

**UNCLASSIFIED**

---

---

**AD 400 527**

*Reproduced  
by the*

**ARMED SERVICES TECHNICAL INFORMATION AGENCY  
ARLINGTON HALL STATION  
ARLINGTON 12, VIRGINIA**



---

---

**UNCLASSIFIED**

NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

63-3-1

63-70  
FTD-TT

CATALOGED BY ASTIA  
AS AD No. 400527

# TRANSLATION

THE PROBLEM OF COOLING GAS TURBINE VANES BY AIR

By

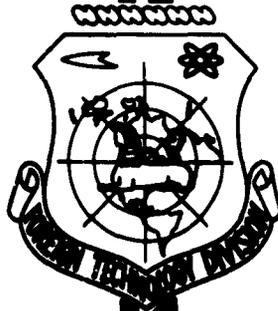
A. G. Zenukov

## FOREIGN TECHNOLOGY DIVISION

AIR FORCE SYSTEMS COMMAND

WRIGHT-PATTERSON AIR FORCE BASE

OHIO



## UNEDITED ROUGH DRAFT TRANSLATION

THE PROBLEM OF COOLING GAS TURBINE VANES  
BY AIR

By: A. G. Zenukov , Kazan' Aviation Institute

English Pages: 11

Source: Izvestiya Vysshikh Uchebnykh Zavedeniy,  
Aviatsionnaya Tekhnika, No. 2, 1962. Pp. 130-137.

SC-1730  
SOV/147-62-0-2-16/20

THIS TRANSLATION IS A RENDITION OF THE ORIGINAL FOREIGN TEXT WITHOUT ANY ANALYTICAL OR EDITORIAL COMMENT. STATEMENTS OR THEORIES ADVOCATED OR IMPLIED ARE THOSE OF THE SOURCE AND DO NOT NECESSARILY REFLECT THE POSITION OR OPINION OF THE FOREIGN TECHNOLOGY DIVISION.

PREPARED BY:

TRANSLATION SERVICES BRANCH  
FOREIGN TECHNOLOGY DIVISION  
WP-APB, OHIO.

# THE PROBLEM OF COOLING GAS TURBINE VANES

BY AIR

A. G. Zenukov

In order to improve the individual parameters of modern aviation gas turbine engines a number of problems must be solved, of which the most important is that of raising the temperature of the gas in front of the turbine.

Scientific research and experimental design directed toward the solution of this problem are at present being carried on by making new heat-resistant materials and also highly efficient designs and methods of cooling components operating in the high temperature regions.

The present article describes the design developed by the author for air cooling of the gas turbine vane and the results of preliminary tests of its reliability.

The design of the vane consists of bearing column 1 which takes the load, easily fitting profiled envelope sleeve 2, and supporting collar 3. The column is made in one piece with the foot of the vane. The supporting collar is welded on or conformed by pressing after the sleeve has been slipped on. There is practically

no contact between the column and the sleeve which expands freely on heating. Under the action of centrifugal forces the sleeve is continuously subject to pressure and presses against supporting collar 3. The whole load of the envelope tube is transferred to the "cold" column.

The air coolant, as shown in Fig. 1, is supplied through apertures in the foot and in the column to the leading edge of the sleeve.

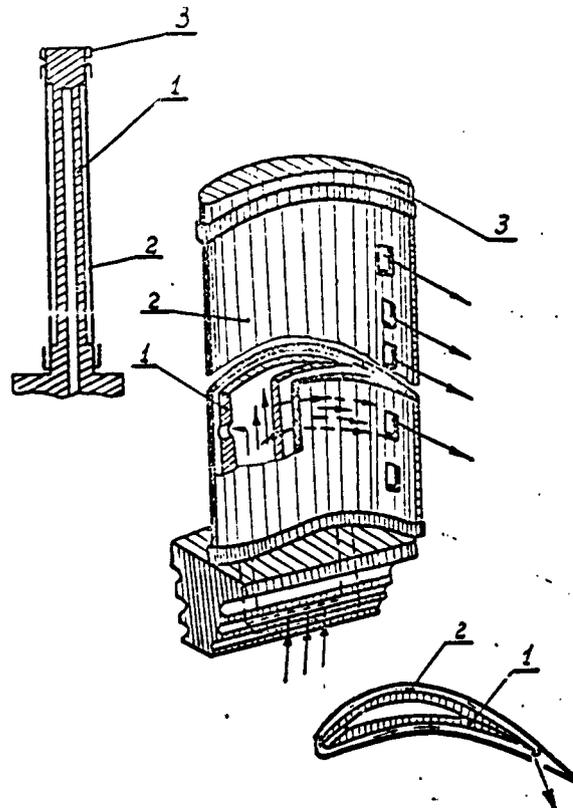


Fig. 1. Diagram of compound sleeve vane developed by author.

Bathing the envelope and the column from the inside in a tangential direction, the air is heated and thrown out into the

flow-through part of the turbine through apertures made near the trailing edge.

The possibility of free temperature deformation of the sleeve in a radial direction and the lack of a rigid bond to the column make the design less stressed. The temperature field along the length of the blade of such a vane must be more uniform (Fig. 2).

The design permits the achievement of a considerable temperature difference between the sleeve and column and thus the provision of temperature conditions for the column which make possible the use of a non-heat-resistant material.

The safety factor as a whole is determined by the safety factor of the envelope. While the envelope and the column are provided with equal strength the column is substantially lightened. Decreasing the weight of the vane leads to relief of the turbine runner or diminishing its weight.

Experiments conducted in 1949 in the turbine engine laboratory of the Kazan' Aviation Institute [1] on a sleeved vane of similar design showed a sufficient temperature uniformity along both the length and the perimeter of the vane (Figs. 3, 4). Figure 5 displays the design of this vane.

As design deficiencies should be considered the low cooling efficiency because of the radial arrangement of the cooling channels and possible warpage of the sleeve after welding which of course entails loss of stability.

The proposed design has been stripped of these drawbacks since  
1) the cooling stream of air bathes the sleeve in a tangential direction, which is more efficient; and

2) the sleeve is affixed to the column by welding after having been heat treated and straightened, and this precludes warpage and

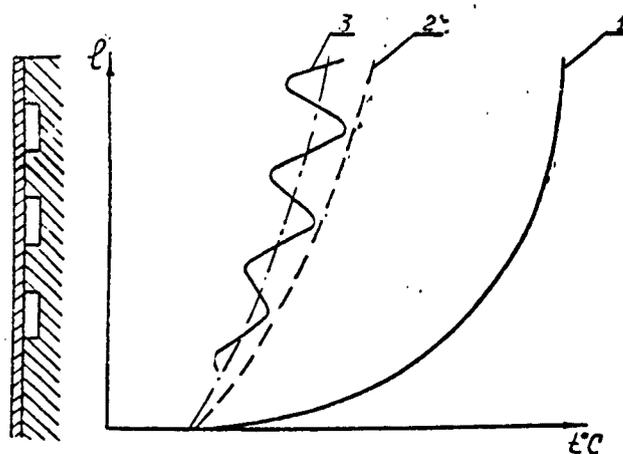


Fig. 2. Temperature distribution along the length of vanes: 1) uncooled; 2) sleeved, free envelope (column not participating in heat exchange); 3) sleeved, envelope united to column (latter participating in heat exchange).

denting, and destruction. It may be expected that the proposed construction will be more efficient from the heat transfer point of view than the preceding.

The first fundamental feature of the design in question consists in that the column of the vane is shielded from the high-temperature action of the sleeve and air current.

In earlier proposed designs of compound sleeved vanes (e.g., Fig. 6) the vane column was drawn into the heat exchange. This was accomplished by welding or soldering the column bearing ribs on its surface to the sleeve. The increase in cooling surface achieved in this process led to a certain decrease in the temperature of the sleeve and increase in column temperature.

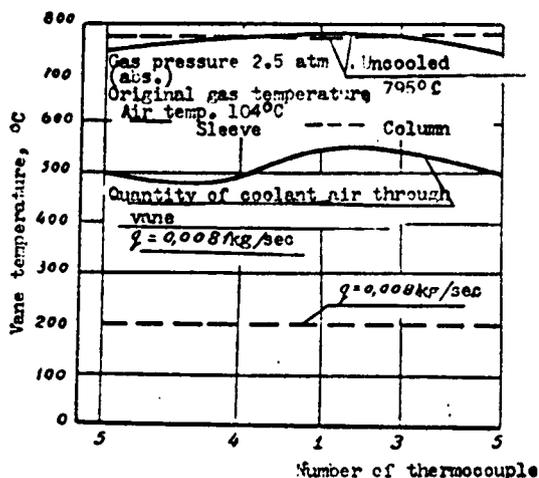
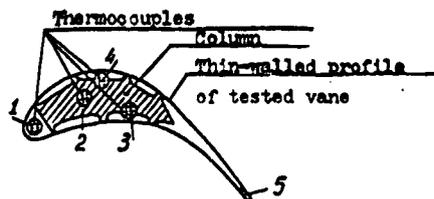


Fig. 3. Temperature distribution on the profile of compound sleeved vane (Kazan' Aviation Institute experimental data [1]).

According to our calculations, the sleeve temperature of this vane because of heat transfer into the column may be depressed by approximately 10% but in this process it will have a nonuniform temperature (see Fig. 2), which leads to significant temperature stresses. The temperature nonuniformity may, as the calculations showed, reach values on the order of 100° C.

Producing such a vane is laborious and its cooling efficiency depends not only on  $\alpha_g$  and the heat-exchanging surface, but also on the reliability of the contact between the envelope and the ribs.

The use of non-heat-resistant materials is impossible in this design, even if the temperature in front of the turbine is moderately

high (800° C).

The second fundamental feature of our design consists in the whole vane sleeve continuously operating under compression.

There is no unanimous opinion on the question of the effect of the deformation direction (compression or tension) on the ultimate strength of the materials at normal temperatures. Thus, N. M. Belyayev [2] considers that their proportional values (and also the yield point for the steel) as well as that of the moduli of elasticity for plastic materials under pressure and tension are approximately the same.

I. A. Odling [3] considers that the structural features of metal very frequently lead to higher values of flow under compression and bending in comparison with the yield point in tension.

Evidently when each concrete material is chosen it is necessary to be guided by experimental data appropriate to the deformation direction adopted in the design.

From the heat-resistant point of view the deformation direction is not indifferent, since at present it is considered that heat resistance should be sought in means which could help decrease the mobility of the atoms on the grain boundaries and strengthen the interatomic bonds in the crystal lattice [4].

If the interatomic distances increase in tensile deformation and decrease under compression, then it is evident that under elevated temperature conditions the atoms of the stretched metal will have greater mobility than those of the compressed metal and the interatomic bonds will prove to be weakened.

Basically this very circumstance is taken into consideration when determining the deformation direction for the envelope of the proposed design.

A rise in heat resistance, even an inconsiderable one, often leads to a very substantial rise in the possibilities of the design as a whole.

In the SAE Journal the following interesting information is given in this regard.

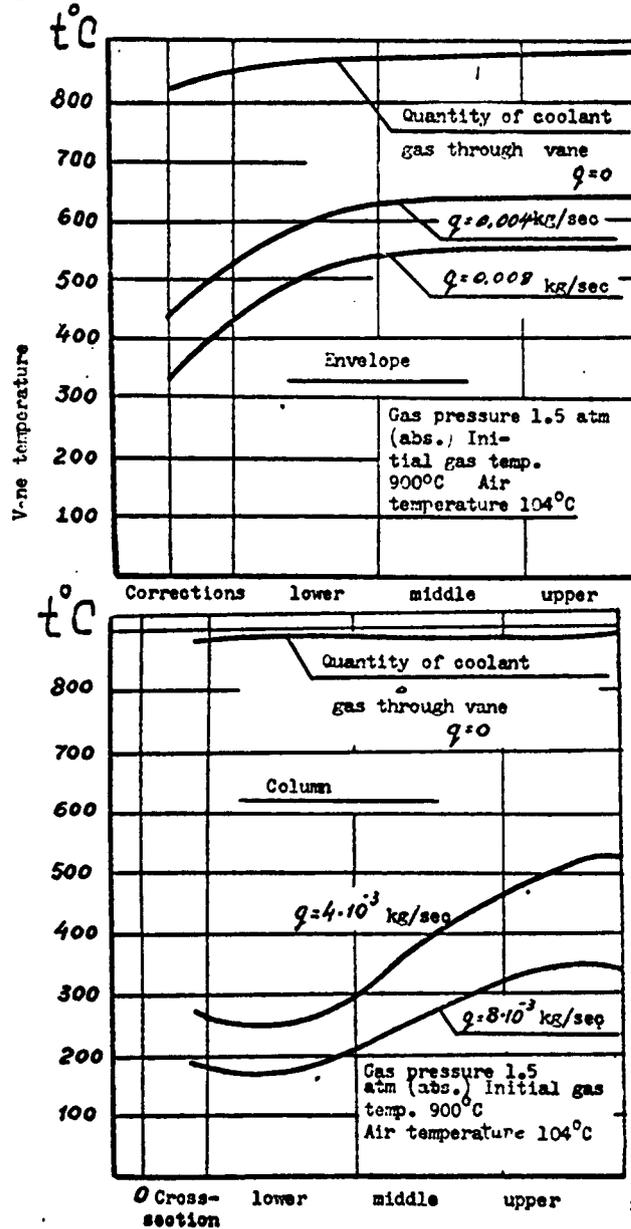
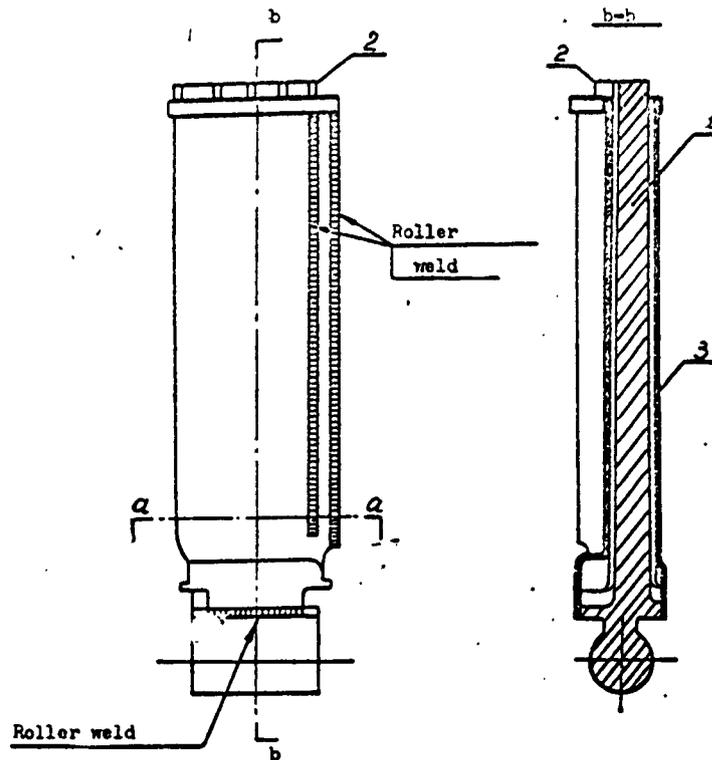
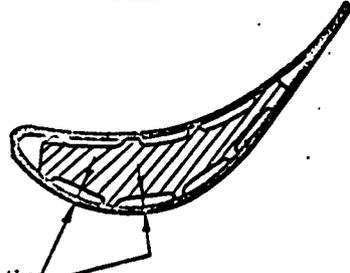


Fig. 4. Temperature distribution along length of compound sleeved vane (Kazan<sup>1</sup> Aviation Institute experimental data [1]).



a-a



Clearance not less than  
1 mm

Fig. 5. Diagram of vane developed by Gas Turbine Department of Kazan' Aviation Institute in 1949. 1) Bearing column, 2) supporting lugs, 3) thin-walled envelope.

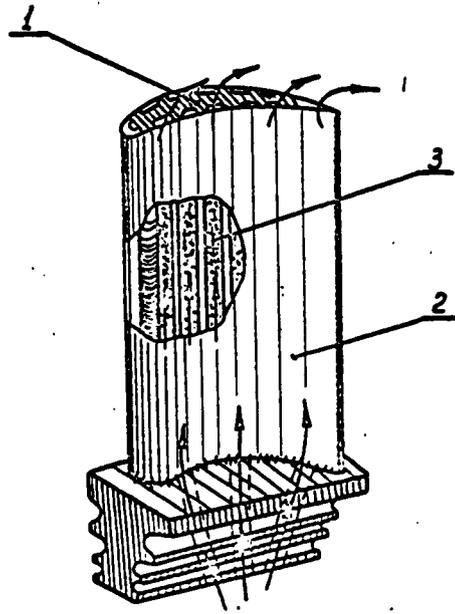


Fig. 6. Diagram of vane, the column of which is drawn into heat exchange by longitudinal ribs.

Investigation of one of the engines showed that the calculated resources of the turbine vanes might be multiplied 44 times when the temperature was lowered by  $55^{\circ}\text{C}$  and the number of revolutions by 4%.

Failure of the thin-walled sleeve under the influence of compressive forces is possible not only because its strength will be disturbed but also because the sleeve will not preserve its designed shape, i.e., will lose its rigidity. Therefore that the structure may operate reliably it is necessary to secure rigidity of all its elements in addition to heat resistance.

In order to verify the reliability of operation of the sleeve under conditions of axial compression the first stage of the investigation was undertaken, which consisted in static tests at normal temperatures.

Sleeves typical of shapes of modern turbine vanes were used as specimens. The length of the tested vanes was from 200 to 50 mm with corresponding chords of from 40 to 30 mm. In all more than 200 experiments were conducted.

The tests were made on a standard Gagarin machine in a special device which decreased possible misalignments. The sleeves were made of sheet stock 0.4-0.5 mm thick of IKhI8N9T, EI696, and EI437 roofing iron.

The technical productions process and the methods of heat treating the sleeves were first worked out.

The tests showed that the sleeves lose their efficiency under the effect of the length and the considerable increase in material deformation under stresses close to the yield point.

All the sleeves tested had the suddenly appearing buckling characteristic of local loss of rigidity (Fig. 7).

The maximum critical stresses at which loss of rigidity began were\*:

EI696 sleeves,  $\sigma_c = 60$  to  $64$  kg/mm<sup>2</sup>;

IKhI8N9T sleeves,  $\sigma_c = 27$  kg/mm<sup>2</sup>.

Yield points under tension of these material were: EI696,  $\sigma_{0.2} =$  kg/mm<sup>2</sup> [sic]; IKhI8N9T,  $\sigma_{0.2} = 29$  kg/mm<sup>2</sup>. The EI696 sleeves were aged; those of IKhI8N9T were tested in the condition in which supplied.

For full characterization of the given vane design information on its efficiency from the heat transfer point of view is necessary. As a first approximation of the cooling efficiency of this vane

---

\* A. A. Kalimullin and R. G. Khayrullin, engineers working in the Turbine Engine Laboratory, took part in determining the rigidity of the envelopes.

we may go by the laboratory experiments of 1949.

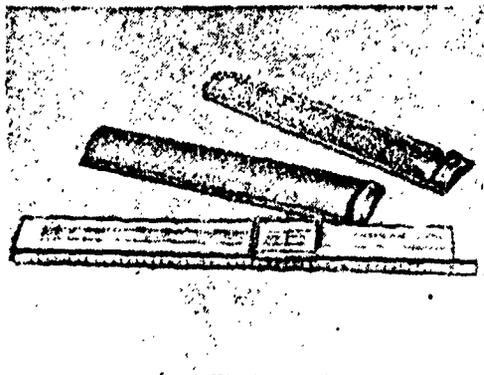


Fig. 7. Photograph of specimens tested. Local loss of rigidity clearly visible.

Figure 8 shows the results of the tests on this vane.

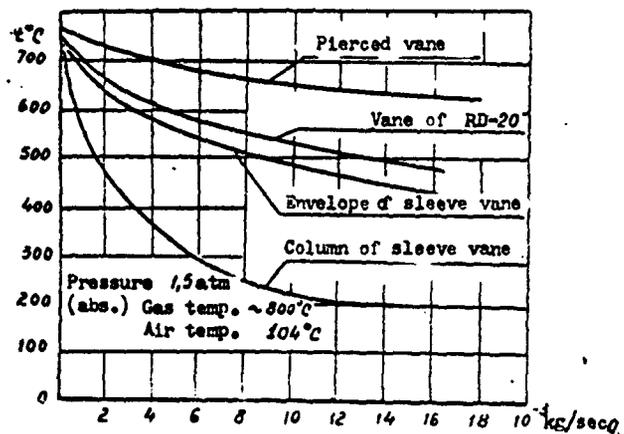


Fig. 8. Experimental data on tests of sleeved vane developed by Gas Turbine Department of Kazan' Aviation Institute in 1949.

## Conclusions

The proposed vane design may be efficiently used at moderately high gas temperatures on the order of 800-900° C. The vane column in these conditions can be made of non-heat-resistant material.

The use of a "cold" column leads to plate relief or decrease in its weight.

Strength tests have demonstrated that this type of sleeve can operate in the given design and that rigidity loss phenomena need not be feared.

Tests at elevated temperatures under static and full-scale engine conditions are necessary for final judgment as to the efficiency of the design.

Special heat tests are necessary to determine the efficiency of the blade in question.

## REFERENCES

- [1. Data from Turbine Engine Department, Kazan' Aviation Institute.]
2. N. M. Belyayev. The Resistance of Materials. Fizmatgiz, 1959.
3. I. A. Oding. Fundamentals of Metal Strength of Steam Boilers, Turbines, and Turbogenerators. Gosenergoizdat, 1949.
4. P. B. Mikhaylov-Mikheyev. The Metal of Gas Turbines. Mashgiz, 1958.
5. SAE Journal. VII, 1959.

Turbine Engine Department.

Received November 30, 1961.

DISTRIBUTION LIST

DEPARTMENT OF DEFENSE	Nr. Copies	MAJOR AIR COMMANDS	Nr. Copies
		AFSC	
		SCFDD	1
		ASTIA	25
HEADQUARTERS USAF		TDBTL	5
		TDEDP	5
AFCIN-3D2	1	AEDC (AEY)	1
ARL (ARB)	1	SSD (SSF)	2
		BSD (BSF)	1
		AFFTC (FTY)	1
		AFSWC (SWF)	1
OTHER AGENCIES			
CIA	1		
NSA	6		
DIA	9		
AID	2		
OTS	2		
AEC	2		
PWS	1		
NASA	1		
ARMY	3		
NAVY	3		
RAND	1		
PGE	12		
NAFEC	1		