

Project Domestic Thermal Systems.

Samples of Calculation of Compression and Expansion Processes of Gases.

1. Note.

All samples below relate to the specific shape of the machine working camera and velocity (both compressor and expander). The geometry code - 348x300x50. Each machine has two cameras and the same revolving speed $n = 25$ rev. per second.

2. Calculation method.

The calculation method of comparison with standard states was chosen after several probes, as the most reliable. Two sources of standard states data were used. The first – is the enthalpy, temperature, pressure, and specific volume diagram [2]. The second – gas standard states tables [3].

3. Calculation samples.

3.1 First sample. Gas code 2 expansion.

Initial state. Temperature $T = 290$ K; Pressure $P = 1$ MPa; Inserted volume per camera $V = 11.52$ cm³; Filled mass per camera $m_c = 0.157$ g; Density $\rho = 13.63$ kg/m³.

Final state. Temperature $T = 188$ K; Pressure $P = 0.065$ MPa; Volume per camera $V = 120.8$ cm³; Density $\rho = 1.29$ kg/m³.

Specific energy extracted per gram of gas $\Sigma E_{extr} = 141.7$ J/g;

Mass per second $M_s = m_c \times 4 \times n = 15.7$ g;

Extracted power $W_{ex} = M_s \times \Sigma E_{extr} = 2225$ W.

3.2 Second sample. Gas code 3 expansion.

Initial state data. Temperature $T = 290$ K; Pressure $P = 7$ bara; Inserted volume per camera $V = 18.75$ cm³; Filled mass per camera $m_c = 0.1601$ g; Density $\rho = 8.54$ kg/m³.

Final state data. Temperature $T = 133$ K; Pressure $P = 0.2$ bara; Volume per camera $V = 292.6$ cm³; Density $\rho = 0.546$ kg/m³.

Specific energy extracted per gram of gas $\Sigma E_{extr} = 154.9$ J/g;

Mass per second $M_s = m_c \times 4 \times n = 16.01$ g/s;

Extracted power $W_{ex} = M_s \times \Sigma E_{extr} = 2479$ W.

3.3 Third sample. Gas code 3 compression.

Initial state data. Temperature $T = 300 \text{ K}$; Pressure $P = 1 \text{ bara}$; Inserted volume per camera total $V = 366.6 \text{ cm}^3$; Filled mass per camera $m_c = 0.4315 \text{ g}$; Density $\rho = 1.177 \text{ kg/m}^3$.

Final state data. Temperature $T = 375 \text{ K}$; Pressure $P = 5.7 \text{ bara}$; Final volume per camera $V = 73.96 \text{ cm}^3$; Density $\rho = 5.89 \text{ kg/m}^3$.

Specific energy consumed per gram of gas $\Sigma E_{cons} = 138.5 \text{ J/g}$;

Mass per second $M_s = m_c \times 4 \times n = 43.15 \text{ g/s}$;

Consumed power $W_{ex} = M_s \times \Sigma E_{cons} = 5980 \text{ W}$.

3.4 Fourth sample. Gas code 3 expansion.

Initial state data. Temperature $T = 320 \text{ K}$; Pressure $P = 3.8 \text{ bara}$; Inserted volume per camera $V = 105 \text{ cm}^3$; Filled mass per camera $m_c = 0.431 \text{ g}$; Density $\rho = 4.037 \text{ kg/m}^3$.

Final state data. Temperature $T = 243 \text{ K}$; Pressure $P = 1 \text{ bara}$; Volume per camera $V = 308 \text{ cm}^3$; Density $\rho = 1.399 \text{ kg/m}^3$.

Specific energy extracted per gram of gas $\Sigma E_{extr} = 78 \text{ J/g}$;

Mass transfer per second $M_s = m_c \times 4 \times n = 43.1 \text{ g/s}$;

Extracted power $W_{ex} = M_s \times \Sigma E_{extr} = 3362 \text{ W}$.

3.5 Fifth sample. Gas code 3 expansion.

Initial state data. Temperature $T = 290 \text{ K}$; Pressure $P = 6 \text{ bara}$; Inserted volume per camera $V = 58.34 \text{ cm}^3$; Filled mass per camera $m_c = 0.427 \text{ g}$; Density $\rho = 7.32 \text{ kg/m}^3$.

Final state data. Temperature $T = 160 \text{ K}$; Pressure $P = 0.52 \text{ bara}$; Volume total per camera $V = 366.6 \text{ cm}^3$; Density $\rho = 1.153 \text{ kg/m}^3$.

Specific energy extracted per gram of gas $\Sigma E_{extr} = 127.7 \text{ J/g}$;

Mass transfer per second $M_s = m_c \times 4 \times n = 42.8 \text{ g/s}$;

Extracted power $W_{ex} = M_s \times \Sigma E_{extr} = 5454 \text{ W}$.

Comparison with sample 3 compression:

$\Delta W_{35} = W_{3cons} - W_{5extr} = 5980 - 5454 = 526 \text{ W}$.

The last result does not include the processes poisoning and other losses.

1.6Sixth sample. Gas code 3 compression.

Compression after expansion without heat exchange. Transportation to compressor without volume exchange. Verification the adiabatic compression reversibility.

Initial state data. Temperature $T = 205 \text{ K}$; Pressure $P = 0.52 \text{ bara}$; Inserted volume per camera total $V = 366.6 \text{ cm}^3$; Filled mass per camera $m_c = 0.427 \text{ g}$; Density $\rho = 1.153 \text{ kg/m}^3$.

Final state data. Temperature $T = 280 \text{ K}$; Pressure $P = 5.4 \text{ bara}$; Final volume per camera $V = 58.34 \text{ cm}^3$; Density $\rho = 7.25 \text{ kg/m}^3$.

Specific energy consumed per gram of gas $\Sigma E_{cons} = 114.54 \text{ J/g}$;

Mass per second $M_s = m_c \times 4 \times n = 42.7 \text{ g/s}$;

Consumed power $W_{cons} = M_s \times \Sigma E_{cons} = 4891 \text{ W}$.

Calculation error with relation of unchanged volume:

$ER = \Delta W_{65} = W_{6cons} - W_{5extr} = 4891 - 5454 = -563 \text{ W}$.

Relative value $er = -0.1 - 10\%$ per 12 steps of calculation.

1.7 Seventh sample. Polytropic compression.

Cooling mode. Steps of adiabatic volume lessen with temperature equilibrium to ambient (Eilat).

Initial state data. Temperature $T = 275 \text{ K}$; Pressure $P = 0.95 \text{ bara}$; Inserted volume per camera total $V = 366.6 \text{ cm}^3$; Filled mass per camera $m_c = 0.4477 \text{ g}$;

Density $\rho = 1.221 \text{ kg/m}^3$.

Final state data. Temperature $T = 350 \text{ K}$; Pressure $P = 5.5 \text{ bara}$; Final volume per camera $V = 89.59 \text{ cm}^3$; Density $\rho = 5.17 \text{ kg/m}^3$.

Specific energy consumed per gram of gas $\Sigma E_{cons} = 96.38 \text{ J/g}$;

Mass per second $M_s = m_c \times 4 \times n = 44.77 \text{ g/s}$;

Consumed power $W_{ex} = M_s \times \Sigma E_{cons} = 4315 \text{ W}$.

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