biomass, solar, wind, hydro, geothermal, tidal energy (Universalis, 2014). In this range of forms of renewable energies, we will focus on energy from biomass and in particular on biofuels. However, even at this level it is necessary to pay attention to the source, it is not necessary that the raw materials used for the production of energy compete with the food of the populations. This is why biofuels are first, second and third generation (Bates, L. 2007, Nadia et al, 2010). The second and third generation do not pose many problems because they do not compete with foodstuffs. On the other hand, the first generation, it is very often in competition with the food. To solve this problem, dedicated crops are recommended.

Our interest will be focused on sugar beet as raw material for the manufacture of ethanol. This last one is in the first generation but its strong production gives it an interesting potential to make dedicated crops. Its use for the production of sugar is very widespread in the countries of Europe. This sugar is also used to produce ethanol. However, we note that this process is very energy-intensive, especially for distillation; Which makes the technology unprofitable. The main target was the optimization of the process of ethanol production from beet. Before going inside this topic, some questions could be asked: How can the yield of the ethanol production process from sugar beet be improved? Can another beet variant be used? What is its impact on the environment?

This problem is of capital interest because the resolution of this problem will be an added value not only for the industrial sector (fuel alcohol production) but also for the agricultural and environmental fields (fight against the greenhouse effect) . A lot of work has been done around this theme; (Mohamed Mehdi KACIMI, 2008; RIESS julien, 2012; BADERTSCHER Ernest, 2005).

The general objective of this work is to propose a low-energy and environmentally friendly method for the production of ethanol from beetroot. To achieve this objective, we will carry out tests on beets, set up a miniature system and make energy balances.

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II. Material and Methods

The choice of the raw material (red beet) was made randomly. Indeed, these different samples were taken from the farmers of the town of Annemasse-France. The red beets were washed by hand to remove any soil residue and then chopped into smaller pieces. A juicer was used to extract the juice from the chopped red beets.

a) *Fermentation*

i. *Microorganisms*

Dried yeasts Saccharomyces cerevisiae, strain DF 639, were used for fermentation to ethanol. The yeasts (produced by SIHA, Germany) are enriched with nutrients and their biggest advantage is they do not need be propagated before application

ii. *Pretreatment*

a. *Beet Slicing*

Sugar beets are bulb-shaped red root vegetables weighing approximately two kilograms each. In order to remove sucrose from them, the beets first must be sliced into much smaller pieces (cossettes), and are shaped approximately like shoe-string French fries. A slicer was used to model this step in SuperPro Designer (Asadi, 2007).

b. *Sucrose Extraction*

Once the beets are sliced the next step in transforming them into ethanol is extracting the sucrose. In this step, cossettes are washed with a water stream in a counter-current arrangement to extract the sugar. Unlike processes that transform corn into ethanol, sugar beets do not require an enzymatic treatment to produce simpler sugars from starches. This makes the process considerably simpler. The extraction process was conducted using the method of Bogliolo et *al*. 1996.

c. *Filtration*

Impurities in the sucrose are removed by treating the raw juice with lime. In the filtration process calcium hydroxide is added to the beats. Then carbon dioxide is bubbled through the mixture and calcium carbonate is formed. This carbonation and clarification process were repeated twice. To simulate the formation of calcium carbonate, a continuous stirred tank reactor was used in order to model the conversion of calcium hydroxide to calcium carbonate (Asadi, 2007).

d. *Fermentation Process*

We propose to ferment the beet directly without passing through the sugar extraction. To extend the analysis we will proceed in two ways: a fermentation with pulp and a fermentation without pulp.

b) *Fermentation with Pulp*

To perform the fermentation, four mixtures were fixed:

- *1st test:* 2.5 kg of red beet + 1 piece of sucrose of 5 g + 10 g of yeast + 30 ml of water.

This first test contains practically no water added. The fermentation will only be carried out with the water contained in the beet.

- *2nd test:* 5 kg of red beets + 3 pieces of sucrose of 5 g + 25 g of yeast + 2 L of water.

This test complies with the rule 250 g of sugar per 1 L of water.

- *3rd test:* 5 kg of red beets + 3 pieces of sucrose of 5 g + 25 g of yeast + 1 L of water.

Here, half the recommended water has been added.

- *4th test:* 5 kg of red beets + 3 pieces of sucrose of 5 g + 25 g of yeast + 0,5 L of water.

Finally, in this last test, one quarter of the reference water quantity. was set

c) *Fermentation without Pulp*

For fermentation without the beet pulp, three tests were carried out in which less water has been chosen to be added because there are fewer molecules to hydrolyse. These tests were carried out in the following manner:

- *1st test (5th test):* 2.5 kg of red beet + 2 pieces of sucrose of 5 g + 14 g of yeast + 0.5 L of water. This test was carried out with half reference water.
- *2nd test (6th test):* 2.5 Kg of red beets + 2 pieces of sucrose of 5 g + 14 g of yeast + 0,25 L of water.

Here one quarter of the recommended amount of water has been added.

- *3rd test (7th test):* 2.5 kg of red beets + 2 pieces of sucrose of 5 g + 14 g of yeast.

The latter test contains practically no water added. The fermentation will only be carried out with the water contained in the beet.

S. cerevisiae strain (ITD00196) was used to conduct batch fermentation process at 35°C with a pH of 5.5. The pH 5.5 was chosen because It has been demonstrate that S. cerevisiae shows an intracellular pH near 5.5 (.Imai and Oho (1995). The number of living cells at packing was $>2.0 \times 10^{10}$ per g.

Fermentation worts were prepared by diluting thick juice with distilled water, initially at a ratio of 1:1 w/w, and then obtaining solutions with an extract content of either 250 or 280 g/kg. The worts were acidified with 25% (w/w) sulfuric acid to pH 5.5 and supplemented with $(NH_4)_2HPO_4$ (0.3 g/L) only or with $(NH_4)_2HPO_4$ (0.3 g/L) and $MgSO_4 \cdot 7\ H_2O$ (0.1 g/L) as nutrients for yeast.

d) *Distillation*

When fermentation was complete, all ethanol was distilled from worts using a laboratory distillation unit consisting of a distillation flask, a Liebig cooler, a flask for collecting ethanol, and a thermometer. Raw spirits containing 20 to 23% (v/v) ethanol were refined to approximately 43% (v/v) in distillation apparatus equipped with a bi-rectifier unit (dephlegmator according to Golodetz), and subjected to chemical analysis .

e) Analytical Methods

Thick juice was analyzed by the methods recommended for the sugar industry (AOAC, 1995) Solid substance (total extract) was measured by using a hydrometer, which indicates the concentration of dissolved solids, mostly sugars, calibrated in g of saccharose per kg of water solution. Total nitrogen was determined by the Kjeldahl method. Volatile acids (expressed as acetic acid) were assayed using steam distillation. Reducing sugars and total sugars (after inversion with hydrochloric acid) were estimated by the Lane-Eynon method. Both were expressed in g of invert sugar per kg of thick juice. Saccharose concentration was calculated as the difference between total sugars and reducing sugars (taking into consideration a conversion coefficient of 0.95). Also pH was measured (with a digital pH-meter).

f) Fermentation Evaluation

The intake of total sugars (the percentage yield of sugar consumption during fermentation) was calculated as a ratio of sugars used during the fermentation to their content in the wort prior to this process, and expressed in percent. The yield of ethanol was calculated according to the stoichiometric Gay-Lussac equation in relation to total sugars and expressed as a percentage of the theoretical yield.

g) Methanisation

Methanisation can be carried out on any organic matter. In the case of our work, we chose the beet pulp (fermented beforehand or fresh) as substrate. The pulps will be introduced directly into the digester without further pretreatment for those which have previously been fermented; we add just the remains of the centrifugation. Fresh pulps will undergo in addition to the mechanical treatment (grinding) they have had, dilution. methanisation in mesophilic zone, was chosen exactly around 40 ° C. The given tRH is about 15 days (Boileau, A. S. , 2013).. The particularity of our system is to have as inner gas reservoir tubes. It will therefore be necessary to choose a digester capable of containing the entire substrate. two digesters were chosen, one for the fresh pulp and one for the fermented pulp. This will allow us to make comparisons and optimize our study. It should be mentioned here that the gas was not purified as it is used for combustion. It will be led directly into pipes and burnt with the burner provided for this purpose.

h) Statistical Analysis

All samples were prepared and analyzed in triplicate. Statistical analysis was carried out using the Micromal Origin ver. 6.0 software (Northampton, USA).

III. Results and Discussion

a) Production of Ethanol

- *1st test:* 2.5 kg of red beets + 1 piece of sucrose of 5 g + 10 g of yeast + 30 ml of water.

For this test, after fermentation and centrifugation 1.02 liters of fermented juice and 802 g of fermented pulps was obtained. After the first distillation, 87 mL of a non-flammable liquid, was collected, which indicated the sufficient or effective presence of ethanol in the mixture. Therefore a second distillation was carried out in order to improve the purity of the mixture. After the second distillation, a mixture of 13 mL was obtained with a density of 923 kg / m^3; The shape of the curves of the two distillations is given in Figure. 1 and 2.

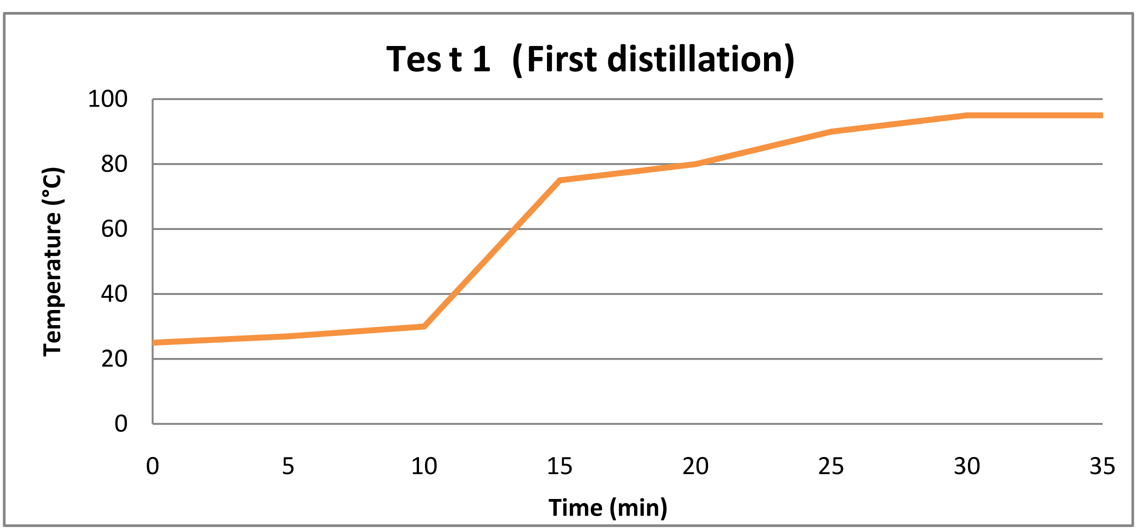

Figure 1: Variation of temperature with time in the first distillation in test 1

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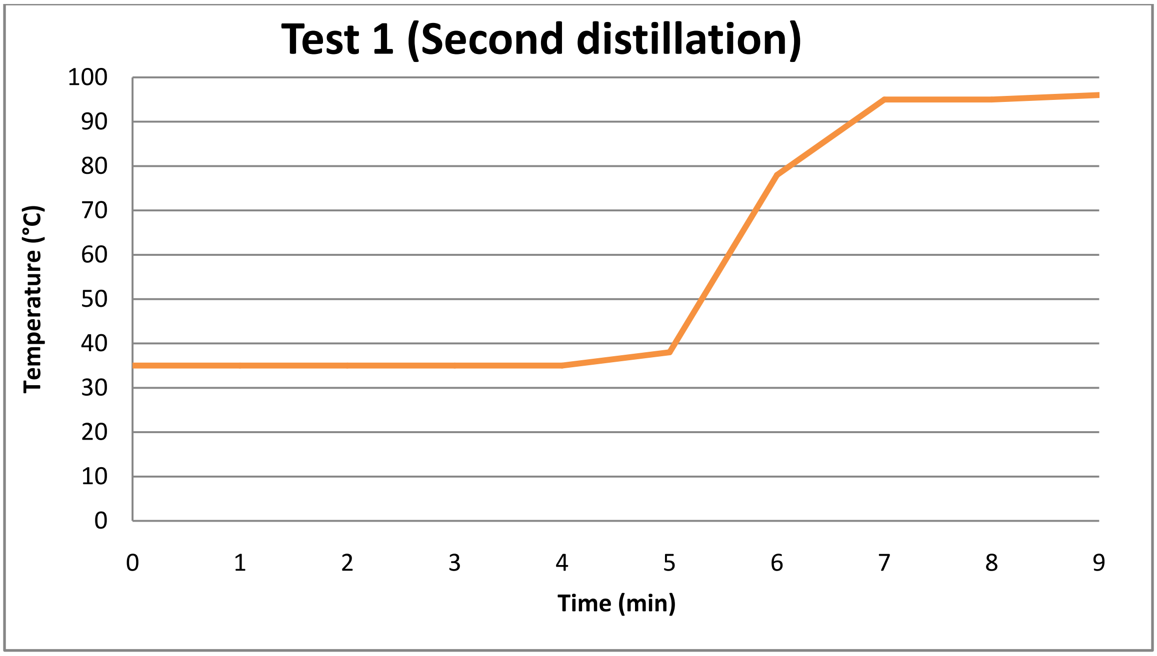

Figure 2: Variation of temperature with time in the second distillation in test 1

Figure 1 shows that during the first 10 minutes, a slow increase in temperature was notted. From the 10th to the 15th minute, there is a rapid increase in temperature which characterizes the phase change of at least one component of the mixture. From minute 15 to minute 25, the temperature continues to grow and stabilizes from the 30th minute. The distillation is then stopped. The shape of this curve is similar to that of Williamson K. L. et *al* (2007). It is characterized by good separation. However, the stabilization temperature is too high (95° C). This could be explained by the presence of a large proportion of water in the mixture and consequently the absence of inflammation.

In Figure. 2, the temperature is stable within the first 4 minutes. It rises slightly between the 4th and the 5th minute. From the 5th to the 7th minute, there is a rapid rise and stabilizes after the 5th minute. The distillation is stopped by cutting off the heat source. The stabilization temperature is always too high (96° C). Following the second distillation, the results are similar to those of the first: good separation but no ignition: This first test is therefore inconclusive.

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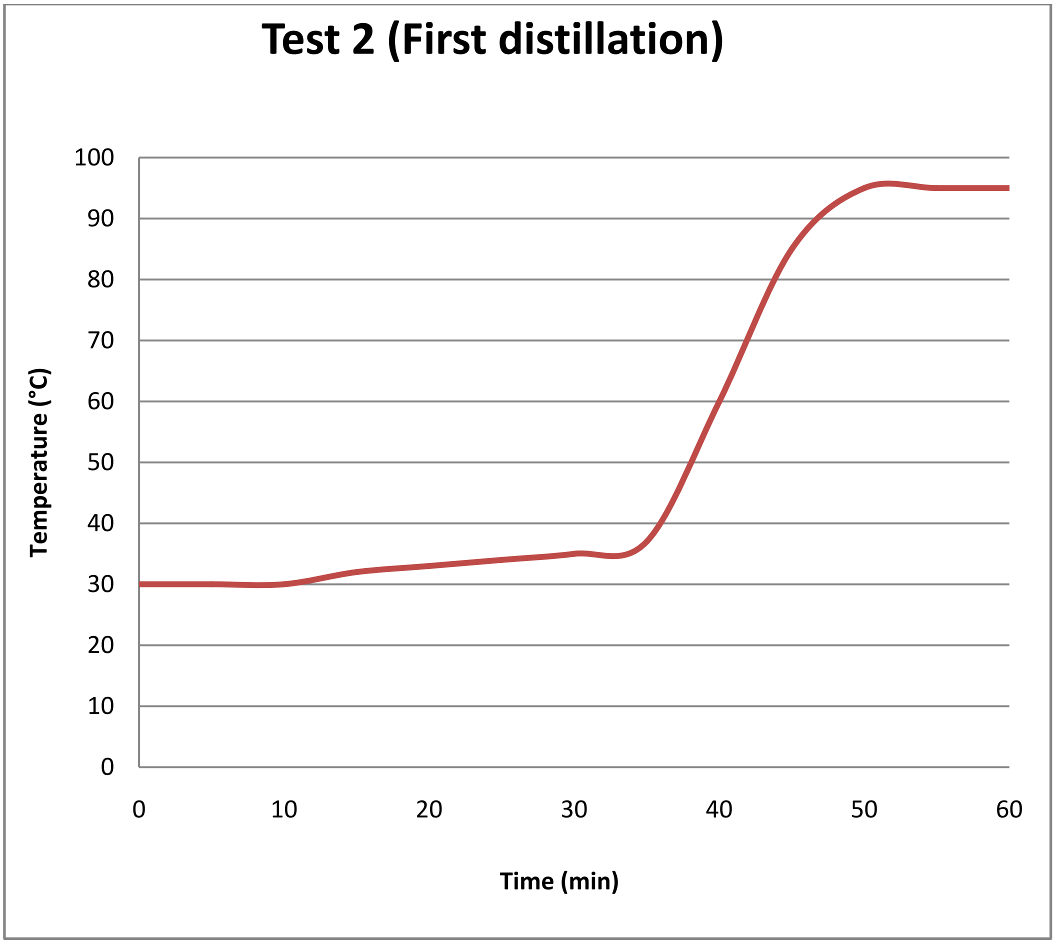

Figure 3: Variation of temperature with time in the first distillation in test 2

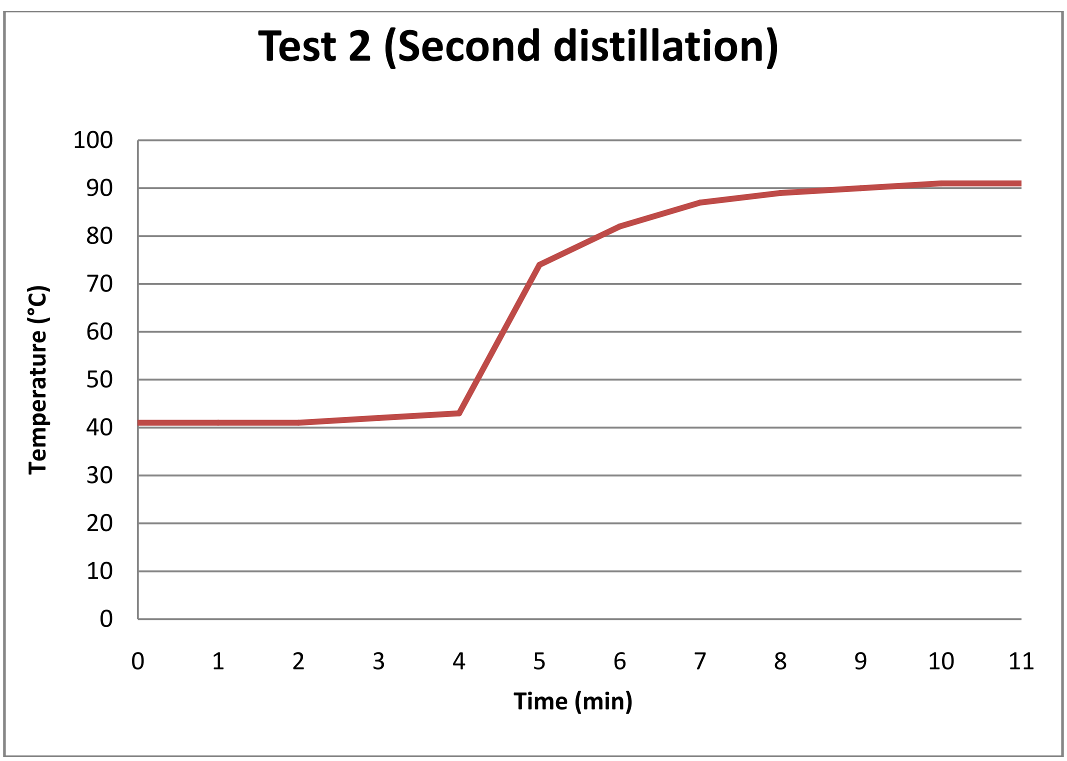

Figure 4: Variation of temperature with time in the second distillation in test 2

It can be seen on the shape of the curve shown in FIG. 3 that the temperature is stable for the first 10 minutes. It then rises slightly from the tenth to the thirty-fifth minute. Then from the thirty-fifth minute to the fiftieth minute, there is a rapid elevation which characterizes the phase change. Finally, the temperature stabilizes again and the distillation is stopped. It is demonstrated, based on the works of Boots K. *et* al. (2011), that the separation was good during the distillation. However, despite the good separation, It was observed a stabilization of high temperature (95 ° C), so the mixture does not ignite.

In Figure 4, it was observed that the temperature were stable during the first 4 minutes. It had then risen rapidly in one minute, then more slowly in 2 minutes. Finally, it had stabilized after the seventh minute and the distillation is stopped. Then, according to Boots K. *et* al. (2011), the second distillation of this test has a good separation: In addition, the point of stabilization acceptable (91 ° C), the collected liquid is flammable and odorous. 67 mL. After measuring the density, 776.11 kg / m ^{3} was found. Using alcohol tables, this mixture is an alcohol at 98.7 °. This test is therefore conclusive.

- *3rd test:* 5 Kg of red beets + 3 pieces of sucrose of 5 g + 25 g of yeast + 1 L of water. Following fermentation and centrifugation, we obtained 2.85 liters of fermented juice and 1.44 kg of pulp. The shape of the distillation curves is given in Figure 5 and 6.

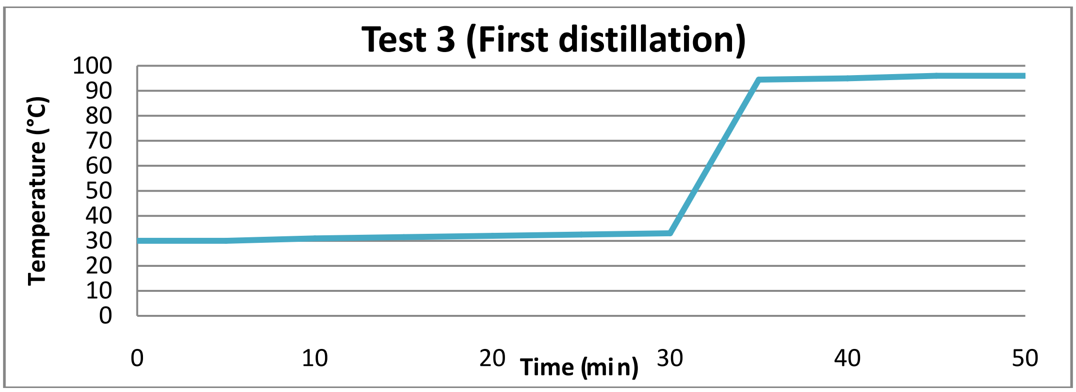

Figure 5: Variation of temperature with time in the first distillation in test 3

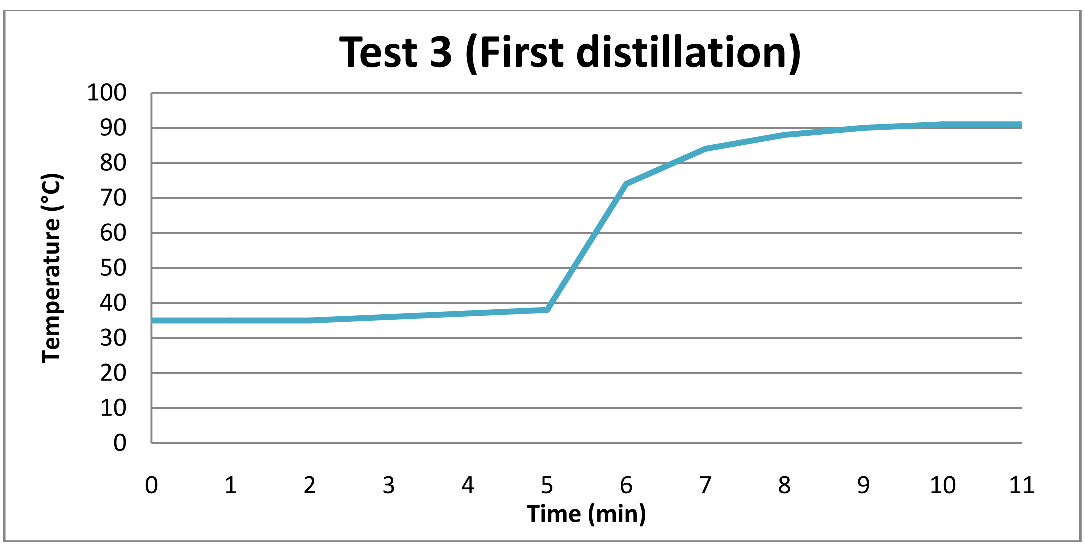

Figure 6: Variation of temperature with time in the second distillation in test 3

Figure 5 shows that for the first 30 minutes the temperature is almost stable (it only rises by 3 ° C.), then there is a sudden rise in 5 minutes and then stabilization. The distillation is stoppe the conclusion was, that according to Boots K. *et* al. (2011), separation approaches perfection. However, the stabilization temperature is still too high (96 ° C) and there is no ignition.

The second distillation curve of test 3 is recorded in FIG. 6. The following observations are made: the first 5 minutes, the temperature does not vary. The next minute there is an abrupt rise of 40 ° C, the two minutes after the continuous rise but it is 15 ° C, and finally the temperature stabilizes again from the ninth minute. The distillation is stopped. The separation is good, the temperature of stabilization acceptable (91°C),

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the smell test is positive and in addition there is inflammation. In addition, a total volume of 73 mL and a density of 795.21 kg / m^3 was found. According to the alcoholic tables, there is an alcohol of 94,5 °; this test is therefore conclusive. Similar result was obtained by Legrand, G. (2005).

- The 4th test was conducted as follow: 5 Kg of red beets + 3 pieces of sucrose of 5 g + 25 g of yeast + 0.5 L of water. After fermentation and centrifugation, 1.31 kg of fermented pulp and 2.7 liters of fermented juice was obtained. Then the distillation of the juice was realized. The shape of the distillation curves is shown in Figure 7 and 8.

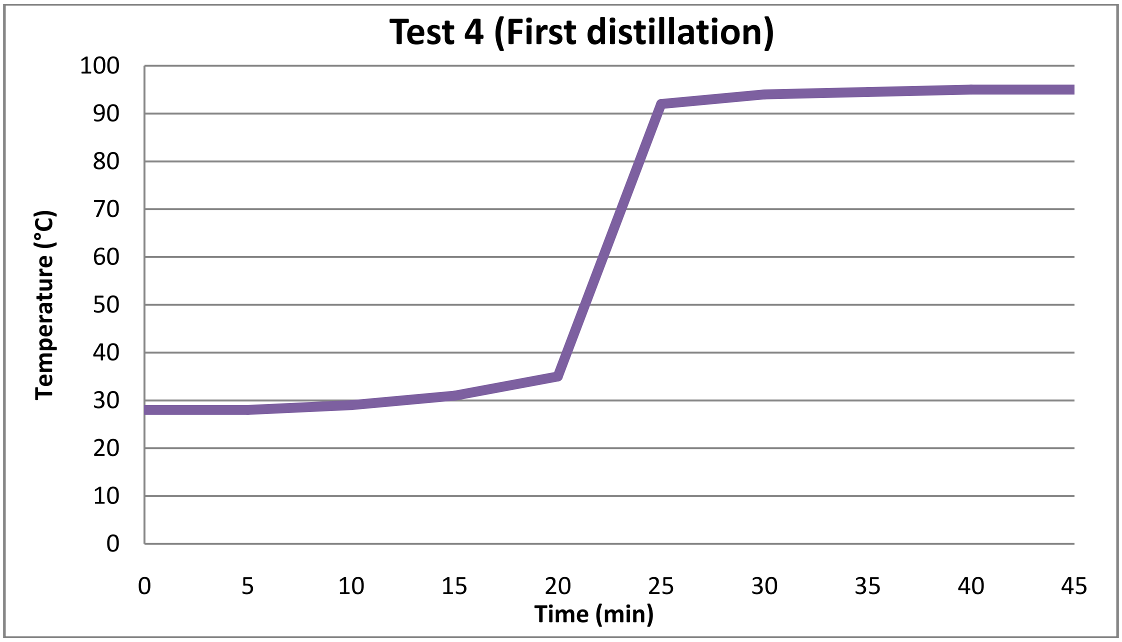

Figure 7: Variation of temperature with time in the first distillation in test 4

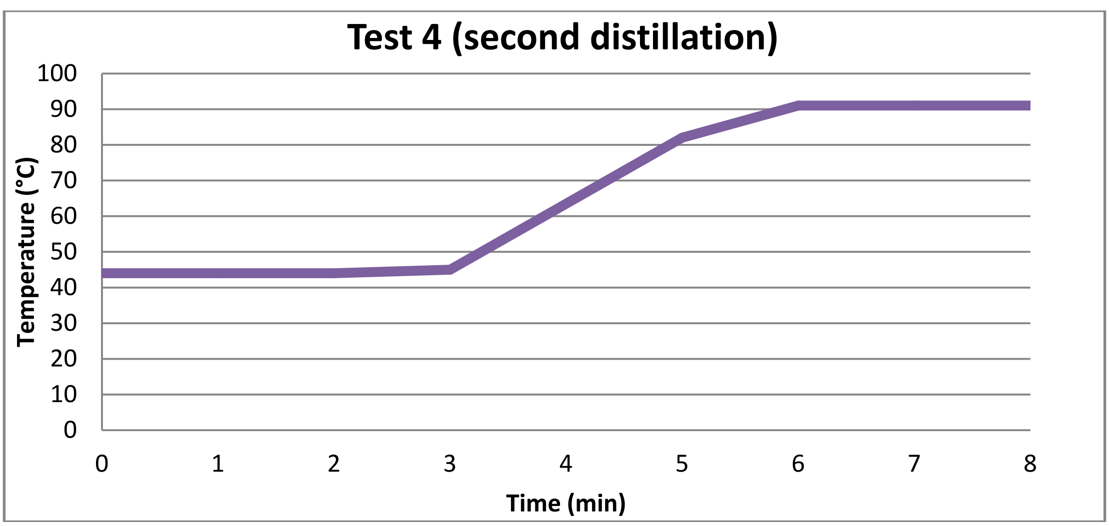

Figure 8: Variation of temperature with time in the second distillation in test 4

The first 15 minutes is a stable temperature, rising slightly from the 15th to the 20th minute, then more rapidly from the 20th to the 25th minute and stabilizing after 25 minutes. The distillation is stopped after 45 minutes. Figure 7, similar to that of Boots K. *et* al. (2011), allows us to conclude that there is a very good separation. But the stabilization temperature was too high (96°C) and there was no inflammation; a second distillation is then carried out.

From the course of the curve observed in Figure 8, it can be seen that during the first 3 minutes the temperature is stable. It then rises quickly from the 3rd to the 6th minute. Finally, it stabilizes after the 6th minute. The distillation is stopped in the 8th minute. On the basis of the results of Boots K. *et* al. (2011).

It can be indicate that the separation is very good. In addition, the stabilization temperature is acceptable (91°C). The flame and smell tests were positive. So we move on to the measures. There are 82 mL and 810 Kg/m^3. By consulting the alcohol tables, the conclusion is that, there is an alcohol at 90.2°. This test is therefore conclusive.

- *For 5th test:* 2.5 kg of red beet + 2 pieces of sucrose of 5 g + 14 g of yeast + 0.5 L of water.

Following fermentation and centrifugation, 1.6 liters of fermented juice was obtained. The shape of the distillation curves is shown Figure 9 and 10.

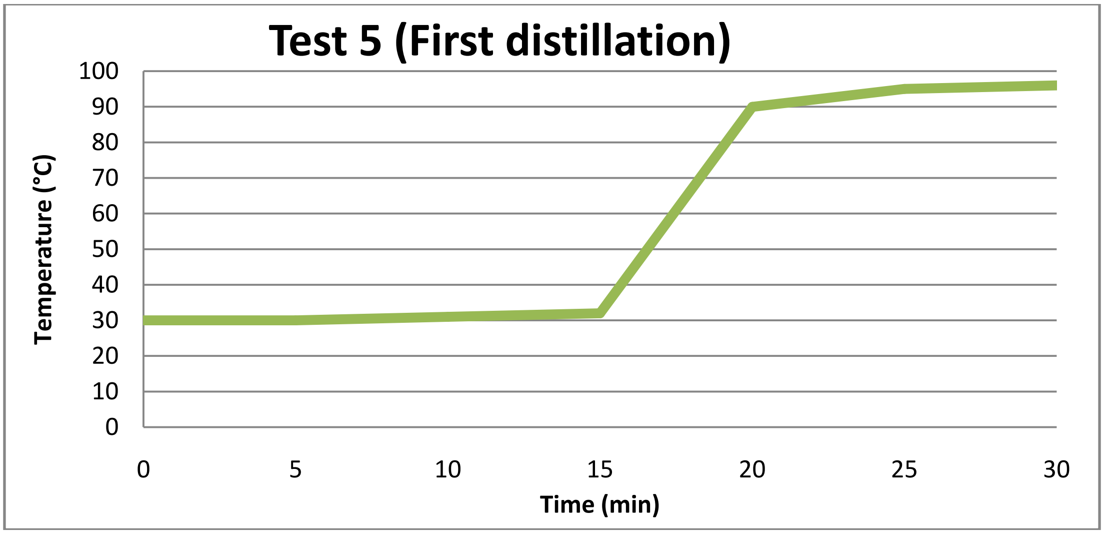

Figure 9: Variation of temperature with time in the first distillation in test 5

For this first distillation of test 5, we observe a stable temperature during the first 15 minutes. There is then a rapid rise between minute 15 and minute 20. Then the temperature stabilizes gradually and the distillation is stopped at the 30th minute. According to BORDA (1980) and Boots K. *et* al. (2011), we are in the presence of a very good separation. However, the absence of ignition and the too high stabilization temperature (96°C.) lead to a second distillation.

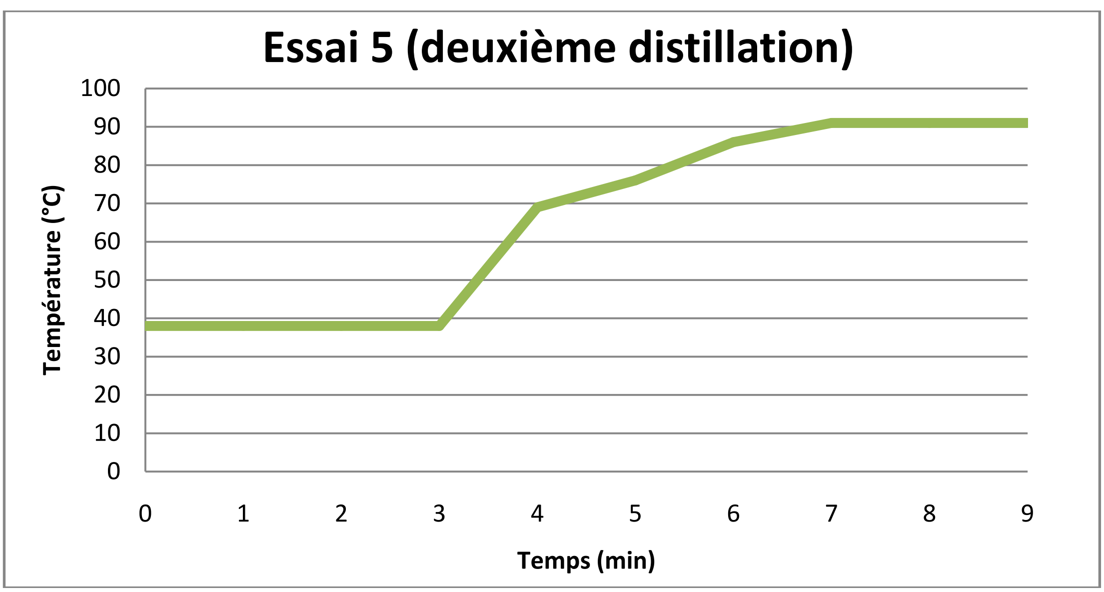

Figure 10: Variation of temperature with time in the second distillation in test 5

In Figure 10, we observe a stable temperature during the first 3 minutes. Then, from the 3rd to the 6th minute, we have a progressive evolution. Finally the temperature stabilizes after the 7th minute and the reaction is stopped in the 9th minute. At the end of this second distillation, there is a product which has an odor of alcohol and which ignites. After measurement, a volume of 40 mL and a density of 800.00 kg / m^3 are found. By consulting the alcohol tables, the conclusion was that we are in the presence of an alcohol at 96.7°.

This test is therefore conclusive.

- *The 6th test was conducted as follow:* 2.5 kg of red beets + 2 pieces of sucrose of 5 g + 14 g of yeast + 0.25 L of water. After fermentation and centrifugation, 1.48 liters of fermented juice are obtained. We have carried out two distillations of which the appearance of the curves is the subject of figures 11 and 12.

In Figure 11, it has been observed that the temperature was practically stable during the first 15 minutes. Then there was a rapid rise from the 15th to the 20th minute and then to stabilize. The distillation lasted for 25 minutes.

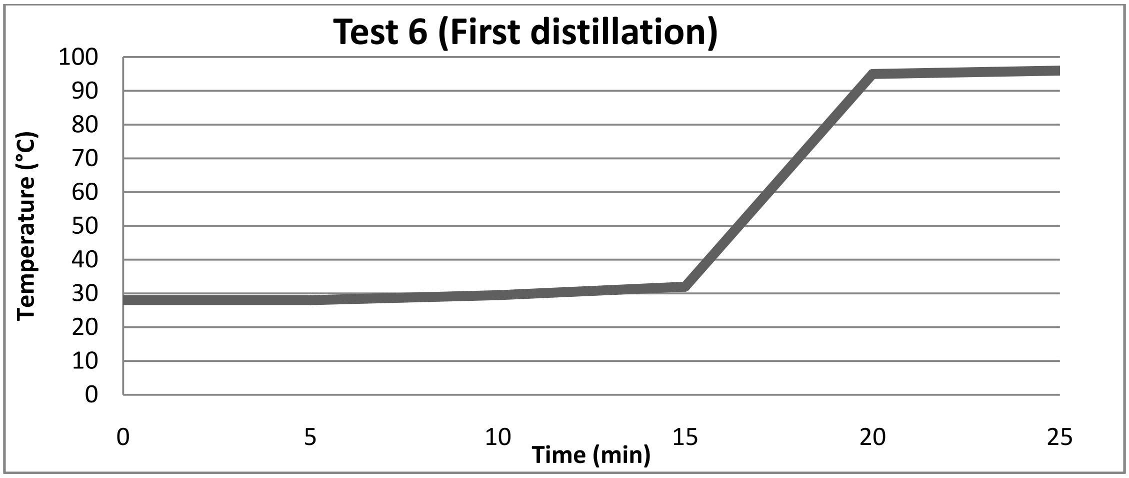

Figure 11: Variation of temperature with time in the first distillation in test 6

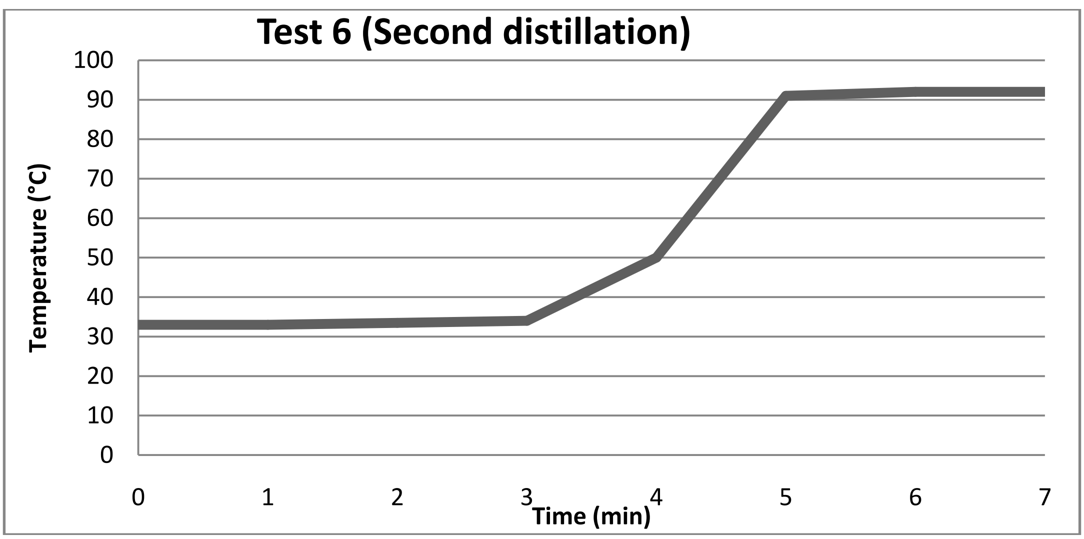

Figure 12: Variation of temperature with time in the second distillation in test 6

The conclusion can be taken according from the work of Grandbois, D. (2004). and Boots K. *et* al. (2011), that there has been a good separation. However, the mixture has retained the smell of beetroot and is non-flammable. In addition, the stabilization temperature is too high (96°C.).

In Figure 12, a stable temperature was observed for the first 3 minutes. Then there was a rapid rise from the third to the fourth minute. This was followed by a slower rise from the fourth to the fifth minute. Finally, the temperature stabilized again after the fifth minute. The distillation lasted 7 minutes. The result of this distillation gave a mixture having the smell of alcohol and flammable. After measurement, 47 mL of volume and 900.10 kg / m^3 of density were found. The alcoholic tables led to the conclusion that it is an alcohol at 61.9°. This trial was conclusive.

- In the 7th test, the ingredients were as follows: 5 kg of red beet + 3 pieces of sucrose of 5 g + 25 g of yeast + 1 L of water. After fermentation and centrifugation, 0.91 liters of fermented juice is obtained. The distillation curves are shown in Figure 13 and 14.

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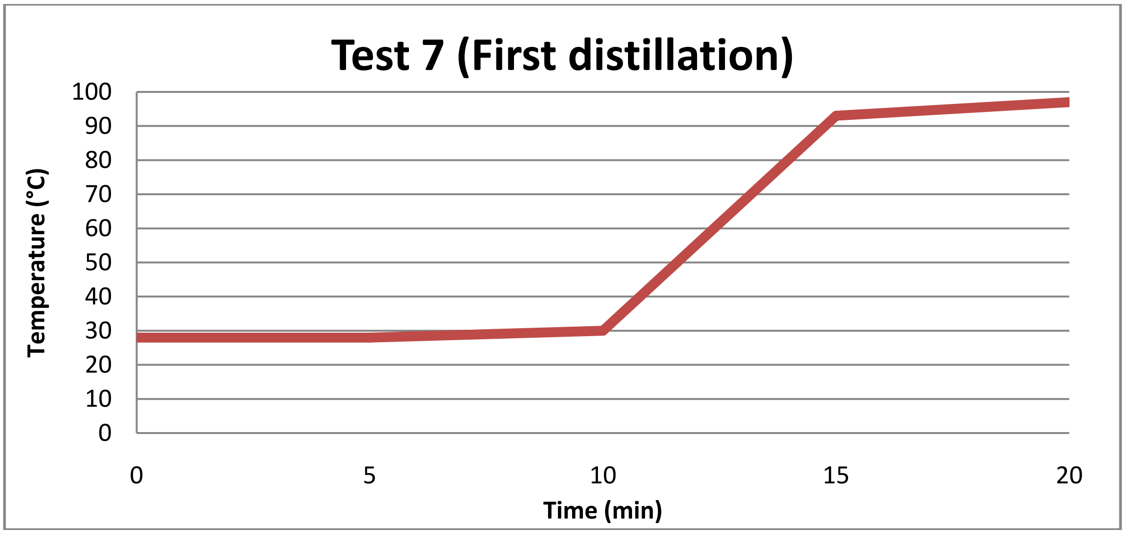

Figure 13: Variation of temperature with time in the first distillation in test 7

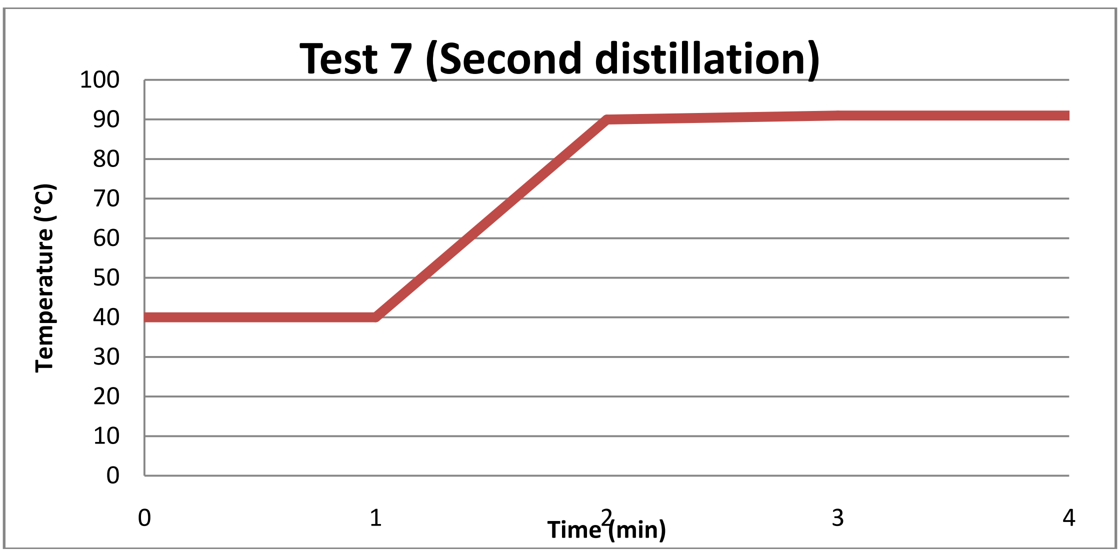

Figure 14: Variation of temperature with time in the second distillation in test 7

In FIG. 13, a stable temperature was noted during the first 10 minutes. From the tenth to the fifteenth minute, there was a rapid rise followed by a stabilization. The distillation was carried out for 20 minutes. The mixture which was obtained was not odorous and did not ignite. the stabilization temperature was too high (97°C). A new distillation of the mixture was carried out again.

The Figure 14 had shown a stable temperature during the first minute. The next minute was a rapid rise and the last two minutes the temperature stabilization was noted. The separation curve was good and the mixture was odorous and flammable. A volume of 54 mL and a density of 969.3 Kg/m^3 were obtained. The correspondence of the tables made it possible to note the presence of an alcohol at 22°. This test is conclusive.

It should be mentioned here that the densities measured on the mixtures were made at 40°C for the first four tests (fermentations with pulp) and 25° for the last three (fermentation without pulps). During the flame test, all the flames were blue. Table 1 summarizes the results obtained for the production of alcohol.

Table 1: Results of alcohol production

Number of test	Volume of alcohol produced (mL)	Degree of alcohol produced	Flammable?	Remarks
1	13	Not exploitable	No	Test non conclusive.
2	67	98.7°	Yes	Test with pulp, good separation.
3	73	94.5°	Yes	Test with pulp, good separation.
4	82	90.2°	Yes	Test with pulp, good separation, some losses in the junction
5	40	96.7°	Yes	Test without pulp, good separation.
6	47	61.9°	Yes	Test without pulp, good separation, some losses in the junctions.
7	54	22°	Yes	Test without pulp, good separation, some losses in the junctions

b) Production of Biogas

In the perspective of producing biogas, two digesters have been set up: the first (Figure 15) for pre-fermented pulps and the second (Figure 16) for fresh pulp. The production was observed for 18 days. At the end of this period, a production of 19 liras of biogas for the digester 1 and a production of 12 liters of biogas for the digester 2 were recorded. This result is different to the result obtained by Fry, L. J. (1975), GTZ, (1989), Corrot, G. (1989) and Funda C. E. (2011). Those authors produced biogas in 25 days. The different observed in our experiment related to the production of biogas would be to the high biological degradability of the beet in general, and particularly in the digester 2.

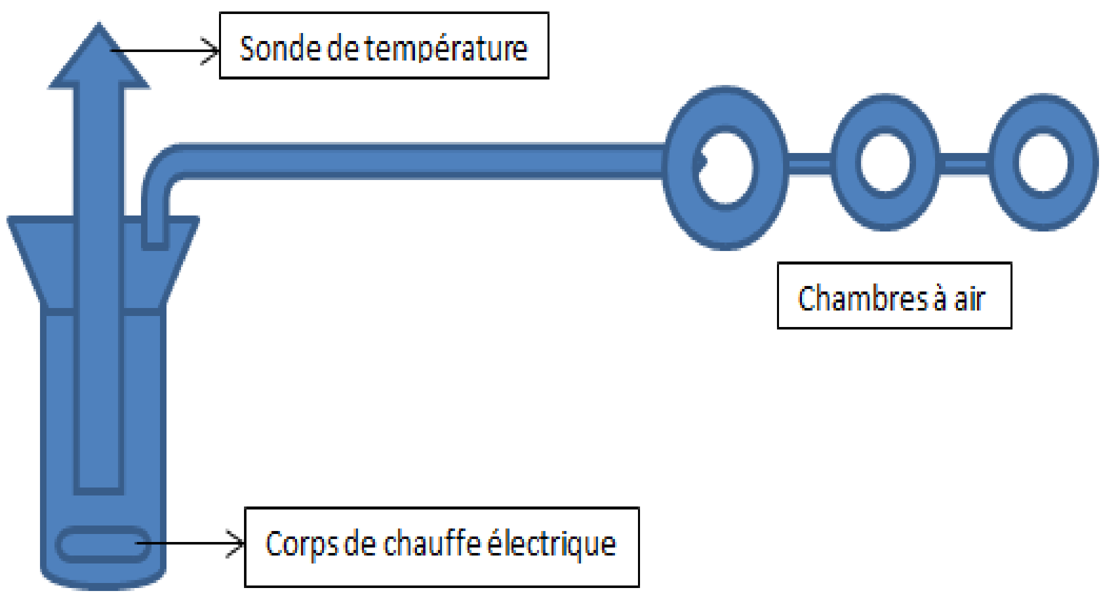

Figure 15: Digester 1

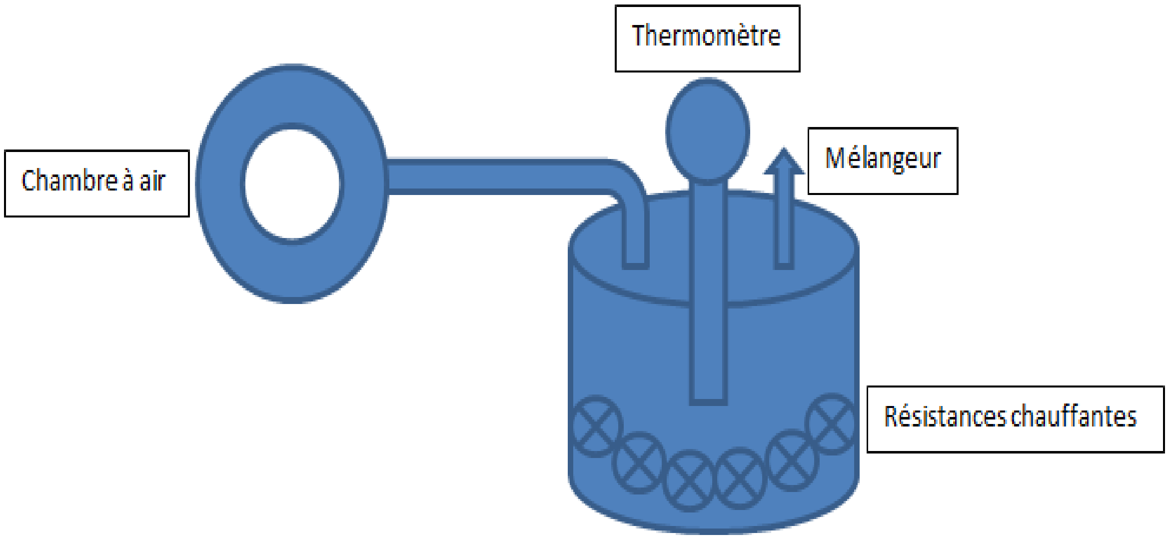

Figure 16: Digester 2

c) Energy Balance Sheet

i. *Energy Expenditure*

Energy expenditure is grouped in two: energy costs related to the production of alcohol and those related to the production of biogas.

ii. *Production of Alcohol*

Table 2 summarizes the different energy expenditures we have identified in our trials of ethanol production from red beet.

Table 2: Energy consumption related to ethanol production

Energy consumption element	Energy consumed
Distillation (250 W; 1h)	6000Wh
Blender (450 W; 1h)	250 Wh
Extractor (250 W; 0.5h)	225 Wh
Balance (0.75 W; 1h)	0.75 Wh
Centrifuge (814 W; 1h)	814 Wh
Oump (48 W; 1.8h)	86.4 Wh
Total for Ethanol production	7.37 KWh

Production of biogas

Energy consumption element	Energy consumed
Heaters	129.75 Wh
Heating resistors	171.29 Wh

The production of ethanol gave an energy expenditure of 7.37 KWh, while that of biogas gave 171.29 Wh. This gives a total expenditure of 7, 54 KWh. Similar result was found by Guy Roulier. (2015)

d) Energy Gains

Energy gains are recorded in four areas: alcohol production, biogas production, water heating and fertilizer fertilizer production.

i. *Production of Alcohol*

Table 4 gives the energy values of the alcohol of the various tests. It is to be recalled that the first 4 tests were carried out with the pulp and the last 3 without. In test 2, 2 L of water were put , in test 3, 1 L, in tests 5 and 6, 0.5 L and in the test 7, 0, 25 L.

Table 4: Energy produced by alcohol

Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Total alcohol
--------	0.42KWh	0.45KWh	0.49KWh	0.25KWh	0.21KWh	0.10KWh	1.92 KWh

It has been noted here that for pulp fermentation, the amount of energy produced decreases with the addition of water. On the other hand for the fermentation without pulp it is the opposite. This result was different to the result obtained by Gunnerson, C. G. and Stuckey, D. C. (1986) those authors found the increase of the production with the addition of water.

ii. *Production of Biogas*

Table 5 represents the energy production of biogas.

Table 5: Energy produced by biogas

Digester 1	Digester 2	Vinasse	Total biogas
0.12 KWh	0.07 KWh	14.38 KWh	14.57 KWh

The energy produced by Vinasses (14.38 KWh) are higher than those obtained from digesters. This result was closed to the result obtained by Henning, R. and Andres, C. (1986.)

iii. *Heating Water*

The temperature rise of the water used to condense the alcohol during each test was on average 15 ° C. and 5 liters of water were used for each test. A a total energy production of 0.7 KWh was obtained.

iv. *Production of fertilizer*

The potential of digestate in terms of fertilizer is estimated at 0.36 KWh for nitrogen, 0.04 KWh for phosphorus and 0.6 KWh for potash. That makes a total of 1 KWh.

The total energy gain is 18.19 KWh

The yield is 58.54%, which is almost double the conventional yield.

Ethanolic fermentation is an exothermic process. The heat released is 1.2 MJ / kg of ethanol produced. The evacuation of the calories produced, which is not problematic with the current small operating procedures, could certainly become so by doubling or tripling the productivities, as could also become the entrainment of ethanol in the effluents, with a concomitant increase the production and superficial velocities of CO_2 release. The process we propose is more ecological because it emits no waste and uses less energy. All energies are recovering and exploiting. Similar result was obtained by DE WULF AGRO (2015)

The methanisation of the pulps makes it possible to supply the distillation energy and to heat the digester. The anaerobic digestion of the vinasses contributes to the distillation without fossil energy input and makes it possible to obtain a non-acidic, odorless and mineral-rich liquid residue, directly applicable to the fields, which is not the case for an acidic vinasse . The return to crops of liquid residues avoids the purchase of fertilizers; the nitrogen cycle is closed. The impact on the environment is remarkable; no polluted water, no fossil energy, remarkable CO_2 balance. For the agro-food industries and for energy production, this initiative can be a lifeline.

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Numerical Simulation of Non-Uniform Roughness Distribution on Compressor Performance

By Sun-Haiou, Wang-Meng, Wang-Zhongyi & Ma-Jingyuan
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Abstract- This paper investigated the roughness of NASA Stage 35 test compressor. Surface roughness can change the geometric line in the microcosm, which causes the compressor operation to deviate from the design point under working conditions. Wall function was used in this study to describe roughness. Roughness calculation model in non-uniform distribution was established along the chord and spanwise directions. Basing on certain rules, rotor blades were attached with roughness to determine the influence of blade roughness position distribution on the overall performance of the compressor and internal flow. Results show that when roughness was distributed from the blade leading edge to 40% of the chord, the compressor performance was greatly influenced; in severe performance, compressor efficiency decreased by more than 2%. Roughness position distribution in blade height direction exhibited a minimal effect on the entire compressor performance, which can be ignored.

Keywords: *compressor, surface roughness, flow field, numerical simulation.*

GJSFR-I Classification: *FOR Code: 010301*

NUMERICALSIMULATIONOFNONUNIFORMROUGHNESSDISTRIBUTIONONCOMPRESSORPERFORMANCE

Strictly as per the compliance and regulations of:

Numerical Simulation of Non-Uniform Roughness Distribution on Compressor Performance

Sun-Haiou [α], Wang-Meng [σ], Wang-Zhongyi [ρ] & Ma-Jingyuan [ω]

Abstract- This paper investigated the roughness of NASA Stage 35 test compressor. Surface roughness can change the geometric line in the microcosm, which causes the compressor operation to deviate from the design point under working conditions. Wall function was used in this study to describe roughness. Roughness calculation model in non-uniform distribution was established along the chord and spanwise directions. Basing on certain rules, rotor blades were attached with roughness to determine the influence of blade roughness position distribution on the overall performance of the compressor and internal flow. Results show that when roughness was distributed from the blade leading edge to 40% of the chord, the compressor performance was greatly influenced; in severe performance, compressor efficiency decreased by more than 2%. Roughness position distribution in blade height direction exhibited a minimal effect on the entire compressor performance, which can be ignored.

Keywords: compressor, surface roughness, flow field, numerical simulation.

I. Introduction

The surface roughness of compressor blade increases gradually during operation because of corrosion, fouling, abrasion, and other factors. An inlet guild van from a compressor which served for 37 months was observed by David Linden; he showed that the aperture could even reach 3.2mm, depth can be 0.8mm caused by pitting. Moreover, Lu Mingliang did some experiments under laboratory condition, after seven days, 14 days and 21 days, the blade surface roughness correspond increased to 6.3μm, 31.7μm, and 86.7μm from original 2μm. Both these researches have shown that surface roughness is nonnegligible in a compressor. Position distribution of blade surface roughness exhibits significant difference that depends on the operating environment. Increase in blade roughness causes compressor blades to deviate from the design point under working conditions. This phenomenon results in the decrease of performance of the entire compressor. Numerous studies have been conducted to determine the influence of different blade surface roughness on gas turbine properties. Bonus et al. measured a large number of gas turbine blades and obtained practical measurement data of blade corrosion. Their results were statistically analyzed to study heat transfer characteristics of rough blade surfaces. Pailhas studied how different Reynolds numbers affect the development of turbulent boundary layer of the roughened surface. Fouflias et al. performed a test method to study the effect of operating characteristics of gas turbine compressor blades when roughness increases uniformly. Basing on the study of Foulias, Back et al. discussed the effects of different roughness distributions and different Reynolds numbers on compressor blade performance. Chen et al. studied corrosion properties on compressor rotor blades using the computational fluid dynamics (CFD) method. All these studies focus on the overall performance influenced by blade roughness, and no studies were conducted to determine the effect of different roughness distributions on compressor performance. Therefore, this paper established a blade model with non-uniform roughness distribution in tangential and spanwise directions. A wall function method that can describe roughness was also performed to investigate the effect of non-uniform roughness on compressor performance.

II. Principle of Numerical Simulation

In this paper, the wall function used in CFX, a commercial software computational tool, to describe surface roughness is the extension method proposed by Launder. In the logarithmic law region, the tangential velocity and wall shear stress near the wall have a logarithmic relationship. We used an empirical formula to connect the near wall boundary conductions of the average flow and the turbulent transport equation. The logarithmic relation of the near wall velocity is

$$u^+ = \frac{U_t}{u_\tau} = \frac{1}{\kappa}\ln(y^+) + C \quad (1)$$

In the formula,

$$y^+ = \frac{\rho \Delta y u_\tau}{\mu} \quad (2)$$

$$u_\tau = \sqrt{\frac{\tau_w}{\rho}} \quad (3)$$

Wall surface roughness can significantly increase near-wall turbulence generation items, which leads to increased wall shear stress and heat transfer

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coefficient. To show better agreement between the surface roughness and experimental data, the following relationship was used to consider the effect of roughness.

$$u^{+}=\frac{1}{\kappa}\ln(y^{+})+B-\Delta B \qquad (4)$$

In the formula, B equals to 5.2; offset ΔB is the function of dimensionless roughness h^{+} ($h^{+}=hu_{\tau}/\upsilon$).

For roughness, the offset ΔB can be expressed as follows:

$$\Delta B=\frac{1}{\kappa}\ln(1+0.3h_{s}^{+}) \qquad (5)$$

In the formula, h_s is the average of roughness parameters and h_s^+ is the non-dimensional parameter of h_s. In general, equivalent sand roughness k_s is used to measure the roughness. The relationship between k_s and h_s is molded by Sigal and Danberg and is widely used in roughness research. Also, an empirical equation proposed by Koch and Smith show that k_s are about 6.2 times h_s.

III. Model with Non-Uniform Roughness Distribution along the Tangential and Spanwise Directions

In this investigation, NASA research single-stage compressor Stage 35 is used. The design parameters are provided in table 1. Stage 35 produces 1.8 total pressure ratio at a mass flow rate of 20.2 kg/s at the design speed of 17188 rpm. Details of the Stage 35 geometry are shown in table 1.

Table 1: The design parameters of NASA stage 35

Rotor rpm at 100% speed	17188.7
Tip speed (m/s)	454.456
Hub/tip aspect ratio	0.7
Rotor aspect ratio	1.19
Stator aspect ratio	1.26
Number of rotor blades	36
Number of stator blades	46

NASA Stage 35 rotor blade was divided into 12 regions along the chord direction to establish a model with non-uniform roughness distribution. Except for the leading and trailing edge regions, other regions are aliquot in chord direction (Figure 1).Given the same roughness along the leading edge and chord of the first subregional area, the trailing edge and last area along the chord had also the same subregional roughness. The ten regions divided along the tangential direction are C1, C2,... C10. Depending on the different distributions, roughness was attached to the blade. Ten computing models were set up to simulate the effect of non-uniform roughness on compressor performance. The allocation rules are shown in Table 2, in which all the regions are smooth in CNR0 case to verify and compare the results. From the blade leading to trailing edge, the roughness of CNR1, CNR3, and CNR5 increased linearly, whereas that of CNR2, CNR4, and CNR6 decreased linearly. From the leading to trailing edge, CNR 7 initially increased then decreased, but CNR8 first decreased then increased linearly. For CNR9, roughness increased by a quadratic law from the leading to trailing edge. For CNR10, the roughness increased logarithmically in the same direction.

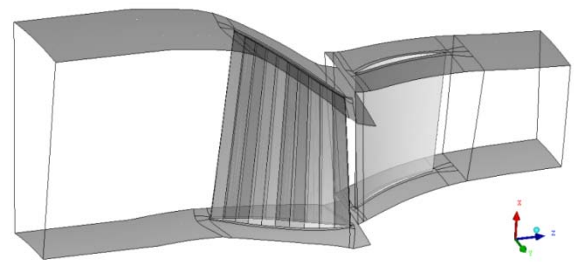


Figure 1: Model with non-uniform roughness distribution along the tangential direction

Table 2: Non-uniform regular roughness distribution along the tangential direction (k_s, μm)

Number	C1	C2	C3	C4	C5
CNR0	0	0	0	0	0
CNR1	0.1	6.7	13.4	20.1	26.8
CNR2	60.0	53.6	46.9	40.2	33.5
CNR3	0.1	3.3	6.6	9.9	13.2
CNR4	30.0	26.4	23.1	19.8	16.5
CNR5	30.0	33.3	36.6	39.9	43.2
CNR6	60.0	56.4	53.1	49.8	46.5
CNR7	0.1	15.0	30.0	45.0	60.0
CNR8	60.0	45.0	30.0	15.0	0.1
CNR9	0.1	2.4	5.4	9.6	15
CNR10	0.1	18.1	28.6	36.1	41.9
Number	C6	C7	C8	C9	C10
CNR0	0	0	0	0	0
CNR1	33.5	40.2	46.9	53.6	60.0
CNR2	26.8	20.1	13.4	6.7	0.1
CNR3	16.5	19.8	23.1	26.4	30.0
CNR4	13.2	9.9	6.6	3.3	0.1
CNR5	46.5	49.8	53.1	56.4	60.0
CNR6	43.2	39.9	36.6	33.3	30.0
CNR7	48.0	36.0	24.0	12.0	0.1
CNR8	12.0	24.0	36.0	48.0	60.0
CNR9	21.6	29.4	38.4	48.6	60.0
CNR10	46.7	50.7	54.2	57.3	60.0

The rotor blade was also divided into ten domains along the spanwise direction. Every area was quoted along the spanwise direction and attached to corresponding roughness values. The areas are named from the root to tip (S1, S2,... S10) and are shown in Figure 2. Ten group computational models were established in different distribution rules. The distribution rules of roughness in every area are shown in Table 3. Similarly, CNR0 was smooth in all domains and used to verify and compare results. From the root to tip, the roughness of SNR1, SNR3, and SNR5 increased linearly, whereas that of SNR2, SNR4, and SNR6 decreased linearly. SNR7 initially increased and then decreased linearly. By contrast, SNR8 first decreased and then increased linearly. For SNR9, roughness increased by a quadratic law from the root to tip. For SNR10, roughness increased logarithmically in the same direction.

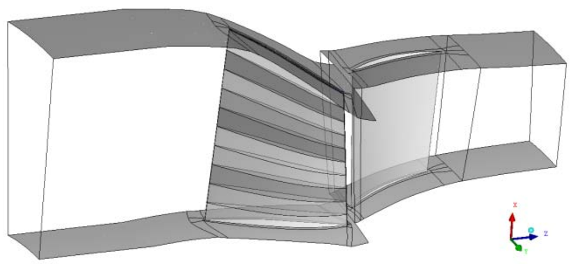


Figure 2: Model with non-uniform roughness distribution along the spanwise direction

Table 3: Non-uniform regular roughness distribution along the spanwise direction (k_s, μm)

Number	S1	S2	S3	S4	S5
SNR0	0	0	0	0	0
SNR1	0.1	6.7	13.4	20.1	26.8
SNR2	60.0	53.6	46.9	40.2	33.5
SNR3	0.1	3.3	6.6	9.9	13.2
SNR4	30.0	26.4	23.1	19.8	16.5
SNR5	30.0	33.3	36.6	39.9	43.2
SNR6	60.0	56.4	53.1	49.8	46.5
SNR7	0.1	15.0	30.0	45.0	60.0
SNR8	60.0	45.0	30.0	15.0	0.1
SNR9	0.1	2.4	5.4	9.6	15
SNR10	0.1	18.1	28.6	36.1	41.9
Number	S6	S7	S8	S9	S10
SNR0	0	0	0	0	0
SNR1	33.5	40.2	46.9	53.6	60.0
SNR2	26.8	20.1	13.4	6.7	0.1
SNR3	16.5	19.8	23.1	26.4	30.0
SNR4	13.2	9.9	6.6	3.3	0.1
SNR5	46.5	49.8	53.1	56.4	60.0
SNR6	43.2	39.9	36.6	33.3	30.0
SNR7	48.0	36.0	24.0	12.0	0.1
SNR8	12.0	24.0	36.0	48.0	60.0
SNR9	21.6	29.4	38.4	48.6	60.0
SNR10	46.7	50.7	54.2	57.3	60.0

According to literature, average roughness can be used to measure a partial non-uniform distribution of roughness on the entire measurement of roughness height. In this study, average roughness parameter $\overline{k_s}$ was used:

$$\overline{k_s} = \frac{1}{A}\int_A k_s dA \tag{6}$$

In non-uniform distribution models, roughness is attached in 10 partially discrete domains; thus, the blade average roughness $\overline{k_s}$ can be calculated by the following formula:

$$\overline{k_s} = \frac{1}{A}\sum_{i=1}^{10}\left(k_{s,i}A_i\right) \tag{7}$$

According to Eq. (7), the average roughness of every model can be calculated and are shown below.

Table 4: Average roughness of each model ($\overline{k_s}$, μm)

Number	CNR1	CNR2	CNR3	CNR4	CNR5
$\overline{k_s}$	28.7	31.6	14.2	15.6	44.2
Number	CNR6	CNR7	CNR8	CNR9	CNR10
$\overline{k_s}$	45.6	26.9	33.1	21.7	38.0
Number	SNR1	SNR2	SNR3	SNR4	SNR5
$\overline{k_s}$	31.3	29.0	15.5	14.3	45.5
Number	SNR6	SNR7	SNR8	SNR9	SNR10
$\overline{k_s}$	44.3	27.1	33.0	24.2	40.6

IV. CFD Results and Analysis on Roughness of Non-Uniform Distribution Models

In this paper, ICEM CFD, a business software, was adopted for mesh generation. CFX physical model was used for the calculation. HOH mesh structure was adopted in computational domains, and O mesh was used near the wall region of the blade. Tip clearance of rotor blade was divided by a "butterfly grid" structure. The grid near the blade was encrypted, and the height of the first layer was set to 5 μm. Finally, a model with 2.315 million grids divided as above was established and used for grid-independent verification. The value of wall y+ on computational domain was less than ten overall. Figure 3 shows the mesh schematic of the computational domain model.

After a complete mesh generation, blade roughness is given equivalent sand roughness k_s by the approach that deals with wall function of a roughened surface in CFX software. The effect of different roughness distributions on compressor aerodynamic characteristics was calculated. Other boundary conditions are set as follows:

Inlet: Given total airflow pressure 101325 Pa, total temperature 288.15 K, air intake axially.

Outlet: Average static pressure was given by radial equilibrium equation. Pressure value to the analog compressor was adjusted in different operating points.

Wall: Heat insulation, velocity meets the no-slip condition.

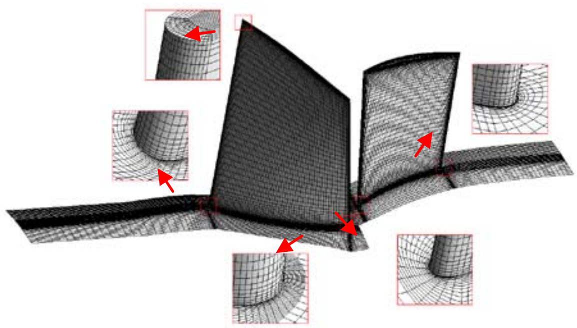


Figure 3: Mesh generation of computational domain

Comparison between CFD results and experimental data about Stage 35 smooth blade computing model (CNR0) is shown to verify the accuracy of the calculation method. Experimental data related to this compressor were obtained from NASA report, which was put forward by Moore and Reid. To evaluate the model, performance at 100% and 90% speeds were considered, and results are shown below.

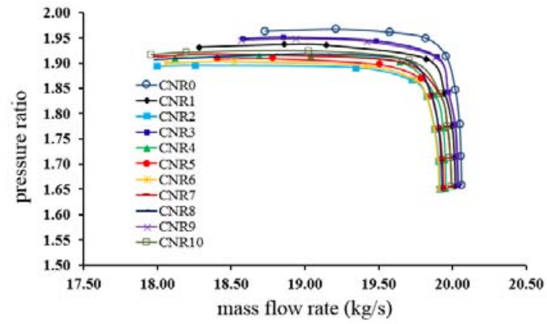
Table 5: Comparison of numerical and experimental results on the peak efficiency point

	100% of design rotate speed	
	Numerical results	Experimental results
Mass flow rate (kg/s)	20.05	20.46
Pressure ratio	1.845	1.842
Temperature ratio	1.229	1.225
efficiency	0.834	0.845
Rotate speed (r/min)	17188	17119.1
	90% of design rotate speed	
	Numerical results	Experimental results
Mass flow rate (kg/s)	18.83	19.13
Pressure ratio	1.63	1.574
Temperature ratio	1.17	1.16
efficiency	0.862	0.865
Rotate speed (r/min)	15469	15451.3

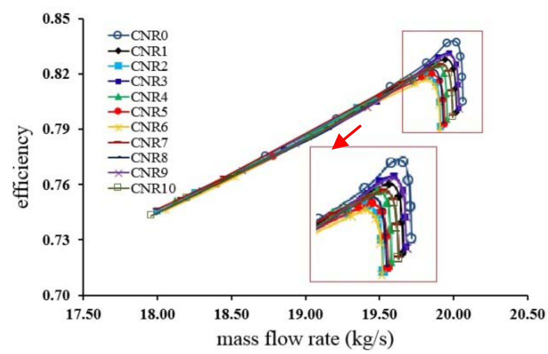
Table 5 shows the peak efficiency and experimental data in CFD at 100% and 90% speeds. Given that literature has not pointed peak point at 90% speed, the operating points in its vicinity are compared in the table. Except for the pressure ratio at 90% speed, which shows large errors in the table, errors of other parameters are all smaller than 2%. Based on the above analysis, the numerical simulation can be defined as effective.

a) CFD results and analysis on models of non-uniform roughness distribution along the tangential direction

Using the above method, models with different regular distributions along the chord direction under design speeds were calculated. Characteristic line of flow versus pressure ratio and compressor operation efficiency were obtained under corresponding conditions, as shown in Figure 4.



(a) Characteristic line of pressure ratio–mass flow rate



(b) Characteristic line of efficiency–mass flow rate

Figure 4: Characteristic line of models with different regular distributions along the chord direction

As shown in Fig. 4, the overall performance parameters of compressor decreased with additional roughness to the rotor blade, such as pressure ratio and efficiency. CNR3 and CNR9 correspond to the compressor performance with the least decline (peak efficiency decreased by 0.7% and 0.76%). CNR2 and CNR6 correspond to the compressor performance with the most serious decline (peak efficiency decreased by 2.15% and 2.39%). By comparing different roughness distribution laws and its corresponding numerical simulation results, we conclude that both the value of the average roughness and local distribution of rough surface on compressor played important roles in the overall performance of the compressor. When the roughness distribution rules were the same, higher average roughness value indicated more decreased compressor performance. When the average roughness value was same, a higher value of the leading edge of local roughness (before 40% along the chord direction) caused a greater effect on the compressor performance. The blade trailing edge of the local roughness exhibited a minimal effect on the performance of the compressor.

Figure 5 shows the limit streamlined on the suction side of the rotor blade when the compressor was under CNR3, CNR9, CNR2, and CNR6, which are four different sets of the model that correspond to the peak efficiency point. CNR3 and CNR9 caused the least decline in compressor performance. CNR2 and CNR6 caused the highest decline in compressor performance.

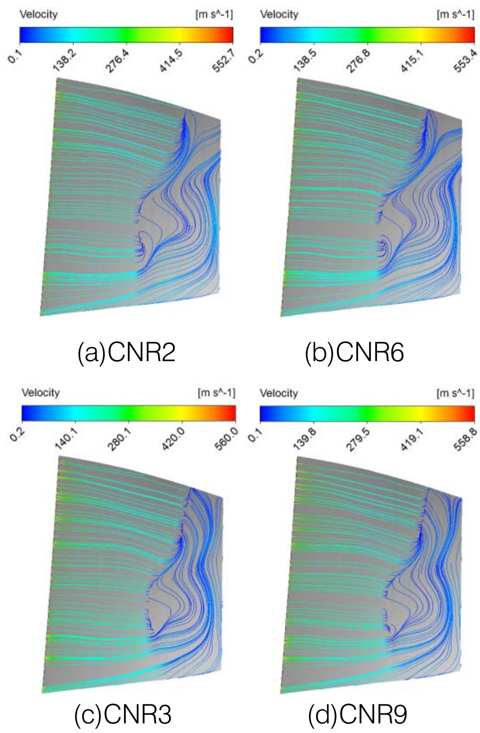


Figure 5: Limit streamlines on the suction side of the rotor blade that corresponds to the peak efficiency point

Fig. 5 shows that the limit streamlines distribution is similar on the suction side of the blade in each condition (i.e., CNR2, CNR6, CNR3, and CNR9), in addition to the different separation zones near the blade tip. The separated airflow near the root of the blade and that along the spanwise direction in the blade tip direction in CNR2 and CNR6 were involved in the main flow before reaching the blade tip and forming a wake. To model CNR3 and CNR9, the separation of airflow rose to the blade tip and then involved into the vortex near the tip. The structure and location of the vortex differed in different conditions. On the one hand, this phenomenon is attributed to the higher average roughness of CNR2 and CNR6. On the other hand, a major factor for this phenomenon is due to the roughness areas that are mainly distributed in the leading edge (before 40% along the chord direction). The disturbance is exacerbated in CNR2 and CNR6 so that the boundary layer separates earlier than the other conditions, resulting in increased losses in the compressor and reduced work efficiency.

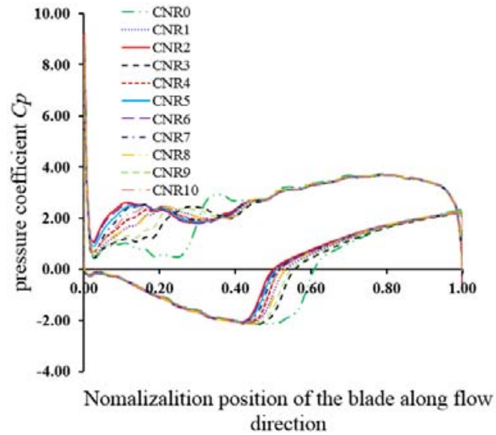


Figure 6: Pressure coefficient number on the middle section of the rotor blade

Figure 6 shows that the effect of surface roughness on the pressure coefficient is concentrated at the leading edge of the 40% chord region on the pressure side and 40%–70% chord region on the suction side. The flow of the boundary layer near the wall was affected by the roughness surface, subsequently increasing the pressure gradient within the boundary layer. This phenomenon led to the forward movement of the inverse pressure gradient area along the chord direction and then the advanced separation of the boundary layer, increasing the losses. The inverse pressure gradient area was closest to the leading edge in CNR2 and CNR6, which caused greatest pressure loss and the most serious performance degradation. Compared with CNR2 and CNR6, the pressure coefficient curve corresponding to models CNR3 and CNR9 was closer to the initial model (with no roughness surface model); the distance between the turning point and the leading edge was longest and caused a slight performance degradation. This result is due to the smaller average roughness of CNR3 and CNR9 and smaller roughness value close to the leading edge.

b) CFD results and analysis on non-uniform roughness distribution models along the spanwise direction

Similarly, models with different regular distributions along the spanwise direction were calculated under design speeds. Characteristic line of flow versus pressure ratio and compressor operation efficiency under corresponding conditions were obtained, as shown in Figure 7.

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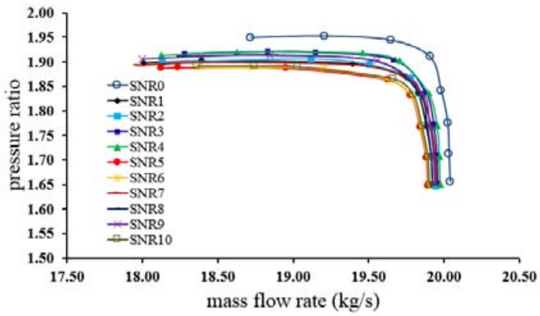
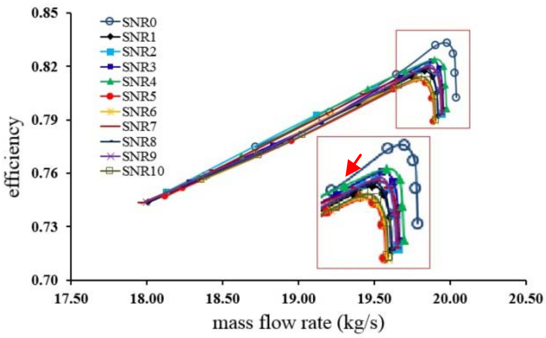


(a) Characteristic line of pressure ratio–mass flow rate



(b) Characteristic line of efficiency–mass flow rate

Figure 7: Characteristic line of models with different regular distributions along the spanwise direction

As shown in Fig. 7, the overall performance parameters of compressor decreased with additional roughness to the rotor blade, such as pressure ratio and efficiency. The working characteristic line of the compressor moved to the lower-left corner. By comparing different numerical simulation results and its corresponding roughness distribution laws, we conclude that the simulation results are different from the non-uniform distribution along the chord of the roughness model. Concentrated roughness in the hub or tip of the blade did not show a special effect on the overall compressor performance parameters. The decline in compressor performance was mainly due to the value of the average roughness.

Figure 8 shows the limit streamlined on the suction side of the rotor blade when the compressor was under SNR3, SNR4, SNR5, and SNR6, which are four different sets of the model that correspond to the peak efficiency point. SNR3 and SNR4 caused the least decline in compressor performance (peak efficiency decreased by 0.86% and 0.92%). SNR5 and SNR6 caused the highest decline in compressor performance (peak efficiency decreased by 1.87% and 1.92%).

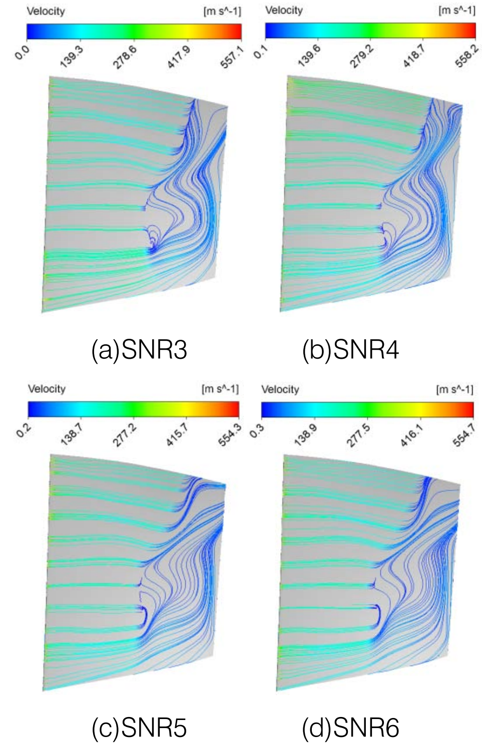


Figure 8: Limit streamlines on the suction side of the rotor blade corresponding the peak efficiency point

Fig. 8 shows that the limit streamlines distribution is similar on the suction side of the blade in each of the SNR3, SNR4, SNR5, and SNR6 conditions. Compared with SNR3 and SNR4, the main differences in SNR5 and SNR6 are the closer turning point near the root of the blade to the leading edge, the advance occurrence of the boundary layer separation, and more serious flow vortex in SNR5 and SNR6, which allow greater flow loss. This phenomenon is primarily attributed to the larger average roughness in SNR5 and SNR6 than in SNR3 and SNR4 and is not due to the value of the local roughness.

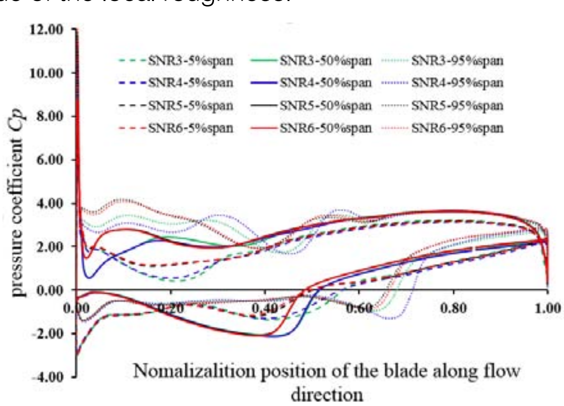


Figure 9: Pressure coefficient number on different heights of the rotor blade

Figure 9 shows the slight difference between SNR3 and SNR4, as well as between SNR5 and SNR6. This result is due to their similar average roughness value. The pressure coefficient curve almost coincided at the middle section of the blade although an evident difference exists in the local roughness between each model. In the 95% spanwise section, the difference in pressure coefficient curve between these four models varied widely. This difference is due to the existence of the tip clearance, which makes the flow at the tip more complex. Therefore, we conclude that in the spanwise direction, local roughness had a slight effect on the overall compressor performance. The degradation of compressor performance was mainly due to the value of the average roughness.

V. Conclusions

Models with different regular distributions along the chord and spanwise directions under design speed were calculated, and the degradation of the compressor performance was obtained. Conclusions drawn were as follows:

1) Methods of wall function were used in this paper; a function that can measure the roughness of surface was added into the wall function. The wall function was used to simulate different models with different roughness distributions, and then the degradation of Stage 35 was obtained.
2) The numerical simulation results of models with different regular distributions along the chord direction are as follows. Both the value of the average roughness and local distribution of the rough surface on compressor played important roles in the overall performance of the compressor. When roughness was distributed from the blade leading edge to 40% of the chord, the compressor performance was greatly influenced; in severe performance, compressor efficiency decreased by more than 2%. Roughness distribution near the trailing edge had a minimal influence to the compressor and can be ignored.
3) The numerical simulation results of models with different regular distributions along the spanwise direction showed that local roughness, which is distributed along the spanwise direction, had a slight effect on the overall compressor performance and can be ignored. The degradation of compressor performance was mainly due to the value of the average roughness.

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Nomenclature

ρ Air density

u^+ Near surface velocity

u_τ Frication velocity

U_t Tangential velocity

Δy Distance to the wall

y^+ Dimensionless distance to the wall

μ Viscosity coefficient

A Total surface area

τ_w Wall shear stress

κ Constant number of von Karman

C Constant number related to roughness

B Constant number of rough height

ΔB Offset of rough height

h^+ Dimensionless number of roughness

h Average roughness of blade surface roughness

h_s Average of roughness parameters

h_s^+ Dimensionless number of h_s

ν Dynamic viscosity

k_s Equivalent gravel roughness

$\overline{k_s}$ Average roughness

C_p Pressure coefficient factor $C_p = (P_0-P)/(P_0-P_{2S})$

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Assessment of Prescribing Practices through WHO Prescribing Indicators at Nekemte Referral Hospital, West Ethiopia

By Balisa Mosisa, Mihiret Yirdaw & Getu Bayisa
Wollega University

Abstract- Background: The ultimate goal of drug utilization related studies are to figure out the actual practices on the ground, and comparison of that with set standard, so that improvement can be made to achieve maximum possible health out come for a patient. One of the players of this game to achieve this goal is prescribers on which this study spins.

Methods: This study was a descriptive cross-sectional survey which investigated the prescribing practices of prescribers using WHO core prescribing indicators at Nekemte Referral Hospital in west Ethiopia. 770 Prescriptions were retrospectively reviewed in outpatient pharmacy of the hospital selected through systematic random sampling over the period from January 2, 2015 to March 2, 2015.

Keywords: prescribing indicators, rational prescribing, prescribers, and drug utilization.

GJSFR-I Classification: FOR Code: 111599

ASSESSMENTOFPRESCRIBINGPRACTICESTHROUGHWHOPRESCRIBINGINDICATORSATNEKEMTEREFERRALHOSPITALWESTETHIOPIA

Strictly as per the compliance and regulations of:

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Balisa Mosisa [α], Mihiret Yirdaw [σ] & Getu Bayisa [ρ]

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Results: Of all prescriptions, the mean numbers of drugs per prescriptions were 2.1, the generic name prescribing practices were 98.26%, and prescriptions carrying antibiotics were 69 %, while those carrying injections were 21.94%. Out of all drugs prescribed in the hospital, 1.74% of them were not found in Ethiopian STG. Also 18.45% of them were with incorrect name and strength, 11.82% haven't the right doses, and 6% haven't right frequency, while 20.5% of them haven't right duration of treatment.

Conclusion: On the basis of the finding of this study, the prescribing practices for antibiotic use and poly Pharmacy show deviation from the standard recommended by WHO. These two commonly overused and high probability of drug side effect and interaction forms of drug therapy need to be regulated closely. Drug use evaluation should be done for some of the antibiotics to check whether they were appropriately prescribed or not. On the other hand, injection use, generic prescribing and prescribing from EDL were not found to be a problem in this study. Referral hospitals have a special responsibility to society to prescribe selectively with strong caution to save lives of patients as a final treatment facility.

Keywords: prescribing indicators, rational prescribing, prescribers, and drug utilization.

I. Introduction

The rational use of drugs requires that patients receive medications appropriate to their clinical needs, in doses that meet their own individual requirements for an adequate period of time, and at the lowest cost to them and their community [1].

Rational use of medicines is a mechanism through which safe, effective and economic medication is provided. It is promoted through the collaborative efforts of prescribers, dispensers, patient and policymakers. Rational prescribing ensures adherence to treatment and protects medicine consumers from unnecessary adverse medicine reactions and wrong treatment practices [2].

Irrational or non-rational use is the use of medicines in a way that is not compliant with rational use as defined above. Worldwide more than 50% of all medicines are prescribed, dispensed, or sold inappropriately, while 50% of patients fail to take them correctly [3].

Common types of irrational medicine use are: The use of too many medicines per patient (polypharmacy); inappropriate use of antimicrobials, often in inadequate dosage, for non-bacterial infections; over-use of injections when oral formulations would be more appropriate; failure to prescribe in accordance with clinical guidelines; inappropriate self-medication, often of prescription only medicines [3].

Inappropriate use and over-use of medicines waste resources - often out-of-pocket payments by patients and result in significant patient harm in terms of poor patient outcomes and adverse drug reactions. Furthermore, over-use of antimicrobials is leading to increased antimicrobial resistance and non-sterile injections to the transmission of hepatitis, HIV/AIDS and other blood-borne diseases. Finally, irrational over-use of medicines can stimulate inappropriate patient demand, and lead to reduced access and attendance rates due to medicine stock-outs and loss of patient confidence in the health system [3].

Irrational use of medicines is a major problem worldwide. WHO estimates that more than half of all medicines are prescribed, dispensed or sold inappropriately, and that half of all patients fail to take them correctly. The overuse, underuse or misuse of medicines results in wastage of scarce resources and widespread health hazards. Examples of irrational use of medicines include: use of too many medicines per patient ("poly-pharmacy"); inappropriate use of antimicrobials, often in inadequate dosage, for non-bacterial infections; over-use of injections when oral formulations would be more appropriate; failure to prescribe in accordance with clinical guidelines;

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inappropriate self-medication, often of prescription-only medicines; non-adherence to dosing regimes [4].

Without knowledge of how drugs are being prescribed and used, it is difficult to initiate a discussion on rational drug use or to suggest measures to improve prescribing habits [5].

Indicators of prescribing practice measure the performance of health care providers in several key dimensions related appropriate use of drugs. The indicators are based on the practice observed in samples of clinical encounters taking place at outpatient health facilities for the treatment of acute or chronic illnesses. World Health Organization developed a core prescribing indicators to measure the degree of polypharmacy, the tendency to prescribe drugs by generic name and the overall level of use of antibiotics and injections. The degree to which the prescribing practice conformed to the essential drug list, formulary or standard treatment guideline were also measured by searching for the number of drugs prescribed from essential drug list available [6].

Prescribers can only treat patients in a rational way if they have access to an essential drugs list and essential drugs are available on a regular basis [7].

In the absence of such facility related factors, the risk of irrational prescribing could raise several folds. Irrational use of drugs leads to different consequences including but not limited to ineffective treatment, unnecessary prescription of drugs particularly antimicrobials and injections, development of resistance to antibiotics, adverse effects and economic burden on both patients and society. It has been estimated that 50% or more medicine expenditure is being wasted through irrational prescribing, dispensing and patient use of medicine [8].

There was no published drugs prescribing practices assessment in this study area, even though periodic assessment of the prescribing practices in a health facility is necessary to identify specific drug use problems, sensitize practitioners on rational drug prescription and provide policy makers with relevant information that could be useful in review of drug procurement policies and implementation of policies on drug prescribing practices in the affected institutions and regions.

This retrospective basic cross-sectional survey was therefore meant to analysis the prescribing practice of clinicians using World Health Organization (WHO) prescribing indicators at Nekemte Referal Hospital found in west Ethiopia.

II. Methods

a) Study Setting

Nekemte is located in the western part of Ethiopia. The study was conducted at Nekemte Referral Hospital, in Nekemte, which is about 331km west of Addis Ababa. It is one of main referral hospitals in western regions of the Nation.

b) Study Design

A retrospective, quantitative, and cross-sectional survey designed to describe the current prescribing practices at Nekemte Referral Hospital.

c) Data Collection and Analysis

One well-trained pharmacy personnel collected data on prescribing indicators retrospectively by using prescriptions and prescription registration books. The specific types of data necessary to measure the prescribing indicators were recorded for each patient encounter and entered directly into an ordinary prescribing indicator form.

According to the WHO document "How to investigate drug use in health facilities," at least 600 encounters should be included in a cross-sectional survey to describe the current prescribing practices, with a greater number, if possible [6]. For this particular study, the total population, N=9,425, the level of precision, d=0.05, the probability of making prescribing error was not known in the area, so, p=0.5 was assumed, level of significance, α=0.05 were used as inputs to compute sample size. The total required sample size after doubling was almost 770. 770 prescriptions were collected retrospectively by doubling the sample obtained by the statistical method from prescriptions prescribed and issued from January 2 to March 2, 2015.

The sample was selected using a systematic random sampling method. First, total number of prescriptions written from January 2, to March 2, 2015 were selected and identified. Total numbers of prescription papers in the selected study period were 9,425. Then this number was divided for determined sample size (770), and the resulting number is used as sampling interval. Therefore, sampling interval is 12. After sampling interval is known, with interval of every 12 prescriptions, the desired prescription samples to be investigated were selected.

All data in the ordinary prescribing indicator recording form were first analyzed manually and then using Microsoft Excel 2007. In the statistical analysis, frequencies, averages/means, standard deviations and percentages were obtained.

d) Prescribing Indicators

The WHO prescribing indicators were used in this study. The indicators were pretested, and slight modification was made so that they could be used easily to provide accurate data. The final versions of the pretested indicators are described below. The prescribing indicators that were measured included:

1. *The average number of drugs prescribed per encounter* was calculated to measure the degree of polypharmacy. It was calculated by dividing the total

number of different drug products prescribed by the number of encounters surveyed. Combinations of drugs prescribed for one health problem were counted as one.

2. *Percentage of drugs prescribed by generic name* is calculated to measure the tendency of prescribing by generic name. It was calculated by dividing the number of drugs prescribed by generic name by total number of drugs prescribed, multiplied by 100.
3. *Percentage of encounters in which an antibiotic was prescribed* was calculated to measure the overall use of commonly overused and costly forms of drug therapy. It was calculated by dividing the number of patient encounters in which an antibiotic was prescribed by the total number of encounters surveyed, multiplied by 100.
4. *Percentage of encounters with an injection* prescribed was calculated to measure the overall level use of commonly overused and costly forms of drug therapy. It was calculated by dividing the number of patient encounters in which an injection was prescribed by the total number of encounters surveyed, multiplied by 100.
5. *Percentage of drugs prescribed from an essential drug list* (EDL) was calculated to measure the degree to which practices conform to a national drug policy as indicated in the national drug list of Ethiopia. Percentage is calculated by dividing number of products prescribed which are in essential drug list by the total number of drugs prescribed, multiplied by 100.

e) Operational Definitions

Generic Drugs: The essential drug list of Ethiopia is used as a basis to determine drugs as generic or brand name.

Antibiotics: Drugs such as penicillins, antibacterials, antiinfective dermatological drugs, and anti-infective opthalmological agents, antidiarrheal drugs with streptomycin, neomycin, and metronidazole are considered antibiotics when used in the context of antibiotics.

Combination of Drugs: Two or more drugs that are prescribed for a given health condition. For example, triple therapy for helicobacter pylori induced peptic ulcer is counted as one.

Generic Drugs: Is the established non- proprietary or common name of the active drug in drug product. The Essential Drug List of Ethiopia is used as a basis to determine drugs as generic or brand name.

Indicators: Are the variables one cause created and validated by the WHO as they have to measure rational use in health facilities

Prescribers: Any medical practitioner who is licensed or authorized to write prescription.

Prescription: Is an order for a medication issued by a physician, dentist or other properly licensed medical practitioner.

Brand Name: A proprietary name or a registered trade mark of drug product given by the manufacturer.

f) Ethical Consideration

Ethical approval was obtained from the Wollega University Pharmacy Department.

III. Results and Discussion

Samples of 770 patient encounter prescriptions were assessed retrospectively in the medical outpatient pharmacy of Nekemte Referral Hospital from January 2, 2015 to March 2, 2015. Data was collected and analyzed on the line of its objectives based on WHO core prescribing indicators to assess prescribing practices at the Hospital, out of which all of prescriptions contained patients' names; 79.48% bear sex of patients; 73.2% held ages of clients; 71.16% were written with card numbers. Whereas, none of the prescriptions contained weight and address of patients, while 18.44% of prescriptions were bearing diagnosis in the study facility.

a) The Average Number of Drugs Prescribed Per-Encounter

A total of 1616 drug products were prescribed on 770 prescription papers, thus, average number of drugs per encounter or mean was 2.1 (minimum 1 and maximum 6), specifically 25.19% of prescriptions were with one drug, 41.04% with two drugs, 17.66% with three drugs , while 16.62% of them were with four and above drugs on single prescription. This average (2.1) is higher compared with the standard (1.6-1.8) derived as ideal [9].

In a similar study performed in south west Ethiopia at Jimma Hospital, the average number of drugs per encounter was 1.59, which was in the acceptable range [10].

However, in a study on prescribing patterns in three hospitals in north Ethiopia, the average number of drugs per patient was 0.98 at Gondar Hospital, 1.8 in Bahirdar Hospital, and 2.2 in Debre Tabor Hospital [11].

A national baseline study on drug use indicators in Ethiopia in September 2002 also found the average number of drugs prescribed per encounter to be 1.9, which is similar to our finding [12].

In the study of drug use patterns in 3 developing countries, the average number of drugs per encounter was high in Nigeria (3.8), low in Sudan (1.4), and in Zimbabwe (1.3) [14].

Reasons of high average number of drugs per encounter might be due to shortage of therapeutically correct drugs; and/or lack of prescribers' therapeutic training; and/or lack of appropriate diagnostic equipments; and/or un reliable prescribers ability to diagnose and treat common illness or may be prescribers were influenced by patients demands [6].

Poly pharmacy if present is one of the essential indicators of potential drug-drug interactions, risk of fatal combined or synergistic medication side effects, medication non-adherence and hence poor treatment outcomes that even can lead to death. As a measure of poly pharmacy, the average number of drugs per encounter as a whole was determined to be 2.1 in this study showing the presence of overprescribing in hospitals of west Ethiopia as per the WHO recommend limit which is less than 2 [13].

b) Percentage of Drugs Prescribed by Generic Names

The total numbers of drugs prescribed by generic names were 98.26% which is almost similar to the standard (100%) derived as ideal [9].

Use of generic names in prescription eliminate the chance of duplication of drug products and also reduce the cost of the patient [15].

Generic medications offer a cheap alternative to name-brand prescription drugs. Generic drugs can save thousands of dollars in costs. Filling prescriptions with generic versions to can save both the company and the patient money. The Food and Drug Administration (FDA) states that a generic drug is "identical" to a name-brand drug in terms of its "bioequivalence." According to the FDA, bioequivalence includes "dosage form, safety, strength, route of administration, quality, performance characteristics, and intended use." By these standards, the FDA seeks to ensure that the active ingredients in generic drugs are exactly the same as in their name-brand counterparts, but that's where the uniformity may end. "Identical does not mean 'same,'" there is variation which is allowed according to the FDA, which states that a generic must provide "roughly" the same blood level of the active ingredient as the name-brand. Those blood levels can range between 80 to 125 percent of what the name-brand drug achieves. This could be the reason that people have different reactions when they switch from a name-brand drug to a generic. Differences in generic medications likely exist for all conditions and treatments, but it may not be significant [16].

Prescribers can only treat patients in a rational way if they have access to an essential drugs list and essential drugs are available on a regular basis [7].

c) Percentage of Encounters in which an Antibiotics

The percentage of encounters in which antibiotics were prescribed at Nekemte Referal Hospital was 69.1%, which is very high compared to the standard (20.0%-26.8%) derived to be ideal [9]. A national baseline study on drug use indicators in Ethiopia in September 2002 also showed that the percentage of encounters in which an antibiotic was prescribed was 58.1%, less than this finding [12]. In the drug use pattern study in 4 developing countries, the percentage of encounters in which an antibiotic was prescribed was higher in Sudan (63%), lower in Uganda (56%), and Nigeria (48%) and Zimbabwe (29%) compared to current study [14].

This finding suggests that antibiotic prescribing at this facility needs to be regulated. Frequent and inappropriate use of antibiotics can cause bacteria or other microbes to change so antibiotics don't work against them. This is called bacterial resistance to antibiotics. Treating these resistant bacteria requires higher doses of medicine or stronger antibiotics. Because of antibiotic overuse, certain bacteria have become resistant to even the most powerful antibiotics available today.

Antibiotic resistance is a widespread problem, and one that the Centers for Disease Control and Prevention (CDC) calls "one of the world's most pressing public health problems." Bacteria that were once highly responsive to antibiotics have become more and more resistant. Among those that are becoming harder to treat are pneumococcal infections (which cause pneumonia, ear infections, sinus infections, and meningitis), skin infections, and tuberculosis [17].

In addition to antibiotic resistance, overusing antibiotics can lead to other problems. Antibiotics kill many different bacteria, even the good ones that help keep the body healthy. Sometimes taking antibiotics can cause a person to develop diarrhea due to a lack of good bacteria that help digest food properly. In some cases, bad bacteria, like *Clostridium difficile*, may overgrow and cause infections [18].

The average patient facing an antibiotic-resistant infection can expect a medical bill of between $18,588 and $29,069 in 2009 dollars, totaling $20 billion in health care costs each year in the U.S., according to estimates from the Alliance for the Prudent Use of Antibiotics at Tufts University. In 2000, the U.S. lost $35 billion because of premature deaths, hospital stays, and lost wages related to antibiotic-resistant infections, Tufts researchers found [19].

The high percentage of antibiotics prescribed in current study setting may be due to cultural beliefs of community about antibiotics, high percentage of patient expectation to receive certain antibiotics, or prescribers' belief that the therapeutic efficacy of antibiotics is low or lack of sophisticated laboratory facilities for differential diagnosis that lead to empirical therapy [6].

d) Percentage of Encounters with Injections

The percentage of encounters in which an injection was prescribed at Nekemte Referal Hospital was 21.94%, which is with in higher limit range of the standard derived (13.4%-24.1%) to serve as ideal [6]. Possible reasons for the high use of injections could be (i) beliefs and attitudes of patients and health professionals about the efficacy of injection versus oral medication or (ii) our study setting is a referral hospital where patients with serious conditions are treated, and injectable forms produce faster onset of action. A national baseline study on drug use indicators in Ethiopia in September 2002 found that the percentage of encounters with an injection was 23%, which is some what higher than this finding and in the acceptable range [12]. In a prescription pattern study in 6 developing countries, the percentage of encounters in which an injection was prescribed were very high in Uganda (48%) and Sudan (36%) but very low in Zimbabwe (11%), and in the acceptable range in Indonesia (17%), Ecuador (17%), and Mali (19%) [14].

Injections are very expensive compared to other dosage forms and require trained personnel for administration [14]. All methods of injecting are potentially extremely harmful - of all the ways to get drugs into the system, injection has the most risks by far as it bypasses the body's natural filtering mechanisms against viruses, bacteria and foreign objects. There is a greater risk of overdose, infections and health problems [21].

They can some times lead to the following health problems especially if health professional is not well experienced:

1. Increased chance of infection which lead to abscessed infections of injection sites due to lack of hygiene and aseptic technique, and some times to serious systemic infections such as HIV/AIDS, Hepatitis and other blood-born diseases;
2. Increased chance of overdose - because IV injection delivers a dose of drug straight into the bloodstream, it is harder to gauge how much to use. In addition, because of the rapid onset, overdose can occur very quickly, requiring immediate action;
3. Scarring of the peripheral veins- this arises from the use of blunt injecting equipment. This is particularly common with users who have been injecting re-use disposable syringes. IV drug use for an extended period may result in collapsed veins;
4. Arterial damage- arterial aneurysms may form at injection sites, which can rupture, potentially resulting in hemorrhage, distal ischemia, and gangrene. Inadvertent intra-arterial injection can also result in endarteritis and thrombosis, with ultimately similar consequences [20].

e) The Percentage of Drugs Prescribed from the Essential Drug List

The percentage of drugs prescribed from the essential drug list for Nekemte Referral Hospital in the study period was 98.96%, which is almost similar with the standard (100%) derived to serve as ideal [9]. A study of the patterns of prescription at Jimma Hospital, south west Ethiopia, showed similar results, where almost all drugs prescribed for the health problems were on the essential drug list of the country, but few drugs prescribed out of the list were those that were on the national drug list of Ethiopia [8]. A national baseline study on drug use indicators in Ethiopia in September 2002 showed that the percentage of drugs prescribed from the essential drug list were 99%, which is very encouraging [12]. In a study of prescription patterns from 2 developing countries, the percentage of drugs prescribed from the essential drug list were 88% in Tanzania and 96% in Nepal [14].

Essential drugs offer a cost-effective solution to many health problems in developing countries. The national EDL were selected regarding to disease frequency, be affordable, with assured quality and be available in appropriate dosage forms [22].

f) Limitations

The study used the WHO prescribing indicators, which are supposed to record exactly what is prescribed to patients, but not why. In order to explain why, other techniques are needed. The prescribing indicators measure aspects of outpatient treatment. They are designed for use in health centers, dispensaries or hospital outpatient departments.

The prescribing indicators are less useful in specialty outpatient clinics in referral hospitals where the drug use pattern is more complex.

IV. Conclusion

On the basis of the finding of this study, the prescribing practices for antibiotic use show high deviation from the standard recommended by WHO. Also there are slightly higher poly pharmacy cases. These two commonly overused antibiotics and polypharmacy of drug therapy need to be regulated closely. Drug use evaluation should be done for some of the antibiotics to check whether they were appropriately prescribed or not. On the other hand, percentage of injection use, generic prescribing, and prescribing from Essential Drug List were not found to be a significant problem in this study. Baseline data gathered by this study can be used by researchers and policymakers to improve prescribing practice at Nekemte Referral Hospital.

Several activities have proved useful and effective in promoting rational drug use and should be recommended for general use. These are acting according to national standard treatment guidelines; essential drug lists; establishing drug and therapeutic committee; problem-based basic training in pharmacotherapy; targeted continuing education; improving drug availability, improving drug accessibility, and ensuring supply of affordable drugs of a good standard; drug information centers establishment; expansion of drug use evaluation system and preparation and dissemination of drug bulletins.

Abbreviations

AIDS: Acquired immuno-deficiency syndrome;
HIV: Human immune deficiency virus

IV: Intravenous
WHO: World Health Organization

Competing Interest

As the authors (03 in number) of this manuscript, we declare that we have no competing interests.

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Evaluation of Airline Service Quality Attributes: The Nigerian Experience

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Abstract- Airlines are suffering from such competition. Service quality is typically defined regarding consumer satisfaction. The purpose of this paper is to provide a better understanding of how satisfaction level among passenger with Arik and Aero Airlines is and how its managers can improve their service quality. To reach to achieve this purpose, we have studied different models of service quality measurement and adopted Gronroos model as a comprehensive model, we developed and adopted it to encompass various aspects of airlines' services. We inclusively inferred that passengers of Arik and Aero are not satisfied with the perceived services and it warns manager to focus on passengers' expectations. Tangibles, assurance, responsiveness, reliability, empathy, image and technical quality are seven features of the model, and in all of them, passengers feel dissatisfied. Managers should treat employees, improve visual facilities and coordinate all people, departments, and organizations involved with the airline. Finally, with airline must measure passengers' satisfaction and service quality seasonally to keep the services corresponded with customers' opinions.

Keywords: airline, service quality, gronroos model and passenger.

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EVALUATIONOFAIRLINESERVICEQUALITYATTRIBUTESTHENIGERIANEXPERIENCE

Strictly as per the compliance and regulations of:

Evaluation of Airline Service Quality Attributes: The Nigerian Experience

Ejem, E. A [α], Dike, D. N [σ], Chukwu, O [ρ], Igboanusi, C. C [Ѡ], Ezenwa, A [¥] & Erumaka, O [§]

Abstract- Airlines are suffering from such competition. Service quality is typically defined regarding consumer satisfaction. The purpose of this paper is to provide a better understanding of how satisfaction level among passenger with Arik and Aero Airlines is and how its managers can improve their service quality. To reach to achieve this purpose, we have studied different models of service quality measurement and adopted Gronroos model as a comprehensive model, we developed and adopted it to encompass various aspects of airlines' services. We inclusively inferred that passengers of Arik and Aero are not satisfied with the perceived services and it warns manager to focus on passengers' expectations. Tangibles, assurance, responsiveness, reliability, empathy, image and technical quality are seven features of the model, and in all of them, passengers feel dissatisfied. Managers should treat employees, improve visual facilities and coordinate all people, departments, and organizations involved with the airline. Finally, with airline must measure passengers' satisfaction and service quality seasonally to keep the services corresponded with customers' opinions.

Keywords: airline, service quality, gronroos model and passenger.

I. Background Information

There are no doubts the impacts of air transport industry to the socio-economic development of Africa cannot be overemphasized. According to ATAG (2008), the air transport industry generates around 430,000 jobs in Africa and contributes USD 9.2 billion to Africa GDP (direct, indirect and induced impacts). Similarly in its regional air traffic figures and forecast for Africa sees a 5.6 and 4.6%, respectively in the economic induced increase in passengers and freight for the continent (ICAO, 2007). Also, the integration of Africa economies with the global economies has been enhanced through air transport. Moreover, it has buoyed the comparative advantage of most African countries and especially Nigeria on some special economic activities as tourism and allied industry. Tourism developments in Nigeria have been reliably linked to the development of air services to tourism destinations in Nigeria (Ogunkoya, 2008).

Remarkably, airline services are seen as a veritable instrument of globalization and market expansion, political and cultural integration and destination value enhancement (ATAG, 2008). Air services make possible multinational institutions, corporations and companies to expand rapidly growing distant markets. It facilitates competition among industries leading to efficiency, innovations, entrepreneur development, revenue enhancement and increased productivity. It has changed the global supply chain and helps rapid and realizable movement of goods and services worldwide. Similarly, political and cultural integration of the nations of the world has been greatly improved through open skies treaties among the nations of the world creating political and cultural interference and optimal diplomacy. The values of numerous destinations across the globe have been enhanceddue to improvement in the accessibility of destinations. Notably, policy interventions and innovations as deregulation and liberalization, recapitalization, the institutional framework as well as globalization have impacted on the airline services in Nigeria. For instance, the reality of air transport services in Nigeria (Akpoghomeh, 1999; Adeniji, 2000). Similarly, the institutional restructuring and reforms of government's agencies have created a regime of efficiency and effectiveness which have impinged on air services operations in Nigeria (Ogunkoya, 2008). Also, the re-capitalization policy of the federal government on all airlines operating in the country resulted in the consolidation of the investment portfolio of most airlines operations leading to merger and acquisition. The effects led to the acquisition of brand new aircraft, route expansion, and capital base enlargement.

The Nigeria airline industry has gone through a roller-coaster ride for the past few years. Among factors contributing to the situation are increasing fuel prices, escalating security insurance, rapid deregulation of the industry, as well as natural disaster, ranging from the outbreak of diseases, etc. that hinder the growth of air transport. In the past decade, air travel has grown by 7% per year. Many of the Nigerian airlines have made significant investments in aircraft amenities (e.g. Overhead bin space, seating) at the same time that they have sharply reduced the number and the compensation of employees (Armstrong 2001). These actions suggest an alternative view of the service value profit chain for air travel and freight forwarding- that customer satisfaction is more dependent on physical attributes of the service than on employee interactions. I consider this possibility in the context of service operations failure.

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Nigeria Aviation sector has had its ups and downs and is still growing. Operators have therefore had to deal with the challenges while at the same time reaping the benefits. As cooperation increasingly are attracted to international markets to overcome stagnant domestic market growth and stimulate revenues in various industries, enlightened appreciation of the needs and wants of consumers of other countries are increasingly important for those companies exposing the market concept. Customer satisfaction is determined by customer perceptions of quality, expectations, and preferences (Barsky, 1995) said another way, "satisfaction, or lack of it, is the difference between how a customer expects to be treated and how he or she perceives being treated."Parasuraman et al. 1988, described service quality as: the ability of the organization to meet to exceed customer expectations. Customer expectations may be defined as the "desires and want of consumers," i.e. what they feel a service provider should offer rather than would offer (Parasuraman, 1988).In their empirical findings, Cronin and Taylor specifically explored the relationship between service quality, satisfaction, and purchase intention. Furthermore, the compared SERVQUAL's efficacy with attitude based methods (as applied in consumer satisfaction/dissatisfaction research) of measuring service quality. Attitude–based conceptualization would argue for either an importance-weighted evaluation of specific service attributes or even just an evaluation of performance on specific service attributes.

The service quality models they examined were (1) a performance measure, (2) a performance measure weighted by importance, and (3) SERVQUAL weighted by importance. Their analysis suggests that service quality is an antecedent of customer satisfaction and that satisfaction has a stronger influence than service quality on purchase intentions. Further empirical scrutiny (Parasuraman et al. 1988) resulted in a 22-item scale, called SERVQUAL, which measures service quality based on dimensions, tangibles, reliability, responsiveness, assurance, and empathy. The entire approach was based on the tenet that customers entertain expectations of performances on the service dimensions, observe performance and tater form performances perceptions. The authors described service quality as the degree of discrepancy between customer's normative expectations for the service and their perceptions of the service performance. On the other hand, Gronroos believed that service quality is made up of three dimensions, that is the technical quality of the outcome" the "functional quality of the encounter" and the "airline corporate image". Thus, it has been suggested (i.e. Cuningham, et al. 2002) that measuring service quality based only on the perceptions of service performance would suffice, as in the so-called the SERVQUAL model; namely, SQ=P.

This paper will help aviation industry practitioners to diagnose the needs and expectations of passengers. It will also play a role in identifying their present situation and future strategies for giving better services to passengers and for better new markets both at international and the domestic markets.

II. Methodology

Based on the measurement scale for service quality, we further analyzed the differences in perceived quality between Aero and Arik Airlines passengers. Here, respondents were asked to separately evaluate each service attribute, according to the gap between their perceptions and expectations, using a five-point Lickert scale: 'Much better than Expected' Better than expected Equal to Expected', Worse than Expected' and 'much worse than Expected. Five different scored were assigned: 5, 4,3,2,1, to represent this five-point scale.

We used the one-sample t-test for our data analysis. The one-sample t-test procedure tests whether the mean of a single variable differs from a specified constant. This test assumes that the data are normally distributed; however, this test is robust to departures from normality. The sample in my paper was more than 30 and biased. On "Central limit Theorem' we were allowed to presume the data are normally distributed approximately. A 95% confidence interval for the difference between the mean, and the hypothesized test value was supposed. Satisfied passengers must have received perceptions equal to or more than expectations. So the hypothesized test value in our paper is 3 and, it can split passengers into satisfied and unsatisfied passengers and we can specify the null and alternative hypotheses as below.

Null hypothesis H_o: ų ≥ 3

Alternative hypothesis H_a: ų < 3

As noted earlier, we specify the level of sampling error (0.05). The scores for each attributed are tabulated. As shown in most of the items, there are negative mean differences, and we cannot say that our test value is in 95% confidence interval of the difference. In another word, in most items, the null hypothesis can be rejected because the calculated value is larger than the critical value.

Cronbach's was used as an examination indicator to determine the reliability of the measurement scale. The value of Cronbach's alpha is required to be over 0.7, and the calculated results were over 0.847 and 0.816 in Aero and Arik service quality variables respectively. The figures were representing the output of research survey, it was observed that the reliability of all service quality attributes in the research sample regarding Cronbach's alpha, weremore than 0.7. It means that the research measurement scale, applied in this paper, was reliable.

Table 1: Reliability Statistics for Airlines Data

Cronbach's Alpha for Aero	Cronbach's Alpha for Arik	No. of Items
.847	.816	39

III. Results

a) *Service Quality and Passengers' Satisfaction for Arik Airline*

Prompt response of employees of the airline to your request or complain" was much worse than expected and it also has the least standard deviation and shows most passengers agree that it is the first worst attribute. It is a reliable airline "was much better than expected and it was the first attribute. But in 15 items, the null hypothesis cannot be rejected, and it shows that 95% percent confidence, passengers are satisfied in some parts of the Arik airline performance. They are TAN 1, TAN 2, REL 3, RES 4, RES 5, ASS1, ASS 2, ASS 3, ASS 4, ASS 8, EMP 2, EMP 5, TEC1, TEC 3, and IMA 2. However, in most items, the null hypothesis is rejected, and this means that the general perception of travelers is that the performance service quality of Arik Airline is worse than expected. The comparison to 7 group items means (i.e., Tangibles, Reliability, Responsiveness, Assurance, Empathy, Technical and Image), the first attribute was "Technical" and "Assurance" was the second. The others in priorities were "Responsiveness," "Tangible" "Empathy" "Reliability' and "Image." So we can conclude that from the passengers' "image" items were the worst expected and "Reliability" items following (see table 2).

Table 2: Service Quality Group Items Means

Service Quality Group	Group itemmean for Arik	Group item mean	Rank for Arik	Rank for Arik
Tangibles	2.88	2.81	4th	5th
Reliability	2.71	2.66	6th	6th
Responsiveness	2.92	3.30	3rd	2nd
Assurance	3.11	3.11	2nd	4th
Empathy	2.74	2.21	5th	7th
Technical	3.60	3.68	1st	1st
Image	2.68	3.19	7th	3rd

b) *Service Quality and Passengers Satisfaction for Aero Airline*

'Prompt respond of employees of the airline to your request or complaint" was much worse than expected and to also have the least standard deviation. "Probability of flight breakdowns" was much better than expected and it was at the first attribute. But in 17 items, the null hypothesis cannot be rejected, and it shows that 96 percent confidence, passengers are satisfied in some parts of aero airline performances. They are TAN 1, TAN 2, RES 4, RES 5, ASS1, ASS 2, ASS 3, ASS 4, EMP 1, EMP 2, TEC 1, TEC 2, TEC 3, IMA 1, IMA 2, and IMA 3, IMA 4. However in 22 items, the null hypothesis is rejected and this means that the general perception of travelers is that the performance service quality of Aero Airline is worse than expected. The comparison to 7 group items means; the first attribute was "Technical" and "Responsiveness" was the second. The others in priorities were "Image," "Assurance," "Tangible," "Reliability and "Empathy". So from the passengers "empathy" items were the worst expected and "Reliability items following (see table 2).

c) *Friedman Analysis of Service Quality Attributes of Aero and Arik Airlines*

Because the chi-square of 448.794 and 422.115 for Aero and Arik airlines respectively with 39 degree of freedom are unlikely to have arisen by chance, the 100 passengers of the of each airline interviewed do not have equal preference for their services. The asymptotic significance is the approximate probability of obtaining a chi-square statistics as extreme as 448.794 and 422.115 for Aero and Arik airlines respectively with 39 degrees of freedom in repeated samples if the rankings of each airline's service quality attributes are not different. Hence, this is satisfied between the airlines.

Table 3: Test Statistics For The Airlines

	Aero	Arik
N	100	100
Chi-Square	448.794	422.115
Df	39	39
Asymp. Sig.	.000	.000

Table 4: Ranks for Aero and Arik Airlines

Service Attributes	Mean Rank for Aero	Remarks	Mean Rank for Arik	Remarks
TAN 1	22.14		22.75	
TAN 2	21.90		23.65	
TAN 3	14.51	Ranked highly among Tangibles	15.19	Ranked highly among Tangibles
TAN 4	16.60		19.26	
TAN 5	18.55		17.96	
REL 1	19.13		17.23	Ranked highly among Reliability
REL 2	17.00		17.70	
REL 3	17.65		20.79	
REL 4	14.88	Ranked highly among Reliability	17.25	
REL 5	16.72		17.60	
REL 6	19.14		19.53	
RES 1	18.57		20.08	
RES 2	19.08		19.50	
RES 3	19.25		19.31	
RES 4	23.27		22.76	
RES 5	24.44		24.23	
RES 6	15.33	Ranked highly among Responsiveness	16.24	Ranked highly among Responsiveness
ASS 1	21.23		21.45	
ASS 2	26.15		25.79	
ASS 3	25.52		25.16	
ASS 4	22.71		22.66	
ASS 5	19.18	Ranked highly among Assurance	19.68	
ASS 6	20.25		20.43	
ASS 7	20.40		18.82	Ranked highly among Assurance
ASS 8	21.10		22.27	
EMP 1	21.77		20.15	
EMP 2	21.81		21.67	
EMP 3	18.57		17.70	
EMP 4	17.08		13.84	Ranked highly among Empathy
EMP 5	19.58		21.51	
EMP 6	17.17		19.02	
EMP 7	14.17	Ranked highly among Empathy	15.78	
TEC 1	23.36	Ranked highly among Technical	21.71	Ranked highly among Technical
TEC 2	33.91		32.76	
TEC 3	23.51		23.10	
IMA 1	21.98		15.13	Ranked highly among Image
IMA 2	23.37		22.80	
IMA 3	23.03		19.73	
IMA 4	21.78	Ranked highly among Image	19.32	

In summary, from Friedman test analysis, the following service attributes were highly rated among the dimensions of service quality

Table 5: Comparison of Service Attribute Ratings

Service Quality Group	Highest Rating for Aero	Highest Rating for Arik
Tangibles	TAN 3	TAN 3
Reliability	REL 4	REL 1
Responsiveness	RES 6	RES 6
Assurance	ASS 5	ASS 7
Empathy	EMP 7	EMP 4
Technical	TEC 1	TEC 1
Image	IMA 4	IMA 1

The two airlines shared similar rankings in tangibles, responsiveness and technical attributes among their passengers.

IV. Discussion

Managers should pay more attention to reliability items and prepare short-term plan to create critical changes. Probability, passengers, suffer most from consistent courtesy to employees while it seems they are satisfied most the probability of flight breakdown. Also the second most important factor for aero airline is Responsiveness items. Passengers show more satisfaction in the prompt response of employees of the aero airline to request or complaint. The third feature in order of importance was Responsiveness items that Image for the Aero airline. The responsiveness items that exhibited the highest satisfaction by passengers were the prompt response of employees of the Arik airline to request or complaint. However, the image item 3 (good reputation) received the highest satisfaction to Aero airline passengers. The fourth feature was tangible for Arik Airline and Assurance for Aero Airlines. It appears that Arik airlines has a lot of weak points in the tangibles that cause dissatisfied passengers. Passengers of Aero airlines perceived half their expectation in assurance items. The Aero airline was not sincere and responsive to passenger complaint about services which they paid for.

However, the Aero airlines should put it their policies and promote it steadily to keep their customers for a long time. The fifth feature was Empathy (caring, individualized attention) for Arik airline and tangibles for the Aero. So Arik airline should change their mind about delivering services to customers. Warmth and supportiveness in behaving with passengers can create impressive results. Managers of Arik airline may want to offer some services to their passengers in hiring cars and reserving hotels. However, the Aero airline should have verity ad quality in-flight meals, entertainment facilities and visually appealing equipment. The sixth feature was reliability for both airlines passengers showed dissatisfied faction in almost all the reliability factors except in the on-time performance of scheduled flights in which Arik airline passengers were satisfied.

Hence, the airline should consider these factors and try to improve and develop services dependably and accurately. The last feature was Image for Arik airline and Empathy for Aero airline. Passenger contends that empathy has the least mean in Aero performance. While image (the public perception about Arik airline) has the critical effect on the perceived services quality. Travelers did not make a good judgment about the reputation and image, placed in evaluating Arik performance.

V. Conclusion

The seven Dimension of Gronroos model has been ranked in this case paper. 39 attributes have been derived and found by interview and questionnaire. The model was used for the airline industry in Nigeria. In addition to 22 factors of SERVQUAL model, the image and technical quality supplemented, and all factors changed to cover aspects of these services of the airlines. Arik and Aero chosen as our case studies.

Customer's expectations and perceptions of service quality in the two airlines were examined by Gronroos model in this paper. The result can be used by airline managers and other airlines managers to plan for increasing their market share. Managers of both airlines have identified passengers' attitudes and opinions about their provided services, andin result, they can create modifications and strengthen their weak points to increase satisfaction level among their consumers.

Also, other airlines' managers can use these results to measure and compare with their passengers' satisfaction. But in 15 attributes out of 39 attributes, we saw satisfaction of passengers for Arik Airline. Technical quality in passengers' view was the first choice as the most important aspect and gained the highest mean in Arik and Aero performance. It shows that the airlines often instrumental in bringing about the desired outcome. Pilot's technical knowledge and skills is a strong point for Arik and Aero Airlines. The second in the most important factors for Arik Airline was Assurance items (sincerity and patience in resolving passenger's problems, the probability of flight breakdown, the safety performance of airline and knowledgeable,skillful provision of services). However, Assurance items means was second in position, it appears that Arik airline has weak points in three Assurance items that cause dissatisfied passengers.

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Appendix: Service Attributes Codes and Meaning

TAN1 Appearance, attitudes and uniforms of employees.
TAN2 In-flight modern and clean facilities.
TAN3 Variety and quality of in-flight meals.
TAN4 Variety and choices of in-flight entertainment facilities.
TAN5 Providing visually appealing equipment
REL1 Efficiency of the check-in process
REL2 Transfer service and efficiency at departure airport
REL3 On-time performance of scheduled flights.
REL4 Remedial procedures for delayed or missing baggage
REL5 Providing ground / in-flight services consistently
REL6 Performing the services right the first time
RES1 Capable to response to emergency situations.
RES2 Prompt attention to passengers 'specific needs.
RES3 Understanding the specific needs of passengers.
RES4 Keeping customers informed about when services will be performed
RES5 Prompt respond of employees of the airline to your request or complaint
RES6 Capacity to respond to cancelled or delayed flights.
ASS1 Sincerity and patience in resolving passengers 'problems.
ASS2 Probability of flight breakdowns.
ASS3 Safety performance of airline.
ASS4 Knowledgeable and skillful provision of services.
ASS5 Sincere and responsive attitude to passenger complaints.
ASS 6 Employees instill confidence to passengers
ASS7 employees are consistently courteous
ASS8 Knowledgeable employees to answer customer question
EMP1 Numerous, easy-to-use ticketing channels.
EMP2 Convenient flight scheduling.
EMP3 Spontaneous care and concern for passengers'needs.
EMP4 Frequent cabin service rounds by flight attendants.
EMP5 Having a sound loyalty programme to recognize you as a frequent customer
EMP5 Having a sound loyalty programme to recognize you as a frequent customer
EMP6 Having a sound mileage programme
EMP7 Having other travel related partners e.g. car rentals, hotels, and travel insurance
TEC1 It is successful to complete a travel
TEC2 Pilot has technological knowledge and skills
TEC3 It is a reliable company
IMA1 It is a successful company
IMA2 It has a superior technology in its flight services
IMA3 It has a good reputation
IMA4 It is sincere to the passengers

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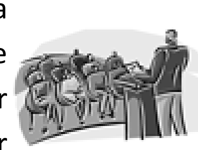

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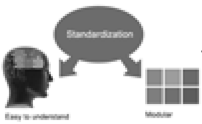

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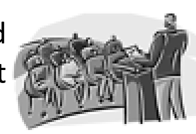

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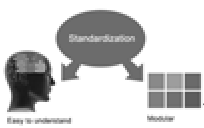

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Abbreviations supposed to be used carefully. The abbreviated name or expression is supposed to be cited in full at first usage, followed by the conventional abbreviation in parentheses.

Metric SI units are supposed to generally be used excluding where they conflict with current practice or are confusing. For illustration, 1.4 l rather than 1.4 × 10-3 m3, or 4 mm somewhat than 4 × 10-3 m. Chemical formula and solutions must identify the form used, e.g. anhydrous or hydrated, and the concentration must be in clearly defined units. Common species names should be followed by underlines at the first mention. For following use the generic name should be constricted to a single letter, if it is clear.

Structure

All manuscripts submitted to Global Journals Inc. (US), ought to include:

Title: The title page must carry an instructive title that reflects the content, a running title (less than 45 characters together with spaces), names of the authors and co-authors, and the place(s) wherever the work was carried out. The full postal address in addition with the e-mail address of related author must be given. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining and indexing.

Abstract, used in Original Papers and Reviews:

Optimizing Abstract for Search Engines

Many researchers searching for information online will use search engines such as Google, Yahoo or similar. By optimizing your paper for search engines, you will amplify the chance of someone finding it. This in turn will make it more likely to be viewed and/or cited in a further work. Global Journals Inc. (US) have compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

Key Words

A major linchpin in research work for the writing research paper is the keyword search, which one will employ to find both library and Internet resources.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy and planning a list of possible keywords and phrases to try.

Search engines for most searches, use Boolean searching, which is somewhat different from Internet searches. The Boolean search uses "operators," words (and, or, not, and near) that enable you to expand or narrow your affords. Tips for research paper while preparing research paper are very helpful guideline of research paper.

Choice of key words is first tool of tips to write research paper. Research paper writing is an art.A few tips for deciding as strategically as possible about keyword search:

- One should start brainstorming lists of possible keywords before even begin searching. Think about the most important concepts related to research work. Ask, "What words would a source have to include to be truly valuable in research paper?" Then consider synonyms for the important words.
- It may take the discovery of only one relevant paper to let steer in the right keyword direction because in most databases, the keywords under which a research paper is abstracted are listed with the paper.
- One should avoid outdated words.

Keywords are the key that opens a door to research work sources. Keyword searching is an art in which researcher's skills are bound to improve with experience and time.

Numerical Methods: Numerical methods used should be clear and, where appropriate, supported by references.

Acknowledgements: Please make these as concise as possible.

References

References follow the Harvard scheme of referencing. References in the text should cite the authors' names followed by the time of their publication, unless there are three or more authors when simply the first author's name is quoted followed by et al. unpublished work has to only be cited where necessary, and only in the text. Copies of references in press in other journals have to be supplied with submitted typescripts. It is necessary that all citations and references be carefully checked before submission, as mistakes or omissions will cause delays.

References to information on the World Wide Web can be given, but only if the information is available without charge to readers on an official site. Wikipedia and Similar websites are not allowed where anyone can change the information. Authors will be asked to make available electronic copies of the cited information for inclusion on the Global Journals Inc. (US) homepage at the judgment of the Editorial Board.

The Editorial Board and Global Journals Inc. (US) recommend that, citation of online-published papers and other material should be done via a DOI (digital object identifier). If an author cites anything, which does not have a DOI, they run the risk of the cited material not being noticeable.

The Editorial Board and Global Journals Inc. (US) recommend the use of a tool such as Reference Manager for reference management and formatting.

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Tables: Tables should be few in number, cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g. Table 4, a self-explanatory caption and be on a separate sheet. Vertical lines should not be used.

Figures: Figures are supposed to be submitted as separate files. Always take in a citation in the text for each figure using Arabic numbers, e.g. Fig. 4. Artwork must be submitted online in electronic form by e-mailing them.

Preparation of Electronic Figures for Publication

Even though low quality images are sufficient for review purposes, print publication requires high quality images to prevent the final product being blurred or fuzzy. Submit (or e-mail) EPS (line art) or TIFF (halftone/photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Do not use pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings) in relation to the imitation size. Please give the data for figures in black and white or submit a Color Work Agreement Form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution (at final image size) ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs) : >350 dpi; figures containing both halftone and line images: >650 dpi.

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6. AFTER ACCEPTANCE

Upon approval of a paper for publication, the manuscript will be forwarded to the dean, who is responsible for the publication of the Global Journals Inc. (US).

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Acrobat Reader will be required in order to read this file. This software can be downloaded

(Free of charge) from the following website:

www.adobe.com/products/acrobat/readstep2.html. This will facilitate the file to be opened, read on screen, and printed out in order for any corrections to be added. Further instructions will be sent with the proof.

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Before start writing a good quality Computer Science Research Paper, let us first understand what is Computer Science Research Paper? So, Computer Science Research Paper is the paper which is written by professionals or scientists who are associated to Computer Science and Information Technology, or doing research study in these areas. If you are novel to this field then you can consult about this field from your supervisor or guide.

TECHNIQUES FOR WRITING A GOOD QUALITY RESEARCH PAPER:

1. Choosing the topic: In most cases, the topic is searched by the interest of author but it can be also suggested by the guides. You can have several topics and then you can judge that in which topic or subject you are finding yourself most comfortable. This can be done by asking several questions to yourself, like Will I be able to carry our search in this area? Will I find all necessary recourses to accomplish the search? Will I be able to find all information in this field area? If the answer of these types of questions will be "Yes" then you can choose that topic. In most of the cases, you may have to conduct the surveys and have to visit several places because this field is related to Computer Science and Information Technology. Also, you may have to do a lot of work to find all rise and falls regarding the various data of that subject. Sometimes, detailed information plays a vital role, instead of short information.

2. Evaluators are human: First thing to remember that evaluators are also human being. They are not only meant for rejecting a paper. They are here to evaluate your paper. So, present your Best.

3. Think Like Evaluators: If you are in a confusion or getting demotivated that your paper will be accepted by evaluators or not, then think and try to evaluate your paper like an Evaluator. Try to understand that what an evaluator wants in your research paper and automatically you will have your answer.

4. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

5. Ask your Guides: If you are having any difficulty in your research, then do not hesitate to share your difficulty to your guide (if you have any). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work then ask the supervisor to help you with the alternative. He might also provide you the list of essential readings.

6. Use of computer is recommended: As you are doing research in the field of Computer Science, then this point is quite obvious.

7. Use right software: Always use good quality software packages. If you are not capable to judge good software then you can lose quality of your paper unknowingly. There are various software programs available to help you, which you can get through Internet.

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9. Use and get big pictures: Always use encyclopedias, Wikipedia to get pictures so that you can go into the depth.

10. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right! It is a good habit, which helps to not to lose your continuity. You should always use bookmarks while searching on Internet also, which will make your search easier.

11. Revise what you wrote: When you write anything, always read it, summarize it and then finalize it.

12. Make all efforts: Make all efforts to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in introduction, that what is the need of a particular research paper. Polish your work by good skill of writing and always give an evaluator, what he wants.

13. Have backups: When you are going to do any important thing like making research paper, you should always have backup copies of it either in your computer or in paper. This will help you to not to lose any of your important.

14. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several and unnecessary diagrams will degrade the quality of your paper by creating "hotchpotch." So always, try to make and include those diagrams, which are made by your own to improve readability and understandability of your paper.

15. Use of direct quotes: When you do research relevant to literature, history or current affairs then use of quotes become essential but if study is relevant to science then use of quotes is not preferable.

16. Use proper verb tense: Use proper verb tenses in your paper. Use past tense, to present those events that happened. Use present tense to indicate events that are going on. Use future tense to indicate future happening events. Use of improper and wrong tenses will confuse the evaluator. Avoid the sentences that are incomplete.

17. Never use online paper: If you are getting any paper on Internet, then never use it as your research paper because it might be possible that evaluator has already seen it or maybe it is outdated version.

18. Pick a good study spot: To do your research studies always try to pick a spot, which is quiet. Every spot is not for studies. Spot that suits you choose it and proceed further.

19. Know what you know: Always try to know, what you know by making objectives. Else, you will be confused and cannot achieve your target.

20. Use good quality grammar: Always use a good quality grammar and use words that will throw positive impact on evaluator. Use of good quality grammar does not mean to use tough words, that for each word the evaluator has to go through dictionary. Do not start sentence with a conjunction. Do not fragment sentences. Eliminate one-word sentences. Ignore passive voice. Do not ever use a big word when a diminutive one would suffice. Verbs have to be in agreement with their subjects. Prepositions are not expressions to finish sentences with. It is incorrect to ever divide an infinitive. Avoid clichés like the disease. Also, always shun irritating alliteration. Use language that is simple and straight forward. put together a neat summary.

21. Arrangement of information: Each section of the main body should start with an opening sentence and there should be a changeover at the end of the section. Give only valid and powerful arguments to your topic. You may also maintain your arguments with records.

22. Never start in last minute: Always start at right time and give enough time to research work. Leaving everything to the last minute will degrade your paper and spoil your work.

23. Multitasking in research is not good: Doing several things at the same time proves bad habit in case of research activity. Research is an area, where everything has a particular time slot. Divide your research work in parts and do particular part in particular time slot.

24. Never copy others' work: Never copy others' work and give it your name because if evaluator has seen it anywhere you will be in trouble.

25. Take proper rest and food: No matter how many hours you spend for your research activity, if you are not taking care of your health then all your efforts will be in vain. For a quality research, study is must, and this can be done by taking proper rest and food.

26. Go for seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

27. Refresh your mind after intervals: Try to give rest to your mind by listening to soft music or by sleeping in intervals. This will also improve your memory.

28. Make colleagues: Always try to make colleagues. No matter how sharper or intelligent you are, if you make colleagues you can have several ideas, which will be helpful for your research.

29. Think technically: Always think technically. If anything happens, then search its reasons, its benefits, and demerits.

30. Think and then print: When you will go to print your paper, notice that tables are not be split, headings are not detached from their descriptions, and page sequence is maintained.

31. Adding unnecessary information: Do not add unnecessary information, like, I have used MS Excel to draw graph. Do not add irrelevant and inappropriate material. These all will create superfluous. Foreign terminology and phrases are not apropos. One should NEVER take a broad view. Analogy in script is like feathers on a snake. Not at all use a large word when a very small one would be sufficient. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Amplification is a billion times of inferior quality than sarcasm.

32. Never oversimplify everything: To add material in your research paper, never go for oversimplification. This will definitely irritate the evaluator. Be more or less specific. Also too, by no means, ever use rhythmic redundancies. Contractions aren't essential and shouldn't be there used. Comparisons are as terrible as clichés. Give up ampersands and abbreviations, and so on. Remove commas, that are, not necessary. Parenthetical words however should be together with this in commas. Understatement is all the time the complete best way to put onward earth-shaking thoughts. Give a detailed literary review.

33. Report concluded results: Use concluded results. From raw data, filter the results and then conclude your studies based on measurements and observations taken. Significant figures and appropriate number of decimal places should be used. Parenthetical remarks are prohibitive. Proofread carefully at final stage. In the end give outline to your arguments. Spot out perspectives of further study of this subject. Justify your conclusion by at the bottom of them with sufficient justifications and examples.

34. After conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print to the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects in your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form, which is presented in the guidelines using the template.
- Please note the criterion for grading the final paper by peer-reviewers.

Final Points:

A purpose of organizing a research paper is to let people to interpret your effort selectively. The journal requires the following sections, submitted in the order listed, each section to start on a new page.

The introduction will be compiled from reference matter and will reflect the design processes or outline of basis that direct you to make study. As you will carry out the process of study, the method and process section will be constructed as like that. The result segment will show related statistics in nearly sequential order and will direct the reviewers next to the similar intellectual paths throughout the data that you took to carry out your study. The discussion section will provide understanding of the data and projections as to the implication of the results. The use of good quality references all through the paper will give the effort trustworthiness by representing an alertness of prior workings.

Writing a research paper is not an easy job no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record keeping are the only means to make straightforward the progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear

· Adhere to recommended page limits

Mistakes to evade

- Insertion a title at the foot of a page with the subsequent text on the next page
- Separating a table/chart or figure - impound each figure/table to a single page
- Submitting a manuscript with pages out of sequence

In every sections of your document

· Use standard writing style including articles ("a", "the," etc.)

· Keep on paying attention on the research topic of the paper

· Use paragraphs to split each significant point (excluding for the abstract)

· Align the primary line of each section

· Present your points in sound order

· Use present tense to report well accepted

· Use past tense to describe specific results

· Shun familiar wording, don't address the reviewer directly, and don't use slang, slang language, or superlatives

· Shun use of extra pictures - include only those figures essential to presenting results

Title Page:

Choose a revealing title. It should be short. It should not have non-standard acronyms or abbreviations. It should not exceed two printed lines. It should include the name(s) and address (es) of all authors.

Abstract:

The summary should be two hundred words or less. It should briefly and clearly explain the key findings reported in the manuscript--must have precise statistics. It should not have abnormal acronyms or abbreviations. It should be logical in itself. Shun citing references at this point.

An abstract is a brief distinct paragraph summary of finished work or work in development. In a minute or less a reviewer can be taught the foundation behind the study, common approach to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Yet, use comprehensive sentences and do not let go readability for briefness. You can maintain it succinct by phrasing sentences so that they provide more than lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study, with the subsequent elements in any summary. Try to maintain the initial two items to no more than one ruling each.

- Reason of the study - theory, overall issue, purpose
- Fundamental goal
- To the point depiction of the research
- Consequences, including definite statistics - if the consequences are quantitative in nature, account quantitative data; results of any numerical analysis should be reported
- Significant conclusions or questions that track from the research(es)

Approach:

- Single section, and succinct
- As a outline of job done, it is always written in past tense
- A conceptual should situate on its own, and not submit to any other part of the paper such as a form or table
- Center on shortening results - bound background information to a verdict or two, if completely necessary
- What you account in an conceptual must be regular with what you reported in the manuscript
- Exact spelling, clearness of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else

Introduction:

The **Introduction** should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable to comprehend and calculate the purpose of your study without having to submit to other works. The basis for the study should be offered. Give most important references but shun difficult to make a comprehensive appraisal of the topic. In the introduction, describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will have no attention in your result. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here. Following approach can create a valuable beginning:

- Explain the value (significance) of the study
- Shield the model - why did you employ this particular system or method? What is its compensation? You strength remark on its appropriateness from a abstract point of vision as well as point out sensible reasons for using it.
- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
- Very for a short time explain the tentative propose and how it skilled the declared objectives.

Approach:

- Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done.
- Sort out your thoughts; manufacture one key point with every section. If you make the four points listed above, you will need a least of four paragraphs.

- Present surroundings information only as desirable in order hold up a situation. The reviewer does not desire to read the whole thing you know about a topic.
- Shape the theory/purpose specifically - do not take a broad view.
- As always, give awareness to spelling, simplicity and correctness of sentences and phrases.

Procedures (Methods and Materials):

This part is supposed to be the easiest to carve if you have good skills. A sound written Procedures segment allows a capable scientist to replacement your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt for the least amount of information that would permit another capable scientist to spare your outcome but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section. When a technique is used that has been well described in another object, mention the specific item describing a way but draw the basic principle while stating the situation. The purpose is to text all particular resources and broad procedures, so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step by step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

- Explain materials individually only if the study is so complex that it saves liberty this way.
- Embrace particular materials, and any tools or provisions that are not frequently found in laboratories.
- Do not take in frequently found.
- If use of a definite type of tools.
- Materials may be reported in a part section or else they may be recognized along with your measures.

Methods:

- Report the method (not particulars of each process that engaged the same methodology)
- Describe the method entirely
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures
- Simplify - details how procedures were completed not how they were exclusively performed on a particular day.
- If well known procedures were used, account the procedure by name, possibly with reference, and that's all.

Approach:

- It is embarrassed or not possible to use vigorous voice when documenting methods with no using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result when script up the methods most authors use third person passive voice.
- Use standard style in this and in every other part of the paper - avoid familiar lists, and use full sentences.

What to keep away from

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings - save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part a entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

Content

- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
- In manuscript, explain each of your consequences, point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation an exacting study.
- Explain results of control experiments and comprise remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or in manuscript form.

What to stay away from

- Do not discuss or infer your outcome, report surroundings information, or try to explain anything.
- Not at all, take in raw data or intermediate calculations in a research manuscript.
- Do not present the similar data more than once.
- Manuscript should complement any figures or tables, not duplicate the identical information.
- Never confuse figures with tables - there is a difference.

Approach

- As forever, use past tense when you submit to your results, and put the whole thing in a reasonable order.
- Put figures and tables, appropriately numbered, in order at the end of the report
- If you desire, you may place your figures and tables properly within the text of your results part.

Figures and tables

- If you put figures and tables at the end of the details, make certain that they are visibly distinguished from any attach appendix materials, such as raw facts
- Despite of position, each figure must be numbered one after the other and complete with subtitle
- In spite of position, each table must be titled, numbered one after the other and complete with heading
- All figure and table must be adequately complete that it could situate on its own, divide from text

Discussion:

The Discussion is expected the trickiest segment to write and describe. A lot of papers submitted for journal are discarded based on problems with the Discussion. There is no head of state for how long a argument should be. Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implication of the study. The purpose here is to offer an understanding of your results and hold up for all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of result should be visibly described. Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved with prospect, and let it drop at that.

- Make a decision if each premise is supported, discarded, or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."
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- You may propose future guidelines, such as how the experiment might be personalized to accomplish a new idea.
- Give details all of your remarks as much as possible, focus on mechanisms.
- Make a decision if the tentative design sufficiently addressed the theory, and whether or not it was correctly restricted.
- Try to present substitute explanations if sensible alternatives be present.
- One research will not counter an overall question, so maintain the large picture in mind, where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

- When you refer to information, differentiate data generated by your own studies from available information
- Submit to work done by specific persons (including you) in past tense.
- Submit to generally acknowledged facts and main beliefs in present tense.

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- Do not give permission to anyone else to "PROOFREAD" your manuscript.
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- To guard yourself and others from possible illegal use please do not permit anyone right to use to your paper and files.

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Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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