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NOZZLELESS PROPULSION UNIT OF LOW ASPECT RATIO

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(57) Claim

1. An acceleration propulsion unit integrated with a ram-jet engine having a gas generator associated with said accelerator propulsion unit, said acceleration propulsion unit including a propellant block secured laterally to the propulsion unit body by means of a combustion inhibitor and including an axial duct, said acceleration propulsion unit having an aspect ratio between 2.5 and 6, said propellant block including at least six substantially identical peripheral ducts, the upstream face of the propellant block including a fitting secured to the body of the propulsion unit, said fitting having a free space between its own upstream face and the base of the gas generator body, the axial duct and peripheral ducts of said block opening into this free space through orifices provided in the fitting and terminating at the opposite end in a divergent part.

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COMPLETE SPECIFICATION

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Complete Specification for the invention entitled:

"NOZZLELESS PROPULSION UNIT OF LOW ASPECT RATIO"

The following statement is a full description of this invention, including the best method of performing it known to me:-

The present invention relates to a propulsion unit for the acceleration of a self-propelled vehicle, such as a missile or a rocket, loaded with a propellant block having several ducts.

The use of a single-duct nozzleless propulsion unit is known, particularly for the acceleration of ram-jet engines with an integral accelerator, such as those described in U.S. Patent 3,535,881. The relevant propulsion units have an aspect ratio below 6. By the aspect ratio of a cylinder is meant the ratio L/D of its length to its diameter.

The combustion rates of composite propellant blocks are too low to allow a sonic section to be established in a duct having an aspect ratio below 6. Since the aspect ratio of the duct is linked to the aspect ratio of the block, it is therefore difficult to use propellant blocks of an aspect ratio below 6. Now in some uses, size constraints prevent blocks of an aspect ratio higher than 6 from being used.

For example, the combustion chamber of a kerosene ram-jet engine of a diameter of 350 mm requires only a length of 800 mm. Its aspect ratio is therefore merely of the order of 2.3. However, on the other hand, it offers sufficient volume to accommodate in it the propellant necessary for accelerating the vehicle so driven up to the so-called transition sped, at which the ram-jet engine is to take over from the accelerator. There is therefore no need to lengthen it.

In the present state of the art, it will not have a nozzleless accelerator incorporated in it, but a conventional accelerator equipped with an ejectable nozzle seated in the nozzle of the ram-jet engine, because it is of a cross-section much smaller than that of the latter, for reasons of the operating pressures, and jetisoned at the cutoff of the accelerator, thus possibly presenting a danger especially when the vehicle is launched from an aircraft.

In accordance with the present invention, therefore, there is provided an acceleration propulsion unit ~~including a~~

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integrated with a ram-jet engine having a gas generator associated with said accelerator propulsion unit, said acceleration propulsion unit including a propellant block secured laterally to the propulsion unit body by means of a combustion inhibitor and including an axial duct, said acceleration propulsion unit having an aspect ratio between 2.5 and 6, said propellant block including at least six substantially identical peripheral ducts, the upstream face of the propellant block including a fitting secured to the body of the propulsion unit, said fitting having a free space between its own upstream face and the base of the gas generator body, the axial duct and peripheral ducts of said block opening into this free space through orifices provided in the fitting and terminating at the opposite end in a divergent part.

The acceleration propulsion unit according to the invention operates without a nozzle, even though it is equipped with a propellant block of an aspect ratio of between 2.5 and 6.

Each of the ducts taken individually has a sufficient aspect ratio to ensure that the velocity of the gases reaches sound velocity in a section near the downstream end of the duct, and downstream of this section possesses a divergent part making it possible to expand the gases with acceptable efficiency. These ducts open onto the rear face of the block in such a way that the resultant of the thrust vectors is borne along the axis of the vehicle to be accelerated.

Because all the ducts open into the free space provided upstream of the block, this space performs the function of a pressure-balancing chamber, and the change of pressure as a function of time in each duct is such that there is substantial equality of the pressures at each moment. To minimize the combustion residues, the peripheral ducts are arranged on one or two concentric circles and number 6 or 12 respectively. According to a preferred feature of the invention, the block has seven ducts, namely 1 axial duct and 6 peripheral ducts.

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According to another preferred feature, the 6 peripheral ducts are parallel to the axial duct.

Furthermore, the peripheral ducts of such a charge are at a distance from the outer surface of the propellant block corresponding to half the thickness separating the ducts from one another.

The central duct can be of circular or hexagonal cross-section.

The peripheral ducts located on the concentric circle or circles can be of a cross-section suitable, on the one hand, for the type of propellant used, to limit the interactions between the various ducts at the moment of combustion, and, on the other hand, for the potential incidence of the combustion residues. The cross-section of these ducts can therefore be a circle, a regular hexagon, a pentagon or a trapezium, with the knowledge that the large base of the trapezium can be curved or straight. advantageously, the peripheral ducts have a cross-section substantially in the form of an isosceles trapezium. The trapezoidal form is useful because it reduces the combustion residues to a minimum and maintains efficient combustion and an efficient gas flow for the longest possible time.

The pressure difference Δp prevailing between the two end faces of the propellant block is increased as a result of the high aspect ratio of the ducts. Now the propellant block thus perforated is more fragile than a single-duct block and consequently than a front-combustion block.

It is well known to an average person skilled in the art to secure the propellant block laterally to the body of the propulsion unit by means of a combustion inhibitor. It has been found that this fastening is insufficient for a multiply perforated propellant block.

The propellant block of the propulsion unit according to the invention has, on its upstream face, a fitting secured to the body of the propulsion unit, this fitting providing a free space between the upstream face of the propellant block and the bottom of the body of the propulsion unit, the axial duct and the peripheral ducts opening into this free space via orifices made in the fitting.

According to a preferred feature of the invention, the said fitting consists of a perforated plate, of which the orifices of the same number as the ducts of the propellant block are in line with the peripheral ducts and the axial duct, and is fastened to the upstream face of the propellant block by means of the combustion inhibitor.

The free space thus provided between the fitting fastened to the upstream face of the propellant block and the bottom of the propulsion unit forms a chamber for balancing the internal pressure, which reduces the pressure differences liable to arise during combustion. This precaution is justified because, if the propellant thickness separating two ducts and becoming increasingly small in proportion as combustion proceeds were subjected to a pressure difference, at the end of combustion this difference would give rise to the premature rupture of the propellant not yet burnt, with a risk of ejection of propellant fragments, and would cause an irregularity at the end of combustion and thereby a considerable loss of efficiency. This pressure-balancing chamber located at the upstream end of the acceleration propellant can be arranged downstream of the gas generator of a ram-jet engine.

The upstream fitting of the propellant has orifices which allow the combustion gases, that is to say the pressure, to be distributed among the ducts by way of the balancing chamber. These orifices can have the exact initial form of the ducts in the propellant or a completely different form. For example, the ducts can be trapezoidal cross-section and the orifices in the fitting can be cylindrical or troconical.

The usefulness of cylindrical or troconical orifices is that this fitting can be used again for the second propulsion phase, within the scope of a ram-jet engine arrangement, in order to distribute the jets of combustible gases; the fitting is then used as a diffuser/injector.

The fitting is fastened to the body of the propulsion unit and incorporates an inhibition, particularly by the return of the inhibitor securing the propellant to the tube of the propulsion unit. The inhibitor serving for protecting this fitting can be arranged on either face of the latter, but will preferably be arranged on the rear face of the fitting, that is to say between the propellant block and the fitting itself, to prevent it from being heated to excess.

According to a preferred feature, the propulsion unit according to the invention forms the acceleration stage of a ram-jet engine. In this case, the downstream end of the propellant block is located in the region of the nozzle of the ram-jet engine and preferably in the region of the divergent part of this nozzle, such a configuration making it possible to accommodate more propellant in the body of the propulsion unit.

Each duct terminates in a divergent part, in order to improve the expansion of the gases, and where the acceleration block of a ram-jet engine is concerned this widened part is positioned in the region of the nozzle of the ram-jet engine.

The combustion of the propellant takes place in parallel layers, and at the end of combustion non-burned remains, called combustion residues, remain on the periphery of the inner inhibitor fixed to the structure of the propulsion unit; the central residues are ejected.

According to a first alternative version, these residues can be partially eliminated by using a combustion-inhibiting material which penetrates into the outer cylindrical surface of the propellant block in at least two zones located in the region of these residues, thus forming longitudinal ribs affording the advantage of reducing the risks that combustion instabilities will occur during the functioning of the ram-jet engine.

According to another alternative version, these residues are eliminated completely and rapidly by using a twin-composition block, the propellant of higher combustion rate being arranged in the zones located in the region of the external combustion residues.

According to a preferred feature of the invention, the propellant used is a composite propellant with a hydroxytelechelic polybutadiene binder and contains up to 5% by mass of ferrocenic catalysts.

In order that the invention may be more clearly understood and put into practical effect there shall now be described in detail a preferred construction of an acceleration propulsion unit in accordance with the invention. The description is given by way of non-limitative example only and is with reference to the accompanying drawings, wherein:

Figure 1 shows a propulsion unit according to the invention used as an integral accelerator of a ram-jet engine;

Figure 2 shows a cross-section AA' through the acceleration propulsion unit according to Figure 1;

Figure 3 shows the theoretical pressure curves existing in the peripheral ducts and in the central duct of the propellant block of the acceleration propulsion unit as a function of the combustion time;

Figure 4 shows the pressure curve as a function of the combustion time; and

Figure 5 shows the thrust curve as a function of the combustion time.

Referring to Figure 1, a ram-jet engine with an integral accelerator consists of an acceleration propulsion unit (1) according to the invention and of a gas generator (2).

The combustion chamber of the gas generator is called a primary chamber (3). The combustion chamber of the acceleration propulsion unit, initially occupied by a propellant block, is called the secondary chamber (4).

The body (5) of the acceleration propulsion unit (1) is equipped, at its upstream end, with air inflow orifices (6) closed by means of caps (7) during the acceleration phase and, at its downstream end, with a nozzle (8) of large cross-section, intended for expanding the combustion gas of the ram-jet engine and initially closed by means of a cap (9).

The secondary chamber of the ram-jet engine is equipped with an acceleration propellant block (10) with a PBHT binder, multiply perforated with a longitudinal central duct (11) and 6 longitudinal peripheral ducts (12). This block (10) has a diameter of 191 mm for a length of 500 mm, that is to say an aspect ratio of 2.61.

This multiply perforated propellant block (10) is secured laterally to the body of the propulsion unit (5) by means of a combustion inhibitor (13). The upstream face of this block has a plate (14) perforated with frustoconical orifices (15) as the same number as and in line with the peripheral ducts (12) and central duct (11) of the propellant block (10), to which it is fastened by means of a combustion inhibiter.

The downstream face of the propellant block (10) is located in the region of the divergent part of the nozzle (8), and the peripheral ducts (12) and central duct (11) terminate in a divergent part (16).

The gas generator is equipped with a suboxygenated propellant block generating reduction gases (18), which is equipped with a central duct (19) and which is secured to the primary chamber (3).

The suboxygenated propellant block does not occupy the entire space of the primary combustion chamber: a free space (20) is provided between the perforated plate (14) and the downstream end of the block (18), to form a pressure-balancing chamber.

An igniter (21) is located at the upstream end of the central duct of the suboxygenated propellant block (18).

It should be noted that the igniter (21) could also have been placed in the region of the free space (20).

According to Figure 2, the multiply perforated propellant block (10) is secured laterally to the body (5) of the acceleration propulsion unit (1) by means of a combustion-inhibiting material (13). This block is perforated with a hexagonal central duct (11) of a height of 42 mm and with 6 peripheral ducts (12) arranged on a circle concentric relative to the central duct (11).

The 6 peripheral ducts (12) have a cross-section substantially in the form of an isosceles trapezium, likewise of a height of 42 mm, and they are arranged in such a way that their flanks are parallel two by two.

The combustion-inhibiting material (13) penetrates into the outer cylindrical surface of the propellant block (10) in three zones located in the region of the combustion residues (22), thus having three longitudinal ribs (23) parallel to the ducts.

During the launching of the vehicle equipped with such a ram-jet engine with an integral accelerator, the combustion gases of the igniter (21) pass through the central duct (19) of the gas-generating block (18) and flow through the orifices in the plate (14) into the ducts of the multiply perforated block (10) of the accelerator which they ignite. The pressure in the entire volume not occupied by propellant (ducts of the accelerator block, balancing chamber and duct of the gas-generating block) rises quickly and causes the cap (9) to be ejected, thus allowing the ejection of the combustion gases of the accelerator and causing the acceleration of the vehicle.

Since the combustion gases of the igniter (21) pass through the central duct of the gas-generating block (18), they also initiate the pyrolysis of the latter. The pyrolysis gases produced during the combustion period of the accelerator are ejected together with the combustion gases of the latter and are lost in terms of the subsequent functioning of the ram-jet engine, but they contribute slightly to the acceleration of the vehicle.

The multiply perforated propellant block (10) burns within approximately 1.8 seconds, and the ejection of the combustion gases accelerates the vehicle up to a sufficient speed to allow the ram-jet engine to take over from the accelerator.

Combustion takes place in parallel layers. As can be seen in Figure 3, the curve of pressure as a function of time is decreasing and the pressure prevailing in the peripheral ducts (12) is substantially equal to that prevailing in the region of the central duct (11), thus reducing the risks of premature rupture of the block. Furthermore, the presence of the ribs (23) in the region of the combustion residues allows combustion to stop sharply.

Once the combustion of the multiply perforated propellant block (10) has ended, the pressure in the combustion chamber decreases, thus causing the ejection of the caps (7) via the secondary combustion chamber (4) and the massive inflow of air through the orifices (6).

The pryolysis gases of the generator ignite spontaneously with the air under the pressure and temperature conditions of the latter. The mixture of air and of pyrolysis gases in combustion experiences a considerable increase in temperature and is ejected through the nozzle of large cross-section (8); this initiates functioning in the ram-jet engine mode.

Figures 4 and 5, illustrating the bench-test launching curves for a multiply perforated accelerator charge, show that the ignition of the charge takes place after 20 mill_ econds and that combustion lasts for 1.8 second. At this time, a pressure peak attributable to the ejection of the central residues is seen on the curves.

The shapes of the pressure and thrust curves are comparable to those of known single-duct nozzleless charges, namely a decreasing pressure curve and a slightly increasing thrust curve.

The claims defining the invention are as follows:-

1. An acceleration propulsion unit integrated with a ram-jet engine having a gas generator associated with said accelerator propulsion unit, said acceleration propulsion unit including a propellant block secured laterally to the propulsion unit body by means of a combustion inhibitor and including an axial duct, said acceleration propulsion unit having an aspect ratio between 2.5 and 6, said propellant block including at least six substantially identical peripheral ducts, the upstream face of the propellant block including a fitting secured to the body of the propulsion unit, said fitting having a free space between its own upstream face and the base of the gas generator body, the axial duct and peripheral ducts of said block opening into this free space through orifices provided in the fitting and terminating at the opposite end in a divergent part.

2. The propulsion unit according to Claim 1, wherein said propellant block has only 6 peripheral ducts.

3. The propulsion unit according to Claim 2, wherein said 6 peripheral ducts are parallel to said axial duct.

4. The propulsion unit according to any one of the preceding Claims, wherein said peripheral ducts have a cross-section substantially in the form of an isosceles trapezium.

5. The propulsion unit according to any one of the preceding Claims, wherein the downstream end of said propellant block is located in the region of said divergent part of a nozzle of said ram-jet engine.

6. The propulsion unit according to any one of the preceding Claims, wherein multiply perforated propellant forming said block contains a ferrocenic catalyst.

7. The propulsion unit according to any one of the preceding Claims, wherein said fitting consists of a perforated plate, the orifices of which are in line with said peripheral ducts and said axial duct.

8. The propulsion unit according to Claim 7, wherein said perforated plate

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is fastened to the upstream face of said propellant block by means of said combustion inhibitor.

9. The propulsion unit according to any one of the preceding Claims, including an igniter located at least partially in the region of said free space.

10. The propulsion unit according to any one of Claims 7 to 9, wherein said orifices in said perforated plate form orifices for the injection of reduction gases of the upstream charge of said propulsion unit.

11. The propulsion unit according to any one of the preceding Claims, wherein said combustion-inhibiting material penetrates into an outer cylindrical surface of said propellant block in at least two zones located in the region of external combustion residues.

12. The propulsion unit according to any one of Claims 1 to 11, wherein said propellant block is of bicomposition, the propellant of higher combustion rate being arranged in zones located in the region of the external combustion residues.

13. The propulsion unit according to any one of the preceding Claims, wherein said propellant block is a composite propellant with a PBHT binder.

14. An acceleration propulsion unit, substantially as described herein with reference to the accompanying drawings.

DATED this 5th day of October 1992.

SOCIETE NATIONALE DES POUDRES ET EXPLOSIFS and SOCIETE AEROSPATIALE
By their Patent Attorneys:
CALLINAN LAWRIE

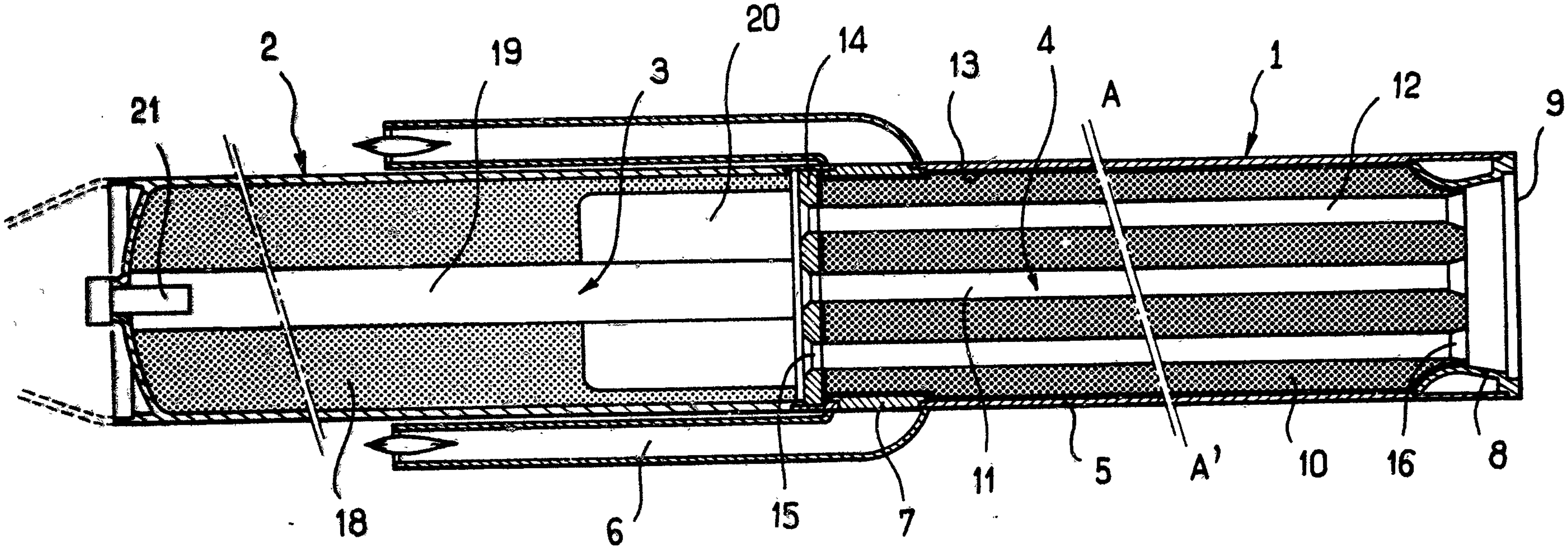

FIG_1

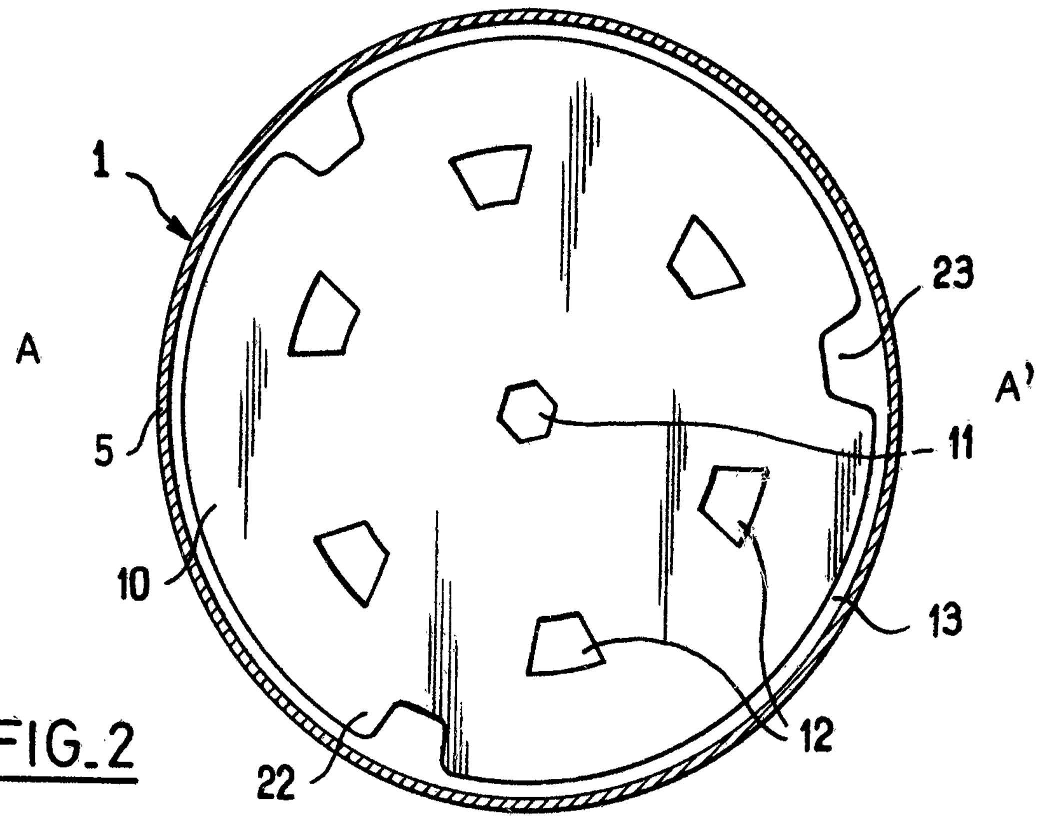

FIG_2

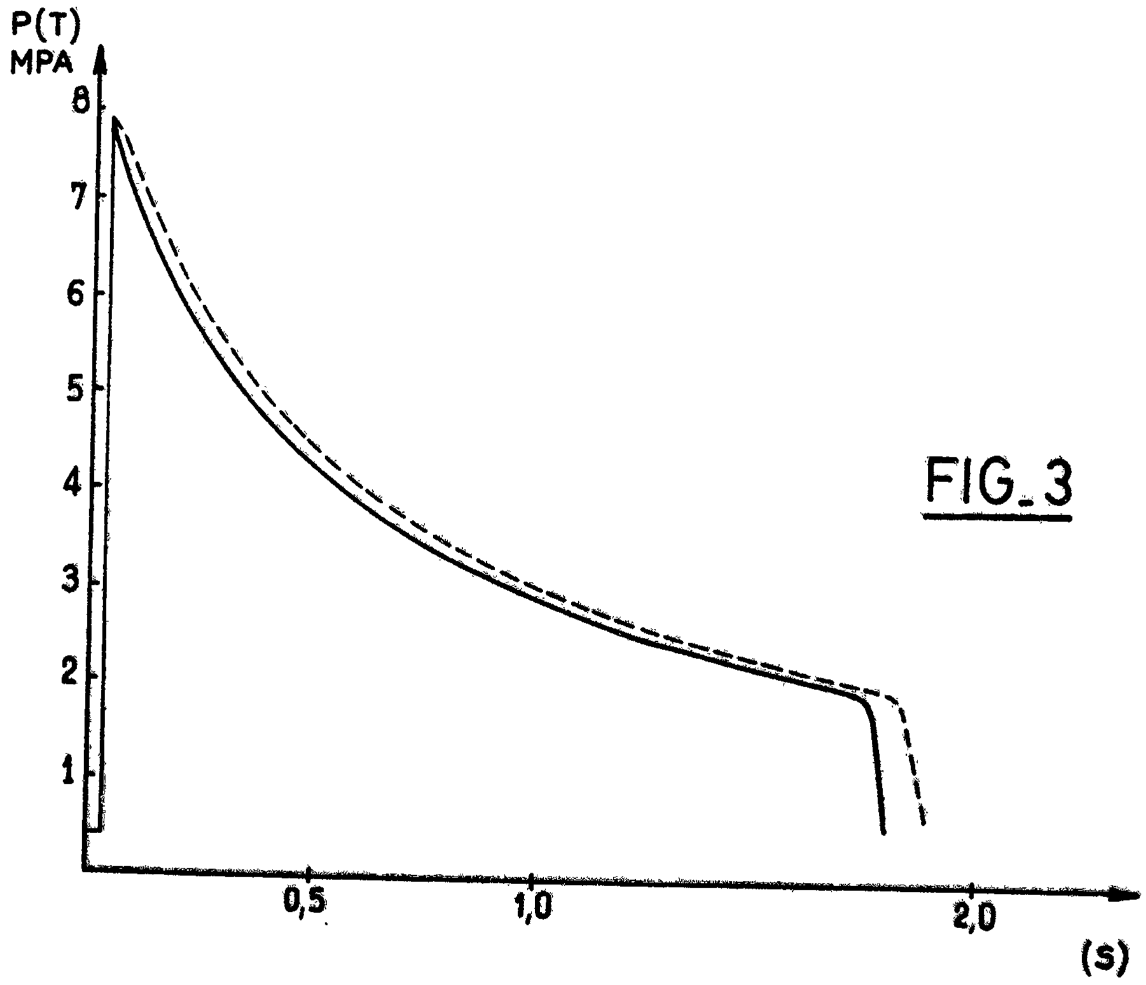

FIG_3

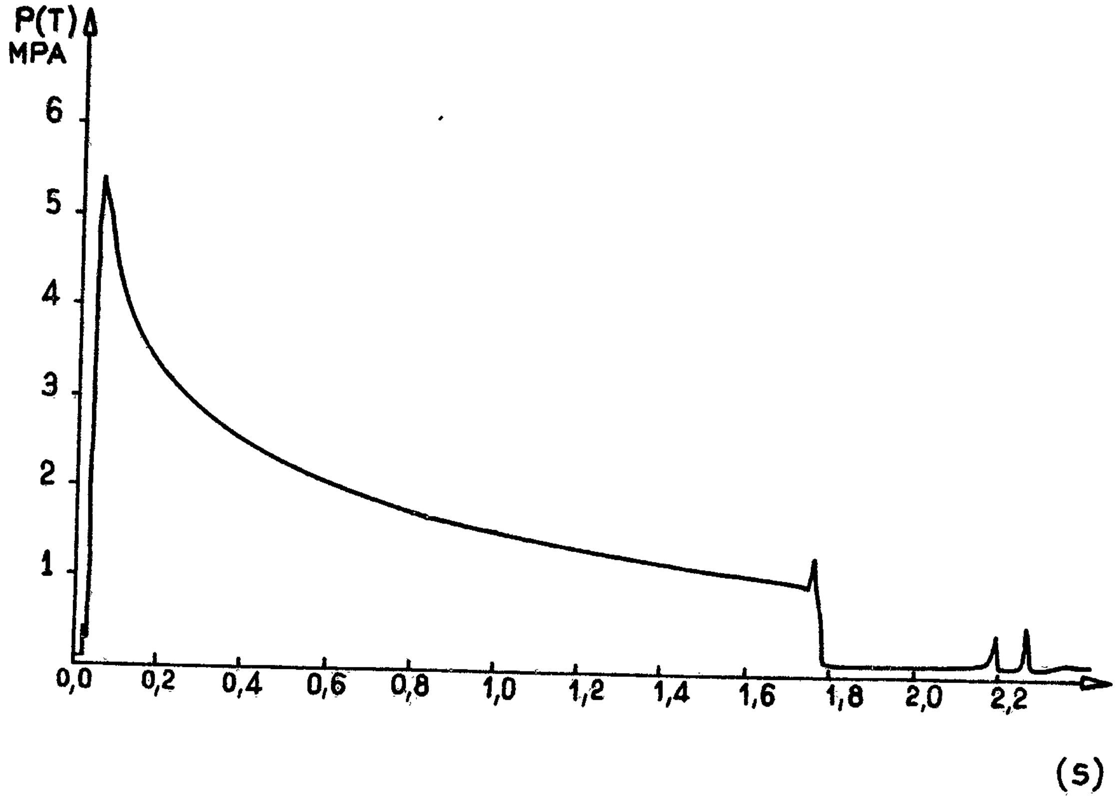
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FIG_4

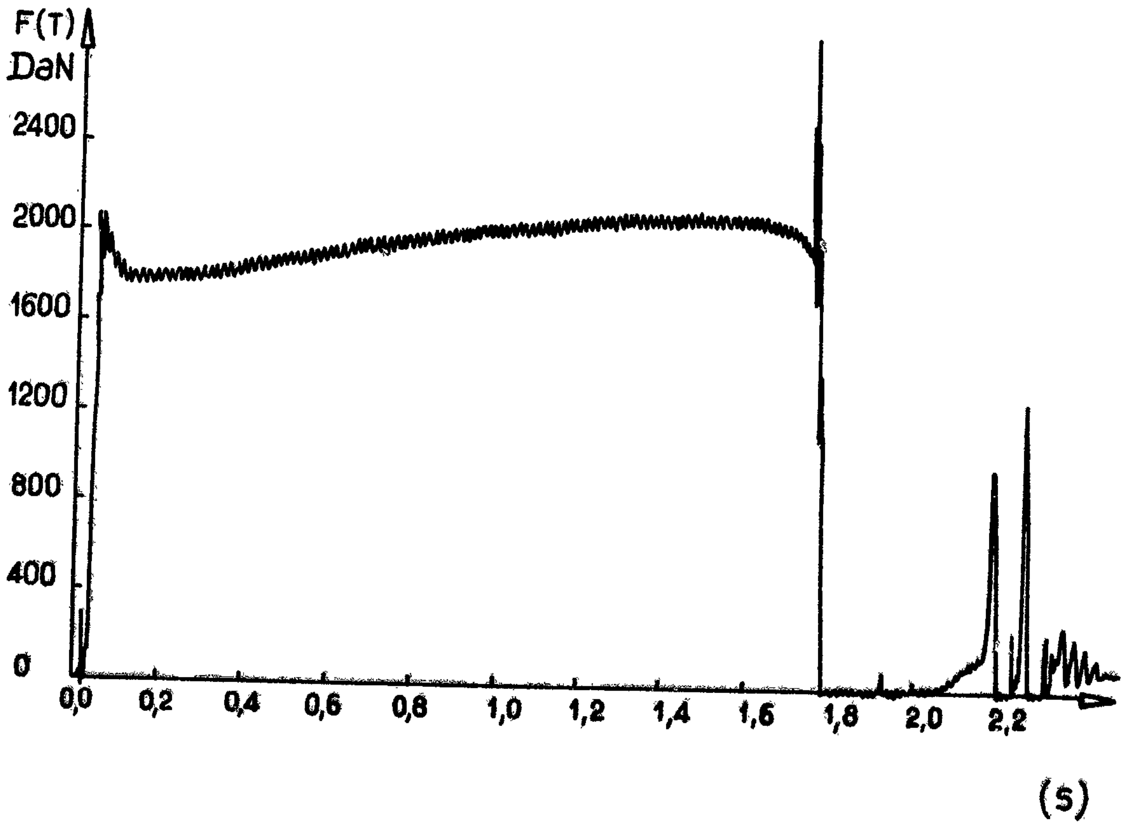
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FIG_5