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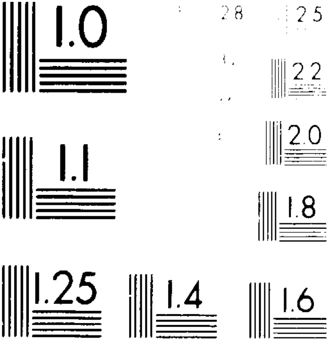

MICROCOPY RESOLUTION TEST CHART

Abteilung für
Consultation & Information

14415

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[Yugoslavia.

DIMENSIONS, FORMULAE, INSTRUMENTATION,
MEASUREMENT OF ENGINE OPERATING PARAMETERS.]

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Final Report on Project of Provision of Services Relating to the Technical Assitance to the Industry of Engine Parts and Allied Components in the Socialist Federal Republic of Yugoslavia

UNIDO Contract No. 83/81

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SUMMARY

In the one year of technical assistance to the Institut za Mechanizaciju (IZM) and the company "27. Mart" AVL advised on

- equipment for testing of internal combustion engines
- test bed installation of engines
- training of project area personnel in test bed routines (operation of engines, measurement of performance and other data, interpretation of results, assessment of engine wear, etc.)

The test bed equipment currently available to IZM is still incomplete or too inaccurate for performing the required homologation tests of engine components. Therefore, it is recommended to install in the future instrumentation for the measurement of

- exhaust smoke
- fuel consumption
- exhaust gas temperature
- oil and water temperature
- oil consumption
- vibration

Besides this additional equipment the Institut za Mehanizaciju will also require further consultation in order to improve their knowledge in today's sophisticated measurement techniques and to train and advise the personnel in test bed work.

According to the contract between UNIDO and AVL executed on May 23, 1984, contract no. 83/31 the work in the project area was started already by end of November 1983. The present report summarizes the work performed for Institut za Mehanizaciju (IZM), Novi Sad by AVL for the contract period from November 1983 to December 1984 in a chronological order. The content of the interim report as submitted to UNIDO on Sept. 24, 1984 is repeated.

1. Nov. 15, 1983: Visit of Mr. Albert Fussi to IZM/Novi Sad

The purpose of this visit was to advise on the installation of an engine test bed by use of existing equipment (Schenk W 230 dynamometer) and of the equipment which was delivered by AVL (high pressure indicating system, HP 306/N and blow-by measuring system, needle lift probe 424).

Main topic of discussion was the installation of the needle lift probe and the quartz transducer of the high pressure indicating system on the engine which will be used for the tests of piston and liners (4-cylinder swirl-chamber diesel engine IMR M34/V, bore 91.4mm, stroke 127mm, 64 hp at 2600 rpm).

The installation of the quartz transducer 8 QP 500 ca in the main combustion chamber together with the adaptor 8ZP30 is difficult because the cylinderhead has to be machined for a sleeve through the water jacket. The feasibility of the installation of such a sleeve has to be studied in advance on a detail drawing of the cylinderhead.

However, since drawings were not available, it was agreed that IZM would provide the required cylinderhead drawings to AVL. Then, AVL would be in the position to sketch the necessary machining and advise on the installation of the sleeve.

In case that the manufacturing of a bore through the water-jacket turns out to be impossible, the installation of a quartz transducer in the swirl chamber should be considered. However, then a transducer of 8QP500 c will be required.

The installation of the needle lift probe in the injector by use of a special adaptor piece was explained in detail.

Further items of discussion were the measurement techniques for intake air flow by rotary piston meters and temperature by Pt 100 probes as supplied by AVL. It was agreed that AVL will provide written information on these systems.

Finally, the homologation tests for pistons, rings and liners manufactured by the Yugoslavian company "27. Mart" to be performed by IZM were discussed. The Yugoslavian company IMR (Industrija Motora Rakovica) as potential users of these components have already prepared directions for such tests. IZM handed over a copy of these directions (written in Serbian). AVL is expected to comment. If necessary, AVL should provide information, how the procedure can be further improved.

2. Analysis of homologation test procedure as established by IMR/IZM, including translation of manual

The manual for the homologation test procedure had to be translated by AVL into German for further analysis by AVL experts. In essence, AVL agreed with the homologation procedure as desribed in the manual. However, several recommendations were made by AVL and discussed on the occasion of the visit of "project area" personnel to AVL on Dec. 2, 1983 (cf. item 3).

3. Dec. 2, 1983: Visit of "Project Area" personnel, Mr. H. Ličen (IZM), Mr. S. Radišić, Mr. B. Mirkić (27. Mart)

a) Discussion of homologation test procedure for piston and piston rings: The procedure as issued by IMR was discussed and in essence approved by AVL. However, AVL would recommend a very thorough check of piston ring dimensions and tangential forces before start of tests. For the control of ring shape sometimes a simple light-gap method is applied. For wear measurement a very sophisticated equipment is required, which in general is too expensive for test laboratories. Therefore, wear measurements are in most cases performed by piston ring manufactureres.

In this context, several publications were handed over to IZM such as: "Allgemeine Abnahmebedingungen für Kolbenringe" (General acceptance specifications for piston rings), "Neue Methoden zur Bestimmung der Genauigkeit von Kolbenringen" (New methods for the determination of the accuracy of piston rings), "Auslegung von Kolbenringen" (Lay-out of piston rings).

b) Test bed installation and test routine
Various methods of air flow measurement were discussed. In any case it is recommendable to install a surge tank between the measurement equipment and the engine in order to avoid the influence of flow fluctuations on the measurements. The most reliable measurements of intake air flow can be performed by a rotary piston meter. As a provisional device a Venturi or an orifice can be used. It is also recommendable to operate the engine at constant intake temperature. This would require the use of an air cooler.

The coolant system of the engine should be operated with a water softener in order to avoid deposits in the system which would deteriorate the heat transfer. For the determination of the heat balance in the engine the water flow has to be measured by a water flow meter and the inlet and outlet temperatures by resistance probes. Also (air) intake and exhaust temperatures have to be recorded.

Measurement of cylinder pressure:
Once again it was stressed by AVL that the measurement of cylinder pressure in the main combustion chamber is advantageous, since the force of the combustion exerted on the piston can be determined (indicated mean effective pressure = IMEP). The measurement in the swirl chamber should be used only provisionally. The cylinderhead drawings by which it would have been possible to determine the possible position of a sleeve for the quartz transducer was not yet available.

c) Comment on piston design as performed by "27. mart" - factory

For a small stationary single cylinder gasoline engine of 200 cc the factory "27. mart" has provided a newly designed piston, which was presented to AVL for comment. AVL approved the general concept but recommended some minor design changes.

4. Telephone consultation in the time frame January to June 1984

In this time frame various consultation subjects were treated by telephone conversations. Some of these conversations resulted also in written statements (letter). Since these letters were all written in German their content will be summarized below.

a) Measurement of ignition energy

A literature research was made and several pamphlets were submitted concerning the inductive measurement of ignition current and capacitive measurement of ignition voltage.

b) Assessment of performance of spark plugs

The required ignition voltage is dependent on

- distance of electrodes
- electrode material
- electrode shape
- mixture conditions (charge motion)
- temperature

By this an assessment of performance of spark plugs is feasible (same order as above):

- electrode burning-off
- aging of electrode material
- access of air-fuel mixture to electode gap
- lean mixtures have higher ignition voltage required and hence increased electrode burning
- The temperature of the spark-plug is dependent on the heat rating

Most of the manufacturers apply empirical methods for the evaluation of spark plug performance, this means that spark plugs have to be tested under various conditions like cold start, full-load-rated speed, etc. Also with respect to this topic, a literature research was made and several publications of spark-plug manufacturers were collected and submitted to IJM.

c) As far as available AVL will submit drawings of pistons of gasoline engines currently under production

d) Consultation on computer software:
AVL presents their own computer programs and informs on programs available on the market.

5. Consultation visit of Dr. R. Rankl (AVL) in "Project Area" on June 27, 1984

The installation of the swirl chamber engine IMR M34/V, 64 hp, 2600 rpm on the test bed at IZM/Novi Sad was completed. This engine will be equipped with pistons, piston rings and cylinder liners produced by the company "27. Mart" for performing homologation tests. The visit of AVL personnel was intended for the check of the test bed set up, to consult on test bed routine and to supervise the first test runs.

The air-flow will be measured by an orifice and the fuel flow by a simple flow meter. Already installed were also the pressure probe for the measurement of transient pressure in the combustion chamber and a probe for the measurement of needle lift in the injector.

For recording the most important performance characteristics the following measurement equipment is still missing:
- smoke meter
- thermo-couples for exhaust temperature measurement
- probes for measurement of oil and water temperature.

It was further recommended to measure the intake-manifold-pressure in order to take account of the pressure loss caused by the orifice used for the air flow measurement and also the exhaust back pressure which could be rather high because of long exhaust sytem, designed without plenum.

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The pressure drop over the orifice for the air flow measurements should be rather performed by a water gauge. The pressure pick-up currently used is very sensitive and follows every pressure pulse so that a reliable reading of the mean value is impossible.

The flow meter used for the measurement of fuel flow seems to be rather inaccurate. AVL recommend the use of a simple Seppeler-meter.

The needle lift probe used by IZM was delivered by AVL. It showed only weak signals. The reason for this defect could not be found. It was therefore decided to check the probe by AVL.

IZM will complete and revise the test bed equipment as recommended by AVL and start already the first test runs. It was decided that a staff member of IZM will visit AVL in the next future for advice on the operation of the measurement equipment as used on engine test beds and information on the test routine.

The next (third visit) of AVL personnel to the project area will be made when the first 50 hours-test run of the homologation test will be completed.

6. Consultation visit of Mr. B. Schukoff (AVL) in "Project Area" on Nov. 19 and 20, 1984 (third and last visit)

As agreed, this visit was payed after the first 50-hours test run of the IMR M 34/V engine equipped with pistons, piston rings and cylinder liners manufactured by the "27. Mart" factory was completet (see point 5.). Although only one-day visits were forseen in the contract, the last visit to the project area was extended to two days because of the many items to be discussed. The additional time spent was deducted from the commitment of man-hours of home office services.

IZM has performed the test runs according to the following test cycle:

- 1 hour of full load at the rated speed of 2400 rpm
- 5 minutes of low idle at 900 rpm
- this cycle is repeated 4 times
- 10 minutes low idle
- full-load curve over speed
- measurement of lube-oil consumption.

This scheme is repeated until 50 operation hours are accumulated.

The ring pack consisted of

1st groove: 2.4 mm keystone ring chrome plated
2nd groove: 2.4 mm rectangular ring
3rd groove: 3.1 mm ring with scraper edge
4th groove: 6.3 mm spring loaded oil ring
5th groove: standard oil ring

The blow-by at full load and rated speed was measured as 0.83 percent of the intake air. At an engine speed of 1800 rpm 1.5 percent and at 1000 rpm 1.3 percent were measured. These values are normal.

For the visit the engine was already dismanteled and a complete visual inspection of all engine components with respect to wear was performed and commented by Mr. Schukoff. In essence the inspection of the pistons and liners as the most important parts for the homologation showed the following results:

piston # 1 - piston (rod) alignment apparently not adequate
- ring grooves only slightly coked
- no bearing trace at ends of chrome plated keystone ring (about 1.5 mm) because of chamfer
- all other piston rings in order
- lower surface of piston crown not colored
- cylinder liner in order

piston # 2 - piston alignment fairly good
- ring grooves only slightly coked
- chrome plated ring does not bear at ring ends (as cyl. # 1)
- all other piston rings in order
- cylinder liner in order

piston # 3 - piston alignment not adequate
- ring grooves only slightly coked
- all piston rings in order
- cylinder liner in order

piston # 4 - piston alignment fairly good
- rig grooves only slightly coked
- all piston rings in order
- cylinder liner in order

It was proposed to measure the gap between ring ends before the engine is assembled in order to obtain information on wear.

7. Visit of Mr. H. Ličen, Mr. M. Dozet and Mr. S. Radišić to Graz on Dec. 3, 1984

This last visit was used to discuss further problems of instrumentation (test bed equipment) and measurement routine.

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The needle lift transducer as delivered by AVL to IZM which seemed to work not satisfactorily was completely checked and found o.k. IZM was advised in detail on the use of this equipment.

Mr. [illegible] stayed at AVL for 4 days for a special test bed training. All necessary equipment for test bed measurement of fuel consumption, smoke, power, temperature, gaseous emissions, pressures, air flow, engine speed, etc. were explained and demonstrated. A descripton of the test bed procedure was handed over.

CONCLUSION

Today, IZM is in the position to perform testing of engines. However, there is still some important measurement equipment missing or is too unreliable for accurate measurements imparative for homologation procedures of engine components. This missing equipment consists in essence of instrumentation for the measurement of

- exhaust smoke
- fuel consumption
- exhaust gas temperature
- oil and water temperature
- oil consumption
- vibration

However, besides the provision of measurement equipment AVL also recommends to continue the consultation of the Institute of Mechanization in Novi Sad in the future. The problem is that engine testing, development work of engines or engine components and finally homologation of engine components require a very extensive experience, which can be provided by a consultant.

AVL Graz-Austria | Memo 847

TABLE OF CONTENT

1. Introduction

The present instruction manual was prepared as a guide for the test-bed engineer. It should present the most important measurement techniques and explain, how the recorded data can be transformed into figures of specific fuel consumption, mean effective pressures, efficiencies, etc., in order to assess the performance and fuel economy of different engines.

2. Measurement Systems, Units

Up until 1978, the official and most commonly used system was the Technical System (T-System) with basic units:

Time	s
Distance	m
Force	kp

Since 1978, the International System (SI for short) has been introduced with the basic units:

Time	s
Distance	m
Mass	kg

It corresponds with the MKS system (Meter-Kilogram-Second).

As the transition from the old system to the new has been very slow, it still happens frequently that both systems are used.

S.I. Basic Units	Name	Symbol
Distance	Meter	m
Mass	Kilogram	kg
Time	Second	s
Current intensity	Ampère	A
Light intensity	Candela	cd
Molecular weight	Mol	mol

Apart from these, a few units are still used which do not correspond exactly with the S.I. system. They are the following:

Pressure in bar	1 bar = 10^5 (N/m^2)
Temperature in ^oC	$t(^oC) = T(K) - 273.15$
Temperature in ^oK	$T(K) = t(^oC) + 273.15$
Speed in rpm	n(rpm)= 60.n(revs. per sec.)

S.I. Units and Resulting Measurements

Space	Distance
	Area
	Volume
	Angle
Mass	Mass
	Density
Time	Duration
	Frequency
	Revolutions per Minute
	Velocity
	Acceleration
	Angular Velocity
	Specific Consumption
Force	Force
Energy	Pressure
Power	Mechanical Stress
	Energy, Work
	Heat Capacity
	Power
	Torque
Temperature	Absolute Temperature

3. Mixing Process

This is the process by which fuel and air are mixed. In the case of a gasoline engine, it takes place in the carburettor and intake manifold and in gasoline engines with injection either in the intake manifold or in the combustion chamber. In a diesel engine, mixing takes place in the piston cavity or in a pre-chamber if any.

3.1. Air Ratio λ ("Breathing Efficiency")

For the total combustion of a given quantity of fuel, a minimum quantity of oxygen is required (O_{min}). This is contained in the air quantity (L_{min}). Usually, however, a different quantity of air will be introduced for combustion. This results in the Air Ratio:

$$\text{Air Ratio } \lambda_v = \frac{L}{L_{min}}$$

The air ratio λ_v is of critical importance for the correct functioning of the combustion.

The volume of fuel introduced into the cylinder needs a minimum amount of air ($L_{v\ min}$) for its complete, stoichiometric combustion. However, stoichiometric conditions do not usually exist in the cylinder.

The combustion air ratio is

$$\lambda_v = \frac{L_v}{L_{v\ min}}$$

$\lambda_v < 1$ lack of air, rich mixture

$\lambda_v = 1$ stoichiometric mixture

$\lambda_v > 1$ too much air, weak mixture

For the combustion of one kg of diesel fuel, a minimum quantity of air L_{min} of 14.6 kg per kg of fuel is necessary.

- Gasoline engines run at $\lambda_v = 0.8$ to 1.2
- Diesel engines run at $\lambda_v > 1.3$

3.2 Gas Exchange

Gas exchange is the phase during which the burnt gases are expelled and the cylinder is filled with a new charge.

3.3 Residual Gas Volume

Since the piston cannot expel the dead volume (compression volume) completely, and, in the case of a two-stroke engine, the fresh charge cannot totally expel the burnt gases, there always remains a certain proportion of left-over burnt-out gas in the cylinder. This is, of course undesirable.

In a four-stroke engine, this can be reduced by having a big valve overlap, so that the exhaust gases can be expelled by the fresh charge while both valves are open.

In a two-stroke engine, it is important to achieve a good flow during scavenging, so that the maximum possible amount of exhaust gases are expelled but none of the fresh charge is lost through the exhaust valve.

3.4 Volumetric Efficiency λ_1

If an engine could be run slowly and without any losses, the air intake in each cylinder would be equal to the swept volume, i.e. the theoretical air volume m_{th} would be aspirated. However, in practice engines can be run neither slowly nor without any losses, so a smaller volume than this is drawn into the cylinder.

When defining the theoretical volume, a distinction is also made between the volume expressed in terms of the ambient conditions (m_{th1}) and the theoretical volume expressed in terms of the conditions prevailing in the intake manifold (m_{th2}).

$$\lambda_{11} = \frac{m_z}{m_{th1}} \qquad \lambda_{12} = \frac{m_z}{m_{th2}}$$

4. Performance, Pressure, Pressure Diagrams

4.1 Mean Effective Pressures: p_i (imep), p_e (Bmep) and p_r (Fmep)

Power P_i (Ihp), P_e (Bhp) and P_r (Fhp).

The power production of an internal combustion engine can be described as the work of a piston moving up and down, the piston being propelled in its working stroke by a constant mean indicated pressure (p_i or imep) and producing indicated power (P_i or Ihp). In the process of transmission to the crankshaft and auxiliary systems, friction losses (P_r or Fhp) occur and at the end of the crankshaft, only the remaining effective power (P_e or Bhp) can be registered.

$$P_i \text{ (or Ihp)} = P_e \text{ (or Bhp)} + P_r \text{ (or Fhp)}$$

The mean effective pressure p_e (Bmep) is that proportion of pressure which produces P_e (Bhp) and the mean friction pressure, p_r (Fmep) accounts for P_r (Fhp).

$$p_i \text{ (or imep)} = p_e \text{ (or Bmep)} + p_r \text{ (or Fmep)}$$

All these mean pressures are imaginary values but they are useful in comparing the performance of different engines.

p_i (imep) and especially p_e (bmep) are a criterion for the utilisation of the cylinder volume during the working cycle.

(From now on, only the European symbols will be used.)

p_r and p_r give information on the friction losses in an engine. These diminish during the first 50 to 70 running hours (running-in time) and thereafter remain constant. The mean friction pressure p_r is then approximately 2 bar.

For two-stroke engines, the relation between power and the respective mean pressure can be expressed thus:

$$\text{Power}^{(kW)} = \frac{V_H^{(lit)} \cdot n^{(rev/min)} \cdot \text{pressure}^{(bar)}}{600}$$

As in the case of four-stroke engines, ignition only occurs every other revolution, the power is halved, thus:

$$\text{Power}^{(kW)} = \frac{V_H^{(lit)} \cdot n^{(rev/min)} \cdot \text{pressure}^{(bar)}}{1200}$$

One of the three indeces e, i or r is to be inserted into this formula.

Calculation of power according to the old technical system is effected thus:

$$P^{(PS)} = \frac{V_H^{(lit)} \cdot n^{(revs/min)} \cdot p_e^{(kp/cm^2)}}{450} \quad \text{2-Stroke}$$

$$P^{(PS)} = \frac{V_H^{(lit)} \cdot n^{(revs/min)} \cdot p_e^{(kp/cm^2)}}{900} \quad \text{4-Stroke}$$

Example:

4-Stroke engine V_H = 3.77 (lit)

n = 5000 (revs/min)

p_e = 7 (bar) or 7.136 (kp/cm^2)

$$P_e(kW) = \frac{3.77 \cdot 5000 \cdot 7}{1200} = 110 \text{ (kW)}$$

$$P_e(PS) = \frac{3.77 \cdot 5000 \cdot 7.136}{900} = 150 \text{ (PS)}$$

Values of reference for mean effective pressure p_e:

Gasoline engines:	2-Stroke	p_e = 4 - 5.5	(bar)	
	4-Stroke	p_e = 7 - 10	(bar)	
Diesel engines	2-Stroke	p_e = 4.5 - 5.5	(bar)	NA
		p_e = 8 - 11	(bar)	TC
	4-Stroke	p_e = 5 - 8	(bar)	NA
		p_e = 10 - 12	(bar)	TC
		p_e = 16 - 20	(bar)	highly TC

In Figure 1 , the pressure diagrams of each working cycle of a four-stroke engine are shown over the piston stroke in the form of a pV diagram and over crankangle in the form of an indicator diagram.

4.2 Combustion Pressures and Pressure Diagrams

The compression ratio is defined by means of the pV diagram thus:

$$\varepsilon = \frac{V_h + V_c}{V_c}$$

V_h = swept volume

V_c = compression volume

Usual compression ratios:

Gasoline engines: ε = 7 - 10 upper limit set by knocking

Diesel engines: ε = 14 - 22 upper limit set by mechanical strength

Usual values for ignition pressure

Gasoline engines: p_z = 35 - 55 (bar)

Diesel engines: p_z = 60 - 90 (bar) NA

p_z = 75 - 140 (bar) TC

5. Efficiencies

Efficiency is calculated as

$$\eta = \frac{\text{power yield}}{\text{effort}}$$

However, in the case of an engine, there are many different ways of calculating the efficiency. The most important are the following:

5.1 Thermal Efficiency (Work Yield) η_e

η_e is the ratio of the energy which can be taken from the crankshaft to that which was put into the engine in the form of fuel, thus:

$$\eta_e = \frac{\text{work yield}}{\text{energy in fuel supplied}}$$

or, in relation to a unit of time:

$$\eta_e = \frac{\text{effective power } P_e}{\text{energy in fuel per time unit}}$$

$$\eta_e = \frac{3600 \cdot P_e^{(kW)}}{B^{(kg/h)} \cdot H_u^{(kJ/kg)}}$$

B = amount of fuel consumed in kg/h

H_u = calorific value of 1 kg of fuel in kJ/kg

OR

$$\eta_e = \frac{3.6 \cdot 10^6}{b_e^{(g/kWh)} \cdot H_u^{(kJ/kg)}}$$

b_e = amount of fuel consumed in g/kWh

Examples:

$B = 25.3 \text{ (kg/h)}$

$H_u = 41899 \text{ (kJ/kg)}$ $\quad \eta_e = \frac{3600 \ . \ 110}{25.3 \ . \ 41899} = 0.374$

$P_e = 110 \text{ (kW)}$

OR

$b_e = 230 \text{ (g/kWh)}$

$H_u = 41900 \text{ (kJ/kg)}$ $\quad \eta_e = \frac{3.6 \ . \ 10^6}{230 \ . \ 41900} = 0.374$

5.2 Mechanical Efficiency η_m

The mechanical efficiency is the quotient of the effective power P_e and the indicated power P_i.

$$\eta_m = \frac{P_e}{P_i} = \frac{P_e}{P_e + P_r}$$

P_r is the power which is lost through friction on the way from the piston to the crankshaft and auxiliary systems (camshaft etc.). It is also possible to replace the power values P_e, P_i and P_r by the mean pressures p_e, p_i and p_r in this equation.

6. Fuels

The fuels used in internal combustion engines are hydrocarbon (C_nH_n) compounds almost exclusively taken from mineral oil.

(a) Gasoline — Mainly chain-like compounds with a low number of atoms (under 8) and slow-to-ignite, ring-shaped compounds.

(b) Diesel Oil — High number of carbon atoms and easy ignition.

(c) Alcohols — These are slow to ignite. They are at present available in limited quantities only (as are synthetic fuels) and are expensive. They are, however, becoming more important, especially in combination with conventional fuels.

(d) Gas Fuels — Mainly Butane and Propane. For gasoline-type engines with additional adaptations (mixing valve) and for diesel engines with jet ignition.

6.1 Calorific Value H_u

The calorific value H_u defines the amount of heat released by the combustion of one kg of fuel. H_u is the "lower calorific value", which takes no account of the heat which could be won back through the condensation of the water vapour produced by combustion. The calorific value expressed in SI terms would be in J/kg or kJ/kg and in the Technical System kCal/kg.

Calorific Values for Various Fuels

Gasoline	41900 kJ/kg	or	10,000 kCal/kg
Benzol	40390 kJ/kg	"	9,640 kCal/kg
Diesel oil	44000 kJ/kg	"	10,500 kCal/kg
Ethyl-alcohol	26800 kJ/kg	"	6,400 kCal/kg

In the case of gas fuels, the quantity is expressed in standard cubic metres (Nm^3).

1 Nm^3 = 1m^3 gas at 760 Torr and 20°C

Mineral gas	36,000 kJ/Nm^3	or	8,600 kCal/Nm^3
Liquid gas	92,000 kJ/Nm^3	"	22,000 kCal/Nm^3

6.2 Octane Value

The octane value is a criterion for the resistance to knocking and the ignition delay of a gasoline engine fuel.

Gasoline with an Octane value (Oz) of 90 has the same resistance to knocking as a mixture of 90% Iso-Octane (C_8H_{18}) and 10% n-Heptane (C_7H_{16}). Iso-Octane with an Oz of 100 has a high resistance to knocking and n-Heptane is extremely inclined to knock. High Octane level means high resistance to knocking and long ignition delay.

Octane levels:	gasoline normal:	86 to 88
	super :	96 to 98

Form 21

MOz (Motor Octane figure) and ROz (Research Octane figure) are arrived at by different methods of measurement. MOz is always a little lower than ROz.

6.3 Knocking in a Gasoline Engine

Combustion correctly starts at the sparking plugs and penetrates the entire combustion chamber as a wall of fire. If the fuel has too little resistance to knocking, i.e. is too readily ignitable, then a sudden combustion occurs in places which the flame wall has not yet reached. Knocking causes a loud noise, reduces the power and increases mechanical stress on the engine.

6.4 Cetane Level (Caz)

The Cetane level is a criterion for ignitability in diesel oil. A high Cetane level means high ignitability. Diesel oil with a Cetane level of 90 has the same ignitability as a mixture of 90% Cetane ($C_{16}H_{34}$, CaZ = 100) and 10% α-Methylnaphthalin ($C_{11}H_{10}$ CaZ = 0).

Commonly used diesel oils have a Cetane level of about 55.

6.5 Knocking in Diesel Engines

This has the same effects as knocking in gasoline engines and occurs when the diesel fuel is too slow to ignite (low CaZ). When ignition takes place, there is too much fuel in the cylinder and this results in a diesel knock.

High CaZ means high ignitability
High Oz means low ignitability

Fuels with a high CaZ have a low Oz and vice versa.

6.6 Fuel Consumption

In order to ascertain the fuel consumption of any given engine, a recording is made of the length of time (T_B) or the number of revolutions (U_{TB}) an engine needs to use up a certain mass of fuel (GKW). GKW is the mass of fuel weighed on the fuel scales.

(a) Specific Fuel Consumption b_e (g/kWh)

b_e (g/kWh) indicates how much fuel (GKW g) an engine needs in one hour to produce Power P_e(kW).

$$b_e/g/kWh = \frac{GKW^{(g)}}{P_e^{(kW)} \cdot t^{(h)}}$$

$$= \frac{60 \cdot GKW^{(g)}}{P_e^{(kW)} \cdot T_B^{(min)}}$$

$$= \frac{60 \, . \, GKW^{(g)} \, . \, n^{(revs/min)}}{P_e^{(kW)} \, . \, U_{TB}}$$

e.g. GKW = 100 (g)
P_e = 180 (kW)
n = 2,800 (revs/min)
U_{TB} = 397

$$b_e = \frac{60 \, . \, 100 \, . \, 2800}{180 \, . \, 397} = 235.1 \text{ (g/kWh)}$$

The possible peak values for b_e are:

for gasoline engines: 270 (g/kWh) = 200 (g/PSh)
for diesel engines: 200 (g/kWh) = 150 (g/PSh)

(b) <u>Fuel Consumption per Hour</u> B/kg/h

B is the amount of fuel consumed in one hour.

$$B^{(kg/H)} = \frac{b_e^{(g/kWh)} \, . \, P_e^{(kW)}}{1000}$$

$$= 0.06 \, . \, \frac{GKW^{(g)} \, . \, n^{(revs/min)}}{U_{TB}}$$

e.g. GKW = 100 (g)
n = 2,800 (revs/min)
U_{TB} = 397

$$B = \frac{0.06 \, . \, 100 \, . \, 2800}{397} = 42.3 \text{ (kg/h)}$$

(c) Injection Volume per Working Stroke β (mm^3/stroke)

This is the volume of fuel per injection.

$$\beta = \frac{1000 \cdot GKW}{\varrho \, (g/cm^3) \cdot z \cdot U_{TB}}$$

e.g. GKW = 100 (g)

U_{TB} = 297

z = 6 — z = no. of cylinders

ϱ = 0.845 (g/cm^3) — ϱ = specific gravity of fuel

$$\beta = \frac{1000 \cdot 100}{0.845 \cdot 6 \cdot 397} = 49.7 \ (mm^3/stroke)$$

6.7 Fuel Consumption Diagrams

(a) Partial load lines: Specific fuel consumption b_e is measured at constant engine speed and varying loads (P_e). See Figure 2. The points I to IV of Figure 2 can be inserted in the "fish-hook" diagram (Figure 3). In the case of diesel engines, the full-load curve resulting from the use of a governor can also be inserted. The governor is intended to limit engine speed to avoid excessive soot formation caused by high β values. Lines representing the same power can also be drawn in, see Figure 3.

7. Test-Bed

7.1 Power Measurement with a Dynamometer

The effective power P_e of an engine can be measured on a test-bed by means of a dynamometer, which indicates the torque generated by the engine. (See Figure 26)

$$P^{(W)} = M . = F . l . \frac{n\, \Pi}{30}$$

$$P_e^{(kW)} = 1.0472 . 10^{-4} . F^{(NJ)} . l^{(m)} . n^{(revs/min)}$$

To obtain simpler formulae, one can choose the length of the lever arm l_1 as follows:

(a) For measurements in kW (kW arm)

$l_1 = 0.9549$ (m)

$$P_e^{(kW)} = F^{(N)} . n^{(revs/min)} . 10^{-4}$$

e.g. $F = 450$ (N), $n = 2800$ (revs/min) $\quad P_e = 126$ (kW)

(b) For measurements in PS (PS-arm)

$$P_e^{(PS)} = \frac{1}{75} . F^{(kp)} . l^{(m)} . \frac{n\, .\, \Pi}{30}$$

$l = 0.7162$ (m)

$$P_e^{(PS)} = F^{(kp)} . n^{(revs/min)} . 10^{-3}$$

e.g. $F = 60$ (kp), $n = 2800$ (revs/min) $\quad P_e = 168$ (PS)

7.2 Engine Power corrected to Standard Conditions N_{red}

Since the power of an internal combustion engine is inevitably dependent upon the ambient pressure and temperature, results obtained under any conditions are always recalculated to correspond with standard conditions.

DIN 6270 gives the correction factors for power and fuel consumption which also take air humidity into account. These factors apply to naturally aspirated gasoline and diesel engines in current use and to engines with mechanical pressure chargers in which the power is limited by the excess air ratio and the mechanical efficiency is 85%.

Standard Conditions according to DIN 6270:

Normal atmospheric pressure	b_o	= 736 Torr (979 mb)
Air temperature	t_o	= 20°C
Relative air humidity	φ_o	= 60%

These standard conditions are equivalent to the standard conditions given by CIMAC:

Normal atmospheric pressure	b_o	= 760 Torr (1013 mb)
Air temperature	t_o	= 30°C
Relative air humidity	φ_o	= 60%

On this basis, brake power at the flywheel is:

$$N_e = N_{eo} \cdot \alpha \quad (kW)$$

The correction factor α may be taken from Figure 5 table 1. These correction factors have to be further corrected according to table 2 in the case of a mechanical efficiency of less than 85%.

The specific fuel consumption under real running conditions is

$$b_e = b_{eo} \cdot \alpha \quad (g/kWh)$$

The correction factor can be taken from the table in Figure 4 .

Calculation Examples

Example 1:

Given: Continuous power 125 kW at standard conditions, Engine with 0.75 mechanical efficiency.

Required: Continuous power at an altitude of 1300 m with relative air humidity of 100% and temperature of 30°C.

Solution: Correction factor from table 1 for 1300 m altitude, 100% humidity and 30°C = 0.81.

Since table 1 applies to a mechanical efficiency of 0.85 and the engine under consideration has a mechanical efficiency of 0.75, the resulting value must be corrected further according to table 2, i.e. by 0.79.

The continuous brake power at actual running conditions comes to 79% of 125 kW = 99 kW.

Example 2

For the engine in example 1, a correction factor of 0.81 was taken from table 1. Taking the mechanical efficiency of η_{m_o} = 0.75 into account, the correction factor for the brake effective power under actual running conditions according to the table in Figure 26 is = 1.05. Assuming that the engine has a fuel consumption of b_{eo} = 180 g/PSh at standard conditions, the fuel consumption at actual running conditions will be:

$$b_e = 260 \cdot 1.05 = 273 \text{ g/kWh.}$$

In the case of vehicle engines, values are corrected to sea level and normal temperature (i.e. 760 Torr or 1013 bar and 20°C) by DIN 70020. Variations in mechanical efficiency and air humidity are not taken into account for motor vehicles since their influence on the final figure is negligible for engines of this size.

$$N_{e\ red} = N_e \frac{760}{b} \cdot \sqrt{\frac{273 + t}{273 + 20}}$$

b = actual air pressure in Torr or mm Hg

t = actual temperature in °C

N_e = actual observed power

Example: N_e = 110 (kW)

t = 35 (°C)

b = 740 (Torr)

$$N_{e\ red} = 110 \frac{760}{740} \sqrt{\frac{273 + 35}{273 + 20}} = 115.8 \text{ (kW)}$$

7.3 Installation of Engine in Test-Bed

On account of the numerous moving parts such as pistons, connecting rods, crankshaft etc., a piston engine produces vibrations which have to be insulated from the surrounding floor and wall surfaces. This can be satisfactorily done by mounting the engine on rubber mounts on a base which is in turn sprung-mounted. It is important to achieve a good correlation between the various weights and springs so that only small forces reach the actual building.

7.4 Test Sheets

In order to check a test measurement it is essential to record certain conditions beforehand. Only then can comparisons be made between results. Important parameters on the engine test-bed are, for example, air temperature, air pressure, oil temperature, cooling water temperature.

Engine specifications must also be recorded if they are subject to alteration: static injection timing, injection line diameter, type of delivery pump, nozzle, pump equipment, sparking plugs etc.

All this information has to be entered accurately into the measurement sheet so that comparisons can be made after numerous tests. An example of such a measurement sheet is shown in the attached illustrations.

See Figure 6 for a sample test sheet for a naturally aspirated, air-cooled diesel engine, and Figure 7 for a sample test sheet for a naturally aspirated, water-cooled gasolene engine.

Barometer ...air pressure in mb

t_R ....mean ambient temperature measured 1 metre away from the engine surface

t_{oil}..........Oil temperature on entry (e.g. into the oil cooler) in ^oC.
Oil temperature on leaving (e.g. the oil cooler) in ^oC.

$p_{ö}$ ....Oil pressure

t_{We}..........Water temperature before entry into the engine (^oC)

t_{Wa}..........Water temperature after coming out of the engine (^oC)

t_K Le ....Cooling-air temperature, entry, ^oC

t_k La ....Cooling-air temperature, exit, ^oC

p_L ....Intake manifold depression in mbar

t_L ....Air temperature, e.g. in intake manifold

t_A ....Exhaust bulk temperature

p_A ....Exhaust back pressure in mbar

F ....Load indication at dynamometer

$t_{meß}$ ....Measuring time for Seppeler consumption measurement

n ....Engine speed in rpm

P_e ....Engine power (kW) calculated with formula

b_e ....Specific fuel consumption in g/kWh, calculated according to formula

p_e ....Brake mean effective pressure, calculated according to formula

p_r ....Mean friction pressure in bar, calculated according to formula

β ....Fuel delivery per stroke in mm^3, calculated according to formula

Further data (consumption per hour, blackness etc.) can be put into the empty spaces.

7.5 Air Flow Measurement

Since there are usually no technical difficulties in bringing enough fuel into the cylinder, the power achieved depends mainly on the mass of air which can be introduced, i.e. from the maximum possible volumetric efficiency. To achieve an optimum design of intake and outlet systems, air and exhaust manifolds, valves, valve timing devices and supply lines, a great deal of design and testing work has to be done.

An engine's aspirated air volume therefore has to be measured. On the basis of this value, the engine power, volumetric efficiency, fuel/air ratio and other parameters can be determined.

The measurement of air through-flow is most simply effected with measurement nozzles or orifice plates built into sufficiently long, stabilizing sections of pipe (see Figures 8a und 8b).

Another way of measuring air-flow is by using an "air-box". This gives good results provided the fitting instructions are followed precisely. It consists of an air-contiainer of sufficient size connected to the air intake by means of a flexible tube and having a circular, sharp-edged orifice. The air enters the device through this orifice and the pressure drop across the measurement aperture is measured with a manometer. The pressure drop should be less than 100 mm WS (10 mb) so that the effects of compressibility can be disregarded.

The influence on the volumetric efficiency of the engine is less than 1%. The air through-flow can then be expressed thus:

$$V_L = 10^{-3} \cdot \frac{\pi D^2 K}{4} \cdot 237.3 \sqrt{\frac{h_o \cdot T_L}{10^3 \cdot p_o}}$$

V_L = Quantity of air through-flow in litres/sec.
D = Diameter of orifice in mm
K = Through-flow coefficient of orifice
h_o = Pressure differenceacross orifice in cm WS
T_L = Air temperature in ^oK
p_o = Barometer pressure in kN/m^2

Determination of orifice or nozzle through-flow coefficient with the aid of a bell-jar: for this, a very even flow of air over a longish period of time is necessary. The setting up of this test is depicted in Figure 8c.

Another possible method for measuring the quantity of air is the use of a rotary piston gas-meter. With this, the result is obtained directly, which has the advantage of a high degree of accuracy. Pressure losses are minimal. For use with an electronic integrator and flow-recorder, a mechanical drive is provided. It is also possible to build in a reaction-free pulse generator with analog or digital presentation of measured values.

$$V_L = \frac{V_{mess}}{t} \quad \text{(in } m^3 \text{ per min.)}$$

V_{mess} = measured quantity of air (m^3)

t = time (min.)

Figure 9 shows a diagram of a rotary piston gas-meter.

Example:

1. Calculation of the efficiency of an engine λ_1

Four-stroke engine n = 3200 rpm

swept volume V_H = 4.2 litres

Measured with a rotary piston gas-meter:

Measured volume V_{mess} = 2 (m^3)

Measured time t_{mess} = 0.38 (mins.)

$$\text{Efficiency } \lambda_1 = \frac{\text{aspirated air volume}}{\text{theor. asp.air volume}} = \frac{V_L}{V_{theor.}}$$

$V_{theor.}$ is the volume of air theoretically aspirated by the engine without losses (V_H . K . n).

Two-stroke engine: k = 1

Four-stroke engine: k = 1/2

$$(m^3/h)_{Theor.} = \frac{1}{2} \cdot V_H^{\,lit} \cdot 12^{revs/min} \cdot 10^{-3\ m^3/lit} \cdot 60^{min/h}$$

$$= 0.5 \cdot 4.2 \cdot 3200 \cdot 60 \cdot 10^{-3} = \underline{\underline{403.2\ (m^3/h)}}$$

Form 21

$$V_L = \frac{M_{mess}\ m^3}{t_{mess}\ min} \cdot 60^{min/h} = \frac{2 \cdot 60}{0.38} = 315.8\ (m^3/h)$$

$$1 = \frac{V_L}{V_{theor}} = \frac{315.8}{403.2} = 0.783$$ related to intake conditions

For the calculation of the volumetric efficiency, the air volume must be measured in terms of the conditions in the intake manifold before the cylinder (p_S, T_S).

2. Through-Flow of Air m_L in kg per hour

$$m_L = L \cdot V_L$$

$$L = \frac{p_m}{R \cdot T_m}$$

p_m = 1.013 (bar) = $1.013 \cdot 10^5 (N/m^2)$
R = 287 (J/kg K)
T_m = 25 (^oC) = 298.15 (^oK)

$$m_L = \frac{1.013 \cdot 10^5}{287 \cdot 298.15} \cdot 315.8 = 373.86\ (kg/h)$$

3. Equivalence Ratio λ_v

$$\lambda_v = \frac{m_L}{L_{min} \cdot B_H} \qquad B_H{}^{kg/h} = \frac{b_e{}^{g/kWh} \cdot P_e{}^{kW}}{1000^{g/kg}}$$

L_{min} = 14.2 kg Luft per kg fuel

P_e = 80 (kW)

b_e = 225 (g/kWh)

$$B^H = \frac{80 \cdot 225}{1000} = 18\ (kg/h)$$

$$\lambda_v = \frac{373.86}{14.2 \cdot 18} = 1.46$$

7.6 Pressure Measurement

The measurement of rapid pressure changes such as those in the combustion chamber or injection system requires special pressure transducers. These must withstand high pressures and temperatures but they must also be capable of good resolution and have high frequency response in order to give satisfactory measurements.

Suitable devices which fulfil these conditions are the quartz pressure transducer and the strain gauge transducer.

(a) The Quartz Pressure Transducer

These function on the piezo-electric principle. When a force or pressure is brought to bear on a quartz cristal in the direction of the electrical axis, an electric charge is produced on the surfaces at right-angles to it (see Figures 10 and 11).

AVL quartz transducers have a measurement range of up to 500 bar, a resolution capacity of 0.0002 bar a frequency response of up to 160 kHz and a temperature range of up to 240°C. By means of a water cooling system, however, high mean temperatures such as those in the combustion chamber can be measured satisfactorily.

(b) Strain-Gauge Pressure Transducers

These have the same advantages as the quartz pressure transducers and can also be used for higher temperatures as they are easier to cool (up to 1000 °C mean gas temperature). The measuring element consists of a hollow steel cylinder on which a strain gauge strip is glued.

AVL strain-gauge transducers can be used for pressures up to 1200 bar and at temperatures of up to 1000°C. They have high resistance to shock and mechanical stress. Application: combustion chamber pressures, injection line pressures, etc. (Fig. 12)

Low pressures which change gradually can best be measured with barometers or U-tubes (see Figure 13) in mm Hg (mercury) or mm WS (water). Alternatively, they can be measured with pressure diaphragm capsules if electric outlet valves are required. Such pressures are, for example:

depression in the intake manifold
air pressure
exhaust back pressure.

Conversion: 1 mm WS = $9.81 - 10^{-5}$ (bar) = 9.81 (N/m^2)
1 mm Hg = 1 Torr = $1.333 \, . \, 10^{-3}$ (bar)

7 .7 Temperature Measurement

The simplest device for measuring temperature is the thermometer. It is sufficient for the measurement of ambient temperature, outlet temperature and other low temperatures.

For higher temperatures and when electric signals are needed, thermocouples or resistance thermometers are used. The thermocouple consists of a conductor made of two or more different metals (or semi-conductor) which produces a current when the junctions are subject to different temperatures. The most commonly used thermo-metals are the following:

Metal Combination	Voltage	Temperature Range °C
Iron/Konstantan	0.12	- 50 to + 700
Nickel/Chrome-Nickel	0.08	0 to + 1200
Platinum/Platin-Rhodium	0.03	0 to + 1600

As only differences in temperature can be measured by this method, one junction must be kept at a known constant temperature (see Figure 14).

Engine temperatures often measured with thermo-couples are exhaust, oil, cooling water, cylinder head, cylinder block etc. Rapidly changing temperatures such as those in the combustion chamber cannot be measured by this method on account of the slow reaction of the thermo-couple.

7.8 Dynamometer

The dynamometer takes up the effective power P_e and permits calculation of the power by showing the torque. (See Figure 4a and 4b).

$$P_e^{(w)} = M \; .$$

P_e : effective power in Watt
u : torque in Nm
: angle speed in s^{-1}

The power can be calculated in simpler units thus:

$$P_e^{(kW)} = \frac{M \; . \; n \; . \; \pi}{30000}$$

n : speed in rpm

The dynamometer is mounted on gimbles and has a lever arm (length l) which is connected to weighing scales or a load cell which shows the force F. The transmitted torque is then:

$$m = F \; . \; l$$

F : force in N
l : length of lever arm in m.

The power is then:

$$P_e^{(kW)} = \frac{F \; . \; l \; . \; n \; . \; \pi}{30000}$$

By selecting an appropriate lever arm length for the calculation, it is possible to put together a formula which is easy to work with. For results in kW, for example:

$$l_{kW} = 0.9549 \; (m)$$

$$\underline{\underline{P_e^{kW} = F \; . \; n \; . \; 10^{-4}}}$$

F in (N)
n in revs. per min.

Older devices are designed to give results in PS, thus:

$$P_e^{PS} = F^{kp} = \frac{n\pi}{30} \; . \; \frac{1}{75} \; . \; l \qquad l_{PS} = 0.7162 \; (m)$$

$$\underline{\underline{P_e^{PS} = F \; . \; n \; . \; 10^{-3}}}$$

The actual lever arm length can be different from the theoretical lever arm length (l_{KW}, l_{PS}) to achieve a more compact construction. In this case, only the scale has to be changed accordingly.

7.9 Different Types of Dynamometer

(a) Water-Brake

Water is swirled in the brake housing and in this way the energy from the engine is absorbed. A rotor conveys the measurable torque via the water to the brake-stators. The energy given off by the engine is converted into heat and carried away by the water flowing through. Such devices may be made for working in one or both directions.

(b) Eddy-Current Brake

The braking effect is achieved by means of electric induction processes and the generation of eddy currents which transform the mechanical work of the engine shaft into heat. This is then carried away from the brake by cooling water. The regulation of brake-power is carried out by changing the energizing current. The brake effect may be for one or both directions of revolution according to the type of brake.

(c) DC Motoring Set

A separately-excited DC motoring set can be used either as a generator or as a motor. In this way, it is possible not only to brake but also to motor the engine. The electric energy supplied when the machine is run as a generator is converted into heat by means of resistors. This device can be used as motor and generator in both directions of revolution.

7.10 Test-Bed Coupling-Shaft

Between the dynamometer and the engine, an elastic joint shaft is put in which can equalize both axial and angle displacements provided they are not too great. The elastic joint shaft shown in Figure 15 is the one used with the AVL Demonstrator I and has proved very satisfactory. The elastic parts are rubber elements with sufficient shock-absorbing qualities.

The engine, coupling and dynamometer together form a buffered, vibrating assembly. It should not be run for long close to its natural frequency. If the different parts are not correctly matched, it can happen that the engine causes the system to vibrate excessively. The rubber elements then absorb all the energy and if the engine speed does not rise past the critical point, the rubber coupling elements can be destroyed by overheating.

Since it may happen that the coupling gets damaged, a protective housing is built round it to catch any flying parts.

7.11 Fuel Consumption Measurement with a Seppeler

The Seppeler measures a certain volume of fuel (V_S) used by the engine over a defined period of time (T_B). The measuring container has a volumetrically precise capacity and is marked for the commencement and completion of the measurement period.

In the narrow feed and drain tubes, the fuel level sinks very fast so that the beginning and ending of the measurement can be precisely determined. The most simple method is to register the measurement period with the aid of a stopwatch. However, this has the disadvantage that the accuracy of the test then depends on the person making the observations.

A more accurate recording of measuring time can be made by using an electronic device to register beginning and ending of the measurement from the light variations in the tubes. Human error is then eliminated and the whole measurement can be effected automatically.

The advantages of the Seppeler are its simple and inexpensive construction. It is not fragile and needs little maintenance. Its disadvantages are the limited accuracy given by volumetric measurements, which are influenced by temperature.
(See Figure 16,17)

Calculation of Fuel Consumption with a Seppeler

t_{mess}	Measurement time in seconds
V_S	Seppeler volume in cubic cm
Fuel ρ	Fuel density in grams per cubic cm
B_H	Fuel consumption in grams per hour
b_e	Specific fuel consumption in grams per kW/h
β	Volume injected per working-stroke and cylinder in cubic mm.
N_e	Engine power in kW
n	Engine speed in min^{-1}
i	Number of strokes (2 or 4)

$$B_H = 3.6 \frac{V_S \cdot \rho_{Fuel}}{t_{mess}}$$

$$b_e = 3600 \frac{V_S \cdot \rho_{Fuel}}{t_{mess} \cdot N_e}$$

$$\beta = 6 \cdot 10^4 \frac{V_S}{n \cdot t_{mess}\, i/2}$$

e.g. $V_S = 50\ (cm^3)$ $\quad N_e = 75\ (kW)$

$\rho_{Fuel} = 0.845\ (g/cm^3)$ $\quad n = 2800$ (revs/min)

$t_{mess} = 9.4$ (sec) $\quad$ 4 Stroke

$$B_H = \frac{3.6 \cdot 50 \cdot 0.845}{9.4} = 16.18\ (kg/h)$$

$$b_e = \frac{3600 \cdot 50 \cdot 0.845}{9.4 \cdot 75} = 215.7\ (g/kWh)$$

$$\beta = \frac{60000 \cdot 50}{2800 \cdot 9.4 \cdot 2} = 57\ (mm^3)$$

7.12 Fuel Balance

To arrive at more accurate measurements of fuel consumption, a fuel balance should be used. Such a device is produced by the AVL (System 700, Series 703). The fuel balance permits a gravimetric measurement of fuel which is not influenced by the temperature. Furthermore, the measuring process is completely automatic and therefore not subject to human error.

The fuel balance measures the time (T_B) or the number of engine revolutions (U_{TB}) required by the engine to use up a defined quantitiy of fuel (GKW).

GKW	quantity of fuel in grams
T_B	measurement period in minutes
U_{TB}	engine revolutions
n	engine speed in revs/min
N_e	effective power in kW
b_e	specific fuel consumption in grams/kWh
B_H	fuel consumption per hour (kg/h)

$$b_e = \frac{60 \cdot GKW}{N_e \cdot T_B} = \frac{60 \cdot GKW \cdot n}{N_e \cdot U_{TB}}$$

$$B_H = \frac{0.06 \cdot GKW}{T_B} = \frac{0.06 \cdot GKW \cdot n}{U_{TB}}$$

(see Fig. 18, 19)

e.g. GKW = 100 g

n = 2800 revs/min

N_e = 75 kW

U_{TB} = 940

$$b_e = \frac{60 \cdot 100 \cdot 2800}{75 \cdot 940} = 238.3 \text{ g/kWh}$$

$$B_H = \frac{0.06 \cdot 100 \cdot 2800}{940} = 17.9 \text{ kg/h}$$

Further details about the AVL Fuel Balance are to be found in the advertising leaflet "AVL Fuel Balance System 700".

7.13 Smoke Measurement

The exhaust from diesel engines contains, among other things, soot. This is made up of carbon atoms which result from faulty combustion. There are various ways of measuring the soot content in exhaust emissions.

(a) The filterpaper method
A certain volume of exhaust is sucked through a paper filter. The soot is trapped by the filter and blackens the white paper. The more soot the exhaust contains, the darker the filter paper will be. The degree of blackness can be determined with a photoelectric measuring device and indicated on an electronic display. The AVL produces a soot meter of this kind which permits a totally automatic measurement of the soot content in exhaust

The simplest version uses a Bosch hand-pump for the suction of exhaust into the measurement device.

(b) Scattered Light Method (Bosch)
Here two "windows" are built into the length of line along which the exhaust is pumped for soot measurement. The exhaust absorbs more or less light according to the soot content. The degree of licht absorption is measured with a photocell.

(c) Absorption Method (Hartridge)
Here, a photocell is used to measure the difference between clean air and exhaust. This gives a result in Hartridge Soot Units (HSU).

7.14 Blow-By Meter

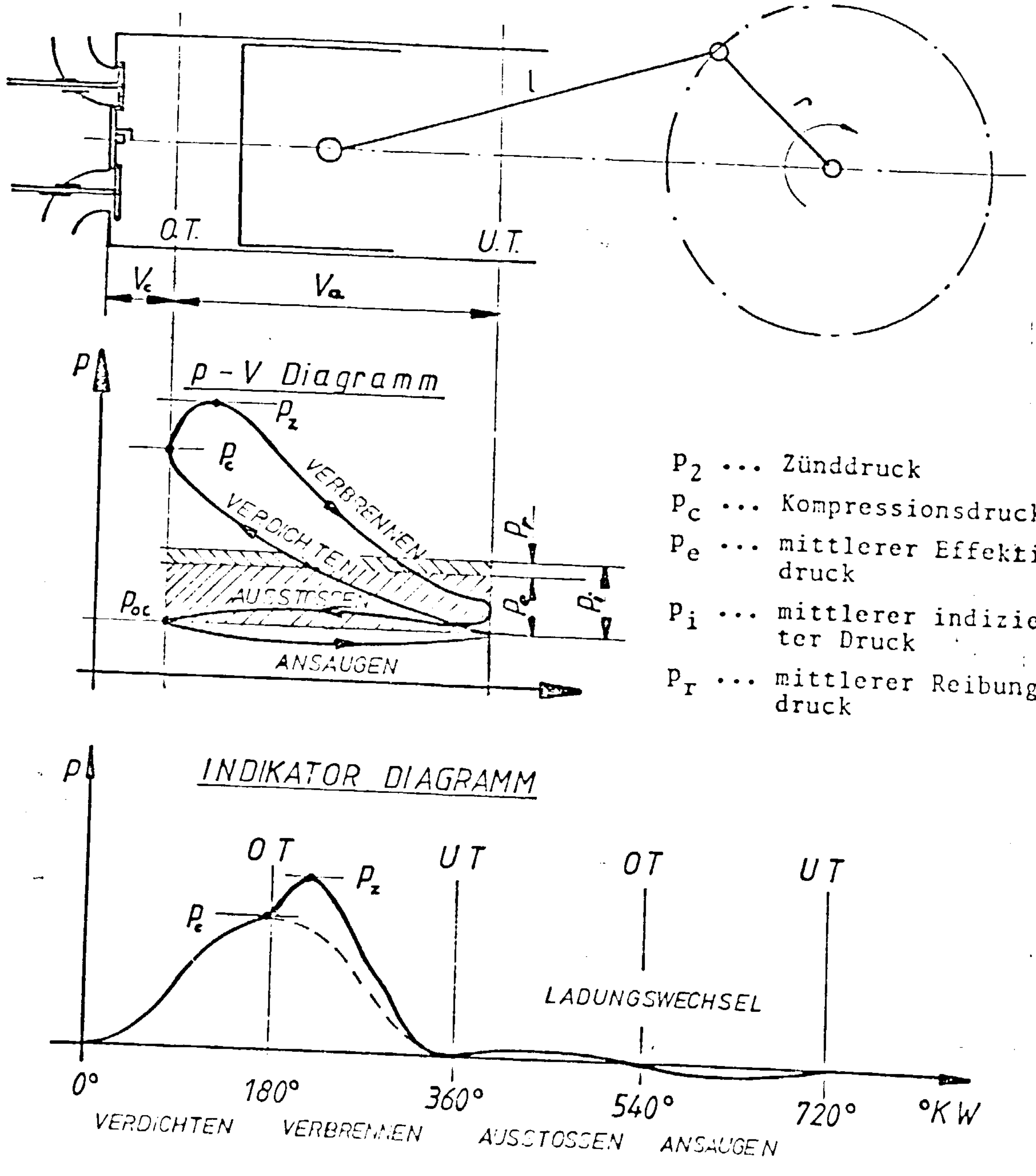
The blow-by meter measures the quantity of gas which escapes from the combustion chamber via leaking piston rings out into the crankcase. The blow-by measurement is a good criterion for estimating the state of wear of an engine. It also indicates the degree of running-in of an engine and can give an early warning of engine damage.

It is possible to set a limit on the permissible amount of blow-by so that the state of the engine can be automatically monitored. The engine can then be withdrawn from service as soon as faults begin to appear and before the damage becomes too severe.

AVL offers devices for measuring blow-by which have extremely low flow pressure loss (only a few mm WS) and a measurement range of 50 to 2500 l/min.

By the use of a stabilizing container, violently puls-ting gas escapes can be measured exactly.

AVL Graz-Austria	Viertaktmotor Zylinderdruckverlauf cylinder pressure	Fig. 1



p_z ··· Zünddruck

p_c ··· Kompressionsdruck

p_e ··· mittlerer Effektivdruck

p_i ··· mittlerer indizierter Druck

p_r ··· mittlerer Reibungsdruck

AVL Graz-Austria	Motorkennlinien	Fig. 2 Fig. 3

$$b_e = \frac{632 \cdot 10^3}{H_u \cdot \eta_e} = \frac{632 \cdot 10^3}{H_u} \cdot \frac{N_e + \Sigma N_v}{N_e} = \frac{632 \cdot 10^5}{H_u} \cdot \frac{p_e + \Sigma p_v}{p_e}$$

Teillastverbrauchslinien

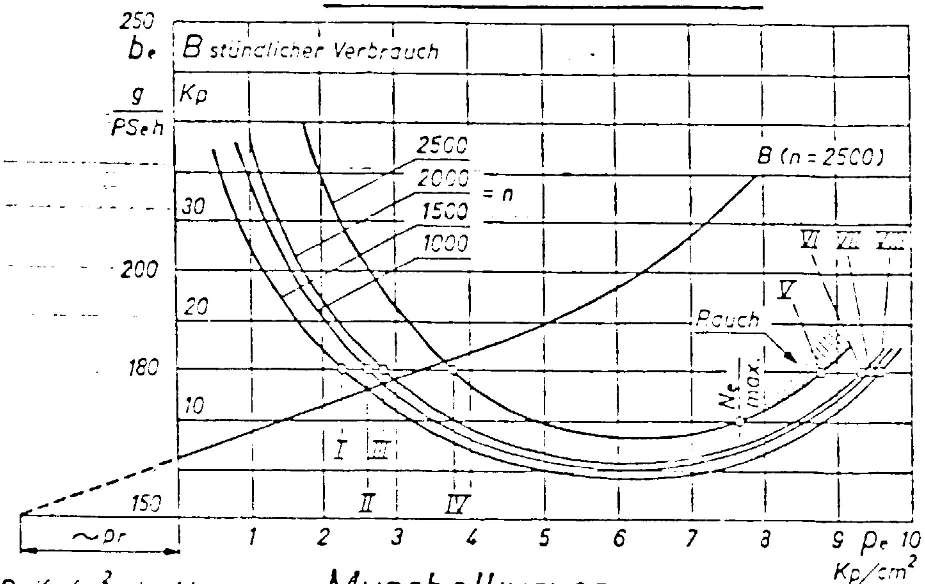


Fig. 2

Muschelkurven

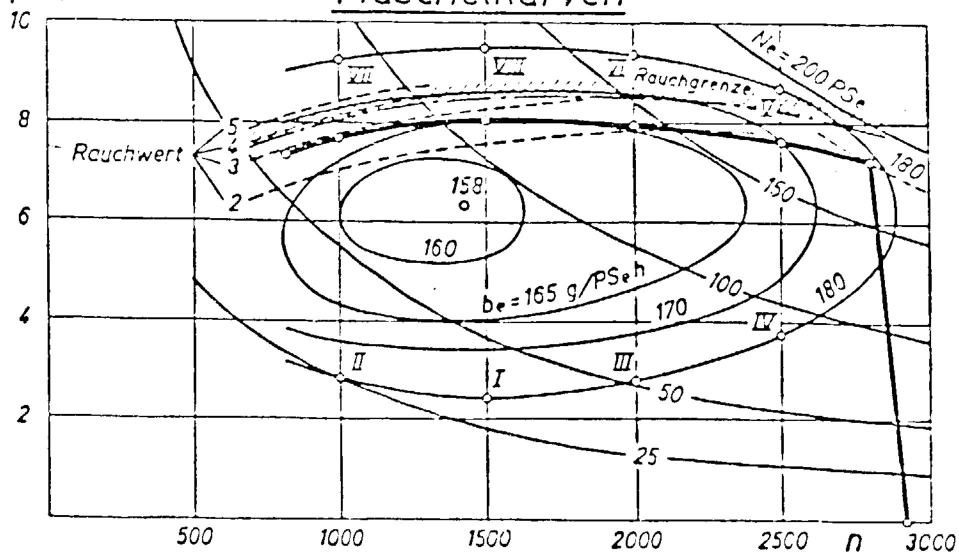


Fig. 3

$p_e = N_e \frac{900}{V_h} \frac{1}{n}$ gibt für jede Leistung eine Hyperbel

Schematische Darstellung einer Leistungsbremse

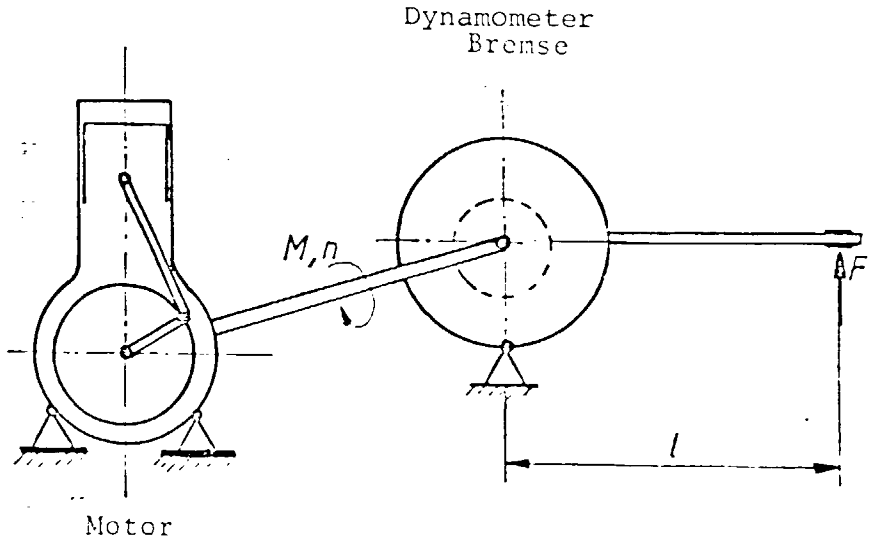


Fig. 4a

Motorprüfstand mit Wasserwirbelbremse

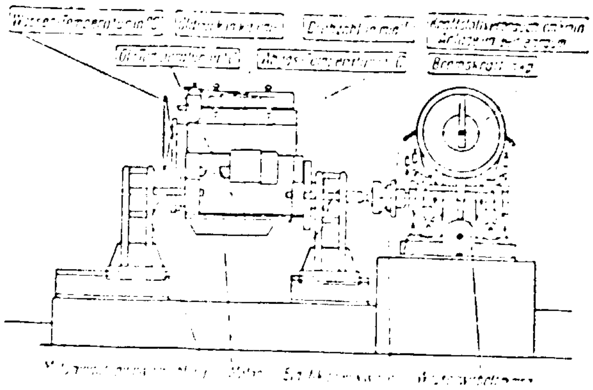


Fig.4b

Umrechnungsfaktoren nach DIN 6270

Tafel 1:

Höhe über NN in m / Altitude above sea level in metres / altitude NN en m / Altura en metros sobre el nivel del mar / altitude acima do nivel do mar em m	Luftdruck in Torr (mm Quecksilbersäule) / Atmospheric pressure in Torr (millimeters of Hg) / pression atmosphérique en Torr (mm Hg) / Presion atmosferica en Torr (MM Hg) / pressão atmosferica em Torr (mm de mercurio)	Temperatur der angesaugten Luft in °C: α bei relativer Luftfeuchtigkeit 60% / Temperature of the aspirated air in degrees Centigrade: α at a relative atmospheric moisture of 60% / Température de l'air aspiré en °C: α à humidité d'air relative 60% / Temperatura del aire aspirado en °C: α en humedad relativa de 60% / Temperatura do ar aspirado em centigrados: α à umidade relativa do ar 60%											α bei relativer Luftfeuchtigkeit 100% / α at a relative atmospheric moisture of 100% / α à humidité d'air relative 100% / α en humedad relativa de 100% / α à umidade relativa do ar 100%										
		0	5	10	15	20	25	30	35	40	45	50	0	5	10	15	20	25	30	35	40	45	50
0	750	111	110	108	106	104	102	[illegible]	97	95	92	89	[illegible]	109	107	105	103	100	98	95	92	89	84
100	751	110	108	106	104	102	100	98	96	93	91	88	110	108	106	104	101	99	96	93	90	87	83
200	742	108	107	105	103	101	99	97	95	92	89	87	108	106	104	102	100	97	95	92	89	86	81
300	733	107	105	104	102	100	98	96	93	91	88	85	107	105	103	101	98	96	94	91	88	84	80
400	725	106	104	102	100	98	96	94	92	90	87	84	105	103	102	99	97	95	92	89	86	83	79
500	716	104	103	101	99	97	95	93	91	88	86	83	104	102	100	98	96	93	91	88	85	82	77
600	708	103	101	99	98	96	94	93	89	87	85	82	103	101	99	97	95	92	90	87	84	81	76
700	699	101	100	98	96	94	92	90	88	86	83	80	101	99	97	95	93	91	88	86	83	79	75
800	691	100	98	97	95	93	91	89	87	85	82	79	100	98	96	94	92	90	87	84	81	78	74
900	682	99	97	95	94	92	90	88	86	83	81	78	98	97	95	93	91	88	86	83	80	77	73
1000	674	97	96	94	92	90	89	87	84	82	80	77	97	95	93	91	89	87	85	82	79	76	71
1100	666	96	94	93	91	89	87	85	83	81	79	76	96	94	92	90	88	86	83	81	78	74	70
1200	658	95	93	91	99	88	86	84	82	80	77	74	94	93	91	89	87	85	82	80	77	73	69
1300	650	93	92	90	88	87	85	83	81	79	76	73	93	91	90	88	86	83	81	78	75	72	68
1400	642	92	91	89	87	86	84	82	80	77	75	72	92	90	88	86	84	82	80	77	74	71	67
1500	634	91	89	88	86	84	82	81	78	76	74	71	91	89	87	85	83	81	79	76	73	70	66
1600	626	90	89	86	85	83	81	79	77	75	73	70	89	88	86	84	82	80	77	75	72	69	65
1700	618	88	87	85	84	82	80	78	76	74	72	69	88	86	85	83	81	79	76	74	71	67	63
1800	611	87	86	84	82	81	79	77	75	73	70	68	87	85	83	82	80	77	75	72	70	66	62
1900	604	86	84	83	81	80	78	76	74	72	69	67	86	84	82	80	78	76	74	71	69	65	61
2000	596	85	83	82	80	79	77	75	73	71	68	66	84	83	81	79	77	75	73	70	67	64	60
2100	589	84	82	81	79	77	76	74	72	70	67	65	83	82	80	78	76	74	72	69	66	63	59
2200	582	83	81	79	78	76	74	73	71	68	66	63	82	80	79	77	75	73	71	68	65	62	58
2300	574	82	80	78	77	75	73	71	69	67	65	62	81	79	77	76	74	72	69	67	64	61	57
2400	567	81	78	77	75	74	72	70	68	66	64	61	80	78	76	75	73	71	68	66	63	60	56
2500	560	79	77	76	74	73	71	69	67	65	63	60	78	77	75	73	72	69	67	62	62	59	55
2600	553	78	76	75	73	72	70	68	66	64	62	59	77	76	72	74	71	68	66	64	61	58	54
2700	546	76	75	74	72	71	69	67	65	63	61	58	76	75	73	71	69	67	65	63	60	57	53
2800	539	75	74	73	71	70	68	66	64	62	60	57	75	73	72	70	68	66	64	62	59	56	52
2900	532	74	73	71	70	69	67	65	63	61	59	56	74	72	71	69	67	65	63	61	58	55	51
3000	526	73	72	70	69	67	66	64	62	60	58	55	73	71	70	68	66	64	62	60	57	54	50
3100	519	72	71	69	68	66	65	63	61	59	57	54	72	70	69	67	65	63	61	59	56	53	49
3200	513	71	70	68	67	65	64	62	60	58	56	53	71	69	68	66	64	62	60	58	55	52	48
3300	506	70	69	67	66	64	63	61	59	57	55	52	70	68	67	65	63	61	59	57	54	51	47
3400	500	69	68	66	65	63	62	60	58	56	54	52	69	67	66	64	62	60	58	56	53	50	46
3500	493	68	67	65	64	62	61	59	57	55	53	51	67	66	65	63	61	59	57	55	52	49	45
3600	487	67	66	64	63	61	60	58	57	55	52	50	66	65	64	62	60	58	56	54	51	48	44
3700	481	66	65	63	62	60	59	57	56	54	51	49	65	64	63	61	59	57	55	53	50	47	44
3800	474	65	64	62	61	59	58	56	55	53	51	48	64	63	62	60	58	56	54	52	49	46	43
3900	468	64	62	61	60	59	57	55	54	52	50	47	63	62	61	59	57	55	53	51	49	46	42
4000	462	63	62	60	59	58	56	54	53	51	49	46	62	61	60	58	56	55	52	50	48	45	41
4100	456	62	61	59	58	57	55	54	52	50	48	45	61	60	59	57	55	54	52	49	47	44	40
4200	451	61	60	58	57	56	54	53	51	49	47	45	61	59	58	56	55	53	51	49	46	43	39
4300	445	60	59	58	56	55	53	52	50	48	46	44	60	58	57	55	54	52	50	48	45	42	38
4400	439	59	58	57	55	54	53	51	49	48	45	43	59	57	56	55	53	51	49	47	44	41	38
4500	433	58	57	56	54	53	52	50	49	47	45	42	58	56	55	54	52	50	48	46	43	41	37
4600	427	57	56	55	53	52	51	49	48	46	44	41	57	55	54	53	51	49	47	45	43	40	36
4700	421	56	55	54	53	51	50	48	47	45	43	40	56	54	53	52	50	48	46	44	42	39	35
4800	415	55	54	53	52	50	49	48	46	44	42	40	55	53	52	51	49	48	46	43	41	38	34
4900	410	54	53	52	51	50	48	47	45	43	41	39	54	53	51	50	48	47	45	42	40	37	33
5000	405	53	52	51	50	48	47	46	44	42	40	38	53	52	51	49	48	46	44	42	39	36	33

Tafel 2:

63% (nach Tafel 1)	80%	75%	70%
110	[illegible]	[illegible]	112
109	109	110	110
108	108	109	109
107	107	108	108
106	106	107	107
105	105	105	106
104	104	104	105
103	103	103	103
102	102	102	102
101	101	101	101
100	100	100	100
99	99	99	99
98	98	98	98
97	97	97	97
96	96	96	95
95	95	94	94
94	94	93	93
93	93	92	92
92	92	91	91
91	91	90	90
90	90	89	88
89	88	88	87
88	87	87	86
87	86	86	85
86	85	85	84
85	84	84	83
84	83	82	82
83	82	81	80
82	81	80	79
81	80	79	78
80	79	78	77
79	78	77	76
78	77	76	75
77	76	75	73
76	75	74	72
75	74	73	71
74	73	71	70
73	72	70	69
72	71	69	68
71	70	68	66
70	69	67	65
69	68	66	64
68	67	65	63
67	65	64	62
66	64	63	61
65	63	62	60
64	62	60	58
63	61	59	57
62	60	58	56
61	59	57	55
60	58	56	54
59	57	55	53
58	56	54	51
57	55	53	50
56	54	52	49
55	53	51	48
54	52	50	47
53	51	48	46
52	50	47	45
51	49	46	43
50	48	45	42
49	47	44	41
48	46	43	40
47	45	42	39
46	44	41	38
45	43	40	36
44	41	39	35
41	41	38	34

Barometer mb	Spez. Gew. g/cm³	Förderbeginn s.t. °KW v.OT	AVL Graz-Austria
Rel. Luftfeuchtigkeit %	Meßmenge cm³	Förderpumpe	
Raumtemperatur °C	Motor.- Type	Düse	Meßblatt Nr. / Konto
Kraftstoff	Einspritzpumpe		Graz, am 19

Nr.	Zeit	$t_{Ein.}$ sec	$t_{öa}$ °C	Po bar	t_{KLe} °C	t_{KLa} °C	PL mbar	t_L °C	t_A °C	PA mbar		F N		T_B	n U/min	P_e kW	b_e g/kWh	p_e bar	B mm³/Hub	B kg/h	

MUSTER EINES PRÜFSTANDSMESSPROTOKOLLES
FÜR EINEN SELBSTANSAUGENDEN LUFTGEKÜHLTEN
DIESELMOTOR

Form 331

Barometer mm/Hg	Spez. Gew. g/cm³	Zündzeitpunkt stat.: °KW vOT	AVL Graz-Austria	
Rel. Luftfeuchtigkeit %	Meßmenge cm³	Förderpumpe		
Raumtemperatur °C	Motor - Type	Zündkerze	Meßblatt Nr.	Konto
Kraftstoff	Vergaser	Zündeinrichtung	Graz, am	19

Nr.	Zeit	t_{Pin} sec	t_{oa} °C	Po bar	t_{we} °C	t_{wa} °C	PL mbar	t_L °C	t_A °C	P_A mbar	α_{dyn} °KW	F N	CO %	T_B sec	n U/min	N kW	b_e g/kWh	Pe bar	β mm³/Hub	B kg/h	[illegible]

MUSTER EINES PRÜFSTANDSMESSPROTOKOLLES
FÜR EINEN SELBSTANSAUGENDEN WASSERGEKÜHLTEN
OTTOMOTOR

Form 131

Fig. 7

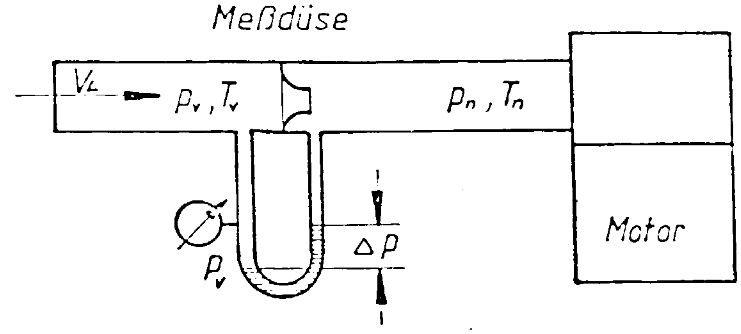


Fig. 8a

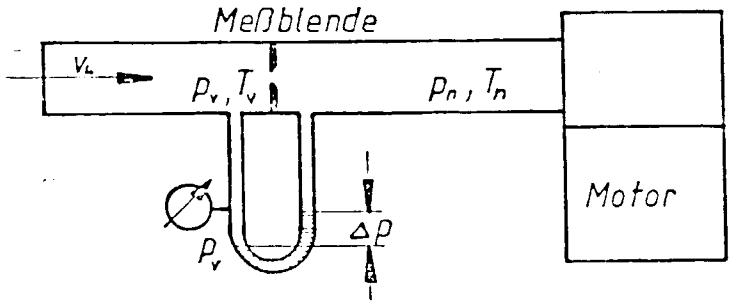


Fig. 8b

Eichung einer Meßdüse mittels Luftglocke:

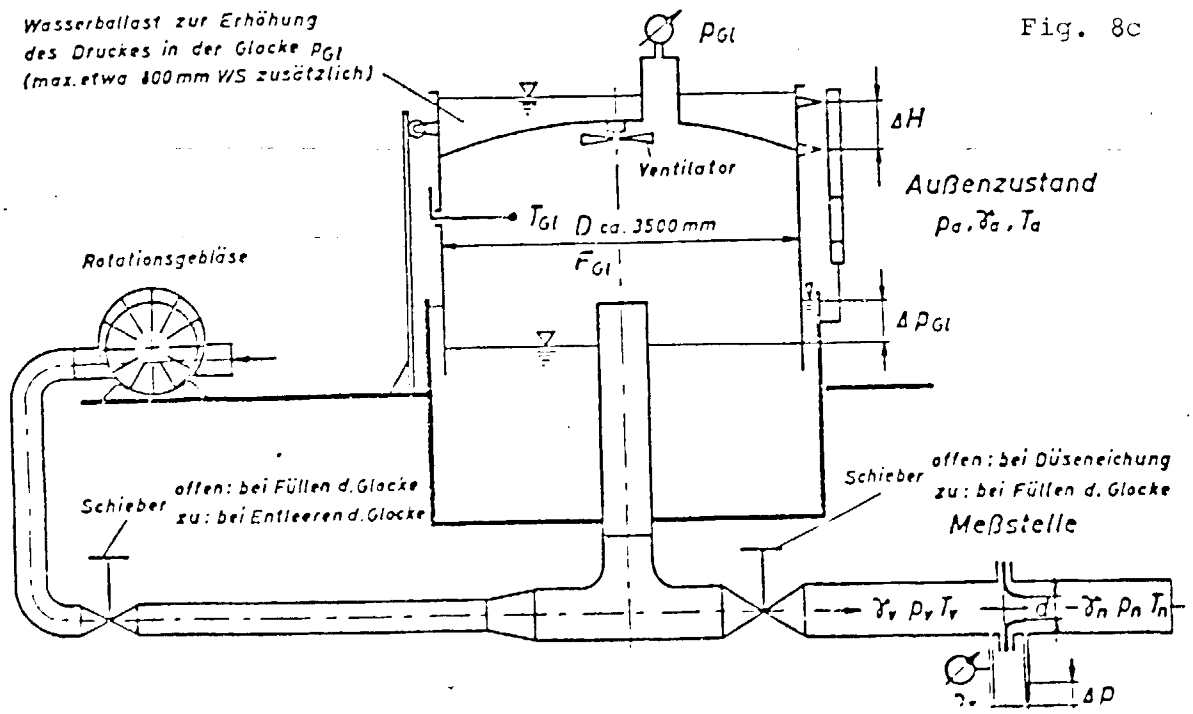
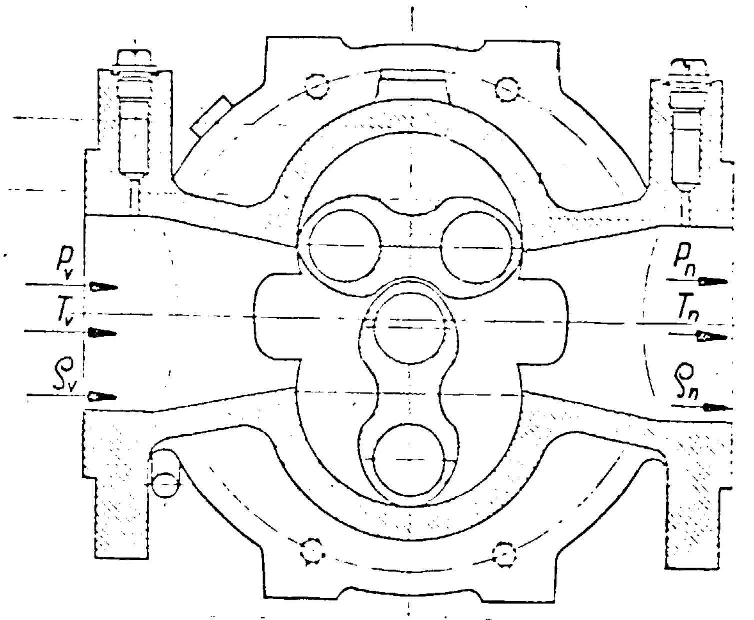


Fig. 8c

Drehkolbengaszähler

(Querschnitt)



PIEZOELEKTRISCHER EFFEKT DES QUARZES

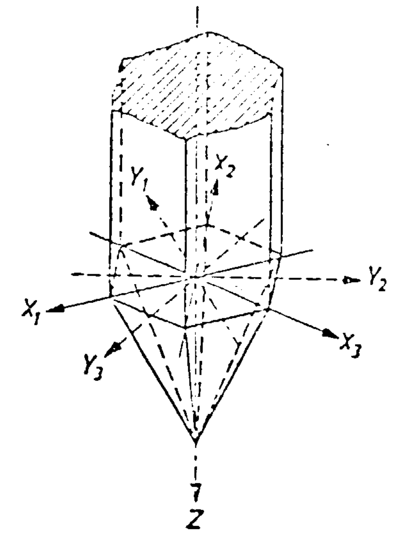


Bild 1

Schema eines Quarzkristalls

X_1, X_2, X_3 elektrische Achsen; Y_1, Y_2, Y_3 neutrale Achsen;
Z optische Achse (Kristall vereinfacht dargestellt)

Longitudinalquarz

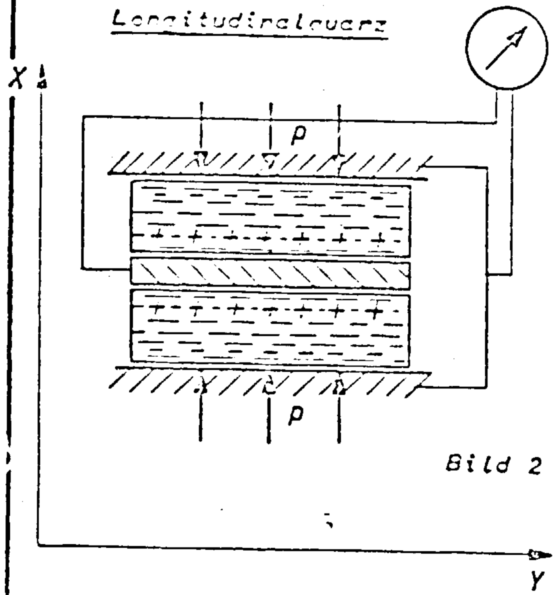


Bild 2

$$q = d_{11} \cdot p \cdot n$$

Transversalquarz

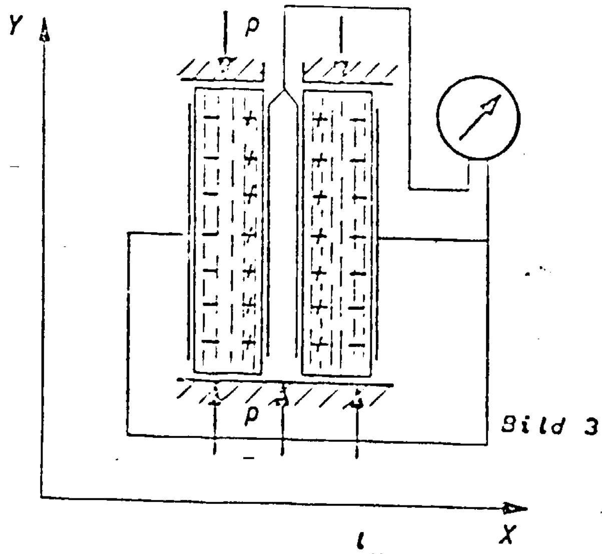


Bild 3

$$q = d_{11} \cdot p \cdot \frac{l_y}{l_x}$$

q spezifische Ladung

d_{11} piezoelektrische Zahl

n Anzahl der Quarzplatten

p Druck

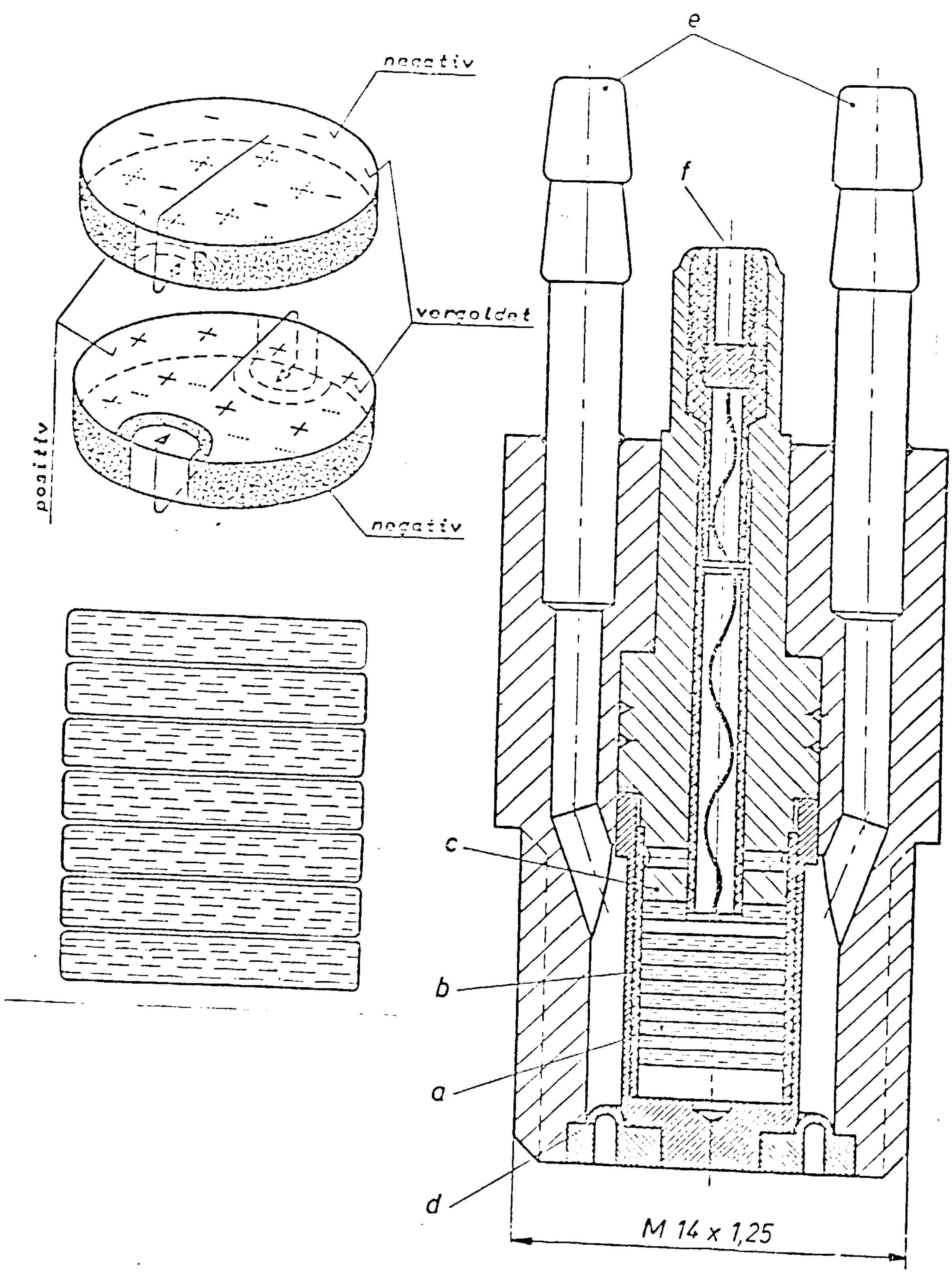
l_Y Ausdehnung in Y-Richtung

l_X Ausdehnung in X-Richtung

AVL Graz-Austria

Fig. 11

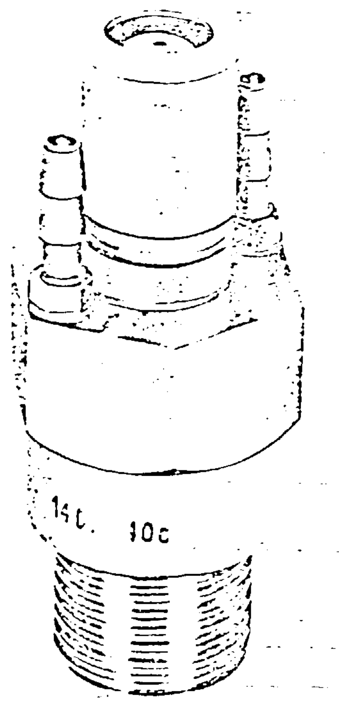
PIEZOQUARZWANDLER ZUR DRUCKMESSUNG

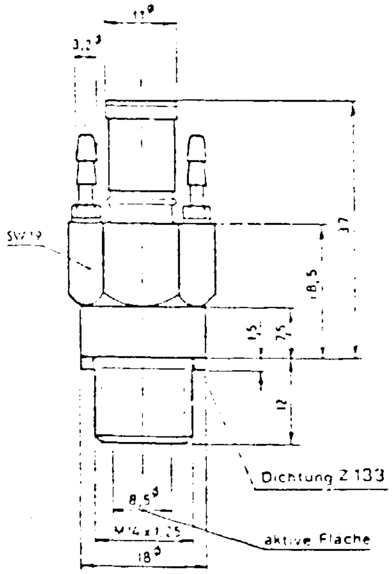


AVL Graz-Austria | Fig. 12

Dehnmeßstreifen-Druckgeber mit Wasserkühlung Typ 14 DP 240 c

Für Druckmessungen bei hohen Temperaturen in Verbrennungskraftmaschinen, Gasturbinen, Raketenbrennräumen usw.



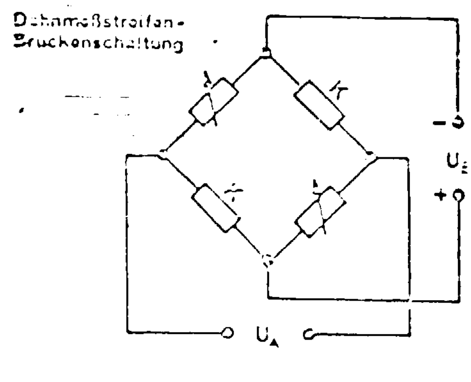


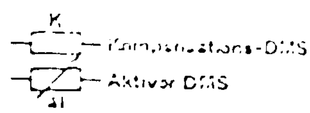
Besondere Kennzeichen:

- Messung statischer und dynamischer Drücke
- Hohe Eigenfrequenz
- Intensive Wasserkühlung, deshalb geeignet für mittlere Gastemperaturen bis 1000° C
- Kleine Einbaumaße
- Bündige Membran
- Material: Chromnickelstahl

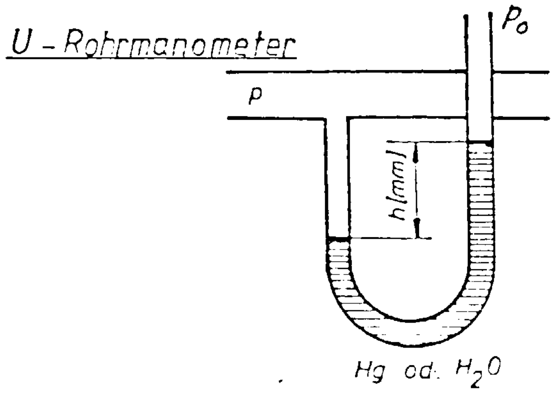
Arbeitsprinzip

Der zu messende Druck wird über die Membranfläche integriert und die resultierende Kraft auf den Meßkörper übertragen. Durch die dabei auftretende sehr kleine Verformung des Meßkörpers wird die Dehnmeßstreifen-Brücke verstimmt; die Spannung an der Brückendiagonalen (Ausgangsspannung) ist dem zu messenden Druck proportional.



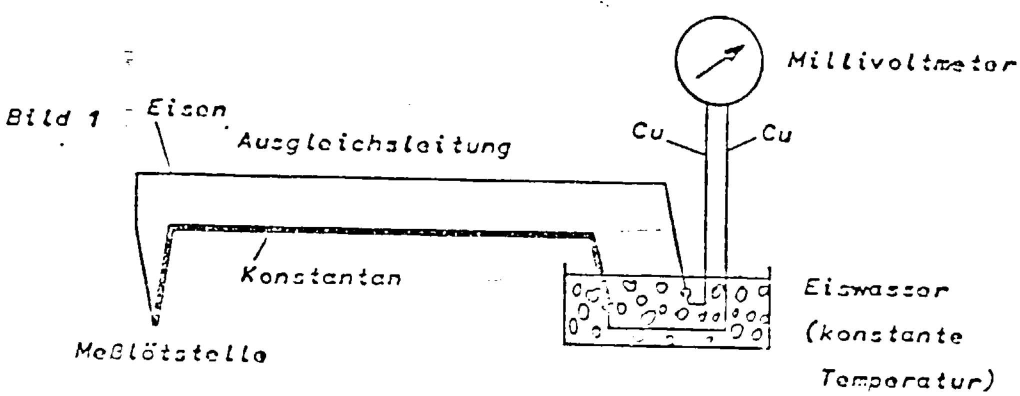


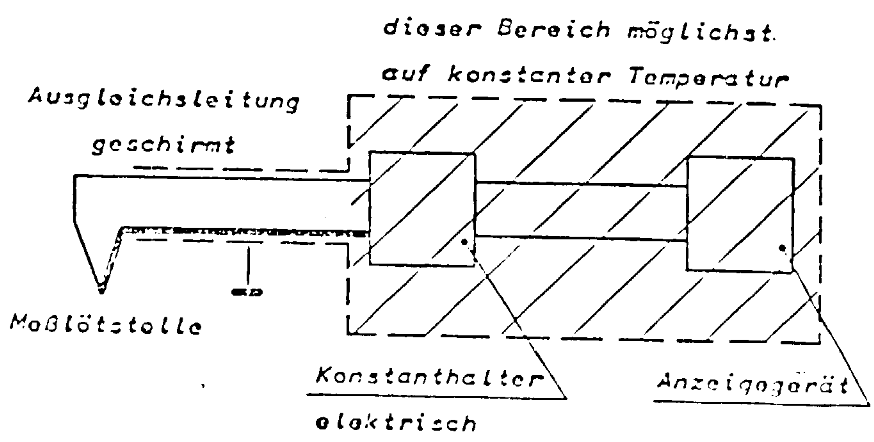
Schematische Darstellung eines
U-Rohr-Manometers



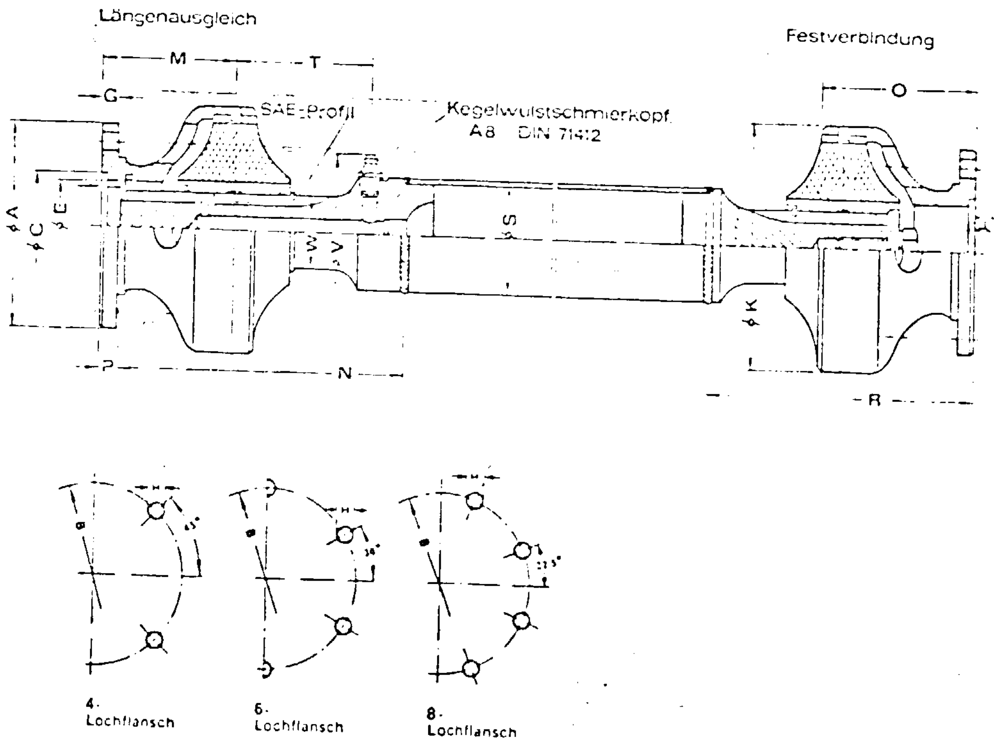
TEMPERATURMESSEN MIT THERMOELEMENT

z.B. Eisen - Konstantan





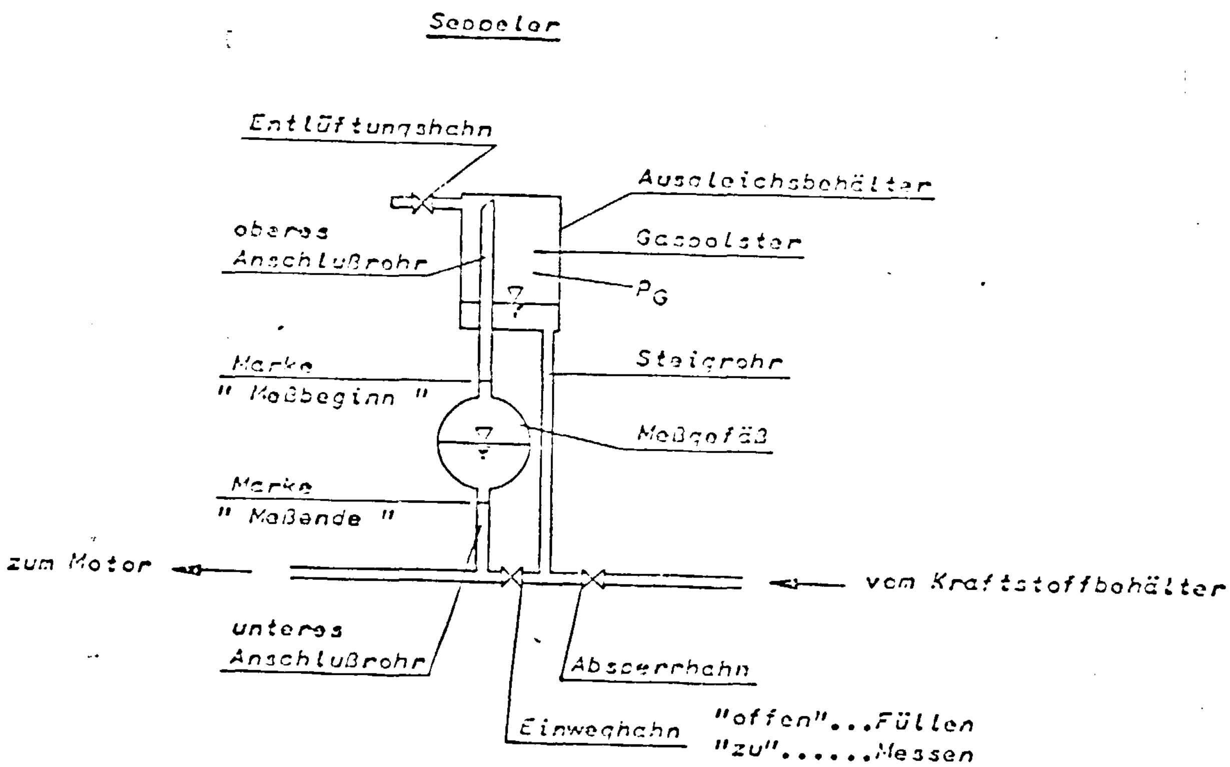
Elastikwelle mit Längenausgleich, Rohrausführung



AVL Graz-Austria		Fig. 16

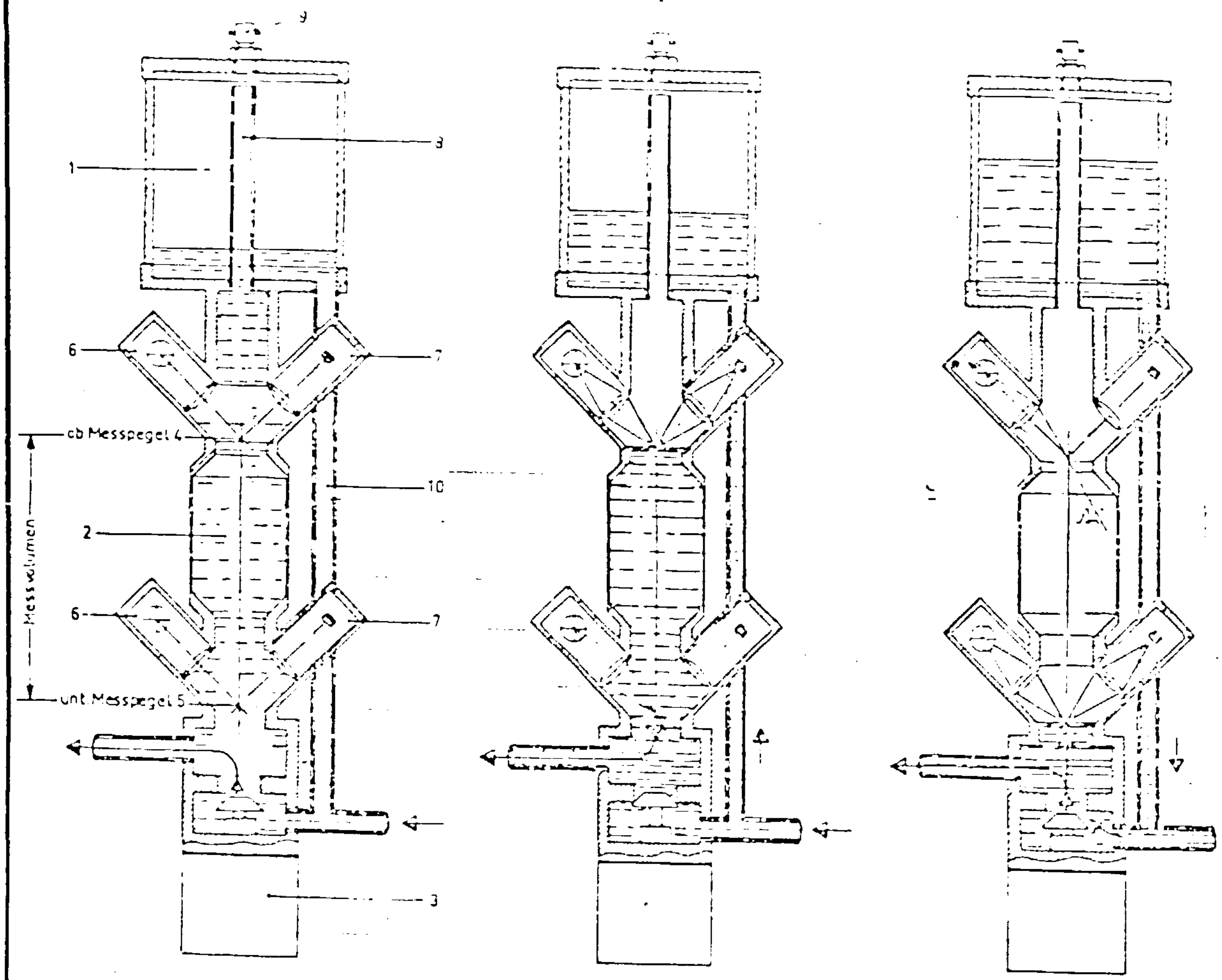
Volumetrische Kraftstoffverbrauchsmessung

Schema



Graz-Austria	Volumetrische Kraftstoffverbrauchsmessung Seppeler	Fig. 17

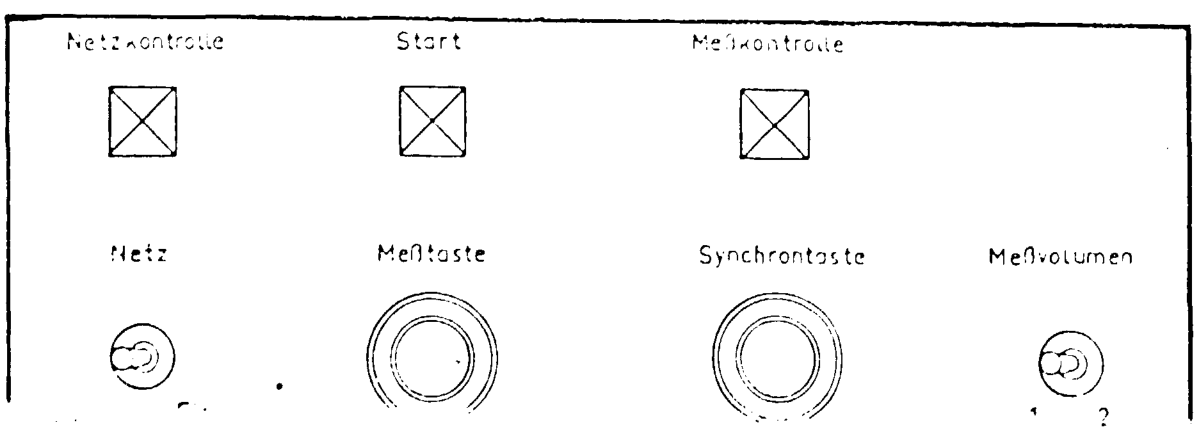
Meßgerät



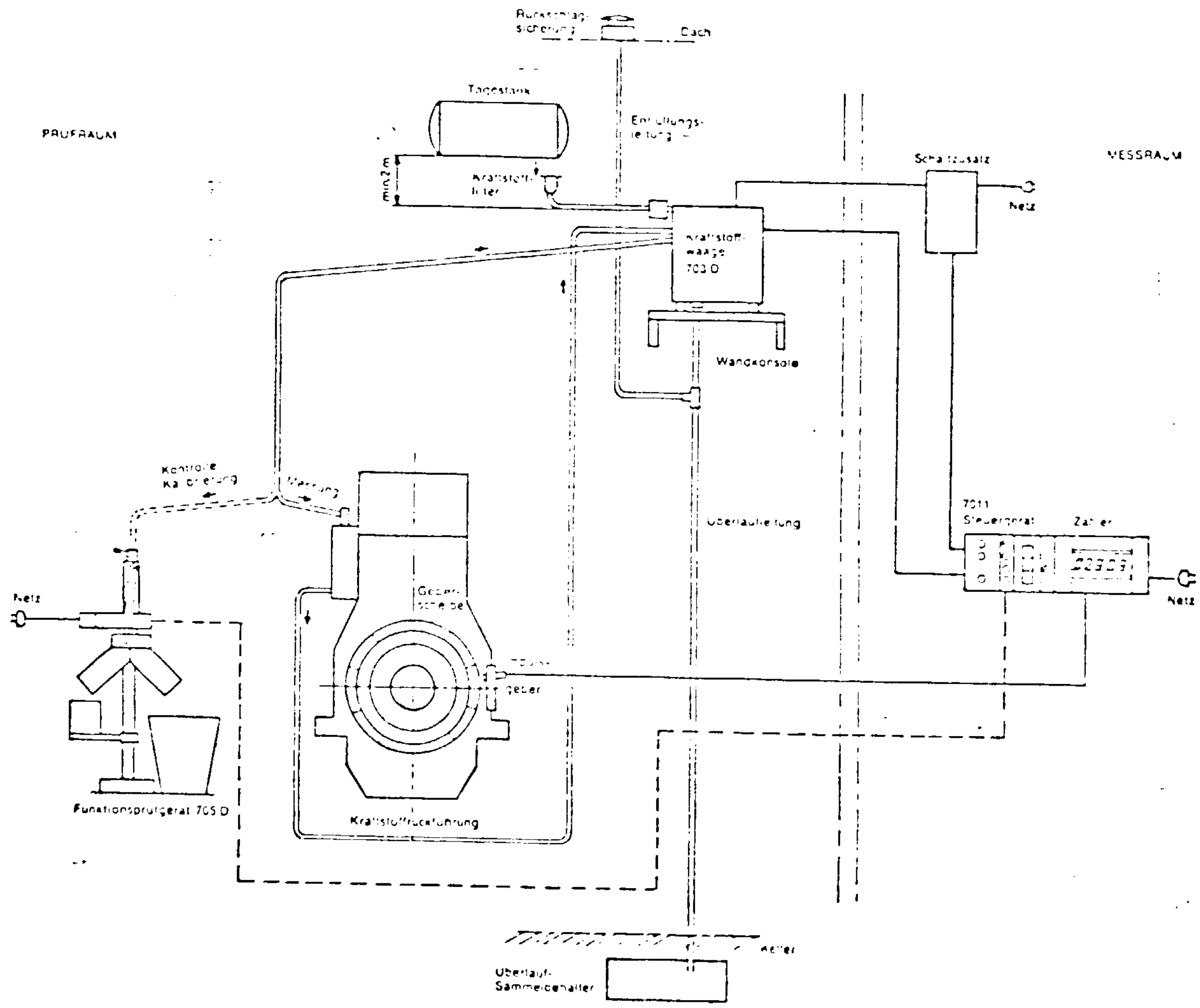
Freier Durchfluß — Meßbeginn — Meßende

1	Ausgleichsbehälter	6	optische Achsen
2	Meßgruppe	7	optische Achsen
3	Magnetventil	8	Luftrohr
4	oberer Meßpegel	9	Entlüftungsventil
5	unterer Meßpegel	10	Pendelleitung

Schaltgerät



AVL-GRAVIMETRISCHE KRAFTSTOFFVERBRAUCHS-MESSEINRICHTUNG SYSTEM 700



Spez. Kraftstoffverbrauch

$$b_e = 4{,}3\cdot 10^4 \cdot \frac{G}{U\cdot P\cdot l} \quad \frac{g}{PSh}$$

P Lastanzeige an der Bremseinrichtung (kp)
U Umdrehungen während der Meßzeit
G Meßgewicht an der Kraftstoffwaage (g)
l Hebelarm der Bremse (m) (im allgem. 0,7162 m)

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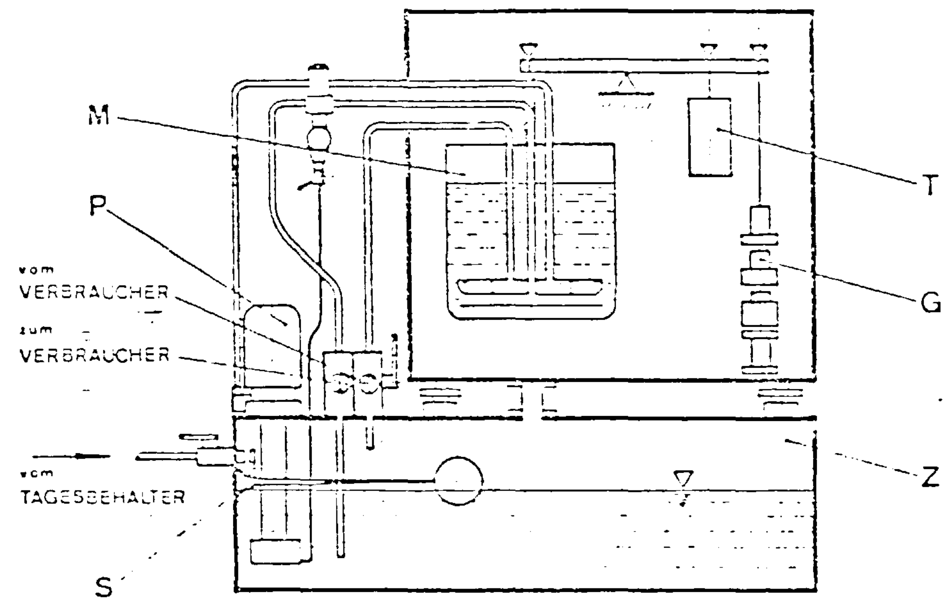
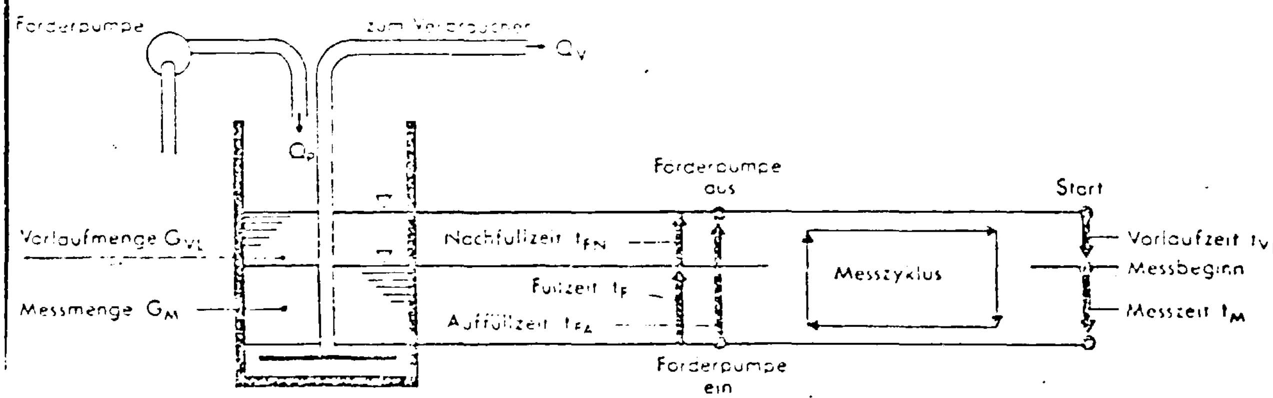
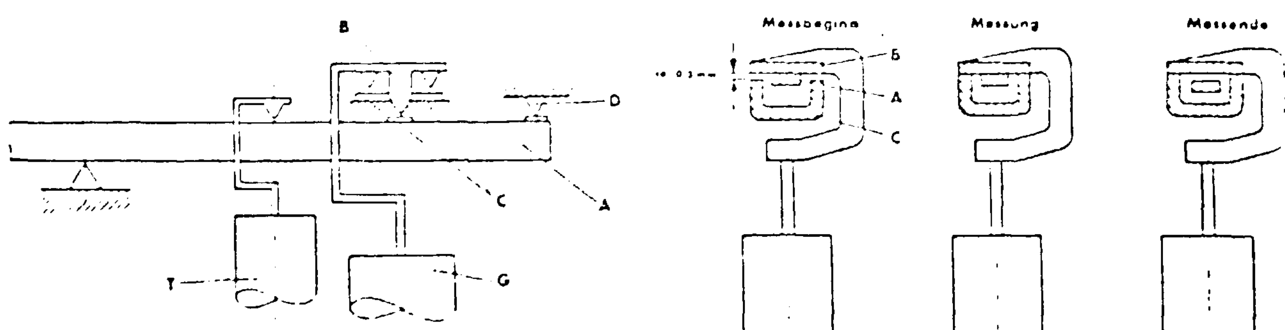
Fig. 19

Kraftstoffverbrauchsmeßeinrichtung



Kraftstoffwaage 702G





A = Waagebalken
B = Schneide d. Messgehänges
D = Kontakt
G = Messgehänge

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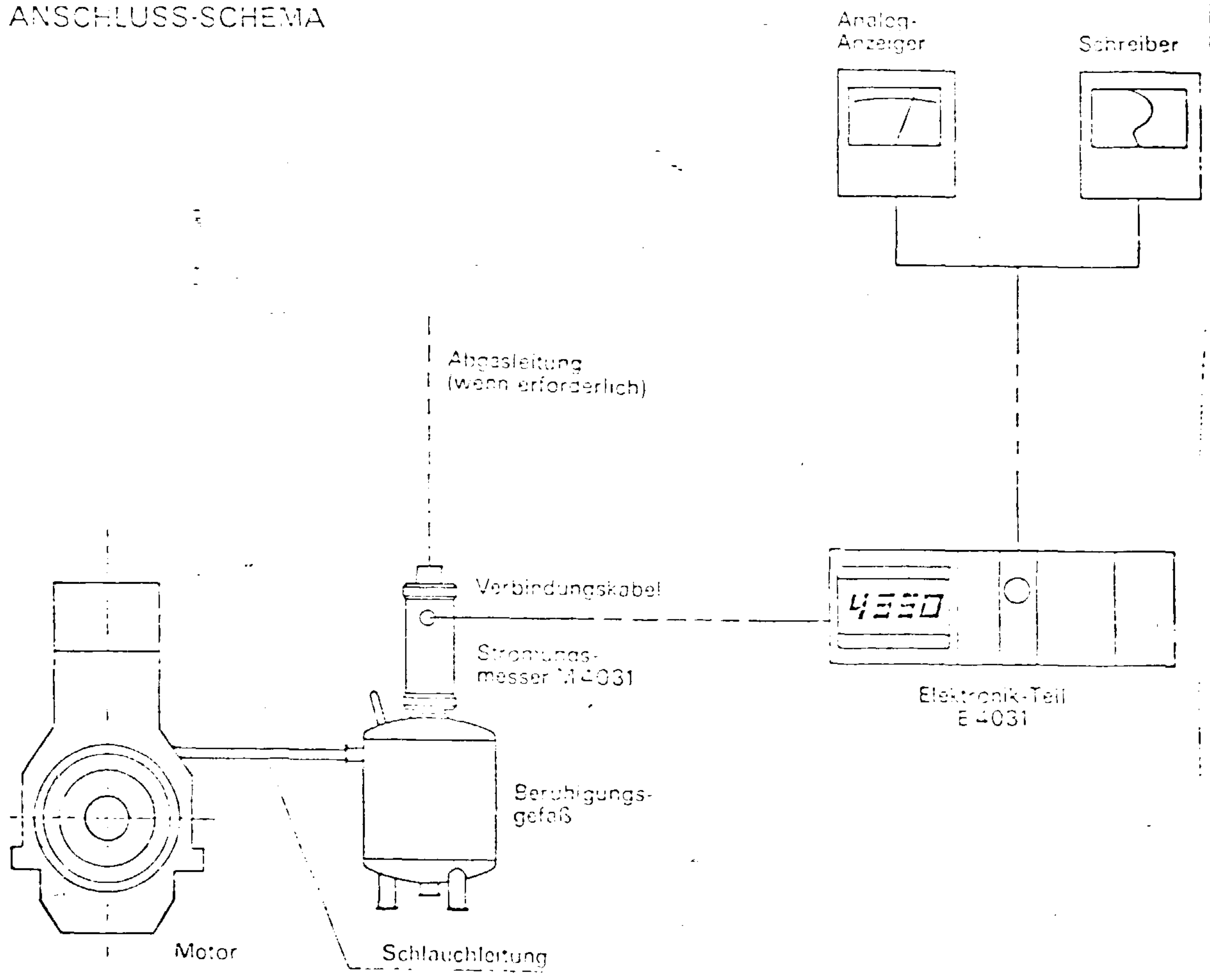
Fig. 20

AVL - Durchblasemengenmeßgerät
(Blow-by-Meter)

ANSCHLUSS-SCHEMA



Graz-Austria

1983-04-19

BRIEF DESCRIPTION

AVL HIGH PRESSURE INDICATING EQUIPMENT HP 306

The High Pressure Indicating Equipment permits examination of combustion and injection line pressure diagrams and, if suitably equipped, of nozzle needle and/or valve lift diagrams relating to internal combustion engines, with simultaneous indication of crank degree marks.

The pressure diagram is an important aid for research and development work on internal combustion engines. It provides detailed information on the combustion process in the cylinder and permits separating the thermodynamic losses from losses due to friction. Valuable conclusions on physical stress of the individual engine parts and on noise generation during combustion may also be derived from the pressure diagram. In addition, evaluation of these diagrams provides valuable information on the qualitative combustion progress, the control of which represents a major part of the possible means for improvement on today's engines.

Equipped with the necessary supplements, the High Pressure Indicating Equipment may also be used for simultaneous indication of the pressure response in the injection line of a diesel engine, as well as nozzle needle and/ or valve lift curves. (Inductive pick-up principle).

Principle of operation

AVL quartz pressure transducers (high pressure piezo-transducers) are used for pressure measurement purposes. Owing to their high natural frequency, high measuring accuracy and linearity these transducers are idealy suitable for measurement of dynamic pressures with high amplitude and high frequency.

/ 2 ....

The electrostatic charge derived from the quartz pressure transducers is converted into a voltage being in linear proportion to the pressure, by means of the charge amplifier 3059B-A02 (the charge amplifier may be considered as an impedance converter with subsequent amplifier). The output of the charge amplifier is connected to the oscilloscope. For determination of the pressure scale on the oscilloscope a calibrating unit 3054-A01 is provided which generates exactly defined calibrating charges.

Inductive displacement transducers in half bridge measuring circuit are used for indicating nozzle needle and/or valve lift. The carrier amplifier 3075-A02 generates a stabilized 100 kHz carrier frequency for supply of the displacement transducer. This carrier is subsequently modulated in the transducer by the measuring signal. After amplification of the modulated carrier in the carrier amplifier the measuring signal is filtered out (carrier supression). The output of the carrier amplifier is connected to the oscilloscope. Static calibration principle is used to calibrate the displacement indicating device.

In addition to the pressure diagram, it is necessary to display crank angle marks. As the angular speed of the crank shaft is not uniform over 1 revolution, time proportional sweeping of the cathode ray would not guarantee a correct relationship between crank angle and scale divisions on the screen. The configuration AVL signal generator wheel 330 E, AVL electro-magnetic pulse pick-up 333 and the crank degree marking unit 3010-A01 permits the display of true crank angle marks independent of speed variations. The electromagnetic pulses generated by the pulse pick-up are fed to the conditioning circuit of the crank degree mark unit, the output of which is connected to a charge amplifier via a switching device or, if available, to a free channel of the oscilloscope.

/ 3 .....

A second pulse pick-up in conjunction with trigger unit 3012-A01 ensures speed synchronous triggering of the oscilloscope, in order to obtain a stationary pattern at any engine speed.

The equipment is designed for mains supply 110 V, 220 V or 240 V, 50 / 60 Hz. If no particular mains voltage is specified with order, standard equipment for 220 V/ 50 Hz will be supplied.

The electronic modules are housed in a 3 height units bench cabinet, having the following dimensions:

Width :		483 mm
Depth :		310 mm
Height:	approx.	150 mm

Some technical details of items not included in the general leaflets are outlined hereunder:

a) Basic Equipment

- 8 ZP 30 Adapter:
  will be supplied with a length of 152 mm

b) Additional Equipment (if provided)

- 7 ZP 65 Injection Line Adapter:
  Thread: M 14 x 1.5 (standard, if not particularly specified with order)
  Adapters with other thread dimensions are available alternatively: M 18 x 1.5 (7 ZP 66) or M 12 x 1.5 (7 ZP 67).

/ 4 ....

- Inductive Nozzle Needle Lift Transducer:

  Inductive plunger type armature system in half bridge measuring circuit.
  Specifications: see data sheet AVL 423 or AVL 424, (please specify required type with order).

  If no type is specified with order, the standard AVL type 424 will be supplied.

Remark:

Fitting the inductive nozzle needle lift transducer to the nozzle holder is not included in the prices.

- Inductive Valve Lift Transducer:

  Inductive plunger type armature system in half bridge measuring circuit.
  Specifications: see data sheet AVL 425.

Remark:

Fitting the inductive valve lift transducer to the valve/ cylinder head is not included in the prices.

- Oscilloscope:

  Four channel 50 MHz-oscilloscope mounted in a 3 hight units 19" bench cabinet, complete with multiplexer and time base and illuminated graticule.

- Camera:

  Special Polaroid camera with hinged mounting frame, suitable to fit a.m. oscilloscope. Supplied with 10 Polaroid films.

/ 5 ....

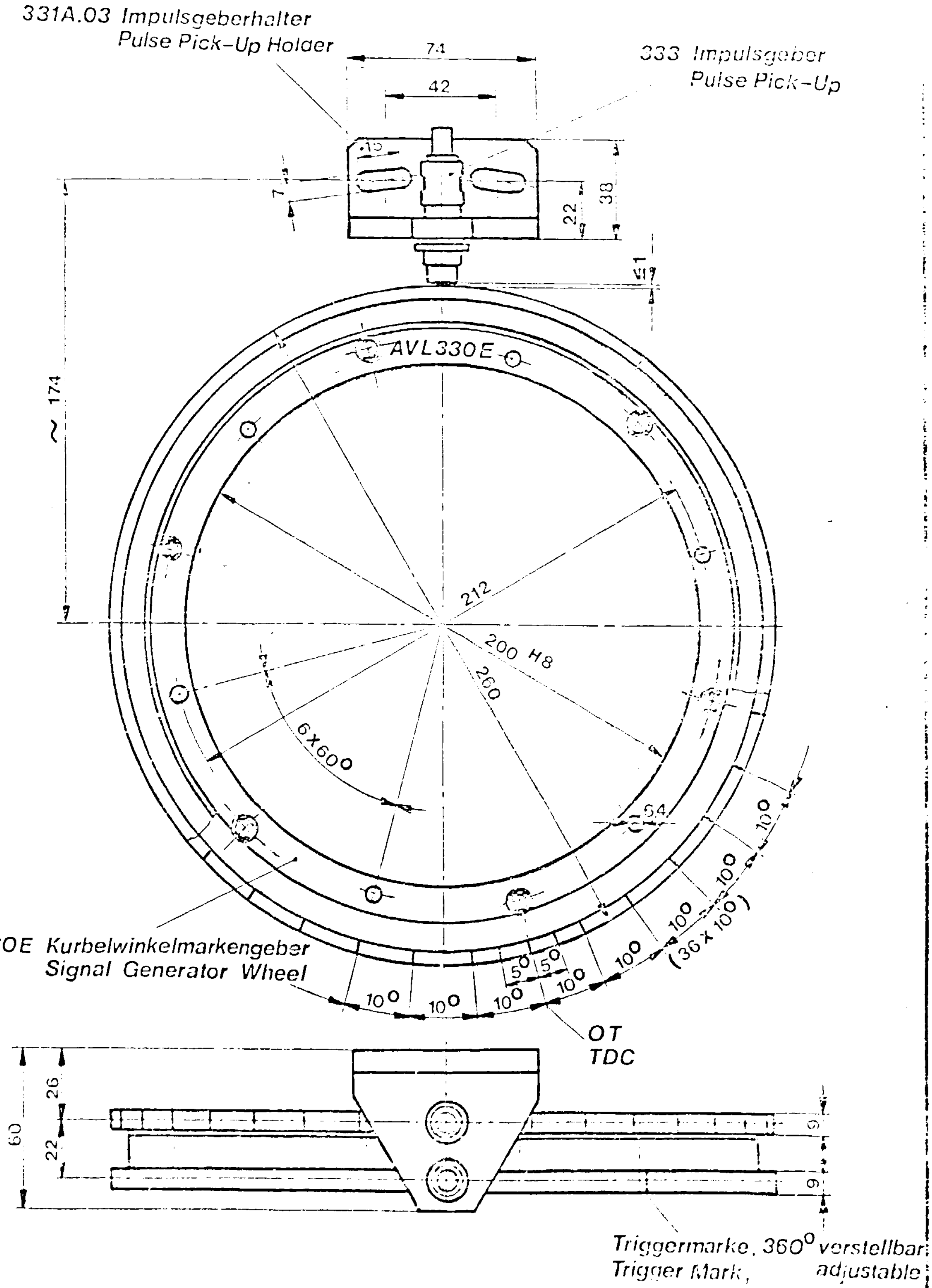
Remark to adapting of nozzle needle lift and valve lift transducers

We would be pleased to quote for these services on receipt of the following information/ material:

Nozzle Needle Lift: Detailed information (drawings or a sample nozzle holder) for the injection nozzle holder.

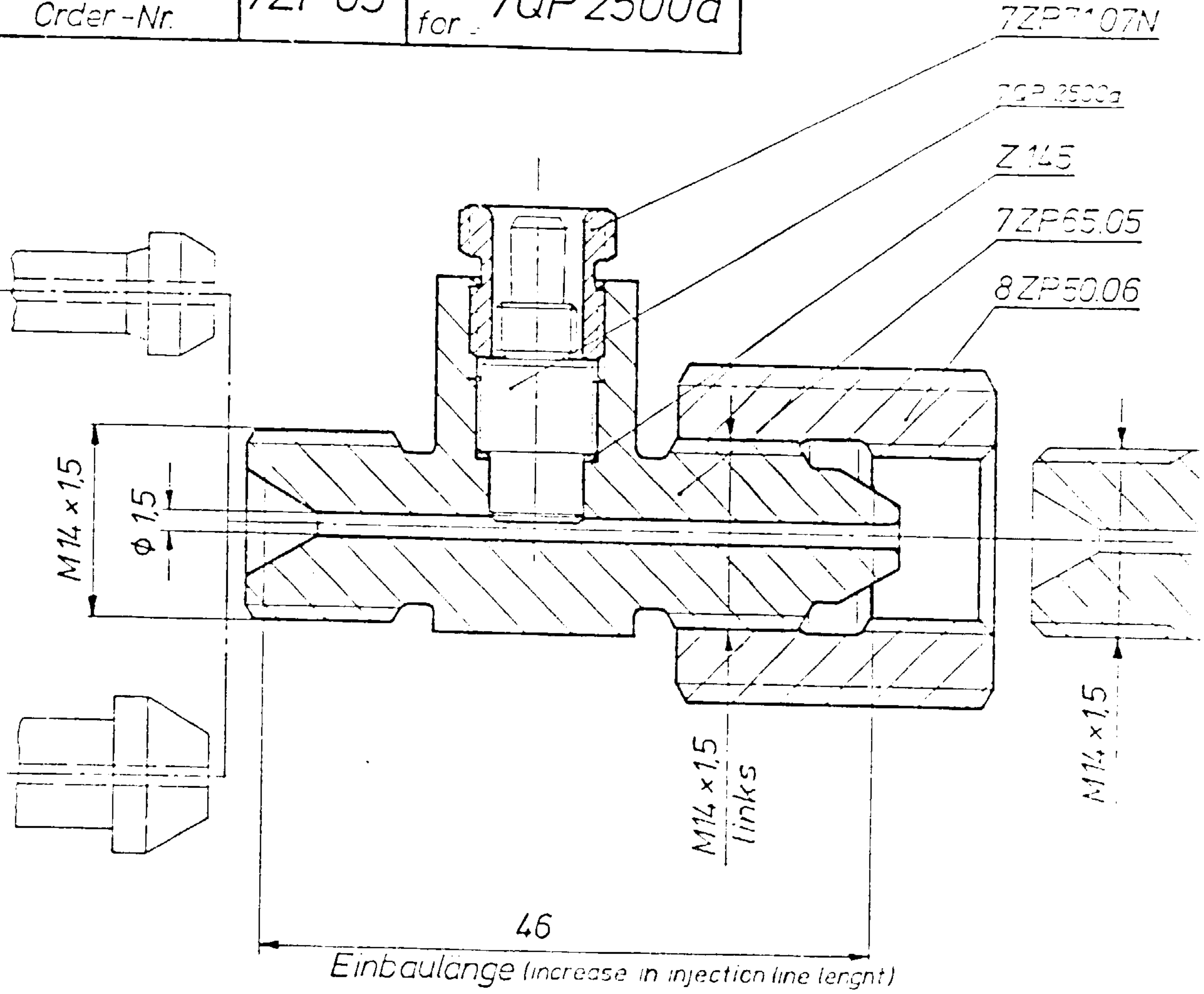
Valve Lift: Detailed information (drawings or one sample cylinder head with valves) for cylinder head and valve guide.

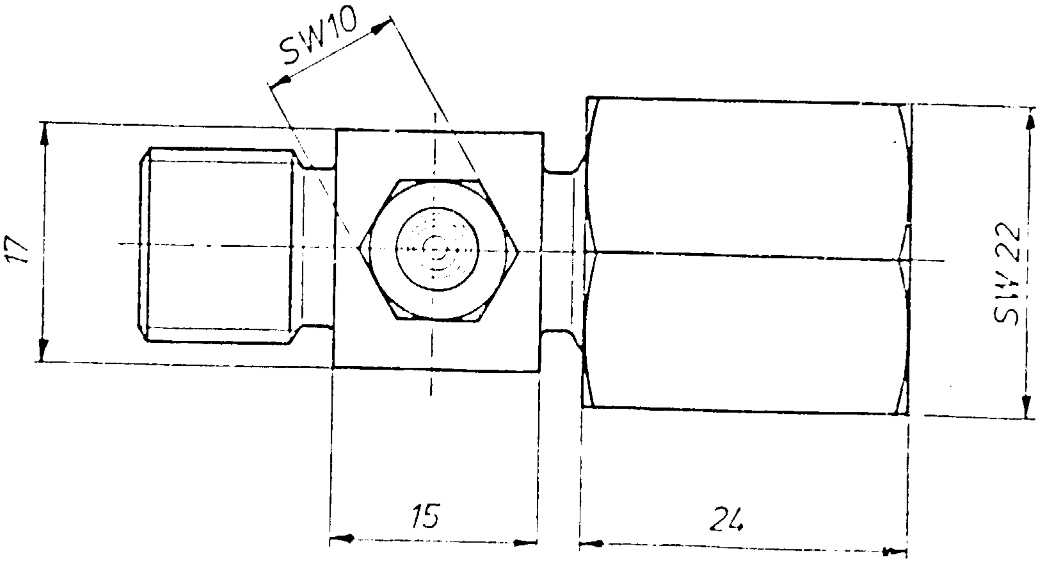
AVL Graz-Austria	KURBELWINKELMARKEN- u. TRIGGER-GEBEREINRICHTUNG CDM-and TRIGGER GENERATOR UNIT	FM 1146 V



AVL Graz-Austria	Einspritzleitungsadapter (Special Injection Line Adapter) Druckrohranschluß nach DIN 73 365 (60°Dichtkonus) (Pressure connection acc. to DIN 73 365 (60°sealing cone)	FM 1636

Bestell-Nr. Order-Nr.	7ZP65	für for	7QP 2500a



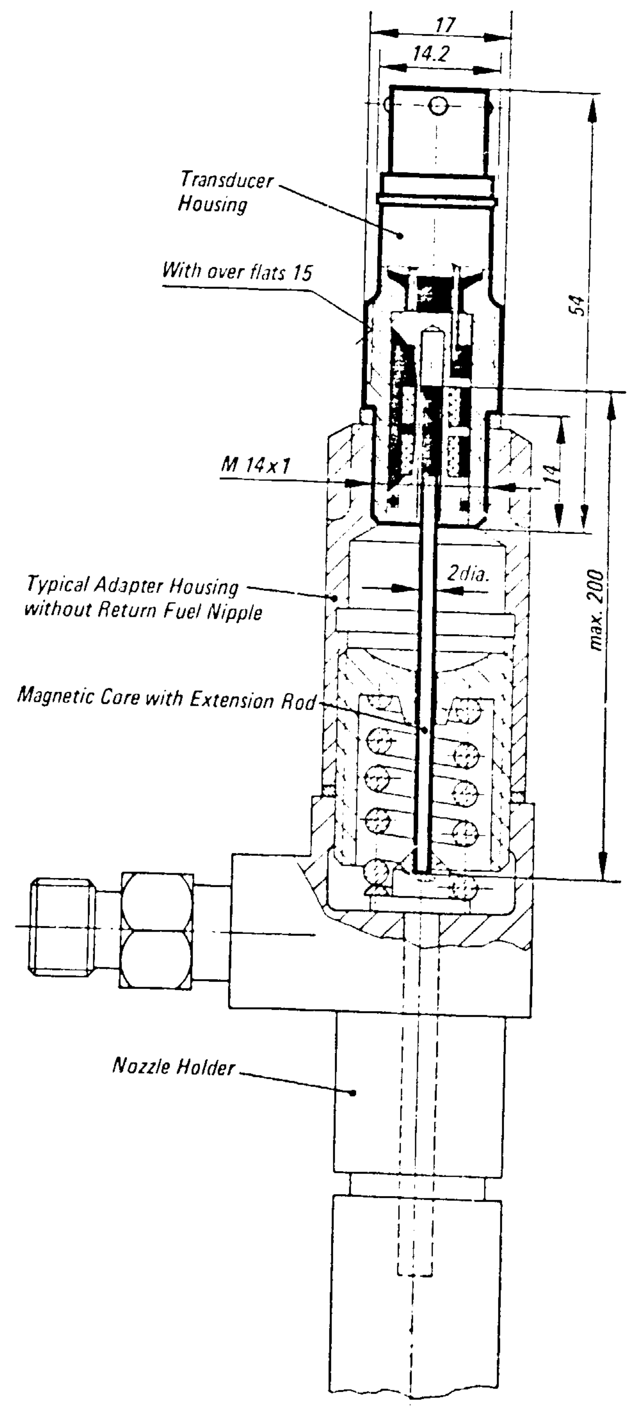


424 INDUCTIVE NOZZLE NEEDLE LIFT TRANSDUCER

For measurement of nozzle needle lift in nozzle holders with spring located at the top. Suitable for operation in conjuntion with a suitable adapter and AVL Type 3075–A02 Carrier Amplifier.

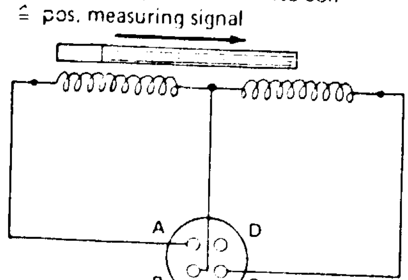
SPECIFICATION

Principle	:	inductive lift transducer half-bridge circuit
Supply	:	max. $12V_{pp}$ at 100kHz ± 10kHz (supplied by 3075-A02 Carrier Amplifier)
Inductance	:	2 x 140 μH
Sensitivity	:	approx. 1V/0.1mm lift at output of 3075-A02 max. gain
Max. Lift	:	± 1mm
Linearity Error	:	< 0.5% up to ± 0.8mm lift
Permissible Temperature at Connector	:	+ 80 °C
Weight of Core	:	approx. 5.1g at 200mm length
Connection	:	4-pin Bendix PTIH-8-4P
Connection Cable	:	E 1946–10 (10m long) E 1946 -S (special length)



Dimensions in mm

Direction of penetration into coil
≙ pos. measuring signal



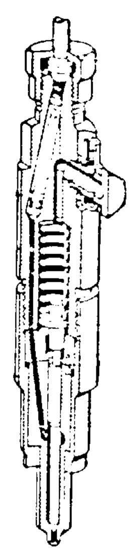
Operating Manual
Instructions on mounting and adjusting
AVL Type 423 and 424 inductive nozzle
needle lift transducers to the nozzle holder

Printed in Austria by AVL

Issued: December 1981

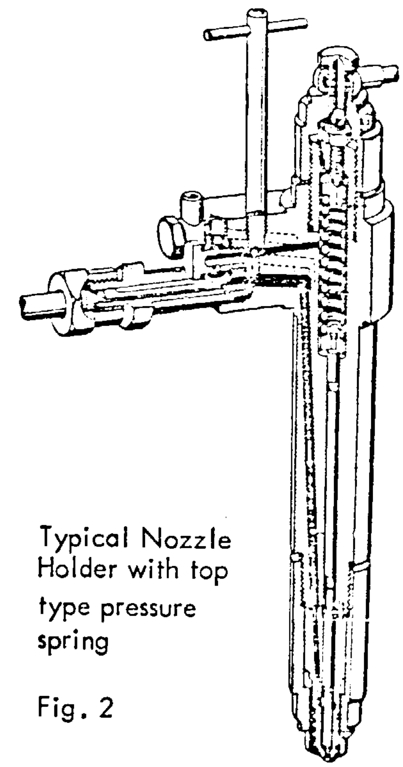
INSTRUCTIONS ON MOUNTING AND ADJUSTING INDUCTIVE NOZZLE NEEDLE LIFT TRANSDUCERS AVL TYPE 423 AND 424 TO THE NOZZLE HOLDER

The AVL type 423 and 424 nozzle needle lift transducers are basically suitabel for mounting to nozzle holders with the spring located on top as shown in fig. 2.
They are not suitabel for mounting to nozzle holders where the spring is located at the bottom (see fig. 1).



Typical Nozzle Holder with bottom type pressure spring

Fig. 1



Typical Nozzle Holder with top type pressure spring

Fig. 2

The AVL 423 and 424 nozzle needle lift transducers are mounted to the setting nut (5) of the nozzle holder by means of a suitable adapter (2). Depending on the design of nozzle holder this adapter must be equipped with a fuel return connector (9).

In the interest of extended life time the instrumented nozzle holder should be used for the duration of the actual needle lift measurement only.

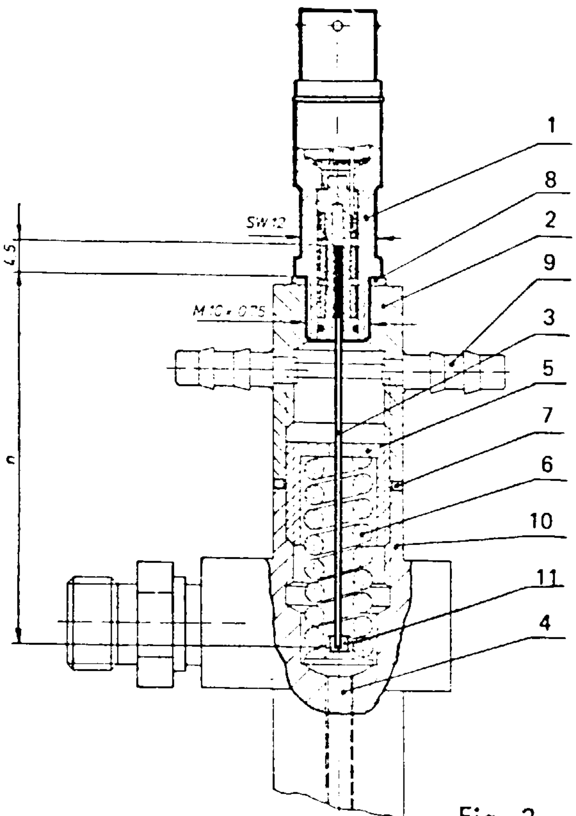


Fig. 3

AVL 423 typical mounting example using adapter <u>with</u> fuel return connector

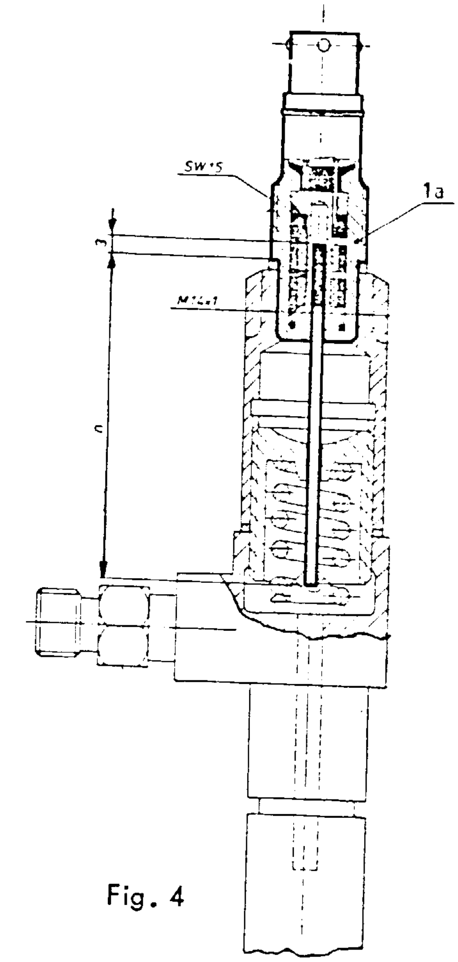


Fig. 4

AVL 424 typical mounting example using adapter <u>without</u> fuel return connector

1. Nozzle needle lift transducer AVL 423
1a Nozzle needle lift transducer AVL 424
2. Adapter
3. Extension rod with magnetic core
4. Spindle
5. Setting nut
6. Pressure spring
7. Gasket (nozzle holder)
8. Gasket (Transducer)
9. Fuel return connector (if necessary)
10. Nozzle holder body
11. Reduction sleeve (if necessary)

The AVL Types 423 and 424 nozzle needle lift transducers differ in mounting thread and in dimensions of the core with extension rod. Due to its heavy duty design, the type 424 transducer (mounting thread M14 x 1 and 2 mm core extension rod diameter) should be used wherever possible. The type 423 transducer features smaller dimensions (mounting thread M10 x 0.75) and lower mass of core with extension rod (according to 1 mm diameter) and is therefore suitable for smaller types of nozzle holders.

Precise measurement of the nozzle needle lift is guaranteed only when the following instructions are adhered to:

The core with extension rod (3) must be mounted to the spindle (4) stable and vibration-proof paying due regard to correct axial alignment. The length of the extension rod should be carefully chosen so that the core positioned in the coil is magnetic/electrically balanced.

Composition of AVL Type 423 and 424 Nozzle Needle Lift Transducers:

The AVL Type 423 and 424 nozzle needle lift transducers consist of the following items (see Fig. 3 and 4).

A) Transducer housing
It contains the transducer coil and the connector for the connection cable.

B) Core
It consists of an extension rod with excessive length fitted with the magnetic core. To avoid that the extension rod is cut on the wrong end the correct side of the rod (opposite to the magnetic core) is flattened.

Mounting the needle lift transducers AVL Type 423 or 424 to a suitable nozzle holder:

1. Remove the upper spring cover until the spindle (4) that connects down to the nozzle needle is accessible. Remove spindle from nozzle holder.

2. Machine spindle (4), as shown in fig. 5, using drills suitable for hard material.

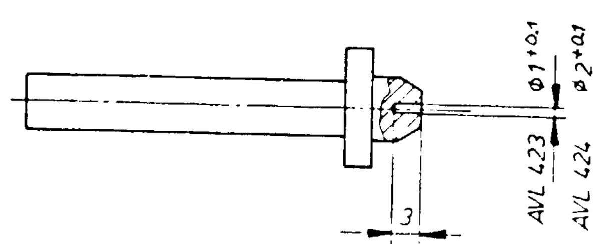


Fig. 5

If the spindle is already equipped with a drilling bigger than $2^{+0.1}$ mm Ø or $1^{+0.1}$ mm Ø, a reduction sleeve (11) must be provided. This sleeve equipped with the drilling as shown in fig. 5, must be inserted centric and brazed into the spindle.

3. If the setting nut (5) of the nozzle holder is not equipped with a drilling sufficiently large to allow free passage of the extension rod with magnetic core (3), it must be drilled accordingly. If a slot is provided for screwdriver-operated adjustment of the opening pressure, this slot may have to be enlarged to permit easy adjustment with the core fitted.

4. Insert the setting nut (5) prepared in this manner into the nozzle holder without pressure spring (6) to a position where approx. 8 - 10 mm thread protudes from the nozzle holder.

5. Manufacturing a suitable adapter (2):
Manufacture a suitable adapter that matches the thread of the setting nut (5) of the nozzle holder on one side and has a M 10 x 0.75 thread on the other side for accomodating the AVL Type 423 transducer (or a M14 x 1 thread for the Type 424 transducer). Depending on the design of the nozzle holder this adapter may need to be equipped with a fuel return connector (9), see figs. 3 and 4.

6. Screw the adapter (2) together with the gasket of the nozzle holder (7) onto the setting nut.

7. Determine total length "L"
of core according to the following formula:

<u>AVL 423</u>: $L = n - \frac{h}{2} + 4.5$ <u>AVL 424</u>: $L = n - \frac{h}{2} + 3$

L .... Total length of core

n .... Length of core inside the nozzle holder and adapter. To determine this measure insert the machined spindle (4) into the nozzle holder, screw the adapter (2) with gasket (7) into position, place gasket (8) onto adapter and measure the distance from the upper surface of the gasket (8) to the base of the spindle drilling.

h .... Nozzle needle lift. This value is either listed in the specification for the injection nozzle or must be measured at the nozzle.

3 / 4.5 ... Length of the core from the mounting base to the end of the core (in zero transition of discriminator), see fig. 3 and 4 .

Having determined h and n to an accuracy of 0.1 mm, the total length of core L may be determined by means of the above formula. Cut extension rod of core to length L at the flattened end.

8. Brazing the core to the spindle
Insert the extension rod of the core with the side that has been cut into the spindle which has been machined as outlined in point 2.

The magnetic core is on the other end of the rod (see fig. 6).

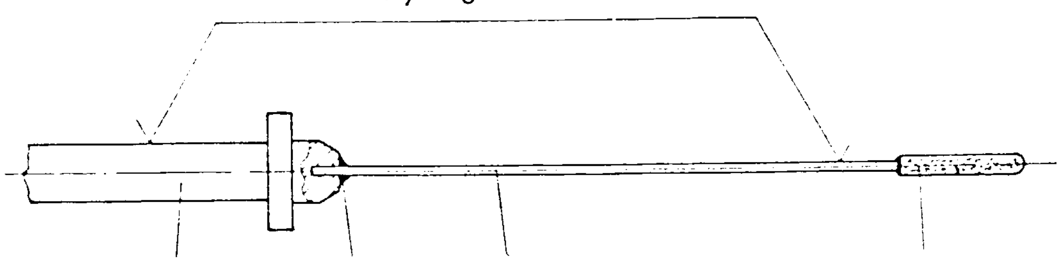


Fig. 6

Braze joint by means of silver braze. It is of particular importance that the axes of both parts are precisely aligned.

This is best achieved on a lathe where the spindle is fixed in the chuck and the core in an aligned drill chuck.

After completion of brazing and removal of the drill chuck the brazing joint should be carefully cleaned and the correct aligning of the spindle with the core should be checked by switching on the lathe.

9. After a final check of the length protuding from the spindle, the nozzle holder may be assembled, the opening pressure adjusted (setting - nut 5) and the nozzle needle lift transducer mounted. After the electric check (see following section) the system is ready for operation.

10. Checking the transducer for correct mounting
Having aligned the nozzle needle lift transducer in conjunction with the Carrier Amplifier AVL Type 3075-A02 (see operating instructions 3075-A02 Carier Amplifier) the final check for correct mounting of the nozzle needle lift transducer may be carried out.

Connect nozzle needle lift transducer to Carrier Amplifier and oscilloscope. Carefully manouver transducer housing over the magnetic core and screw it on to the nozzle holder / adapter. The electric signal on the screen will first go through a minimum and will then gradually approach zero point. The signal must not exceed the point (discriminator).

Any mistakes in measurement or machining resulting in either the minimum not being reached or in the zero point being exceeded may be compensated by fitting a flatter or higher gasket instead of gasket (8).

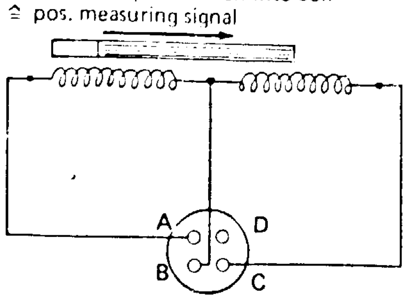
423 INDUCTIVE NOZZLE NEEDLE LIFT TRANSDUCER

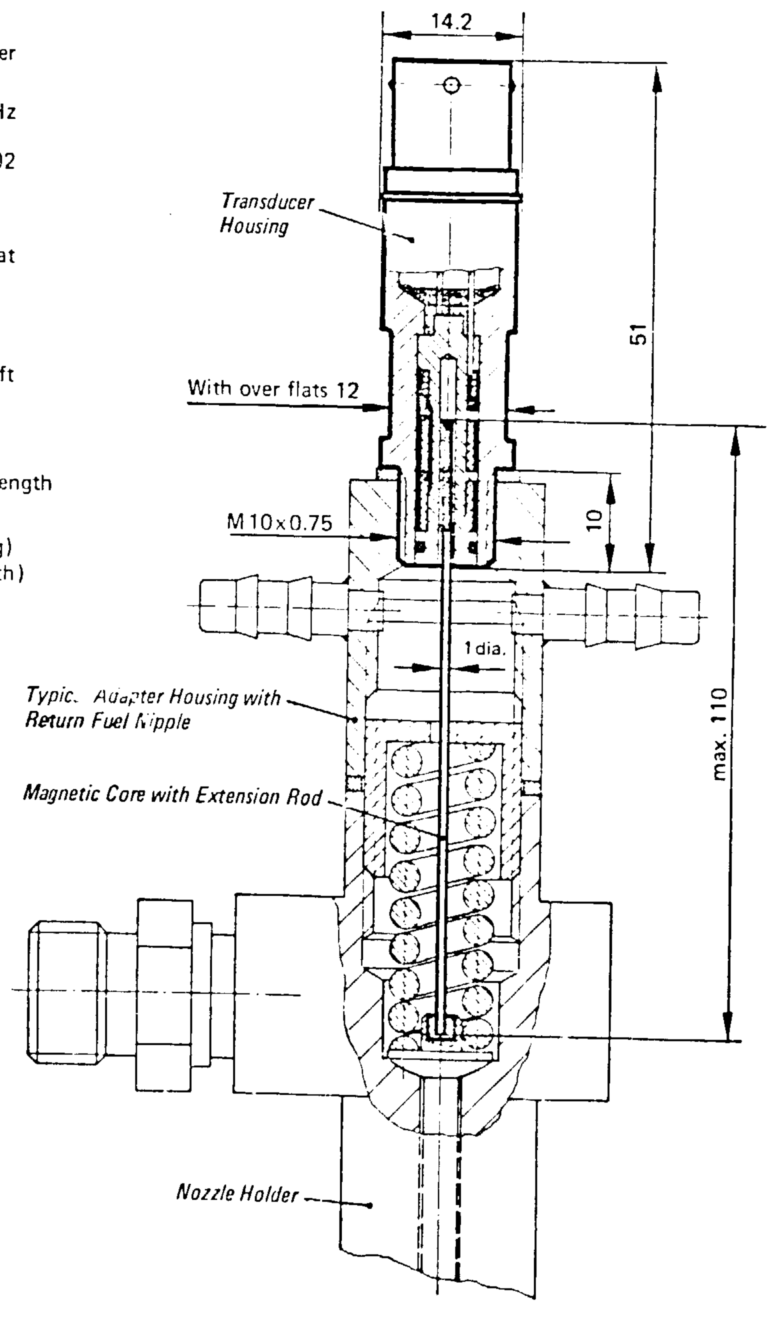
For measurement of nozzle needle lift in nozzle holders with spring located at the top. Suitable for operation in conjuntion with a suitable adapter and AVL Type 3075–A02 Carrier Amplifier.

SPECIFICATION

Principle	:	inductive lift transducer half-bridge circuit
Supply	:	max. $12V_{pp}$ at 100kHz ± 10kHz (supplied by 3075-A02 Carrier Amplifier)
Inductance	:	2 x 140 μH
Sensitivity	:	approx. 2V/0.1mm lift at output of 3075-A02 max. gain
Max. Lift	:	± 1mm
Linearity Error	:	< 0.5% up to ± 0.8mm lift
Permissible Temperature at Connector	:	+ 80°C
Weight of Core	:	approx. 0.7g at 110mm length
Connection	:	4-pin Bendix PTIH-8-4P
Connection Cable	:	E 1946–10 (10m long) E 1946–S (special length)

Direction of penetration into coil ≙ pos. measuring signal





Dimensions in mm

424 INDUCTIVE NOZZLE NEEDLE LIFT TRANSDUCER

For measurement of nozzle needle lift in nozzle holders with spring located at the top. Suitable for operation in conjuntion with a suitable adapter and AVL Type 3075–A02 Carrier Amplifier.

SPECIFICATION

Principle	:	inductive lift transducer half-bridge circuit
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Inductance	:	2 x 140 μH
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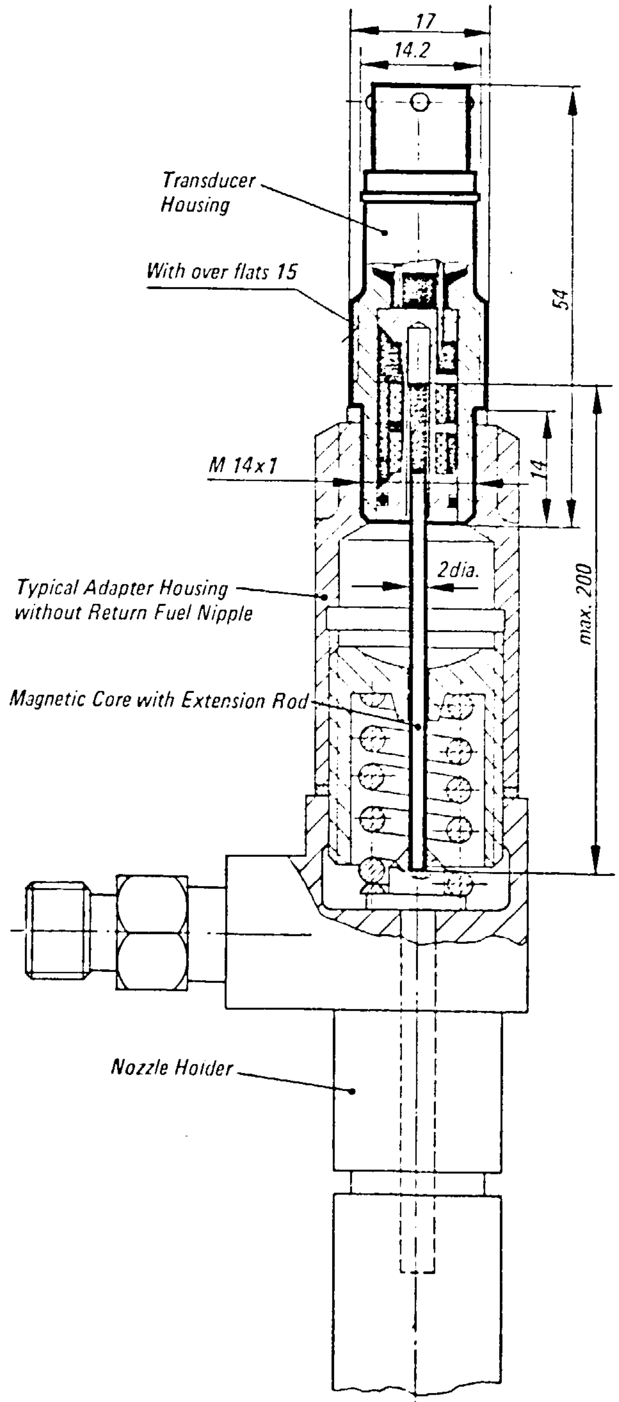
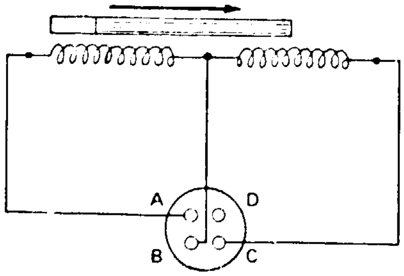
Max. Lift	:	± 1mm
Linearity Error	:	< 0.5% up to ± 0.8mm lift
Permissible Temperature at Connector	:	+ 80°C
Weight of Core	:	approx. 5.1g at 200mm length
Connection	:	4-pin Bendix PTIH-8-4P
Connection Cable	:	E 1946–10 (10m long) E 1946–S (special length)



Dimensions in mm

Direction of penetration into coil
≙ pos. measuring signal



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