RE-WRITE "REED MOTOR"

APPLICATION OF REED VALVES TO 4 CYCLE SPARK IGNITION ENGINE

1. FOREWORD

Automotive engines can be characterized by a wide range of engine speeds and loads. In order to provide acceptable urban driveability and reasonable top speed, the ratio between minimum usable and maximum engine rpm is normally about 6.
This requires the matching of high specific power output at high rpm with high torque output at low rpm. The Alfa Romeo 2.0 l "Twin Spark" engine has the ability to satisfy both of these needs by the use of variable valve timing (VVT) on the intake camshaft, which can vary the intake valve timing in two steps:

- Narrow overlap during idle and low load
- Wide overlap during high rpm and high load

The "Twin Spark" engine provides high specific output through its whole speed range and yet permits low exhaust emission levels. Since the VVT system is not continuously variable, it cannot provide complete optimization for all speed/load conditions. Therefore, a new system of reed valves placed in the inlet ports has been developed.

2. REED VALVE DEVELOPMENT

Reed valves are well known in the two cycle engine field. The reeds are commonly made of steel or composite and close against a rubber covered face. The reed valve opens and closes according to the pressure difference it is exposed to in the inlet tract. In operation, the reeds perform effectively as a check valve which permits air or air/fuel mixture to enter the inlet valve port, but prevent any backflow upstream of their location. The advantage of the reeds are:

- simplicity
- automatic/passive operation
- single direction of flow

By design, the reeds only open when fresh air or air/fuel mixture is desired to enter the cylinder. They assure that this fresh flow cannot escape or "back out" of the cylinders. These characteristics permit a more efficient filling of the cylinders throughout all normal operating conditions. The reed system appears to be simpler than VVT devices which require some kind of actuator device.

Figure 1, shows the Alfa Romeo reed valve pack developed specifically for the 2.0 l "Twin Spark" engine. This pack has been studied to provide higher throughput, at the same pressure difference, than packs commercially available. The production process was developed parallel to the experimental phase of pack development. The production process has had to overcome some problems. The major difficulties were:

- Swelling of the rubber compound due to internal engine environment.
- Obtaining an acceptable surface of the planes upon which the reeds rest closed.

These problems caused poor sealing of the reeds, which in turn allowed some of the air or air/fuel mixture to back out of the cylinder, causing poor running. Needless to say, durability also had to be addressed. The solutions were arrived through the use of a fluorided rubber compound and a new process of bonding the compound to the reed pack support. Durability has been demonstrated both in the dyno cell and on the road by absence of any failures.

3. ENGINE PERFORMANCE

Before prototype reed pack assemblies were built, much time was spent using computer modelling to verify concept feasibility. "SASP" was the fluidynamic computer program that was used, and some results can be seen in figure 2. These results compare volumetric efficiency between single cylinder engines, with and without the use of reeds. Easily seen is the large advantage at low rpm, with little or no difference at high rpm. However, the high rpm difference is affected by the pressure drop used for the calculation. From this point of view, experimental results better demonstrate the true effect at high rpm.

Figure 3. shows the reed pack installed directly into the intake port of the "Twin Spark" cylinder head. The pack is located as close as possible to the intake valve in order to reduce the volume between. At low load, when the intake valve opens, exhaust gases want to exit the cylinder towards the low pressure created by the throttle. A large volume between the reed pack and intake valve can cause poor combustion due to exhaust dilution of the incoming air or fuel/air charge.

High rpm output is reduced somewhat by the pressure drop created by the reed pack, and valve timing has been studied to offset this effect. Earlier valve opening and later closing are provided via a wide cam lobe. Meanwhile, at low load/speed, the volumetric efficiency is ruled by the reed pack. In figure 4, you are able to see a comparison between a production 4 cylinder 2.0 l "Twin Spark" engine with VVT and a reed pack equipped engine of the same type. The reed engine shows a torque gain of from 15 to 30% below 2000 rpm, a 5% gain at 4000 rpm, and the same output as the production engine at maximum rpm.

Figure 5, is a photo of the first reed engine prototype. Figure 6 (cutaway) details the internal construction and location of the reed pack. The reed pack assembly is in figure 7.

4. PRESSURE ANALYSIS UPSTREAM OF THE INTAKE VALVE

To explain the high torque at low speed, one must look at the pressure history in the volume between the reed pack and the intake valve. Measurements have been made with a piezoelectric transducer, signal conditioning/amplification, and oscilloscope, with the engine at 800 rpm idle.

a) Full throttle

Pressure at w.o.t. is shown in figure 8/a. The pressure increases before the closing of the intake valve, due to the one way flow and compression by the piston. The high pressure created by the delay in closing of the intake valve is exploited during the next cycle to sweep out the combustion chamber. Positive results here depend on tight sealing of the reeds, which in turn is production process dependent.

b) Part Load

In figure 8b and c, the part load pressures can be seen, where there is clear indication of exhaust gas filling the volume between the intake valve and reed pack when the inlet valve opens. However this phenomenon gave no negative effects on ignition, probably due to the dual ignition combustion chamber.

5. EXHAUST EMISSIONS

Exhaust gas analysis has been with done a minimum of 5 tests each for ECE and USA test cycles, and the mean values reported. The vehicle used was an Alfa Romeo 75 model. Engine management was Bosch "Motronic".

					CO	HC	NOx
a)	ECE	no cat,	open loop	gr/t	?	?	?
		TWC +	closed loop	gr/t	?	?	?
b)	USA 83						
		TWC + lambda		gr/mi	1.4	.032	0.58

We can see from these results that all of the standards have been met with some margins. Unacceptable HC levels have been measured during accelerations in the cold phase of the test cycle. This may be due to "crossover" of gasoline from intake to exhaust due to the intake over-pressure interacting with low pressure exhaust waves, caused by wide valve overlap. Improvements in these HC emissions can be made without giving away any performance with two approaches.

i Redesign the combustion chamber by relocating the valves to prevent "crossover".

ii Use of metallic pre-catalyst close to the exhaust valves in order to shorten warm-up time.

6. <u>CONCLUSIONS:</u>

I The reed valve system on the Alfa Romeo 2.0 l "Twin Spark" engine provides high performance from idle through 6000 rpm. Optimized intake valve timing permits exploitation of "bootstrapping" (self-boosting).

II There have been no unsolved problems in order calibrating the engine to conform to emission standards. Certainly this work has been eased by the employment of the dual ignition combustion chamber and the Bosch "Motronic" EMS.

III The check valve function of the reed pack is its most important advantage. However, a guarantee of absolute sealing is required.

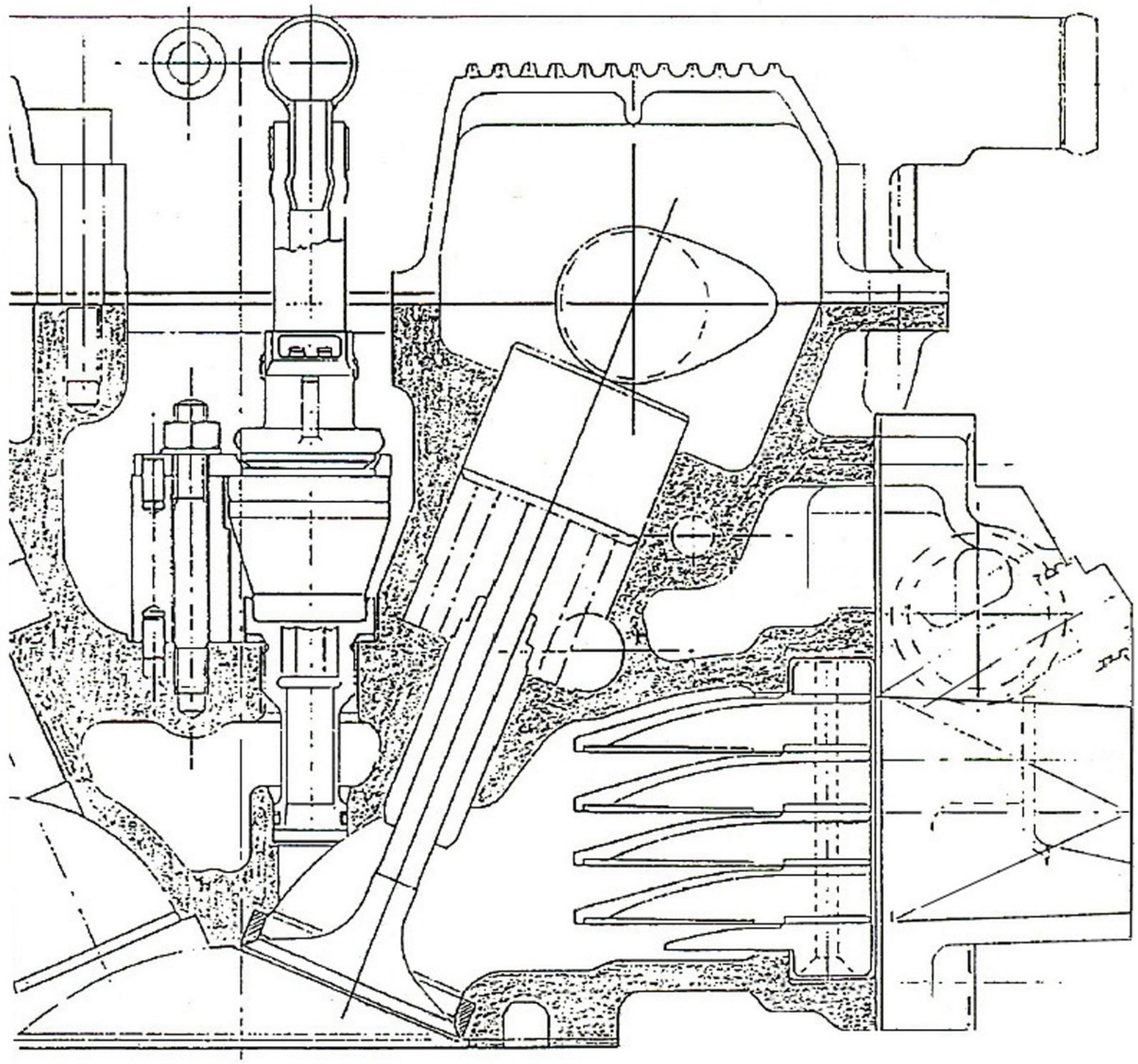
IV The production process of the reed pack has yet to be completed, but there are no problems which remain unsolved.

The authors wish to express their appreciation to Alfa Romeo colleagues and to the Adler company for their personal efforts and enthusiasm for this project.

ALFA – LANCIA Industriale SpA U.P.S. MOTORE	~~ASSEMBLING OF REED VALVE ON THE HEAD OF 2.0 T.S. ENGINE~~ INSTALLATION OF REED ~~VALVES ON THE HEAD~~ OF AR 2.0 T.S. ENGINE	N. 3

inlet Port

PACK in



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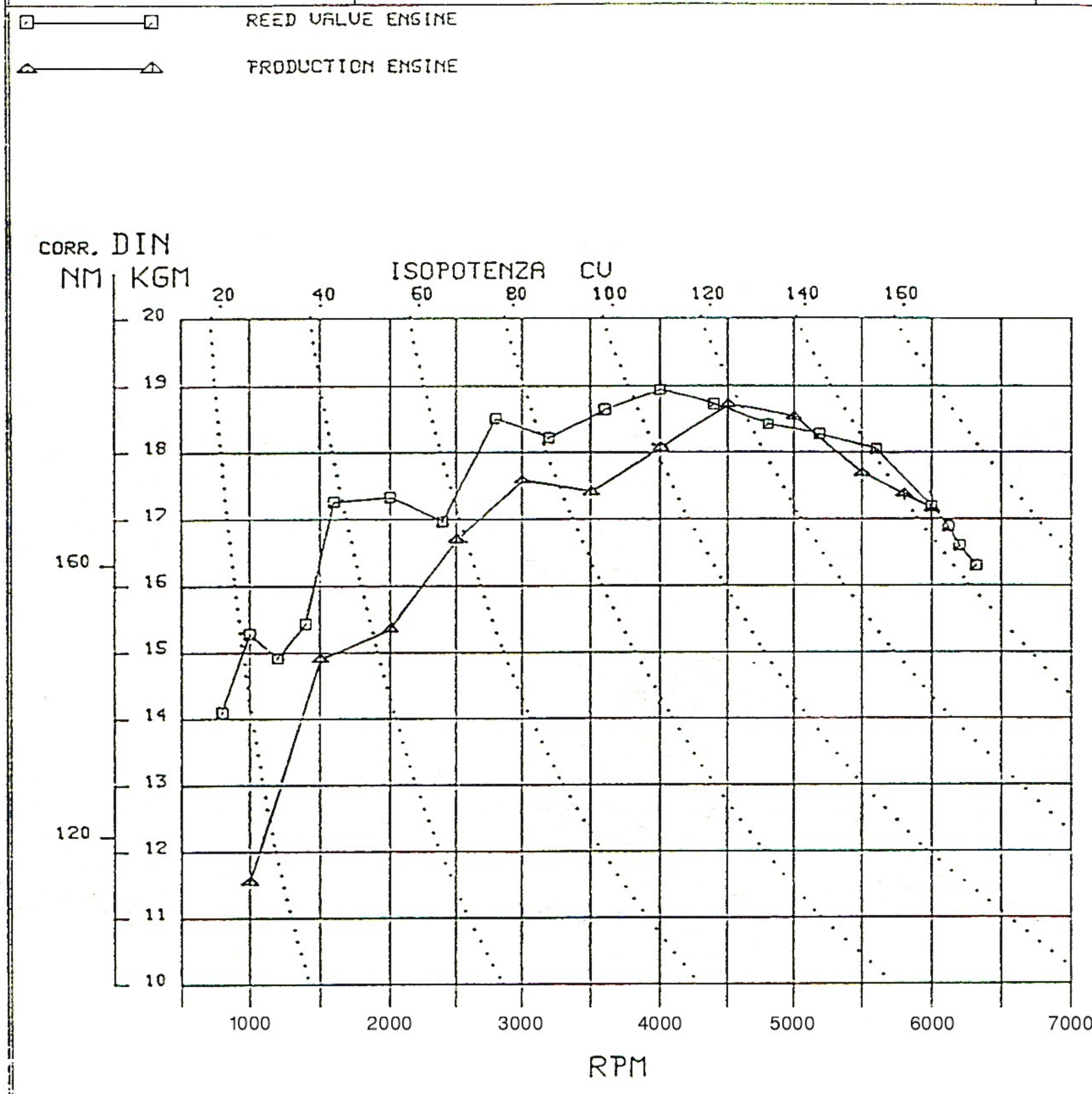
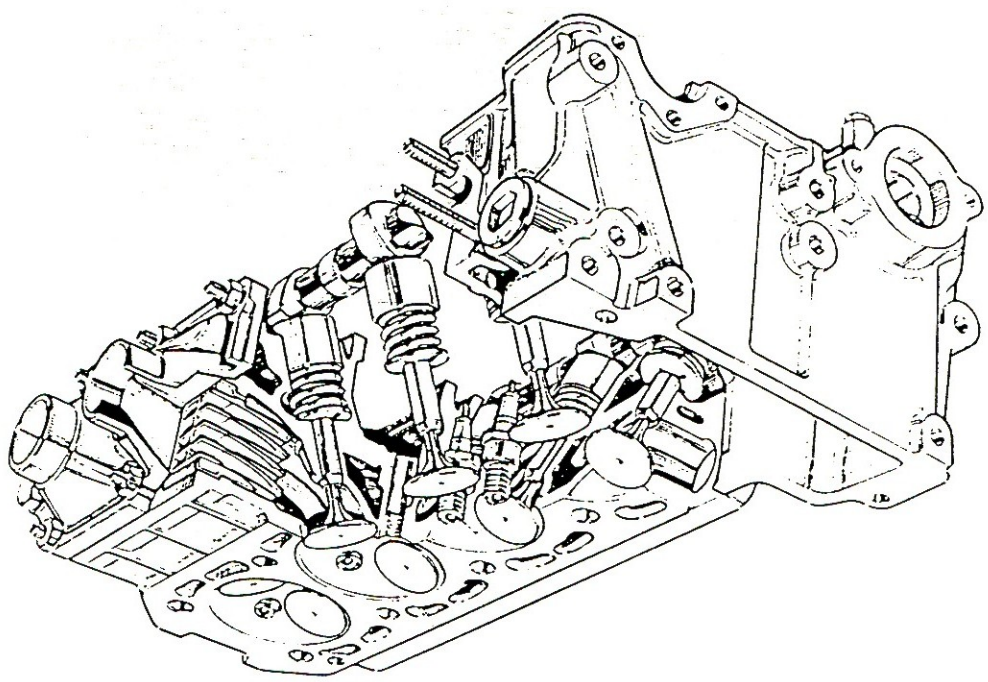


adoption of an electronically controlled timing variator, that is to say, the possibility of having a very "open" timing cycle with no adverse repercussions on engine idling.

Over the timing variator, however, laminar valves have a twofold edge. In fact, their action is:

— automatic, because the laminae open of their own accord only when the pressure inside the cylinder is lower than the pressure in the intake system and they close, spontaneously, when the pressure differential is reversed;
— continuous, since the opening/closing cycle of the laminae varies with no discontinuity as a function of engine utilisation conditions.



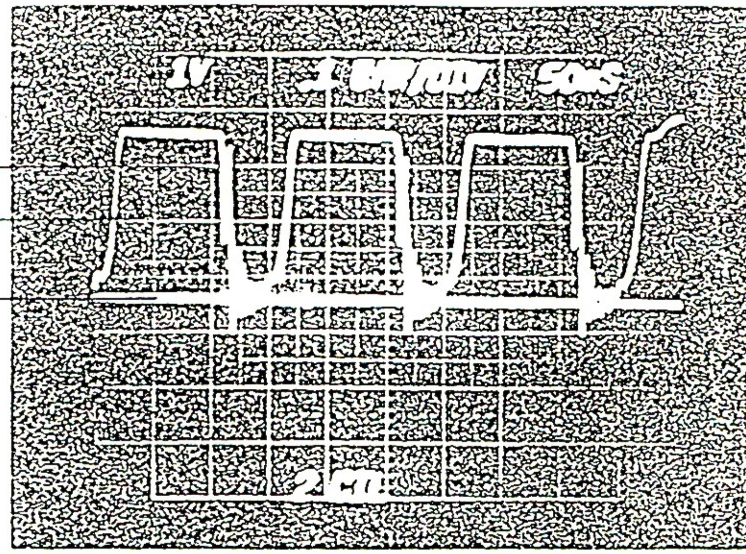
Thanks to these two characteristics – automatic and continuous operation – the new intake system supplemented by laminar valves will effectively prevent the burned gases from flowing back into the intake system during overlapping valve-

ALFA - LANCIA Industriale SpA U.P.S. MOTORE	EXPERIMENTAL FIGURES OF PRESSURE IN THE VOLUME BETWEEN REED AND INTAKE VALUE 800 rpm	N. 8

FULL LOAD

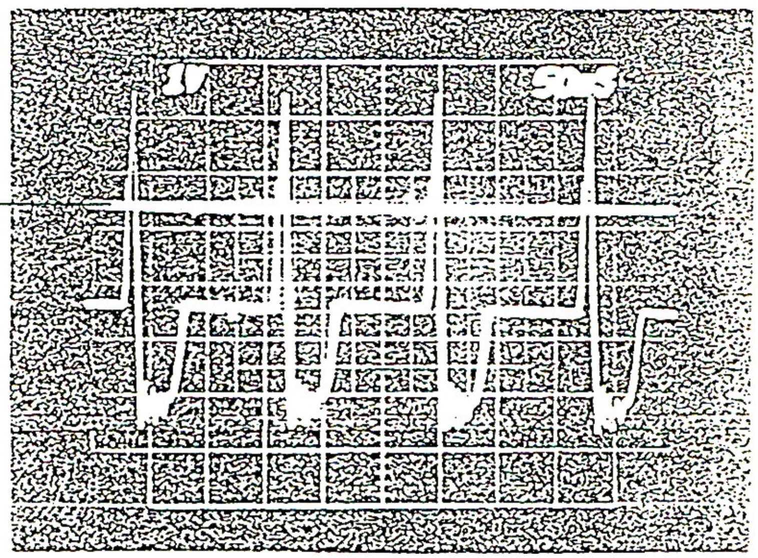
0.1bar

Atmospheric pressure



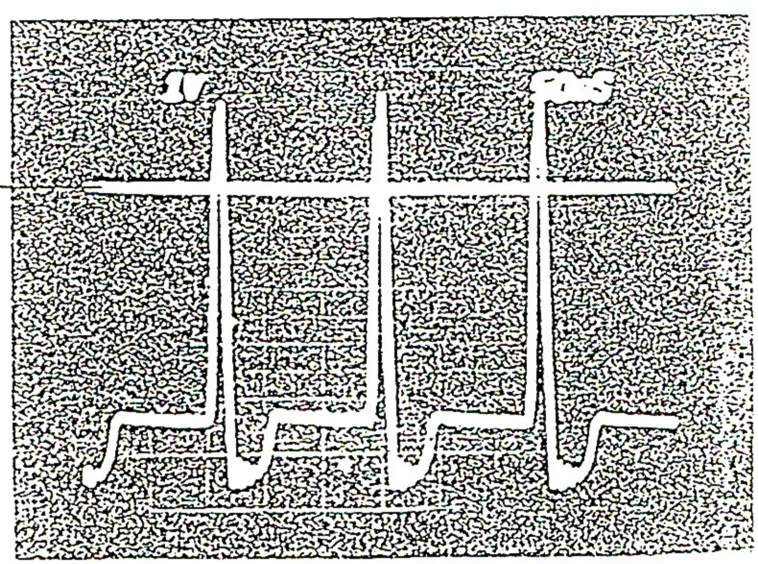
Atmospheric pressure

HALF LOAD



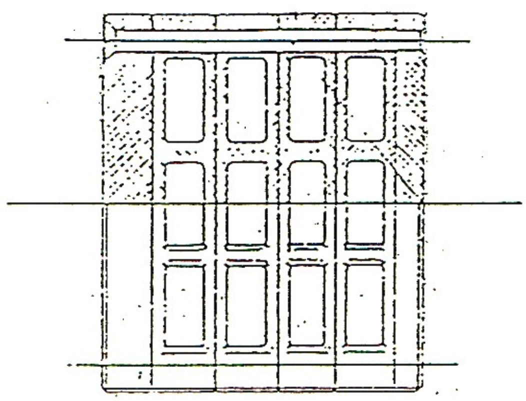
Atmospheric pressure

NO LOAD

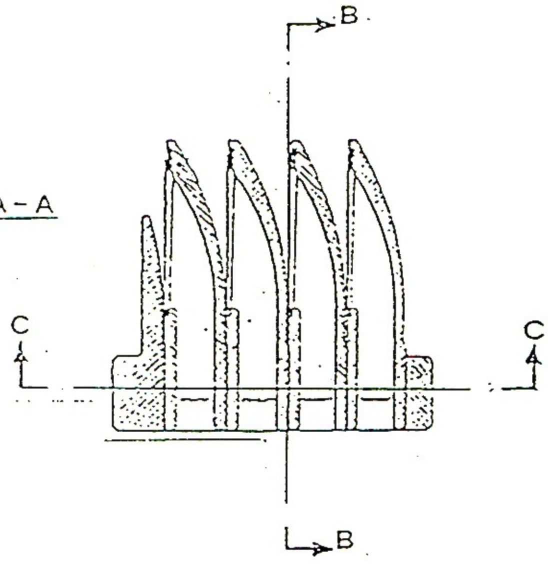


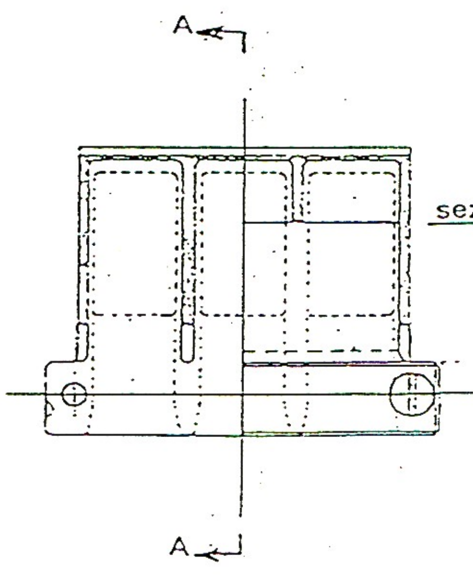
ALFA - LANCIA Industriale SpA U.P.S. MOTORE	ALFA ROMEO REED VALVE PACK	N. 1

sez. C - C



sez. A - A





sez. B - B

ALFA – LANCIA Industriale SpA U.P.S. MOTORE	~~COMPARISON OF~~ CALCULATED VOLUMETRIC EFFICIENCY OF A MONOCYLINDER REED VALVE ENGINE WITH RESPECT A TRADITIONAL ONE	N. 2

VS.