N72 32763

NASA TECHNICAL MEMORANDUM

NASA TM X-68144

NASA TM X-68144

CASE FILE COPY

A CONCEPT FOR JET NOISE SUPPRESSION FOR AN AFTERBURNING TURBOJET ENGINE

by Rene E. Chambellan and Robert J. Turek
Lewis Research Center
Cleveland, Ohio
October 1972

This information is being published in preliminary form in order to expedite its early release.

ABSTRACT

A conceptual design of an afterburner system for turbojet engines which may reduce the jet exhaust noise by approximately 10 decibels is presented in this report. The proposed system consists of an array of swirl-can combustors and jet dividing nozzle tubes. The nozzle tubes translate axially upstream of the swirl cans when not in use. Results of preliminary design calculations and photographs of a kinematic model as applied to a hypothetical turbojet engine are presented.

E-7167

A CONCEPT FOR JET NOISE SUPPRESSION FOR AN AFTERBURNING TURBOJET ENGINE

by Rene E. Chambellan and Robert J. Turek

Lewis Research Center

SUMMARY

A conceptual design having the potential for reducing the jet noise of an afterburning turbojet engine by approximately 10 decibels is presented in this report. The proposed system uses the known techniques for reducing jet noise wherein the exhaust jet is divided into many small jets, each surrounded by air. However, this system is unique in that the afterburner is of the swirl-can type, as opposed to vee-gutters, and the jet-dividing nozzle tubes remain in the turbine exhaust gas at all times but change configuration when in the nonsuppressing mode.

This system was used in the conceptual design for a hypothetical turbojet engine having a gas flow of 633 pounds per second. A kinematic model was built and some preliminary design calculations were made.

The kinematic model only indicates the feasibility of the mechanical concept. Both scale model flow tests and full size component tests of swirl can burners and the nozzle tubes need to be performed before the proposed system can be fully evaluated.

INTRODUCTION

A conceptual design for reducing the jet noise from an afterburning turbojet engine is presented in this report. Most schemes that have been used or proposed for exhaust noise suppression have consisted of dividing the exhaust into a number of small jets as discussed in references 1 to 3. Suppressor flow dividers in the presence of the afterburning high temperature environment render conventional materials and approaches inadequate for reasonable operating life. This requires that one or a combination of approaches such as the use of refractory materials, limited exposure time or cooling be used to obtain reasonable suppressor operating life.

The suppressor concept discussed in this report overcomes the problem of overheating by using an individual afterburner for each of the nozzle tubes forming the small exhaust jets. The afterburner modules proposed are in the form of swirl cans, which have been investigated in primary combustors in references 4 and 5. By proper tailoring of the temperature profile from each of the afterburner modules, excessive temperatures in the suppressor apparatus can probably be avoided. The noise suppressor would be used during takeoff conditions. As soon as sufficient altitude was reached after takeoff where the jet noise would be attenuated to acceptable levels at the ground, the nozzle tubes of the suppressor would be translated upstream of the swirl can afterburner modules to minimize the time the nozzle tubes would be exposed to high gas temperatures.

The preliminary study reported herein was conducted for a hypothetical engine having a gas flow weight of 633 pounds per second, a turbine exit temperature of 1600° F, and an afterburner exhaust temperature of 2200° F for the takeoff condition.

PROPOSED SYSTEM

The proposed system described in this report for jet noise suppression in a large turbojet engine is the one where many small diameter exhaust nozzles (nozzle tubes) are used to divide the exhaust flow. A single element swirl can and nozzle tube are shown in figure 1, the kinematic model of a portion of the complete afterburner is shown in figure 2, and figures 3 and 4 are layout sketches of the complete afterburner. Added side ventilation air is used to produce additional mixing around all the tubes thus reducing the shearing gradient at the outer perimeter of the exhaust jet. The shear gradient noise generated around the interior nozzle jets will be attenuated by the surrounding nozzle jets. Thus two kinds of noise suppression can be accomplished. In one, the noise frequencies would be shifted to higher values and in the other the noise amplification due to high shear gradient would be reduced. Such a system may reduce the jet noise by approximately 10 decibels (ref. 1).

Swirl cans are proposed for this system because it has been established in references 4 to 7 that they produce very stable combustion and require only a short distance to complete combustion. When applied to afterburners they have the potential to produce more efficient combustion afterburner systems. By using a swirl can co-axial with each nozzle tube, the nozzle tubes and supporting grillage are not exposed to high afterburning gas temperatures. The reason for this is that the limited area of combustion downstream of each swirl can is shrouded with turbine exhaust gas which has bypassed the swirl can. The arrangement for one element is shown in figure 1.

In order to minimize exposure of the nozzle tubes to high temperature gas from the swirl can afterburner, it is proposed that the nozzle tubes be in place downstream from the swirl cans only during the period when maximum noise suppression is required. At other times, the nozzle tubes could be translated to a position upstream from the swirl cans and would have been adjusted during translation to produce minimal blockage to the flow of turbine exhaust gas, as shown in figure 5.

The use of hexagonal shapes for the nozzle tubes was chosen over a circular shape because the tubes could be more closely packed with less blocked area between tubes. A larger blocked area would require a larger afterburner diameter for a given required flow area.

Introduction of relatively cold air downstream of the nozzle tubes in the jet noise suppression mode is required to realize the full suppression potential of the system. By the ejector action of the jets leaving the nozzle tubes, it is possible to draw air (side ventilation air - see figs. 1, 3, and 4) from the perimeter of the grid to its innermost nozzle tube. This air also acts as a convective coolant outside of the nozzle tubes. To assure that air reaches the innermost nozzle tubes, it is proposed that some air be ducted through the support grillage and be discharged around the desired tubes. This air would also act as a convective coolant for the grillage.

CONCEPTUAL DESIGN OF MAJOR COMPONENTS

A conceptual design for the major components of a multitube noise suppressor using the proposed system for a hypothetical afterburning turbojet engine has been made. The values of significant parameters used for the design of some of the suppressor components were as follows:

(1) Engine gas weight flow = 633 lb/sec
(2) Nonafterburning exhaust gas temperature = 1600° F
(3) Afterburning exhaust gas temperature = 2200° F
(4) Suppressor flow area at takeoff = 1410 in.^{2}
(5) Suppressor flow area at cruise = 2880 in.^{2}
(6) Ratio of total base area to exhaust area = 3:1
(7) Ratio of side slow area to base area = 1:6.75
(8) Range of ratio of nozzle tube length to nozzle tube diameter from engine periphery to engine center = 3 to 1
(9) Design gas pressure difference across suppressor assembly = 30 psi

The details of how the fuel manifold assemblies would be anchored to the engine, how the swirl can would be mounted to the internal manifolds and how the hexagonal grillage would be translated in the engine were not studied.

A kinematic model of a portion of the conceptual design using solid mock-up swirl cans and grillage, is shown in the suppressing mode, figures 2 and 6, in the nonsuppressing mode in figure 7 and in transition to the nonsuppressing mode in figure 8. A cross-section of the afterburner is shown in figure 3 in the suppression mode, with a partial view of the grillage and nozzle tubes in the stored (nonsuppressing) mode. Figure 4, a view looking upstream into a sector of the 121 module array, shows the arrangement of nozzle tubes, swirl cans and fuel manifolds.

Nozzle Tubes and Grillage

In this design, the suppressor assembly remains in the turbine gas stream at all times. The nozzle tubes, approximately hexagonal in cross-section and articulated so as to open and close like a clamshell, are shown in figure 9. In the nonsuppressing mode the nozzle tubes are open to minimize the resistance to the flow of the turbine exhaust gas. During the translation downstream to the suppression mode location, the nozzle tubes articulate to a closed condition, dividing the afterburner gas flow into discrete small jets and also forming the primary nozzle during takeoff conditions.

These tubes are supported in a hexagonal grillage which is supported perpendicular to the gas flow. The tube hinge pins are located so as to balance the pressure forces in the suppression mode. A preliminary design indicated a weight of approximately 373 pounds for these tubes. The grillage elements are streamlined and are sized so that in the suppression mode all the gas must flow through the nozzle tubes. In the nonsuppression mode, the nozzles provide no reduction of area and the grillage offers little resistance to flow. Figure 10 shows a nozzle tube tube in the grillage. The grillage elements are made hollow, with suitable ports, so as to conduct ventilation air to the space between the nozzle tubes. This air flow exhausts in the region of the engine centerline and is supplemental to the side ventilation air in the noise suppression mode. The weight of the grillage was estimated to be 182 pounds based on results of a preliminary stress analysis.

The mechanism for translating the hexagonal grillage fore and aft in the engine has not been determined. It is anticipated that it would be a hydraulically operated mechanism synchronized so as to prevent cocking and consequent binding of the hexagonal grillage.

Swirl Can Burners

This noise suppressor design accommodates swirl can type afterburners. The selection of size and number of swirl cans was governed by past experience. The swirl cans have been located in an array matching the nozzle tubes. Thus each burner has an individual noise suppressor.

A major problem in designing a jet noise suppressor is to protect the components from exposure to the high temperature gas resulting from afterburning. This high temperature gas usually exceeds the melting temperature of most jet engine "hot" parts. The method used to minimize this problem was to shroud the swirl can high temperature afterburning gas with cooler turbine exhaust gas before it passes through the nozzle tubes. Further protection of the nozzle tubes and grillage is obtained from convective cooling provided by externally supplied ventilation air.

Protection of components is also provided by limiting their exposure to high temperature afterburning gases to the short time during takeoff periods. During takeoff the nozzle tubes and grillage are in the suppression mode downstream of the swirl cans. After takeoff, the suppressor grillage is translated upstream in the engine thus permitting the swirl can burners to extend beyond the nozzle tubes, which have been opened during the translation. Opening and closing of the nozzle tubes is accomplished by a mechanical linkage between the swirl can burner supports and the nozzle tube halves. The linkage details have not been worked out, however, a kinematic mock-up has been built where the actuating mechanism for the nozzle tubes consist of cam surfaces attached to the swirl cans. An estimated weight of the cams and their support is 68.8 pounds and for the swirl cans is 68.4 pounds. The cams force the nozzle tubes to open and close by pushing on pins attached to the nozzle tube halves. Synchronization of all the nozzle tubes and eliminating binding of the mechanism would probably be a major problem.

The swirl can burners are supported in cantilever fashion from fuel manifolds by tubes supplying fuel to the burners. This arrangement is shown schematically in figure 1. In this figure is shown the flow of gases from the turbine exhaust and swirl can burner. Also, the flow of ventilating air through the grillage members and side ventilation air is shown. It is anticipated that the ventilating air flow through the grillage will only be necessary for the center portion of the array since at the outer periphery the side ventilation should provide adequate air flow.

The swirl can fuel tubes are connected to a manifold assembly composed of concentric hexagonal tubular rings. These rings are connected to 12 fuel supply struts (fig. 4), each containing separate supply tubes for each hexagonal manifold (fig. 3). This supply system provides the capability of concentric zone control of the afterburner. The manifold supply at each strut is required to furnish fuel to two to three swirl cans.

The fuel supply tubes and struts are supported at the engine periphery and the fuel supply tubes are connected to zone control manifolds external to the engine.

CONCLUDING REMARKS

Previous theoretical and operational results indicate that dividing an exhaust jet into a multitude of small jets, each surrounded by air, will reduce the jet noise level by approximately 10 decibels. The concept proposed in this report utilizes this method in attempting to reduce jet noise. A kinematic model of the proposed hardware has shown the concept to be workable, but scale model flow tests and full size component testing need to be performed to determine the attenuation capabilities and to solve the structural, mechanical, and operational problems.

The following is a list of advantages and disadvantages of this proposed concept:

1. The use of swirl can combustors produce a more stable and shorter combustor than can be obtained with more common vee-gutter afterburners.
2. Nozzle tubes and supports are shrouded with "cool" turbine exhaust gases and have shorter exposure to extremely high afterburning temperatures than previously proposed systems. For these reasons, conventional turbojet engine materials of construction can be utilized.
3. Smooth transition from suppression to nonsuppression mode is accomplished by programmed articulation and traversing of the nozzle tubes uniformly over the entire afterburner area. The problem of potential binding of the translating parts would require a development effort.

4. The large number of required parts create an extensive assembly problem. In addition to the physical mounting problems there is also the problem of alignment of the more active components.

REFERENCES

1. Eldred, Kenneth M.; White, Robert W.; Mann, Myron A.; and Cottis, Miltiades G.: Suppression of Jet Noise with Emphasis on the Near Field. Western Electro-Acoustic Lab., Inc. (ASD-TDR-62-578), Feb. 1963.
2. Harris, Cyril M., ed.: Handbook of Noise Control. McGraw-Hill Book Co., Inc., 1957.
3. Beranek, Leo L., ed.: Noise Reduction. McGraw-Hill Book Co., Inc., 1960.
4. Butze, Helmut F.; Trout, Arthur M.; and Moyer, Harry M.: Performance of Swirl-Can Turbojet Combustors at Simulated Supersonic Combustor-Inlet Conditions. NASA TN D-4996, 1969.
5. Niedzwiecki, Richard W.; and Jones, Robert E.: Combustion Stability of Single Swirl-Can Combustor Modules Using ASTM-A1 Liquid Fuel. NASA TN D-5436, 1969.
6. Childs, J. H.: Flow Stabilization. Design and Performance of Gas Turbine Power Plants. Vol. XI of High Speed Aerodynamics and Jet Propulsion. W. R. Hawthorne and W. T. Olson, eds., Princeton University Press, 1960, Paragraphs E3 and E12.
7. Reck, Gregory M.; Branstetter, J. Robert; and Diehl, Larry A.: Preliminary Sector Tests at 920 K (1200 F) of Three Afterburner Concepts Applicable for Higher Inlet Temperatures. NASA TN D-6437, 1971.

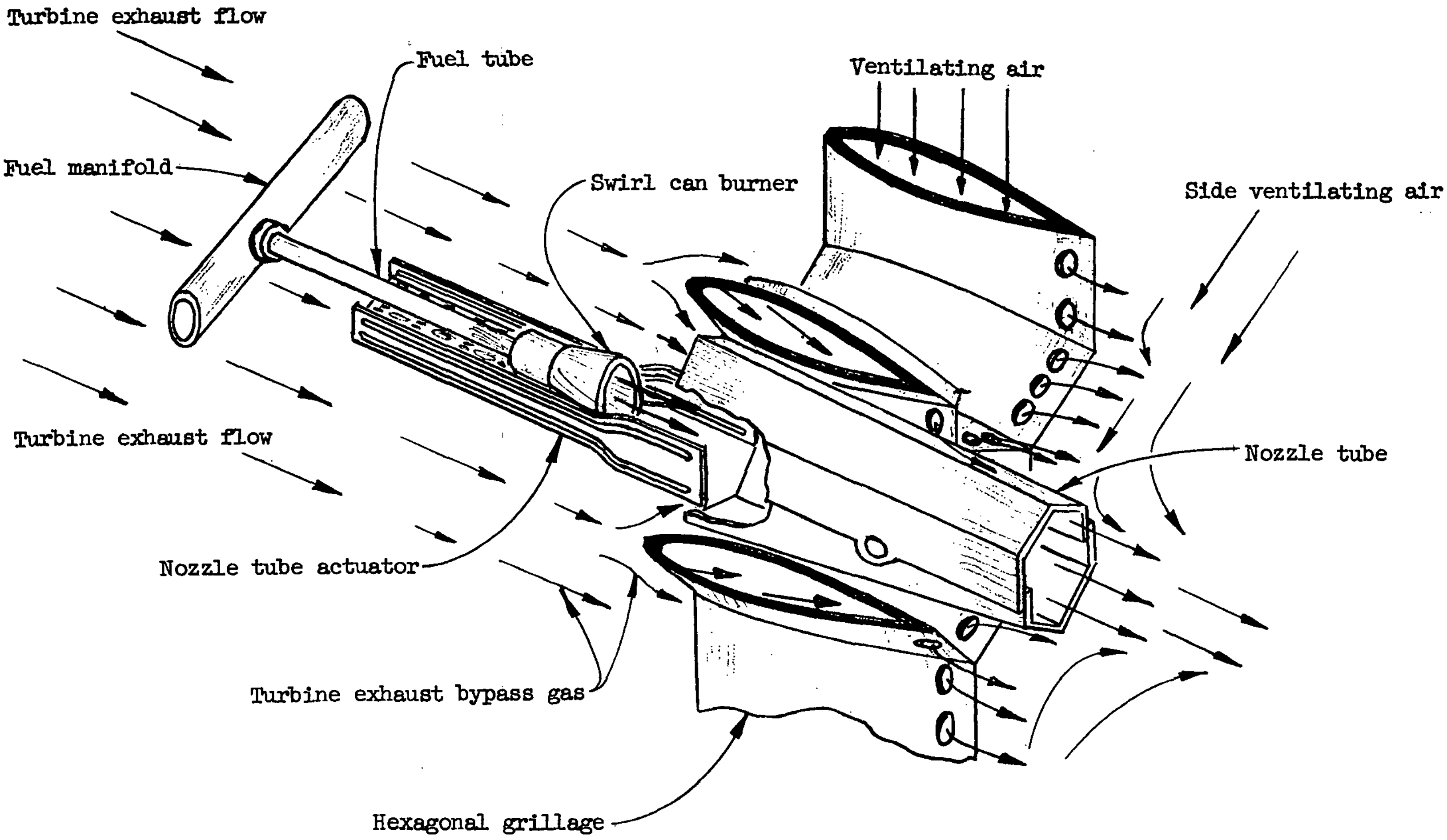


Figure 1. - Single element of nozzle tube/swirl can array in suppression of noise mode

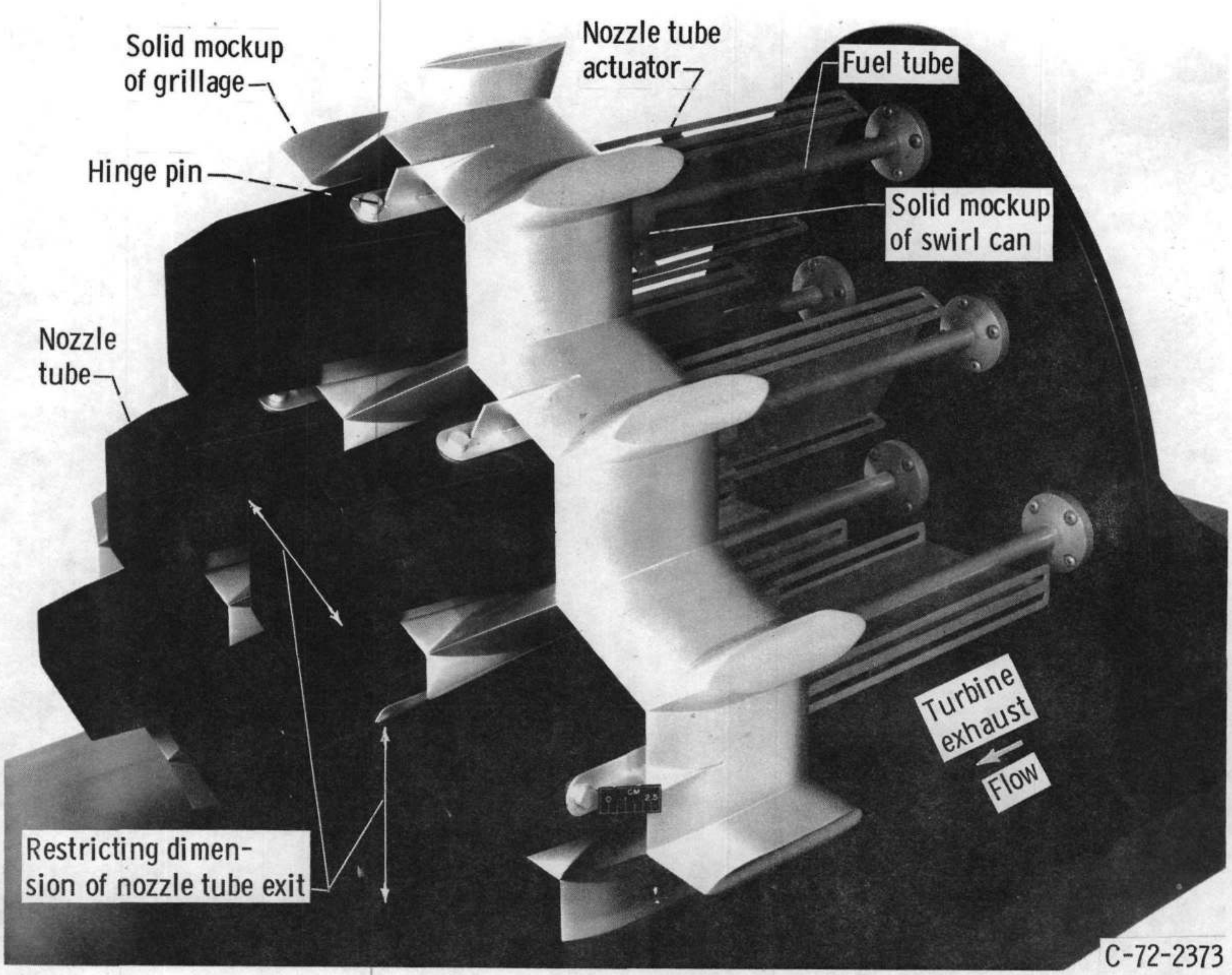
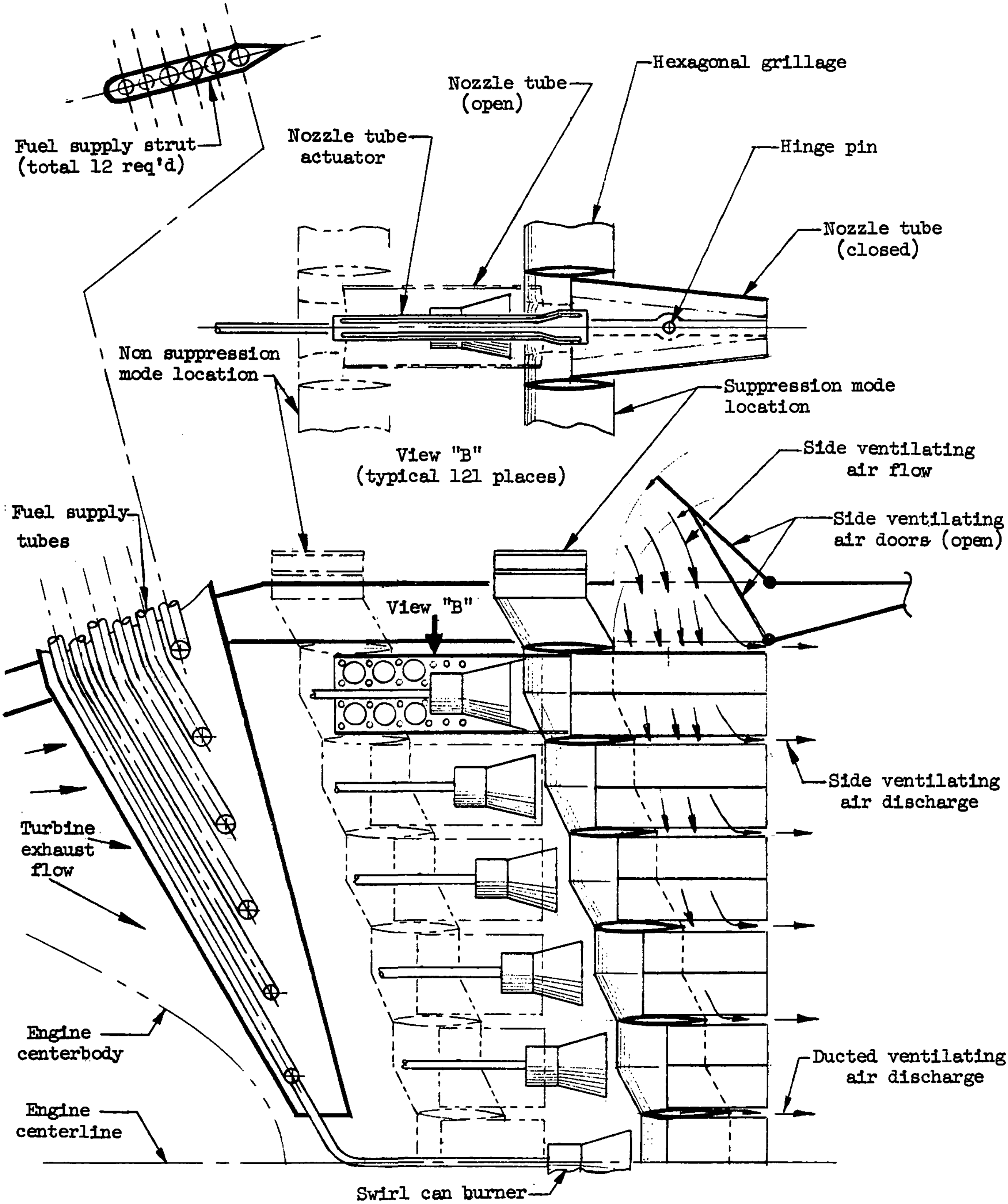


Figure 2. - Kinematic model of a portion of the afterburner in the suppressing mode; view looking upstream.



E-7167

Figure 3. - Cross section through afterburner showing both suppression and non-suppression modes

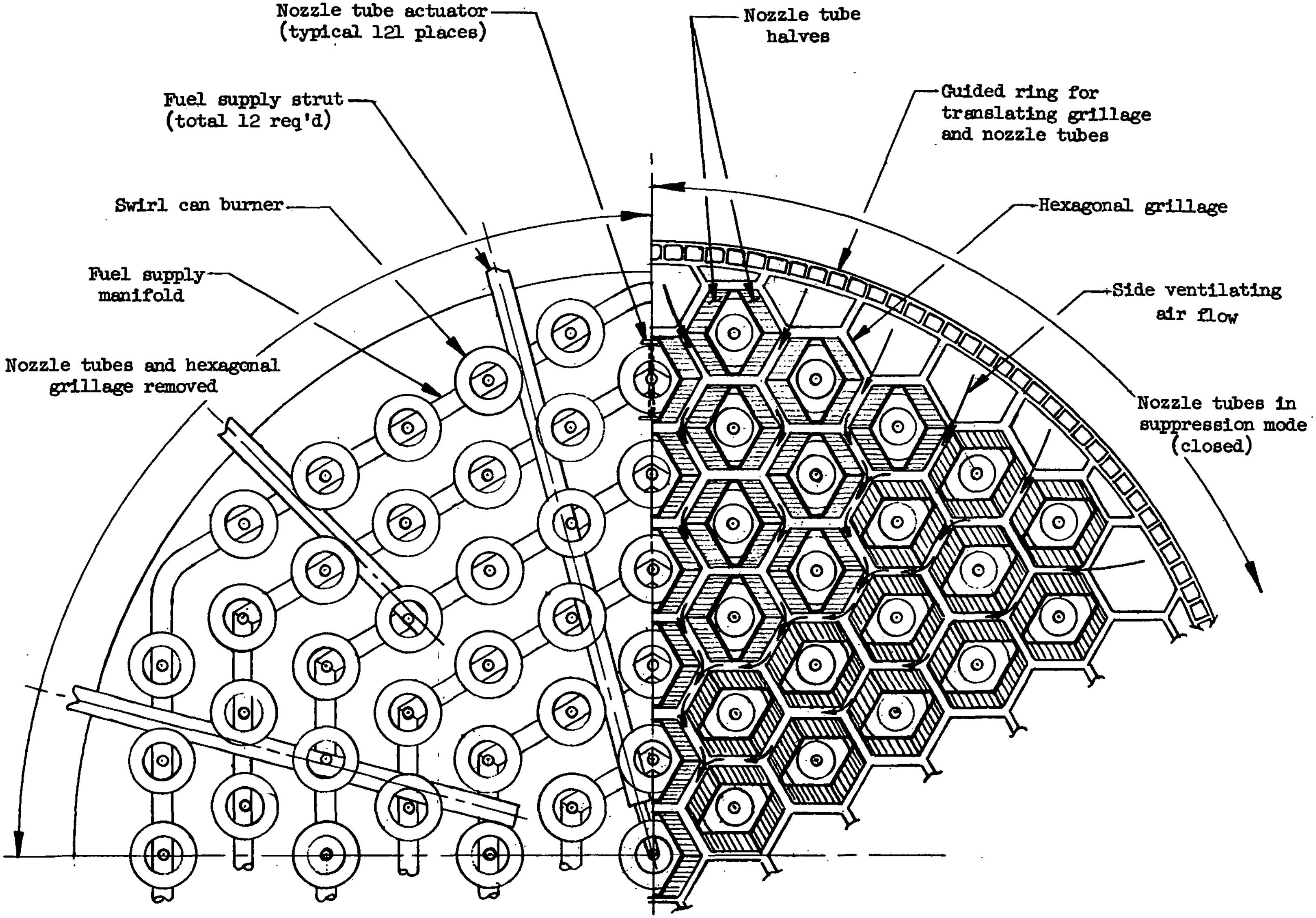


Figure 4. - View looking upstream at two planes through afterburner

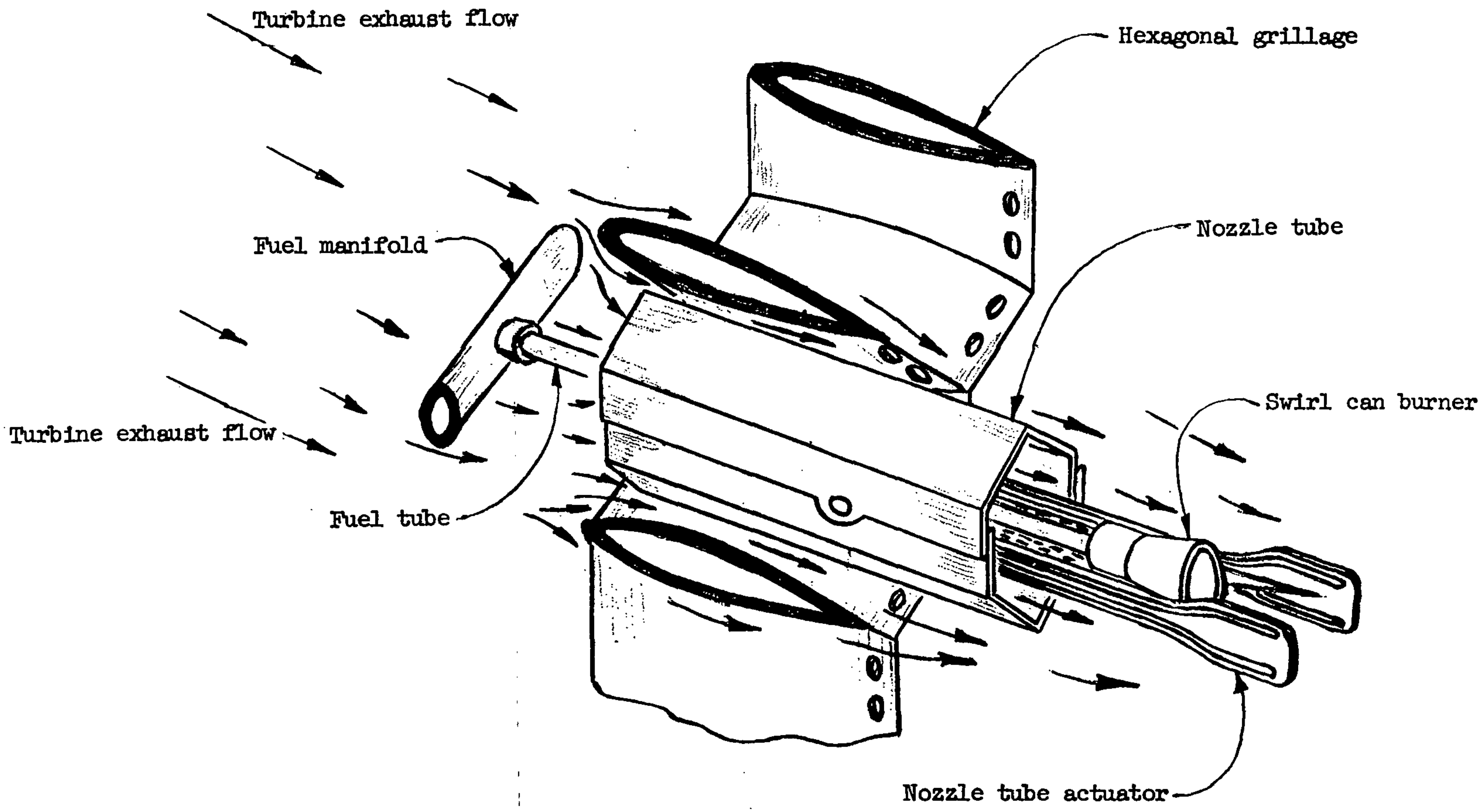


Figure 5. - Single element of nozzle tube/swirl can array in non suppression of noise mode

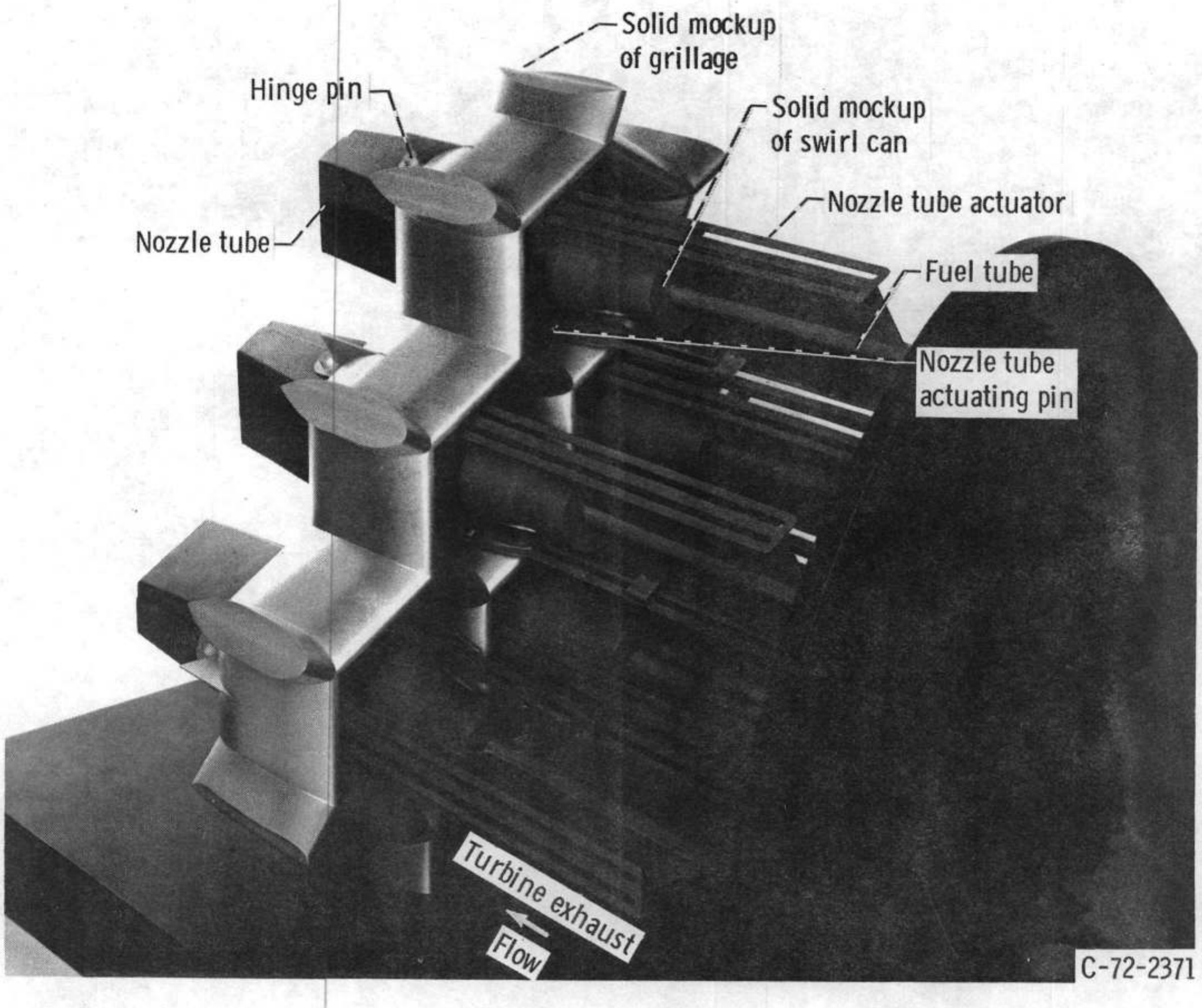


Figure 6. - Kinematic model of a portion of the afterburner in the suppressing mode; view looking downstream.

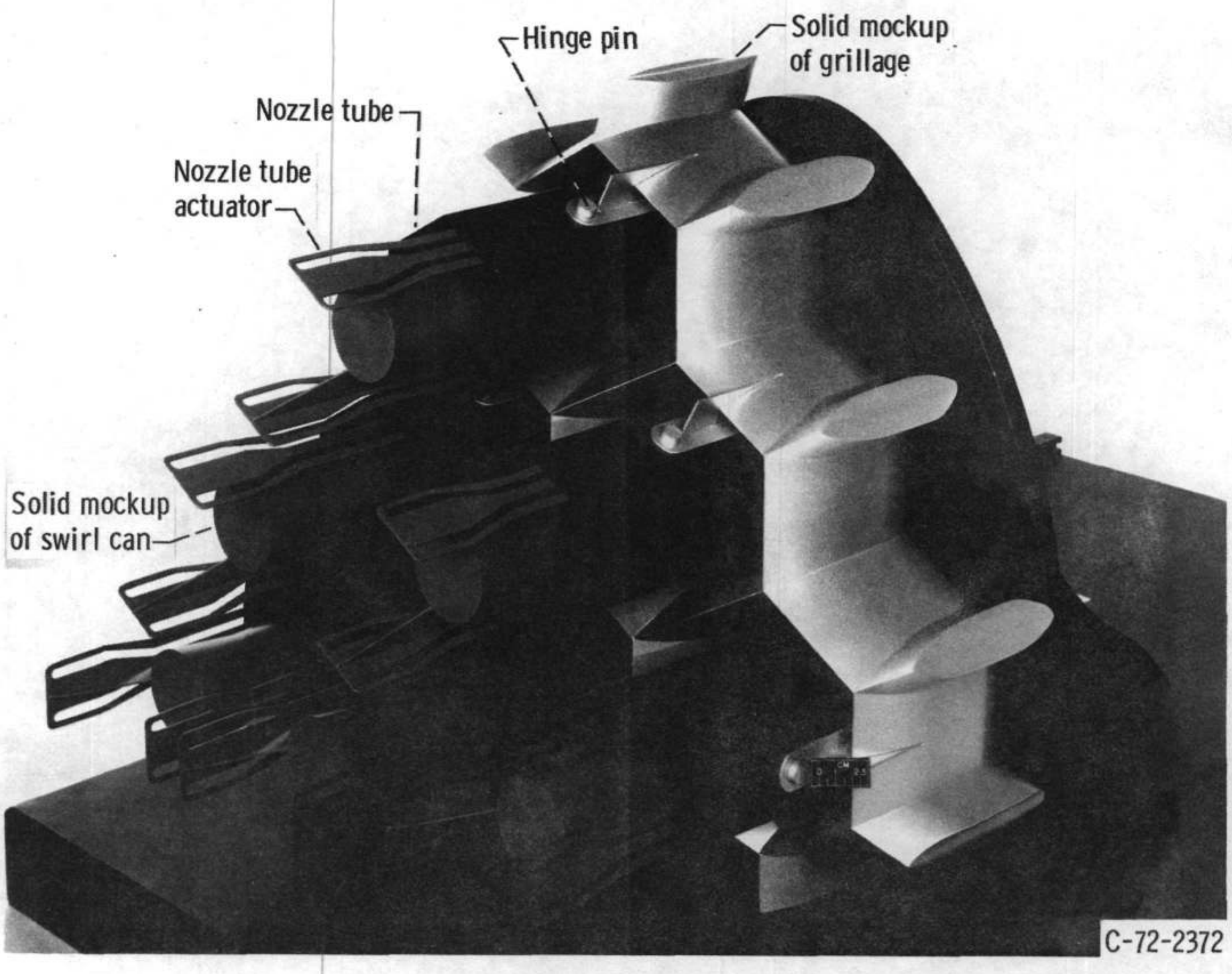


Figure 7. - Kinematic model of a portion of the afterburner in non-suppressing mode; view looking upstream.

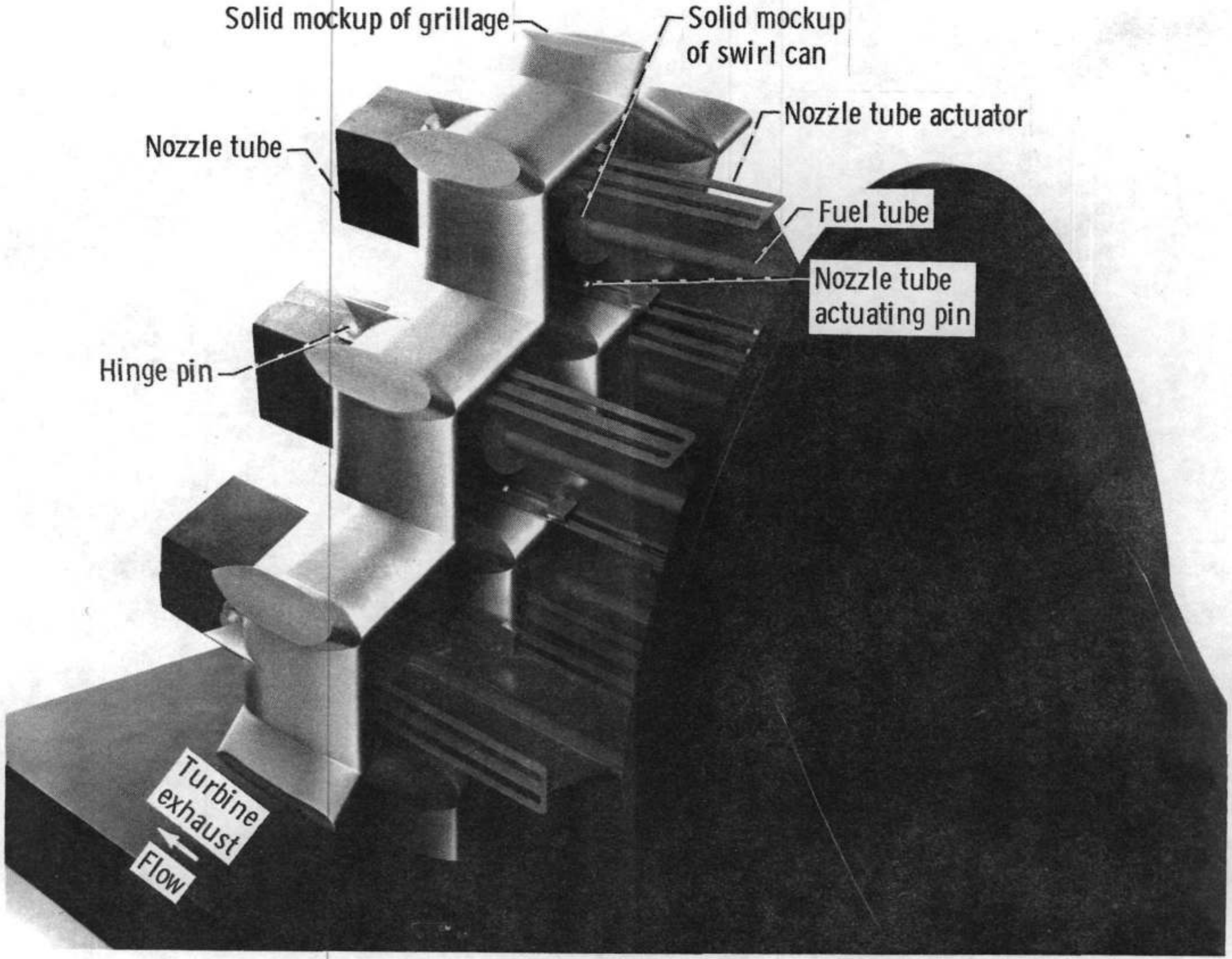
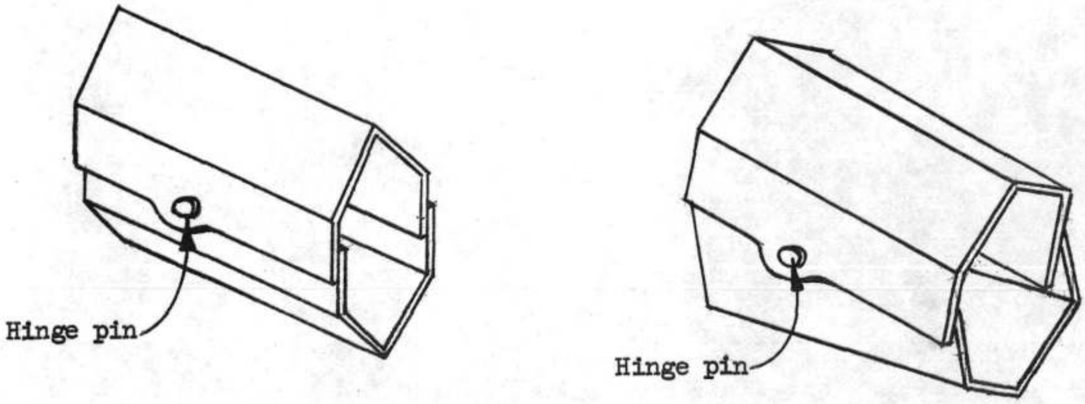


Figure 8. - Kinematic model in transition to non-suppressing mode; view looking downstream.



Non suppression mode

Suppression mode

Figure 9. - Nozzle tube in suppression and non suppression of noise modes

E-7167

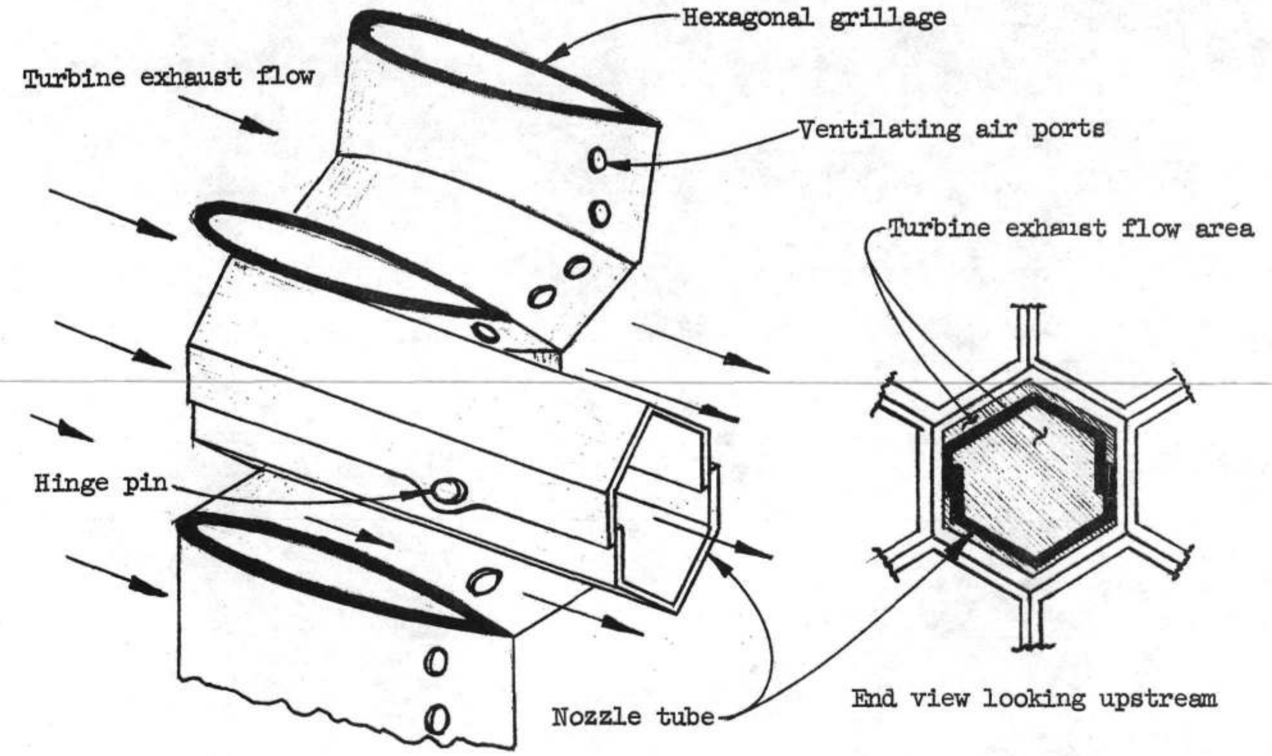


Figure 10. - Nozzle tube installation in hexagonal grillage (non suppression of noise mode)

NASA-Lewis-Com'l