4. Engine Component Operation:

Air Intake

Air Intake Purposes

Air Intake is intended for air supply to the compressor and partial conversion of the kinetic energy of the incoming flow to the potential energy of compressed air.

Subsonic Intakes

Subsonic intakes are used on engines for maximum cruise flight Mach number of about 0.8...0.9.

Static air intake

Lycoming LTS101

Flush (NACA-type) air intake

YF-93a

Pitot type air intake

GEnx

Locations

inside of the fuselage

(MiG-15)

on the sides of the fuselage

(McDonnell Douglas AV-8B Harrier II)

at the level of the wing root

(Tu-124)

under the wings

(An-225)

over the wings (Be-200)

on the aft

(IL-62)

at the foot of the rudder

(DC-10)

at the end of the fuselage

(Boeing 727)

Supersonic Intakes

Supersonic intakes are used on engines for maximum flight Mach number of 1.5 and above.

Configurations:

- planar
- axisymmetric

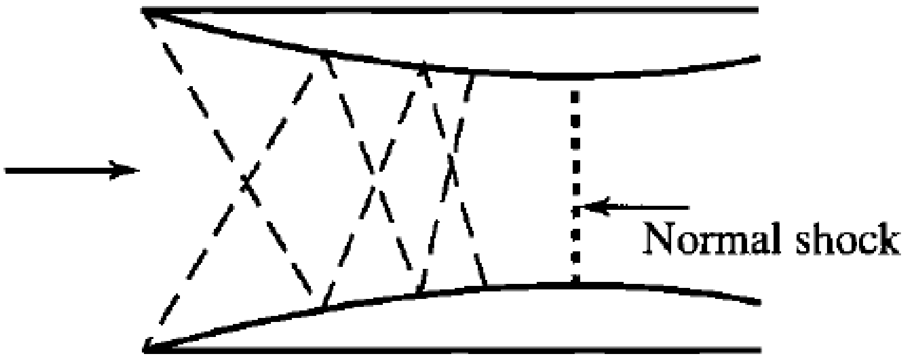
MiG-31

MiG-21

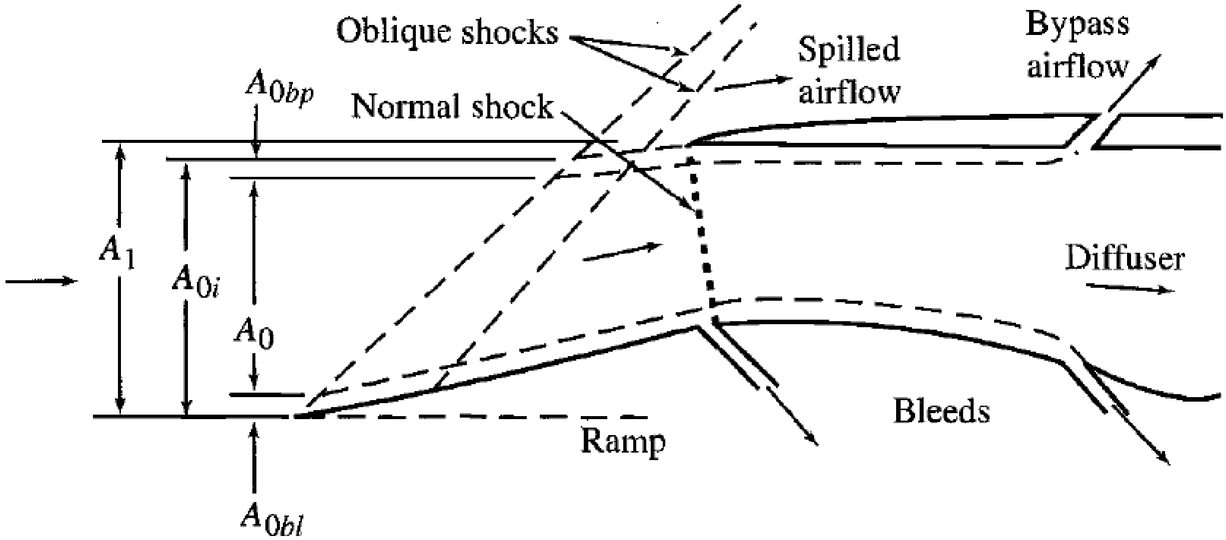
F-111

Supersonic intake types:

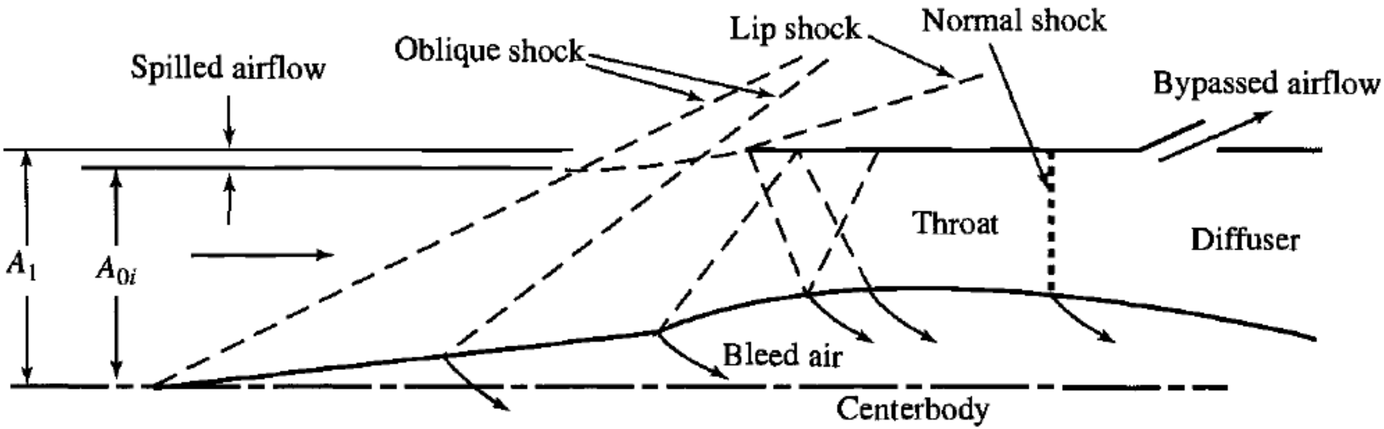
- internal compression



- external compression



- mixed compression



Operational Parameters

Re - Reynolds number.

The Reynolds number is the ratio of inertial forces to viscous forces within a fluid.

The Reynolds number is defined as

$$\mathrm{Re} = \frac{\rho \cdot c \cdot l}{\mu},$$

where:

ρ - density of the fluid, $\frac{\mathrm{kg}}{\mathrm{m}^3}$;

c - velocity of the fluid with respect to the object, $\frac{\mathrm{m}}{\mathrm{s}}$;

l - characteristic linear dimension, m;

μ - dynamic viscosity of the fluid, $\mathrm{Pa} \cdot \mathrm{s}$.

M_{f} - flight Mach number.

Flight Mach number defines the ratio of the total and static parameters of the flow.

$$p_0^* = p_0 \cdot \left(1 + \frac{k-1}{2} M_{\mathrm{f}}^2\right)^{\frac{k}{k-1}};$$

$$T_0^* = T_0 \cdot \left(1 + \frac{k-1}{2} M_{\mathrm{f}}^2\right).$$

$q(\lambda_2)$ - relative flux density at inlet of the compressor.

$q(\lambda_2)$ - defines the operation and performance of the compressor

$$G_2 = \frac{m \cdot p_2^* \cdot F_2 \cdot q(\lambda_2)}{\sqrt{T_2^*}}.$$

Intake efficiency

σ_{intake} - intake total pressure loss factor.

Intake total pressure loss factor is equal to the ratio of the total pressure at the discharge of the intake to the total pressure of the free flow.

$$\sigma_{\text{intake}} = \frac{p_2^*}{p_0^*}.$$

For subsonic intake:

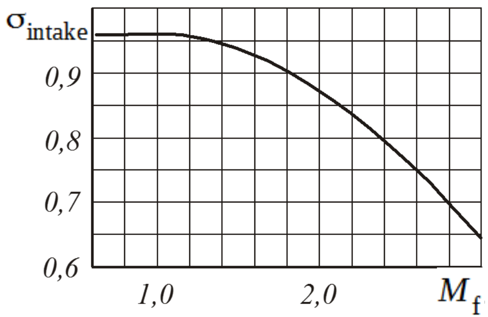
$$\sigma_{\text{intake}} = 0{,}96...0{,}995.$$

For reference supersonic intake:

$\sigma_{\text{intake}} = 0{,}97 - 0{,}11\left(M_{\text{f}} - 1\right)^{3/2}$ - if $1 \le M_{\text{f}} \le 4$;

$\sigma_{\text{intake}} = 0{,}97$ - if $0 < M_{\text{f}} \le 1$;

$\sigma_{\text{intake}} = 0{,}9$ - if $M_{\text{f}} = 0$.

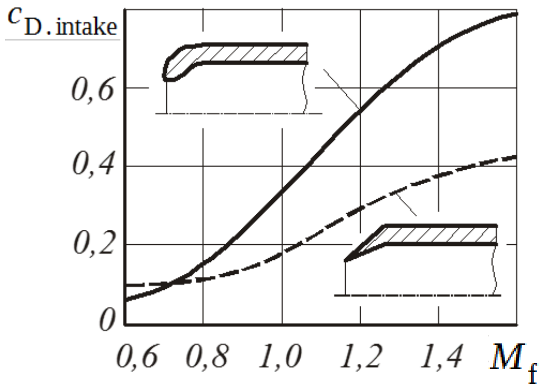


φ - flow factor.

$$\varphi = \frac{F_0}{F_1}.$$

$c_{\mathrm{D.intake}}$ - intake drag coefficient.

$$c_{\mathrm{D.intake}} = \frac{X_{\mathrm{D}}}{q_0 \cdot F_{\mathrm{max.inlet}}},$$



where:

q_0 - dynamic pressure

$$q_0 = p_0^* - p_0 = \frac{k}{2} p_0 \cdot M_{\mathrm{f}}^2;$$

X_{D} - drag force;

$F_{\mathrm{max.intake}}$ - area of the maximum cross-section of the intake.

Calculation of intake operating

Input data:

p_0, T_0 (H_f , ISA);

M_f ($V_{f.h}$);

σ_{intake} ($\sigma_{intake}=f(M_f)$).

Ram pressure rise π_V :

$$\pi_V=\frac{p_0^*}{p_0}=\frac{1}{\pi(\lambda_0)}=\left(1+\frac{k-1}{2}M_f^2\right)^{\frac{k}{k-1}}.$$

Intake pressure ratio π_d :

$$\pi_d=\pi_V\sigma_{intake}.$$

Ram pressure rise π_V dependency on flight Mach number M_f

M_f	0	1	2	3	3,5	4
π_V	1	1,9	7,8	37	76	152
σ_{intake}	0,9	0,97	0,86	0,66	0,54	0,40
π_d	0,9	1,84	6,73	24,2	40,8	60,5
T_0^* ($H_f = 11\,\mathrm{km}$)	216	260	390	606	747	910

Total pressure of free stream p_0^*:

$$p_0^* = p_0 \cdot \pi_V .$$

Total temperature of free stream T_0^*:

$$T_0^* = T_0 \cdot \left(1 + \frac{k-1}{2} M_f^2\right) .$$

Total pressure at discharge of the intake p_2^*:

$$p_2^* = p_0^* \cdot \sigma_{intake} = p_0 \cdot \pi_d .$$

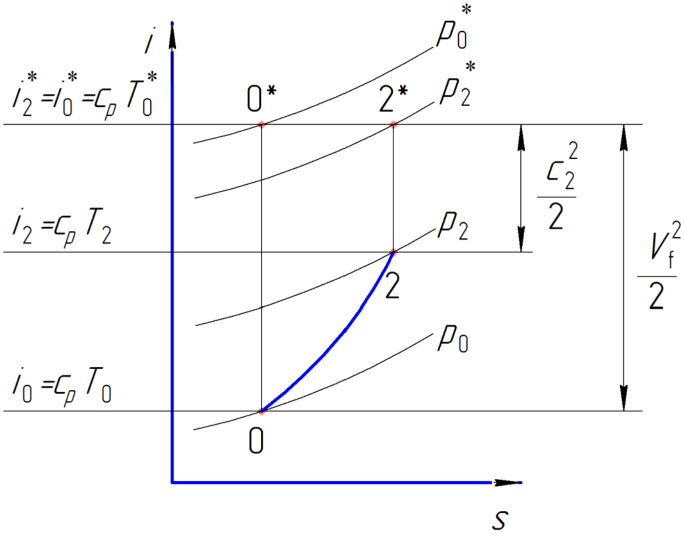
Total temperature at discharge of the intake T_2^*:

$$T_2^* = T_0^* .$$

This relationship follows from the first law of thermodynamics, as energy is not supplied either as work, either as external heat.

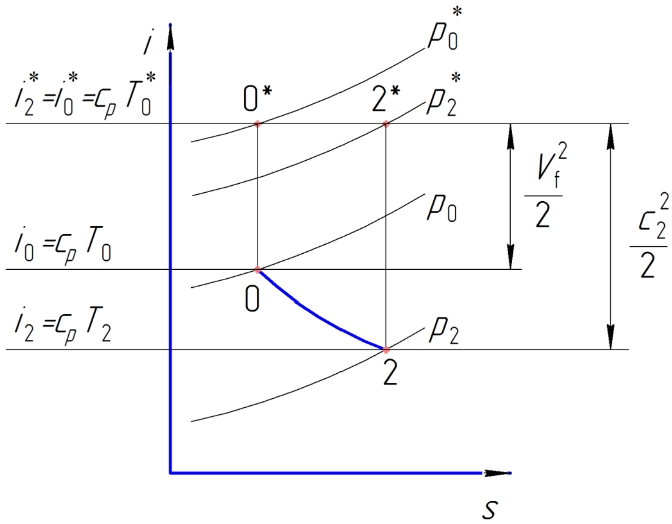
$$\Delta i^* = i_2^* - i_0^* = \pm L \pm Q_{ext} = 0 ,$$

i-s diagram of thermodynamic processes at the air intake.



$V_f > c_2$

Compression



$V_f < c_2$

Expansion