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ODREĐIVANJE PROTOKA FLUIDA ZA SUŠENJE KOMPJUTERSKIM PROGRAMOM U Q-BASIC-U

DRYING MEDIUM FLOW MEASUREMENT COMPUTER PROGRAM IN Q-BASIC

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REZIME

Sušenje zagrejanim fluidom je osnovna tehnološka operacija u poljoprivredi. Poznavanje vrednosti protoka fluida za sušenje je neophodno za proračun performansi sušare i njene efikasnosti. Direktno merenje protoka vazduha za sušenje je veoma komplikovano.

U ovom radu, autori su prezentovali sopstveni, indirektni termodinamički metod za određivanje vrednosti protoka fluida za sušenje, zagrevanog sagorevanjem prirodnog gasa, pomoću računarskog programa. Pomoću napisanog programa u Q-basicu mogu se odrediti i termodinamičke veličine stanja vlažnog vazduha za sušenje.

Program pomoću matematičkih jednačina datih u radu (jednačine 1 – 31) i baze podataka izračunava tražene vrednosti. Bazu podataka formira korisnik programa popunjavajući upitnik koji se pojavljuje na monitoru računara kada se program startuje. Korisnik unosi sledeće parametre - inputi (Prilog 1): ime lokacije, tip sušare, datum merenja, časovnu potrošnju prirodnog gasa, masu isparenu vode na čas, barometarski pritisak okolnog vazduha, relativnu vlažnost i temperaturu okolnog vazduha, temperaturu medijuma za sušenje, temperaturu iskorišćenog medijuma za sušenje, datum i ime korisnika programa. Program na osnovu "inputa" kao izlazne veličine izračunava: koeficijent korisnog dejstva gorionika za sagorevanje prirodnog gasa, stanja okolnog, vazduha za sušenje i izlaznog vazduha (entalpija i apsolutna vlažnost), maseni i zapreminski protok okolnog vazduha, vazduha za sušenje i iskorišćenog vazduha.

Provera programa je obavljena na dehidratoru prikazanom na slici 1, a rezultati merenja su dati u prilogu 2.

***Ključne reči**:protok fluida za sušenje, potrošnja prirodnog gasa, proračun protoka, program u Q-Basic-u.*

SUMMARY

Drying with heated drying medium is a basic operation in agriculture. Drying medium flow values are necessary for calculations of dryer performance and efficiency. Direct measurement of drying medium flow is very difficult.

Authors present their method for indirect thermodynamic method for drying medium flow value, heated with natural gas, with help of measured simple state values.

Authors prepared a computer program in Q-Basic which enables calculations in simple form without necessity of any tables.

***Key words:** drying medium flow, natural gas combustion, flow calculations, program in Q-Basic.*

INTRODUCTION

Drying with heated drying medium is a basic operation in agriculture. Modern agricultural dryers are great and complicated appliances. Direct measurement of drying medium flow is very difficult.

Authors developed in Slovak Agricultural University in Nitra a thermodynamic method for indirect measurement of drying medium flow at dryers with natural gas as fuel. They calculate exact values of drying medium flow with mechanics of wet air with their modified i-x diagram of wet air and combustion gases of natural gas.

Authors present theory of this method, computer program in Q-Basic for comfort calculations and one example at a green matter dryer BS 18.

METHODS AND RESULTS

Green matter dryer BS 18

Authors present in Fig.1 scheme of the green matter dryer BS 18 with natural gas as fuel.

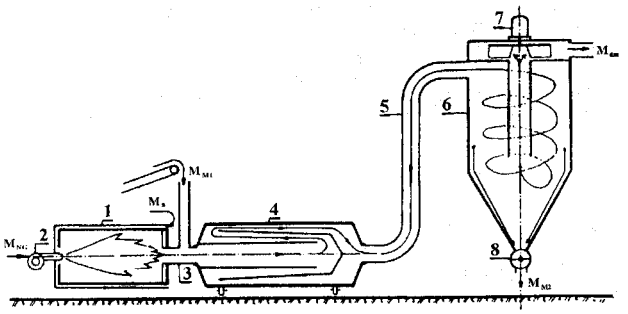


Fig.1 Green matter dryer BS 18
(1) combustion chamber, (2) natural gas burner, (3) drying medium input pipe, (4) cylinder dryer, (5) drying medium output pipe, (6) separating cyclone, (7) air fan, (8) turnstile, and M_{NG} natural gas mass flow, M_a atmospheric air input mass flow, M_{dm} drying medium mass flow, M_{M1} humid material mass flow, M_{M2} dry material output mass flow.

Heat and mass flows in the combustion chamber are demonstrated in Fig.2, where is Q_z thermal loss flow.

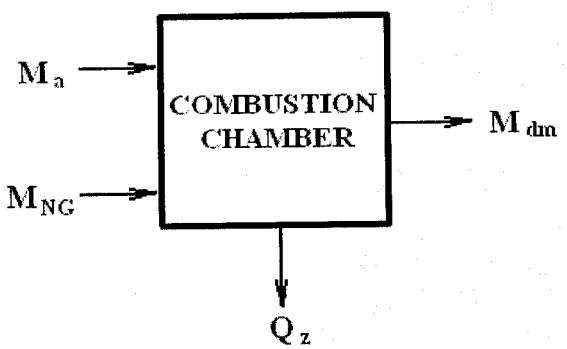


Fig.2 Combustion chamber

Drying medium

Heated drying medium is mixture of ideal combustion gases from natural gas and of added atmospheric air.

Wet air mechanics

Authors developed with tables (Ražnievič, 1969) following simple equations for specific enthalpy of wet air for following temperature ranges:

$0 \div 100\ ^{\circ}C \quad i = 1{,}004.t + x(2499 + 1{,}884.t)$ (1)

$100 \div 500\ ^{\circ}C \quad i = 1{,}004695.t - 6{,}18 + x(2440{,}3 + 2{,}1607.t)$ (2)

$500 \div 1000\ ^{\circ}C \quad i = 1{,}15168.t - 60{,}05 + x(2440{,}3 + 2{,}1607.t)$ (3)

Combustion gases from natural gas

Combustion of natural gas occurs with atmospheric air.

Authors calculated with mass characteristics of NG that were appointed in ZEZ in Bratislava thermal characteristics of combustion gases of NG:
natural gas density $\rho_{NG} = 0{,}7328\ kg.m^{-3}$ (20 °C, 101 323 Pa),
natural gas specific total caloric heat $q_S = 38\ 809\ kJ.m^{-3}$

Ideal burning process of 1 kg NG without air surplus

Atmospheric air minimum necessity	$m_{am} = 16{,}272\ kg.kg^{-1}$
Mass of dry combustion gases	$m_K = 15{,}192\ kg.kg^{-1}$
Increase of humidity of the air	$\Delta x_K = 0{,}1369\ kg.kg^{-1}$
Increase of enthalpy of the air	$\Delta i_K = 3485{,}8\ kJ.kg^{-1}$

Medium flows calculations

Authors demonstrate drying process with advantage with mechanics of wet air in i-x diagram of wet air, Fig.3. In this diagram represents point 0 atmospheric air state, point K ideal combustion gases of NG state, point 1 heated drying medium state, as mixture of ideal combustion gases and added atmospheric air, point 2 output cold drying medium state.

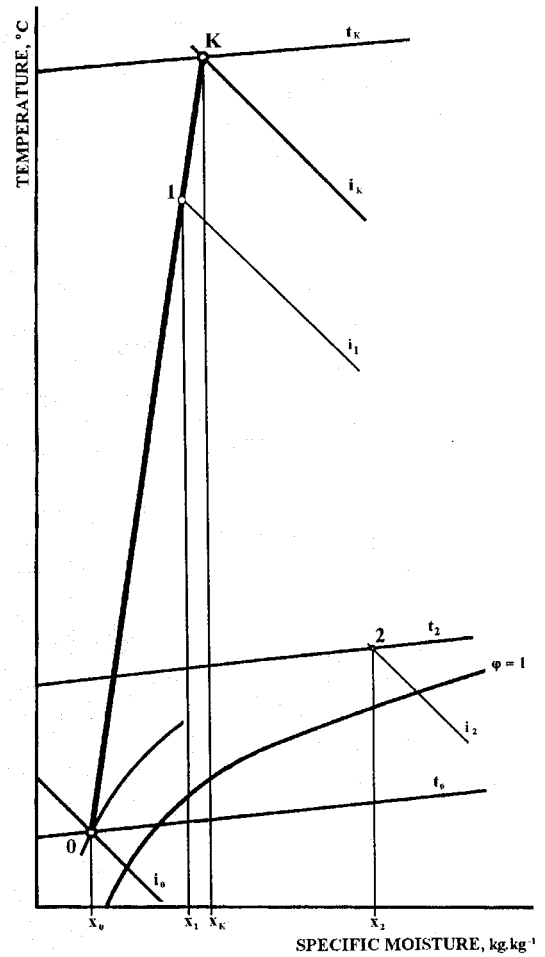


Fig.3 Scheme of i-x diagram of wet air

Atmospheric air, point 0. Given values:
Temperature t_0, relative air humidity φ_0, air pressure p.
Saturated water vapour pressure for temperatures 0 ÷ 20 °C:

$$p_p = 619{,}097.EXP(0{,}670775.t_0) \ \text{Pa} \quad (4)$$

Specific air humidity:

$$x_0 = 0{,}622.\varphi_0.p_p/(p - \varphi_0.p_p) \ \text{kg.kg}^{-1} \quad (5)$$

Specific enthalpy:

$$i_0 = 1{,}004.t_0 + x_0(2499 + 1{,}884.t_0) \ \text{kJ.kg}^{-1} \quad (6)$$

Ideal combustion gases of NG. Given efficiency of NG burner η_t:
Specific humidity of ideal combustion gases:

$$x_K = x_0 + \Delta x_K \ \text{kg.kg}^{-1} \quad (7)$$

Specific enthalpy of ideal combustion gases:

$$i_K = i_0 + \Delta i_K.\eta_t \ \text{kJ.kg}^{-1} \quad (8)$$

Heated drying medium as mixture of ideal combustion gases of NG and added atmospheric air. Given temperature is t_1.

Specific humidity:

$$x_1 = \frac{\Delta x_K}{\Delta i_K . \eta_t}(i_1 - i_0) + x_0 \quad \text{kg.kg}^{-1} \tag{9}$$

Specific enthalpy for temperature range 500 ÷ 1000 °C:

$$i = 1{,}15168.t_1 + x(2440{,}3 + 2{,}1607.t_1) \quad \text{kJ.kg}^{-1} \tag{10}$$

Heat balance of combustion chamber for 1 hour:

$$Q = V_{NG} . q_n . \eta_t = M_S (i_1 - i_0) \quad \text{kJ.h}^{-1} \tag{11}$$

Drying medium mass flow (dry part) is:

$$M_S = V_{NG} . q_n . \eta_t / (i_1 - i_0) \quad \text{kg.h}^{-1} \tag{12}$$

Drying medium mass flow (total mass) is:

$$M_{St} = M_S (1 + x_1) \quad \text{kg.h}^{-1} \tag{13}$$

Density of drying medium is:

$$\rho_1 = \frac{(1 + x_1).p}{r_D . T_1 . (0{,}622 + x_1)} \quad \text{kg.m}^{-3} \tag{14}$$

- where r_D = 461,5 kJ.kg^{-1} is specific gas constante of water vapour.

Volume flow of drying medium is:

$$V_{1h} = \frac{M_{St}}{\rho_1} \quad \text{or}$$

$$V_{1s} = \frac{V_{1h}}{3600} \quad \text{m}^3.\text{h}^{-1} \text{ or } \text{m}^3.\text{s}^{-1} \tag{15;16}$$

Atmospheric air input

Ideal combustion gases mass flow (dry part) is:

$$M_{Si} = V_{NG} . \rho . m_K \quad \text{kg.h}^{-1} \tag{17}$$

Ideal atmospheric air mass flow (dry part) for ideal combustion of NG is:

$$M_{ai} = V_{NG} . \rho . m_{am} \quad \text{kg.h}^{-1} \tag{18}$$

Added atmospheric air mass flow (dry part) in the drying medium is:

$$M_{ap} = M_S - M_{Si} \quad \text{kg.h}^{-1} \tag{19}$$

Therefore input atmospheric air mass flow (dry part) is:

$$M_a = M_{ai} + M_{ap} \quad \text{kg.h}^{-1} \tag{20}$$

Input atmospheric air mass flow (total mass) is:

$$M_{at} = M_a (1 + x_0) \quad \text{kg.h}^{-1} \tag{21}$$

Density of this atmospheric air is:

$$\rho_1 = \frac{(1 + x_0).p}{r_D . T_0 . (0{,}622 + x_0)} \quad \text{kg.m}^{-3} \tag{22}$$

Volume flow of the input atmospheric air is:

$$V_{1h} = \frac{M_{at}}{\rho_0} \quad \text{or}$$

$$V_{1s} = \frac{V_{1h}}{3600} \quad \text{m}^3.\text{h}^{-1} \text{ or } \text{m}^3.\text{s}^{-1} \tag{23;24}$$

Air surplus coefficient as relation between.

Input of atmospheric air M_a and ideal atmospheric air consumption M_{ai} is:

$$a_s = \frac{M_a}{M_{ai}} \tag{25}$$

Output drying medium flow

In the dryer drying medium is cooled at temperature t_2 and becames humidity mass M_W (kg.h^{-1}) evaporated from the dried material. Therefore:

Specific humidity of output drying medium is:

$$x_2 = x_1 + \frac{M_W}{M_S} \quad \text{kg.kg}^{-1} \tag{26}$$

Specific enthalpy of output drying medium is:

$$i = 1{,}004.t_2 + x_2 (2499 + 1{,}884.t_2) \, \text{kJ.kg}^{-1} \tag{27}$$

Density of output drying medium is:

$$\rho_1 = \frac{(1 + x_2).p}{r_D . T_2 . (0{,}622 + x_2)} \quad \text{kg.m}^{-3} \tag{28}$$

Mass flow of output drying medium (total mass) is:

$$M_{2t} = M_S (1 + x_2) \quad \text{kg.h}^{-1} \tag{29}$$

Volume flow of output drying medium is:

$$V_{1h} = \frac{M_{2t}}{\rho_2} \quad \text{or}$$

$$V_{1s} = \frac{V_{1h}}{3600} \quad \text{m}^3.\text{h}^{-1} \text{ or } \text{m}^3.\text{s}^{-1} \tag{30;31}$$

Computer program in Q-Basic

Authors prepared a computer program in Q-Basic to enable at maximum calculations of drying medium flows.

This program has three parts:
Inputted measured values;
Calculations;
Report

In this report are repeated all inputted values and then after calculated state values and mass and volume flow values. Enclosure No 1.

Example of drying medium flow measurement

Authors present one example of drying medium flows calculations for the dryer BS 18. Enclosure No 2.

CONCLUSION

Authors demonstrate with this paper advantage of application of mechanics of wet air for thermodynamic calculations of drying medium flow with measured state values.

The presented computer program in Q-Basic enables very great comfort of calculations. This program is suitable not only for calculations of measured flows but also for modelling of various regimes.

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ENCLOSURE

Enclosure No 2

```
 REPORT: DRYING MEDIUM FLOW  VALUES

Location:Nitra  Dryier type:BS 18  Date:1.4.2006

Natural gas consumption per hour          m3/h: 630
Evaporated humidity mass per hour         kg/h: 6400
Natural gas burner, termal efficiency       %: 97

Atmospheric air :                    temperature grC : 20
 relative humidity %: 60     spec.humidity kg/kg: 8.964847E-03
 spec.enthalpy kJ/kg: 42.82095
Heated drying medium :               temperature  grC : 900
 spec.humidity kg/kg: 5.686175E-02      spec.enthalpy kJ/kg: 1225.803
Output drying medium :               temperature grC: 110
 spec. humidity  kg/kg : .376099 spec.enthalpy  kJ/kg: 1128.254

Atmospheric air flow :
  Mass flow  kg/h : 20730.58     Volume flow  m3/s : 4.871914

Heated drying medium flow
  Mass flow  kg/h : 21187.74     Volume flow  m3/s : 20.46777

Output drying medium flow :
  Mass flow  kg/h : 27587.74     Volume flow  m3/s : 9.828293

Added air surpluss in the drying medium  : 2.75959

In :Nitra                      date :1.4.2006
                                 Workman :Havelka
```

Enclosure No 1

```
PRINT "   INDIRECT MEASUREMENT OF DRYING MEDIUM FLOW "
PRINT
PRINT " 1. Inputed values "
INPUT " Location name :"; ln$
INPUT " Type of the dryier :"; td$
INPUT " Date of measurement :"; dm$
INPUT " Natural gas consumption per hour  m3/h :"; gc
INPUT " Evaporated humidity mass per hour  kg/h :"; mw
INPUT " Atmospheric air, temperature  grC :"; t0
INPUT " Atmospheric air, relative humidity % :"; fo
INPUT " Atmosferic air, pressure  kPa :"; ap
INPUT " Natural gas burner, thermal efficiency % :"; et
INPUT " Heated drying medium, temperature  grC :"; t1
INPUT " Output drying medium, temperature  grC :"; t2
INPUT " Location :"; lr$
INPUT " Date :"; dr$
INPUT " Workman :"; wo$
PRINT
PRINT " 2. Calculations "
pp = 619.097 * EXP(.0670775 * t0)
xo = (.622 * (fo / 100) * pp) / ((1000 * ap) - (pp * (fo / 100)))
io = 1.004 * t0 + xo * (2499 + 1.884 * t0)
kk = (3485.8 * (et / 100)) / .1369
g1 = 1.151686 * t1 - 60.0467
g2 = 2440.26 + 2.1607 * t1
x1 = (g1 + (kk * xo) - io) / (kk - g2)
i1 = g1 + (g2 * x1)
ms = (gc * 38809 * (et / 100)) / (i1 - io)
r1 = ((1 + x1) * (1000 * ap)) / (461.5 * (273.15 + t1) * (.622 + x1))
m1 = ms * (1 + x1)
v1 = m1 / (3600 * r1)
ma = (gc * .7328 * 16.272) + (ms - (gc * .7328 * 15.192))
ro = ((1 + xo) * (1000 * ap)) / (461.5 * (273.15 + t0) * (.622 + xo))
mo = ma * (1 + xo)
vo = mo / (3600 * ro)
x2 = x1 + (mw / ms)
r2 = ((1 + x2) * (1000 * ap)) / (461.5 * (273.15 + t2) * (.622 + x2))
m2 = ms * (1 + x2)
v2 = m2 / (3600 * r2)
i2 = 1.004 * t2 + (x2 * (2499 + 1.884 * t2))
ds = mo / (gc * .7328 * 16.272)
PRINT

PRINT
LPRINT "  REPORT: DRYING MEDIUM FLOW  VALUES "
LPRINT
LPRINT " Location:"; ln$; "  Dryier type:"; td$; "  Date:"; dm$
LPRINT
LPRINT " Natural gas consumption per hour          m3/h:"; gc
LPRINT " Evaporated humidity mass per hour         kg/h:"; mw
LPRINT " Natural gas burner, termal efficiency       %:"; et
LPRINT
LPRINT " Atmospheric air :                    temperature grC :"; t0
LPRINT "  relative humidity %:"; fo; "    spec.humidity kg/kg:"; xo
LPRINT "  spec.enthalpy kJ/kg:"; io
LPRINT " Heated drying medium :               temperature  grC :"; t1
LPRINT "  spec.humidity kg/kg:"; x1; "    spec.enthalpy kJ/kg:"; i1
LPRINT " Output drying medium :               temperature grC:"; t2
LPRINT "  spec. humidity  kg/kg :"; x2; "spec.enthalpy  kJ/kg:"; i2
LPRINT
LPRINT " Atmospheric air flow :"
LPRINT "   Mass flow  kg/h :"; mo; "    Volume flow  m3/s :"; vo
LPRINT
LPRINT " Heated drying medium flow "
LPRINT "   Mass flow  kg/h :"; m1; "    Volume flow  m3/s :"; v1
LPRINT
LPRINT " Output drying medium flow :"
LPRINT "   Mass flow  kg/h :"; m2; "    Volume flow  m3/s :"; v2
LPRINT ""
LPRINT " Added air surpluss in the drying medium  :"; ds
LPRINT
LPRINT " In :"; lr$; "                        date :"; dr$
LPRINT "                                     Workman :"; wo$
```

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Stručna informacija
Profesional information

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TOPICAL STATE OF HUMAN AND TECHNICAL RESOURCE ON POSTHARVESTING GRAIN AND SEED TECHNOLOGY PLANTS IN SERBIA 2006

- Introduction information for Workshop TOSS 17 -

UVOD

Na sednici Izvršnog odbora Nacionalnog društva za procesnu tehniku i energetiku u poljoprivredi, koja je prethodila organizaciji Tematskog savetovanja „Aktuelni problemi centara za doradu zrna 2006" dogovoreno je da se prikupe određene informacije koje bi bile polazna osnova za diskusiju. Određena je Komisija za pripremu uvodnih informacije u sastavu: dr Mirko Babić (koordinator), Poljoprivredni fakultet, Novi Sad, Milivoj Radin, dipl.ing, „Banat seme", Zrenjanin, dr Milovan Pavlov, Institut za kukuruz „Zemun Polje", Zemun, Slavko Ivanišević, dipl.ing, „Jedinstvo" Apatin, Radmila Komatina, dipl.ing, PKB „Inshra", Padinska Skela, Danka Dujović, dipl.ing, PKB - Semenski centar, Padinska Skela. Na sednici su pozvani i ostali članovi Izvršnog odbora i predsedništva Društva da pomognu pružanjem traženih informacija. Veliki broj njih se odazvao, a naročito inženjeri iz semenskih centara. Informacije su pružile i kolege koji nisu članovi navdenih organa Društva. Imenovana Komisija zahvaljuje se svima koji su pomogli u njcnom radu.