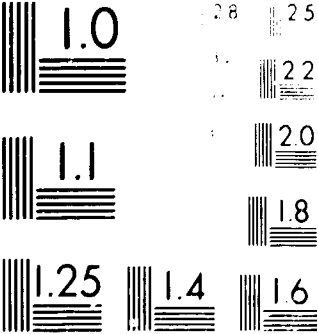
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TECHNICAL EVALUATION OF LOW POWER TRACTORS IN KENYA

US/KEN/78/268

REPUBLIC OF KENYA.

Technical report: Test code for the technical evaluation of low power tractors in Africa *

Prepared for the Government of the Republic of Kenya
by the United Nations Industrial Development Organization

Based on the work of D. Bordet of
the Centre d'Etudes et d'Expérimentation du Machinisme
Agricole Tropical (CEEMAT) under UNIDO subcontract No. 80/40 to CEEMAT

* The views expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO.

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INTRODUCTION

Before coming up with a low powered tractor test code suitable for African countries, it may be useful to justify the need for such a code when testing procedures already exist in OECD countries, and have been used satisfactorily for many years.

To begin with, the necessity for a specific code could well be due to the special working conditions of tractors in Africa as well as to the characteristics of the equipment to be tested or the facilities available.

The working conditions of tractors in Africa are not very different from those in temperate climate countries and the strain is no heavier. For example, the engine cooling systems are usually designed to cope with the hottest climates ; a high dust content in the air and fuel impurities - all of which are particularly applicable to Africa - are generally overcome by the Distributors by increasing the sizes of filtering systems. Never-the-less, some components like those in contact with the soil (tyres, tines, discs etc.) can get worn out very quickly in very abrasive soils. But the quick wearing of the motorized equipment in Africa, often ascertained, is mostly due to poor level of operation repair and maintenance and not to especially difficult conditions.

Therefore, there is no reason to demande more exact testing conditions for tractors in Africa than in developed countries.

The equipment that we plan to test is different from that tested in OECD centres. OECD tests are concerned with conventional tractors, but we are only concerned with small tractors, whose designs are simplified and sometimes unconventional. Even if the OECD testing procedures can be applied to most of the low powered tractors (fitted with a p.t.o.) some specific designs need specific methods of testing e.g. absence of p.t.o. shaft, hydraulic or belt transmission, non-standard linkage.

The testing facilities available in less developed countries are less important than those of OECD centres. The OECD test code requires a testing procedure and equipment that give exact accuracy, but this equipment is sophisticated and expensive. Moreover, part of these tests recreate artifical conditions which provide data of little use for the farmers of the technicians and engineers working with small tractors in Africa. We prefer to recreate testing conditions which are closer to the real working conditions of tractors in the field and are also less expensive.

The main purpose of testing procedures are :

- to measure the performance of a tractor in quantifiable as well as non-quantifiable terms

- in so doing, to be able to compare the performance of several tractors tested in the same conditions

- to be able to make the choice of the most suitable equipment, by appreciating its suitability to local conditions and its operating costs.

We consider the three following kinds of tests necessary to conform to these purposes :

Dynamometer Test

An absorption Dynamometer suitable for power take-off torque measurement is a reasonable investment which can be found in most of the African agricultural machinery testing stations

The data which is collected during the test - mainly power from the p.t.o. and fuel consumption - is the most comparable from one tractor to another, as there are few variable parameters interfering in the measurement.

Field Test

The drawbar pull test recommended by the OECD test code requires a tarmacadam track, not existing in most African testing stations and expensive to build. Moreover, the data obtained is artificial and does not take into account the general balance of the tractor and its implements during field work. This is the reason why we recommend a field test which provides much more useful data on the tractor working in real conditions - capacity of work, drawbar pull, ease of use, balance of tractor, limits of work etc..

Life Test

The life test is not included in the OECD procedures, but is never-the-less necessary to appreciate the reliability of the equipment and its suitability to various conditions.

I - PARAMETERS TO BE MEASURED AND TESTING METHODS

1. Description of the Tractor

A thorough examination of the different parts of the tractor - size, make, mode of operation - can give a first estimation of its expected performance.

For instance :

- from the number of cylinders, bore and stroke, ignition type - one can estimate the power at sea level
- the maximum drawbar pull is judged by the weight on driving wheels and the size of wheels
- the size of the hydraulic cylinder, maximum pressure and the speed of the pump and the geometry of the linkage indicate the lifting capacity

This data should be given by the manufacturer and checked by the testing officer. See Chapter III in a model of test report - the list of data to be collected.

2. Dynamometer Test

2.1. Measurement of the Power

The brake dynamometer gives a measurement of the torque T delivered by the engine through the p.t.o. transmission. Given S, the revolution speed of the bench, the power is : $P = k\ T\ S$

P is in kilowatts

T is in newtons x metres

S is in r.p.m.

$$k = \frac{1}{9549.305}$$

The torque and power will vary with the engine speed. We are interested in getting the curves of power, torque, fuel consumption all functions of the speed of the engine in the two ways of operating :

- in the pump governor zone of action, full throttle, which is where the engine is used most of the time
- at full load and full throttle, in order to assess the "torque stock" available and the range of speeds at which

the engine is really "usable" for powerful work (between maximum torque speed and maximum speed - no load).

Some precise points of these curves must be determined :

- power and speed at the maximum torque
- torque and speed at the maximum power
- torque and power at the rated speed of the p.t.o. (540 or 1000 r.p.m.)

2.2. Variable parameters

Torque, power and fuel consumption will vary with some other parameters which must be recorded.

The temperature of the air and the fuel, the atmospheric pressure, causing variations of the air and fuel densities influence the efficiency of the engine. Every 12 metres in ascent reduces the atmospheric pressure by 1.33 millibars : the altitude has a correlatively important effect.

The relative air moisture has an effect on the engine efficiency as well. The greater the moisture content of the air, the less efficient the engine becomes. See in Annex 1, the charts of conversion coefficients of engine efficiency according to the variations of the temperature, the altitude and the air moisture.

It is then necessary to record these parameters and if possible the limitation of their variations is required :

- a well ventilated testing area with temperatures of no more than 35°C is required. If it appears that usually local conditions of work are above 35°C, a test is to be realized at the usual temperature.

- if the injection returns are re-incorporated with the fuel measuring device, a cooling system may be necessary to maintain the temperature of the fuel at a constant level during the test

- the testing area must be equiped with an exhaust fume expelling system which will withdraw the fumes above the exhaust manifold. Theoretically the ventilation flow in this system should be equal to the flow of the extracted fumes ; that is

$$\text{Flow } F = \frac{\text{cylinder capacity}}{2} \times \text{r.p.m.} \quad \text{litres/mn (minute)}$$

for a 4 stroke engine

The quality of the fuel must be constant from one test to another.

2.3. Measuring Equipment

The absorption dynamometer is the main and most expensive item of equipment in the measuring chain. Most of the dynamometer manufacturers also provide the tachometer and fuel consumption measuring devices as well as the torque transducers.

The main two types of stationary dynamometers used in the testing stations are :

- The Hydraulic Absorption Dynamometer - works like a water centrifugal pump which has a very low rate of efficiency. The water is used directly in the breaking operation as well as to cool the system by getting rid of the energy absorbed and transformed in the form of heat (See Annex 2)

- Foucault's Current Absorption Dynamometer - the breakage is produced by the circulation of the rotor, made of a conducting material, in the stator, which includes windings producing a magnetic field. Inducting and breaking currents create a rise in temperature which is then reduced by the water coolant. (See Annex 3)

Annex 5 shows the range of power absorbed by some models of dynamometers made by a German manufacturers. One can see that the maximum power given at low speeds (500 r.p.m.) is usually very low compared with the maximum power. For instance, if one wants to test some low powered tractors at the power take-off, which delivers about 10 kW to 25 kW between 300 and 700 r.p.m., one has to choose a dynamometer which has a range of upto 600 kW. Comparatively speaking electrical dynamometers can be less oversized than hydraulic dynamometers.

Tractor power take-off tests need oversized dynamometers. Some testing stations have overcome this problem by fitting a gearbox on the bench, between the dynamometer and the p.t.o. shaft, to increase the dynamometer speed. But this introduces a new variable parameter - the loss of power in the gearbox which therefore alters the measurement.

If the level of investment cannot afford such types of dynamometer, bench tests may be realized with a mobile type dynamometer (ie = M x W - P 400 B).

3. Field Test

For the field test the first implement used with the tractor should be the plough. From the point of view of the pull required as well as the general balance of the tractor, the plough provides more difficult working conditions than any other implement. We suggest that the ploughing test should be compulsory, and the tests with other implements optional ; the idea being that if the tractor can plough satisfactorily, it can also perform any other field work required of it.

The tractor manufacturer should deliver a disc plough and a mouldboard, in order that comparative tests be made.

As several tests will be required in different conditions, these tests should all be performed by the same skilled driver, who has familiarized himself with the driving during the running-in period.

3.1. Parameters to be Measured and Measuring Equipment

3.1.1. Capacity of Work

The tractor's capacity of work is assessed by the main characteristics of the work effected, and by the working speed. From this data we deduce the time T which is necessary to plough one hectare :

$$T = \frac{1}{\text{Width x Speed}} \text{ hours/hectare}$$

T is the efficient time necessary to plough one hectare, not including the time for manoeuvre at the end of each run and idling time.

The ratio between total time Tt and time efficiently spent :

$$\frac{100 \times Tt - T \%}{Tt}$$

is the efficiency of the tractor + plough at work.

The efficiency depends on the manoeuvrability of the tractor, its steadiness and ease of use, but also of the length of the run ; the longer the run, the better the efficiency.

To avoid the parameter "length of run" interferring with the ploughing test recordings, the tests should be done on the same length of run ; a length of 100 m is a suitable distance for accurate measurements.

3.1.2. Fuel Consumption

The fuel consumption per hour and per hectare are a good indication of the way in which the tractor transforms the energy in the field.

By referring to the curves obtained with the dynamometer test, we can determine what power was used by the tractor during the work (i.e. the power lost in the transmission, wheels' rolling resistance and wheel slippage, plus the power used to remove the soil). We can then appreciate the rate of load of the engine whilst at work and its suitability to the required work. The correct fuel consumption should be as high as possible per hour, but as low as possible per hectare which means that the tractor is used at a maximum load but a minimum time per hectare. Measuring the fuel consumption can be done by refilling the tank after a certain period of time. But this method is quite inaccurate and a mistake of 20 cc on the measurement is common. So to get a mistake of less than 2 % the operator has to run the tractor for at least 1000 cc's worth of fuel i.e. more than about half an hour for a low powered tractor.

A good accurate fuel consumption measuring device is the flowmeter of the make SOLEX - type micro-oval, working on a 12 V current (See Annex 6). The volumetric cell sends an electrical impulse to a counter every 1 cc. The accuracy is to the nearest 1 cc and so a relative mistake of 2 % is obtained for a consumption of about 50 cc which represents 1.5 minute (approximately 100 m run of ploughing work). At this distance, fuel consumption is comparatively low and the measurement can therefore be repeated many times to ensure accuracy.

3.1.3. Atmospheric Conditions

Just as during the dynamometer test, the performance of the tractor in the field will vary according to the air temperature, hygrometry and atmospheric pressure (altitude), and must be recorded.

3.1.4. Wheel Slippage

Wheel slippage is an important parameter whose value shows the adequacy of the tractor's dimensions to the "pull" required by the plough. The definition of wheel slippage is : $WS = 100 \times \frac{N1 - No}{N1} \%$

N1 is the number of wheel revolutions when the tractor is ploughing over a distance of D metres. No is the number of wheel revolutions when the tractor is moving forward and not ploughing over the same distance. (Assuming that the slippage is nil when the tractor is moving forward and not ploughing - implement lifted).

The simplest method of measuring is to walk beside the tractor whilst counting the wheel revolutions/length of the run. During this period the differential, if existing, should be locked. Instead of a man walking, a rev. counter fitted on the p.t.o. gives the same result with better accuracy. The differential being locked (mechanical transmissions only) the number of p.t.o. revolutions is proportional to the number of wheel revolutions : N p.t.o. = k N wheels

The wheelslip is $WS = \frac{k\ N1\ \text{wheel} - k\ No\ \text{wheel}}{k\ N1\ \text{wheel}} = \frac{N1\ \text{p.t.o.} - N°\ \text{p.t.o.}}{N1\ \text{p.t.o.}}$

3.1.5. Soil conditions

The performance of the tractor depends mainly on the characteristics of the soil and cannot be analysed separately from these.

The main characteristics of the soil to be recorded are :

- the surface condition : amount of trash, stubble, grass height, moisture, all of which influence the slippage

- the general amount of vegetation in the soil (roots) and on the surface, which may be a cause of obstruction and thus idling time, so decreasing the efficiency

- the soil moisture and texture (sand or clay content), the date of the last tillage operation on the field, penetrometry measurements are useful to appreciate how hard the soil is. But the penetrometer test is not a dynamic record of the soil resistance to the "pull" of the plough

A mean of measuring the approximate average "pull" resistance of the soil is to attach the tractor being tested to the drawbar of a more powerful tractor with a horizontal chain and a recording dynamoter. The bigger tractor then pulls the smaller over the same distance and at the same speed as the testing conditions.

If : F_0 is the average pulling force with the plough in the soil, F_1 is the average pulling force with the plough lifted (tractor only).

The difference $F_0 - F_1 = F$ is the average pull delivered by the small tractor being tested, or drawbar pull.

The power delivered by the tractor for inverting the soil is $P = F \times S$ (S = Speed)

The ratio $Rs = \frac{F}{W \times D}$ (W = width of work, D = average depth of work) is a characteristic of the soil in which the tractor is tested. R_s is the specific resistance of the soil. For a given soil, the value of R_s depends on the shape and way of action of the penetrating toll and also of the work speed.

Some testing centres (Wageningen - Netherlands, CNEEMA - France) have developed soil specific resistance measuring devices. The device is made of a standard tine, the shape and working depth of which are very precise. This tine is pulled by a walking tractor at a specific speed. A strain gauge measures the horizontal force required which is then recorded on a graphic or magnetic recorder. This system is the most accurate, but is not commercialised.

Without the record of R_s, there is no way of comparing two tests made in different soils. In that case, in order to make a comparison between two different tractors, they must be tested the same day in the same soil.

3.1.6. General Observations on the Use of the Tractor

All remarks on tractor operation must be recorded :

- ease of driving and manoeuvrability
- stability of the plough in the row ; stability of the tractor
- possibilities of adjustment of the plough
- additional weights required for the adherence, or for the tractor balance, or for the penetration of the plough

- capacity of the lifting system, ground clearance, ease of use
- use of the power, rate of load, black fumes, adequacy of the gear arrangement
- quality of the work effected : depth, soil inversion, weed burial, ground gradient

  To consider the test as reliable the quality of work must reach a minimum standard, which accords with local conditions and the agronomist's estimation
- all breakages that occur during the testing and their causes must be recorded

3.2. A method of Measurement

A method using a simple chain of instruments can be described :

- the fuel consumption, p.t.o. rev and time counters (totalizer and partial counter) all electrically commanded, are set on a box, beside the tractor driver (See Annex 7)
- six poles are planted in the ground, making two lines 100 m apart (Annex 7). When the tractor driver passes the line A_1 A_2 A_3 he presses the switch, starts counting and when he arrives at the end of the run (line B_1 B_2 B_3), he opens the circuit, the counting stops
- measurements of time, fuel consumption and p.t.o. rev are recorded on a test form (Annex 8)
- ten poles are placed at equal intervals along the row ; width and depth are measured in front of each of them

The measurement can be done on each row separately, while the totalizers "count" the data for a series of rows. The time measured on the row is the efficient time (plus idle time), while totalizers measure the total time.

3.3. Analysis of Results and Conclusions

The wheel slippage must be analysed in relation to the drawbar pull. Its value varies correlatively with the quality of the performance of the tractor. One usually estimates that the wheelslip should not be greater than approximately 20 % according to the kind of soil. If the wheelslip is too great, too much power is being lost and the capacity of work and the fuel consumption cannot be satisfactory. Moreover, the tyres get worn out too quickly.

From a theoretical approach (see annex 9) we can deduce :

(1) The greater the weight on the driving wheels, the greater the drawbar pull is. Too much slippage can be overcome by adding weights on the rim or by inflating the tube with water, or by improving the load transfer on the driving wheels : load in front of the tractor (2 WD) (1) good adjustment of the plough

(2) The greater the soil contacting surface, the greater the drawbar pull. Correlatively, the smaller the pressure, the better the adherence. Increasing the diameter and width of the tyre and using low pressure tyres decreases the slippage.

These modifications aiming at reducing the wheelslip are possible until the engine's power becomes insufficient.

The operator has to find the compromise between weight, dimensions of the wheels, dimensions of the work or of the ploughing and the speed of work which then gives the most satisfactory performance. This compromise will be different for each kind of soil. It may occur that no compromise can be found in some of the very difficult soils (very poor performance).

This series of tests will allow one to evaluate the tractor in as many different conditions as possible in order to recognise and draw out the limitations of the use of this tractor - conditions such as : wet or dry soil, new or old land, clay soil etc.

Some modifications may appear to be necessary to improve the performance of the tractor or of the plough. These modifications must be carried out with the manufacturer's instructions and approval and they should be recorded in the test report.

4. Life Test

4.1. Purpose of a Life Test

The purpose of this test is to put the tractor in conditions as close a nature to those that it will be used during farming activities in order to evaluate the durability of its components and to discover any constraints that had not appeared during previous tests.

The tractor should be operated by a skilled driver - a farmer, if possible - with full agricultural experience, a minimum of 300 hours of operation and, if possible, during a whole agricultural season.

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(1) If loading is done too much ahead of the front axle of a 2 WD tractor, the load transfer can be negative during artificial track tests (OECD test procedure)

During this time the whole chain of implements should be used according to the cultivation requirements.

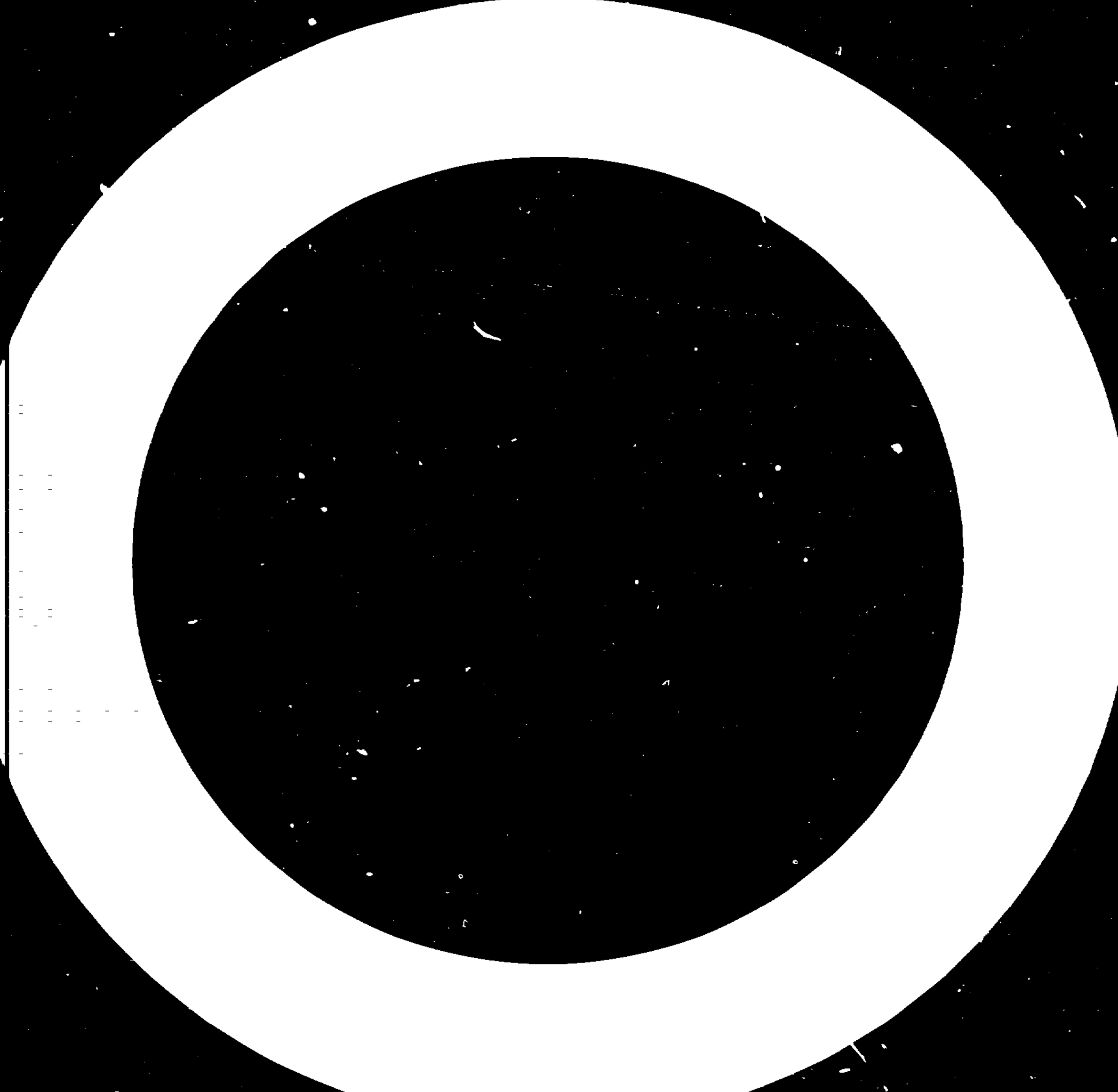
4.2. Measurements

A precise record of the tractor's operation must be kept daily :

- number of hours of operation per day and the type of field operation (ploughing, harrowing, planting, transport, stationery working etc.)
- the fuel consumption per day and per hour
- the time/hectare and surface of work
- the conditions of work (soil condition, temperature, atmospheric pressure)
- the kind of work effected
- all observations on the tractor's use : adjustability, balance

For all these records see Annex 10 : Daily form
Annex 11 : Monthly form

The data will of course only give a rough preliminary result as to the real durability of the tractor. The best test is still that of practical experience. Therefore, this test is more profitable for tractors still at the prototype stage. However, for tractors already on the market, this test should be carried out with a few farmers using the tractors on their own farms.



II - LOW POWER TRACTOR TEST CODE - A PROPOSAL

1. General Arrangements

1.1. Sampling

The tractor to be tested must have been selected by the manufacturer from the production line with the agreement of the testing station. The tractor must be a standard production model and from every point of view, strictly conforming to the specification given by the manufacturer.

1.2. Manufacturer's Instructions

During the tests, the tractor must always be used in accordance with the manufacturer's instructions and any adjustments, maintenance or repairs will be effected according to the "Users' Manual". If a modification of any part is necessary in order to improve its performance, it will not be done without the manufacturer's agreement. Any adjustments, repairs or modifications undertaken during the test must be recorded in the test report.

1.3. Running-in Period

The period of running-in can be carried out by the manufacturer or left at the responsibility of the testing station. Preliminary adjustments to the injection pump, carburettor or governor can be effected during this period and will not be changed during the test (except if great variations of altitude require re-adjustments).

1.4. List of Specifications

The manufacturer must provide the technical specification. This should include all the points detailed in the model test repo[illegible] This specification must be checked by the testing station.

1.5. Power-Driven Attachments

During the tests, any attachment (e.g. the hydraulic pump) must not be disconnected, except if this operation can be performed by the user in normal conditions of use without having to use a wrench.

1.6. Testing Conditions

During every testing session, the following data should be recorded :

- atmospheric pressure
- relative humidity
- air temperature at the engine inlet, or ambient air temperature

2. Power-Take-off Dynamometer Test

2.1. General Arrangements

All values of the torque and power written in the test reports will be read without correction due to the transmission losses. The transmission between the power-take-off and the dynamometer must be as straight as possible. The ambient air temperature must be higher than 15°C and lower than 35°C, or similar to local reality.

If an exhaust fume evacuating system is used it must not alter the performance of the engine.

The different tests must be performed continuously, with the governor control lever fully open.

2.2. Maximum Power Tests

For this test the tractor must be operated for two hours, after a warming up period sufficient to stabilise the power.

The maximum power recorded in the test report is the average of several measurements (at least six) made during these two hours.

2.3. Test at Varying Speed - Maximum Load

The fuel consumption per hour, the torque and the power are measured according to the speed.

2.4. Test at the Rated Speed of the pto

If the engine speed recommended by the manufacturer for the maximum power test does not correspond with the rated speed of the pto, the torque power and fuel consumption will be recorded at the rated speed and indicated on the curves.

2.5. Part Load Test

In the operation zone of the governor, the hourly fuel consumption, the torque and the speed are recorded according to the power. Some points of the curve must be identified in the test. They are the power, the speed and fuel consumption at part load such as :

- at 75 % of the torque delivered at the maximum power
- at 50 % of the same torque
- at 25 % of the same torque
- at no load (the dynamometer must be disconnected if the residual load is superior to 5 % of that torque)

2.6. Graph of the Results

The following curves must be included in the test report :

- power according to the speed
- equivalent crankshaft torque according to the speed (excepted in the case of hydraulic transmission)

- fuel consumption per hour and specific fuel consumption according to the speed

- specific fuel consumption according to the power.

2.7. Engine Tests made in Substitution to the pto Test

If the tractor is not fitted with a pto, or if the pto cannot deliver completely the engine power in the above conditions, the engine must be tested separately in the same conditions.

3. Field Test

3.1. Choice of Implement

The tractor will be tested with two different ploughs, a mouldboard and a disc plough. The choice and delivery of these ploughs will be made by the manufacturer or by the testing station with the manufacturer's acceptance.

3.2. Soil Conditions of Test

The tractor will be tested in as many different soil conditions as the testing station estimates necessary, according to the conditions the tractor is called to work in. At least two different conditions must be provided : moist soil or old land and dry soil or new land. The tractor will be tested up to what the testing officer estimates to be the limit of work i.e. a given size of work and given performances in a certain kind of soil. This limit will be detailed in the report.

For every test, all observations concerning the soil conditions will be reported i.e. surface condition, weeds, trash, stubble, moisture, texture, root density, penetrometry index and any other factor influencing the tractor's efficiency.

The average specific pull resistence of the soil will be recorded in the test report for every test. The method of measurement and the size and shape of the soil penetrating tool used for the measurement will be specified.

3.3. General Test Conditions

3.3.1. The governor control lever will be fully open during every test

3.3.2. The plough will be adjusted as well as possible, so as to provide an agronomically acceptable work

3.3.3. All the tests with one tractor or more in the same field will be performed with the same skilled driver

3.3.4. The gear choosen for the test will be the one recommended by the manufacturer, or the most suitable for the kind of work effected. If the choice is possible between two gears, the tractor will be tested alternatively with each gear.

3.3.5. Any modification of the driving wheel size, additional weight on the wheels of the tractor occurring during the testing session will be tested. The test report should indicate for each test the weight on the driving axle and the size of the tyres.

3.3.6. The tractor will be operated on a 100 meters length of run for every test.

3.3.7. The land opening will be done according to the recommended methods. Measurement will be taken several runs after the land opening, when the depth of work has been stabilised.

3.4. Record of Results - The following data should be written in the test reports :

3.4.1. The average speed of work, measured on the run, excluding turns

3.4.2. Average depth and average width of work

3.4.3. The total time Tt necessary to plough one hectare, including time for turns and idle time

3.4.4. The time efficiently spent Te, necessary to plough one hectare, excluding time for turns and idle time

3.4.5. The efficiency at work : $100 \frac{Tt - Te}{Tt} \%$

3.4.6. The fuel consumptions per hour and per hectare. These fuel consumptions will be measured on the total time, the tractor ploughing, turning and idling.

3.4.7. The wheelslip -If N is the number of wheel revolutions on distance D, the tractor ploughing.

If No is the number of wheel revolutions on the same distance, the tractor not ploughing

the wheelslip is : $100 \frac{N - No}{N} \%$

3.4.8. The quality of the work effected. An estimation of the degree of acceptability of the ploughing according to agronomical criterious must be recorded.

4. Life Test

4.1. General Arrangements

The tractor will be tested for a minimum of 300 hours under conditions as close as possible to those under which it will be used. If possible the tractor should be tested on a farm performing all the work needed throughout an agricultural season.

4.2. The range of implements provided with the tractor should be as complete as possible. Disc and mouldboard plough, disc or tine harrow, tine cultivator, ridger, weeder, planter, trailer, whose suitability to the tractor will be evaluated.

4.3. The driver should be very skilled and if possible a farmer working on his own farm.

4.4. Any breakages occurring during the test will be recorded and analysed thoroughly in order to discover the origin of the breakage i.e. whether it be technical failure of the tractor due to faulty design or manufacture, poor operation or accident, or lack of maintenance and repair.

4.5. Record of Results

For every kind of field operation records will be kept of the fuel consumption, time of work, acreage covered and conditions of work as shown in the test report model.

The results will be followed by the general estimation of the driver and the testing officer - of the behaviour of the tractor with each of the implements used.

III - TEST REPORT MODEL

Name and address of the manufacturer : ....
....

Place of running in : ....
Period of running in : ....

1. Specification of the tractor

Tractor :
Make :
Model:
Serial Number :

Engine :
Make :
Model:
Type :
Serial Number :
Cylinders - Number : .... bore/stroke : ....
Capacity ....cc compression ratio : ....

Feeding & Igniting Device :
Kind of feeding device : ....
Make, model of fuel filter : ....
Fuel tank capacity : ....
Make, model of injection pump : ....
Make, model of injectors : ....
Make, model of ignition coil & distributor : ....
Make, model of carburettor : ....

Governor :
Rated speed : ...... Range of speed : ......

Air filter :
Main filter - make, model, type : ....
oil capacity : ....
Prefilter - make, model, type : ....

Lubrication system :
Oil capacity : .... litres
Number and type of oil filters : ....

Cooling system :
Type : ....

Starting system:
Type, make : ....

Electrical system :
Voltage : V
Generator - make, type : . ...
Battery - type, make : ....

Transmission :

Clutch - make, type : ....
size : ....
control system : ....

Gearbox - make, type: ....
number of gears: ....
oil capacity: ....

Back axle & final transmission -

make, type : ....
differential lock : ....
operated by : ....
oil capacity : ....

Any other data on the transmission : ....
....

Number of gear	Number of engine revolutions for one revolution of wheels	Speed at the nominal speed of the engine (kph)

Power Take-off :

Transmission type : ....
Number of splines : ...... conform/not conform to ISO standard

Speed : ...... rpm for : .... engine rpm
Range of speeds : from .... rpm to .... rpm

Lifting system :

Make, type : ....
Oil capacity : .... way of acting of the cylinder : ....
Other data : ....

Linkage :

Conform/not conform to ISO standard
Category : ....
Drawbar size : ....
Hook, height above ground : ....

Wheels :

- Driving wheels dimensions : ....
  Ply rate : ....
  Maximum load : ....
  Inflation pressure : ....
- Steering wheel dimension : ....
  Ply rate : ....
  Maximum load :...................................
  Inflation pressure : ....

Weight :

Tractor without driver with full tank

	Front (kg)	Rear (kg)	Total
Without additional weight			
With additional weight			

Additional weights available : front : kg

wheel weight : kg on each wheel
(not including water)

Track Adjustment : from .... cm to .... cm

Location of centre of gravity

	Tractor	
	ballasted	unballasted
Height above ground		
Distance forward from the vertical plane containing the axis of the rear wheels		
Distance from the median plane parallel to the longitudinal axis of the tractor bisecting the track		

2. Power Take-off Dynamometer Test

Date and location :

Make of Dynamometer :

	Power	Speed		Fuel Consumption	
		Engine rpm	pto rpm	Litres/hour	Specific g/kWh
2 Hours Test at Maximum Power					
Test at the Rated Speed of the pto					
Part Load					
75 % of torque of maximum power					
50 % "					
25 % "					
No load					

Maximum speed of the engine unloaded : rpm
Torque at the maximum power : Nm
Maximum torque : Nm at rpm
Average atmospheric conditions : temperature : oC
pressure : millibars
relative air moisture : %

Observations :

3. Field test n° :

Date and Test Site : Driver :

Equipment Tested :

Tractor : Additional weights front : kg

rear : kg

Total weight on back axle : kg

Plough : Width of cut : cm per share

Average Atmospheric Condition :

Temperature : °C
Pressure : mbars
(Altitude : m)
Air moisture : %

Soil Conditions :

Results

	Average Width cm	Average Depth cm	Speed km/h	Total Time hrs/ha	Eff.Time hrs/ha	Fuel Consom. l/h	Fuel Consom. l/ha	Efficiency	Wheel Slip
1									
2									
(...)									

(1) and (2) and (...) corresponding to different adjustments of the tractor (gear, additional weights, depth or width adjustment...)

Average pull resistance of the soil : Rs = ... $\frac{N}{dm^2}$

Average drawbar pull : F = ... N

Method of measurement of Rs and F :

Observations :

FIELD TESTS : General Conclusions and Recommendations

Observations on the tractor operation : (balance, adjustability, manoeuvrability, level of the performance)

Limiting soil conditions of work :

Recommendations or proposed modifications :

Other observations :

4. Life Test :

Test Site :

Dates : between the .... and the ....

Driver :

Equipment tested :

Tractor : additional weights :

Implements :

A. Total number of hours of work effected :

	Hours Total	Fuel consom/ houe Average	Acreage Total	Average Time/ha
Ploughing				
Harrowing				
Planting				
Cultivating Weeding				
Transport				
Stationary p.t.o. work				
Travelling to & from field				
Other				
Total				

B. General Observations on the ease of use :

Ease of Starting :

Accessibility of elements for maintenance :

greasing :
adjustment :
usual repairs :
oil changes :

Average dayly maintenance time :

Linkage adjustment :

Suitability of the linkage to different implements :

Manoeuvrability, balance, stability on row width :

plough :
harrow :
cultivator :
ridger :
others :

Manoeuvrability during transport:

on the road :
in the field :

Gear arrangement :

Ergonomics : disposal of controls, drivers seat, noise :

C. Specific observations and record of breakages on the tractor parts :

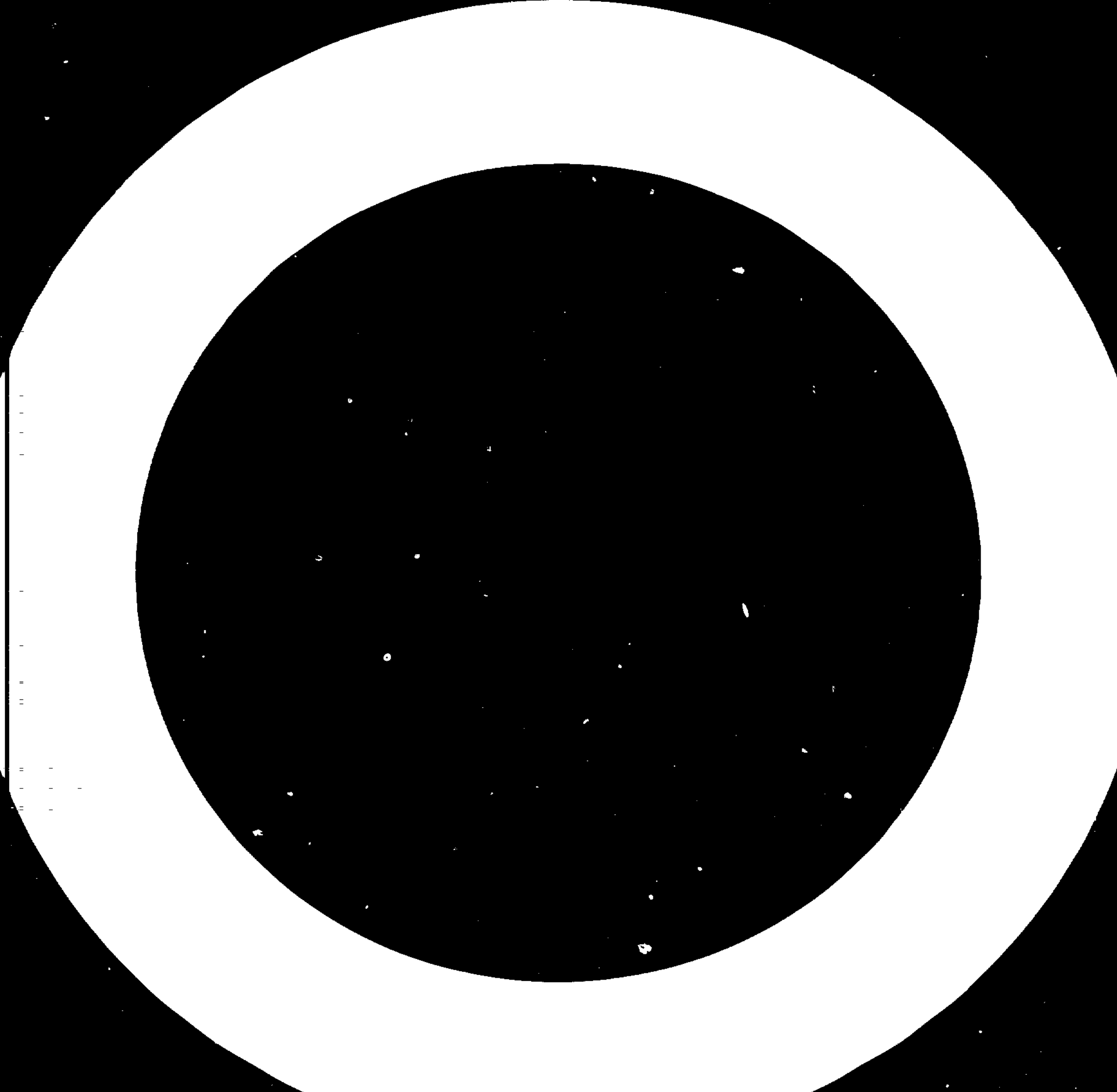
engine :
feeding system :
lubricating system :
starting device :
cooling system :
steering system :
governor :
clutch :
gearbox :
transmission :
controls :

wheels, tyres :
brakes :
battery :
electrical system :
linkage :
hydraulic lift :
chassis :
other :

(specify after how many hours breakages occured)

D. Any observation or recommendation :

design improvement, modifications etc.



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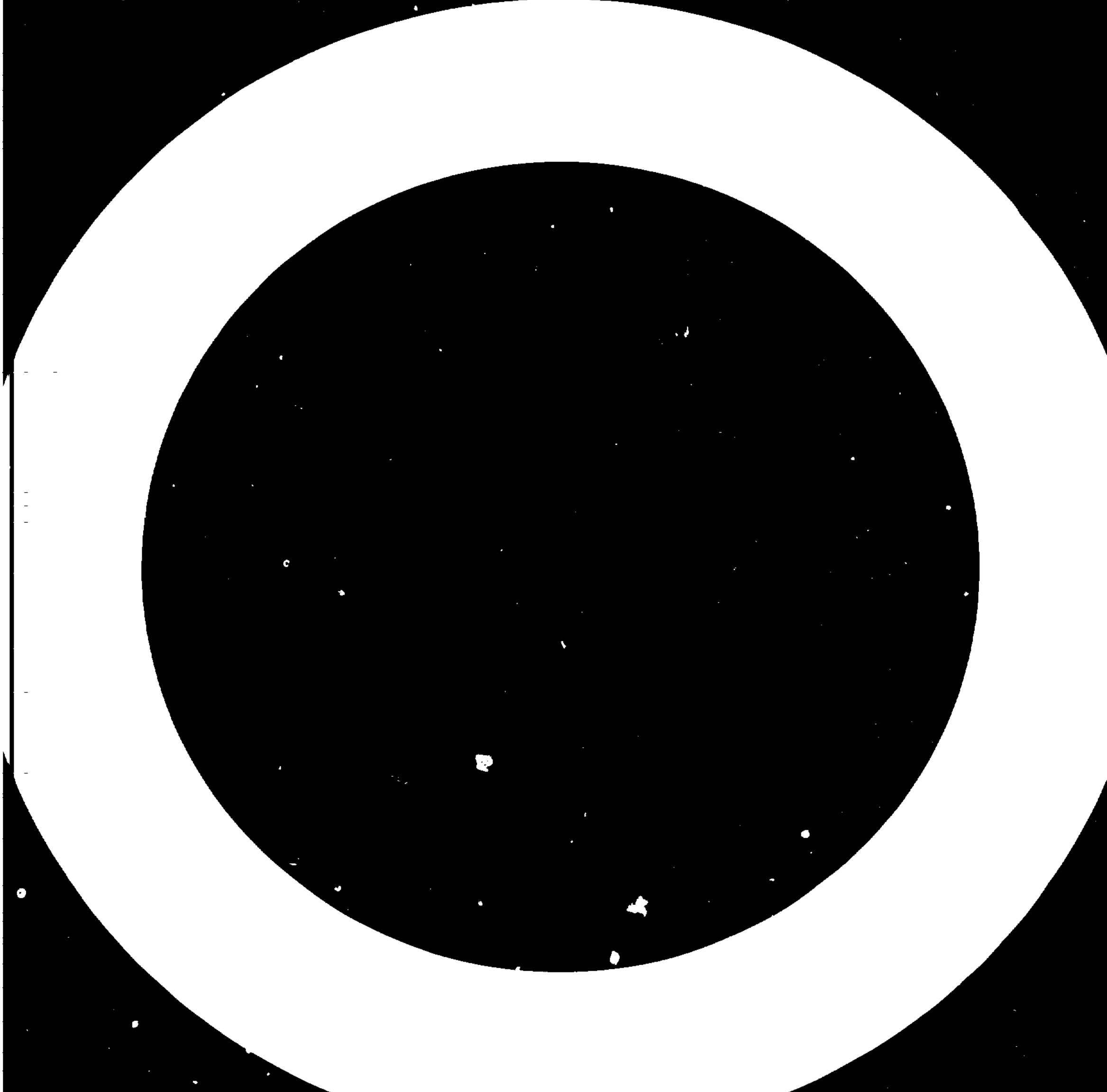
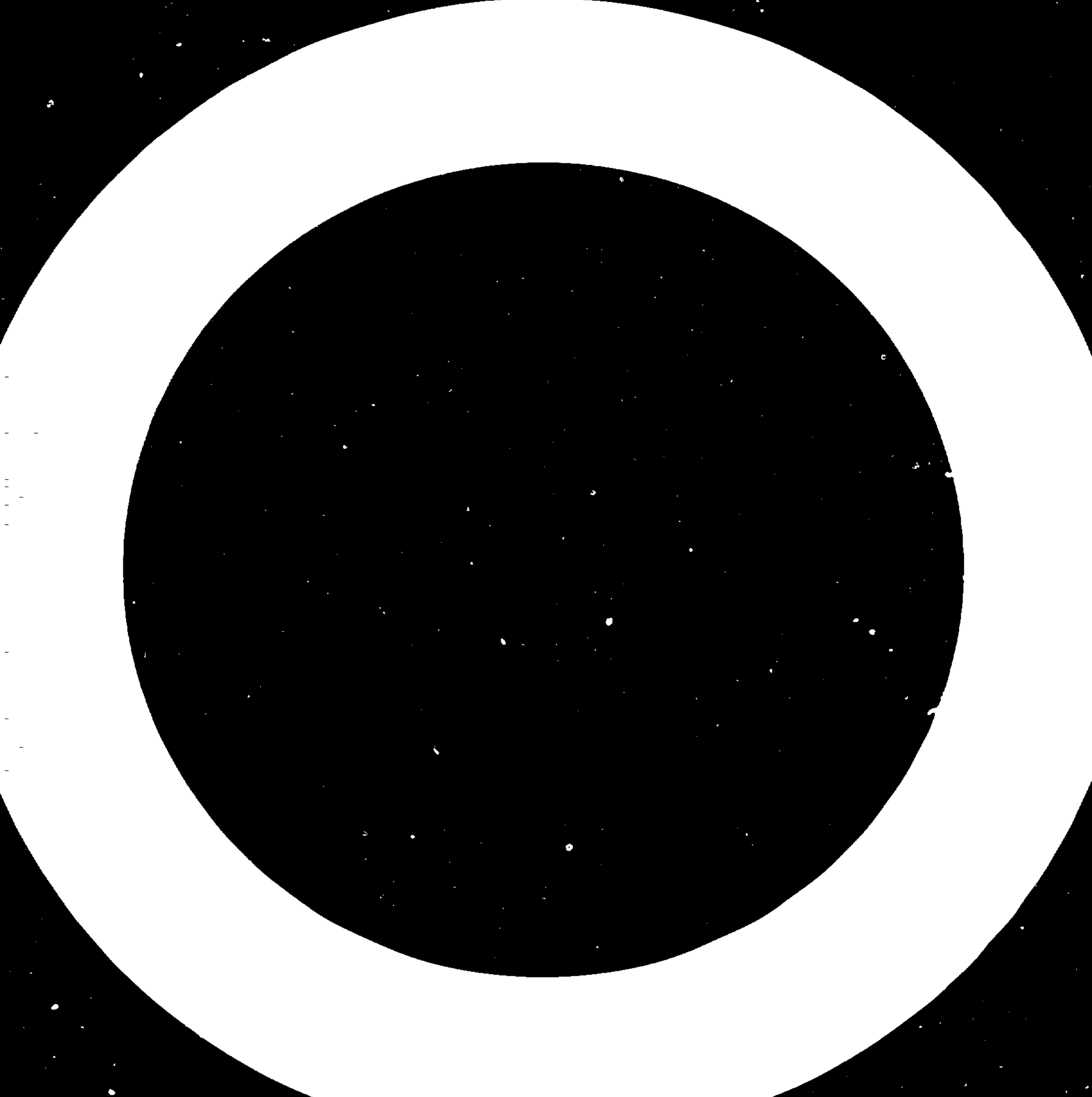


ANNEX 1

Conversion coefficient of the efficiency at the place of operation of the engines in relation to the normal conditions according to DIN 6270.

These coefficients (in per cent) are applicable to the Otto and diesel engines without charger and to the engines with blowing charger the power of which is limited by atmospheric conditions and the mechanical efficiency of which is 85 %.

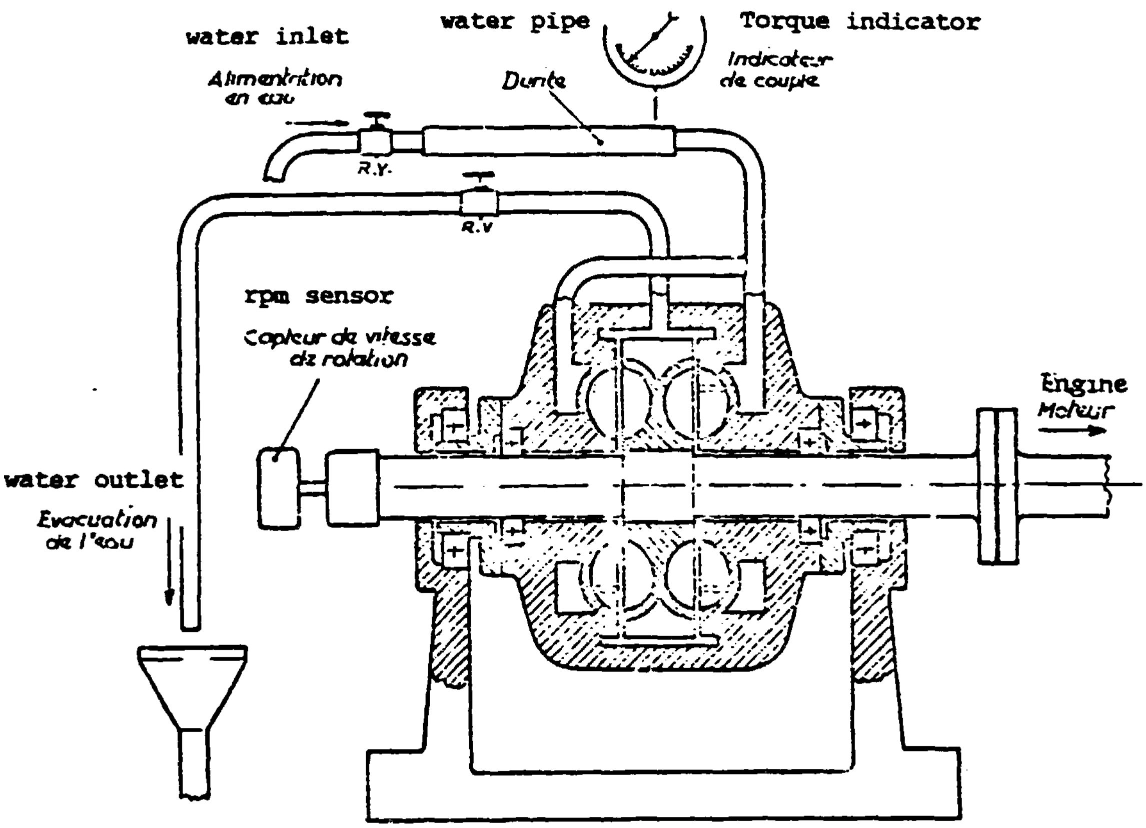
Altitude (meters)	Atmospheric Pressure (mm Hg)	Temperature of the aspirated air in degrees centigrade — At a relative atmospheric moisture of 60 %											At a relative atmospheric moisture of 100 %										
		0°	5°	10°	15°	20°	25°	30°	35°	40°	45°	50°	0°	5°	10°	15°	20°	25°	30°	35°	40°	45°	50°
0	760	111	110	108	106	104	102	100	97	95	92	89	111	109	107	105	103	100	98	95	92	88	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	106	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	89	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	641	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	88	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	66	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	66	[illegible]	64	[illegible]	60	57	75	71	72	70	68	66	64	62	59	56	52
2900	532	74	73	71	70	68	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	51	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	61	62	60	58	56	54	52	49	46	43
3900	468	64	63	61	60	59	57	55	54	52	50	47	63	62	61	59	57	55	53	51	49	46	42
4000	462	61	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	51	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	49	47	45	42	40	37	33
5000	405	53	52	51	50	49	47	46	44	42	40	38	53	52	51	49	48	46	44	42	39	36	33



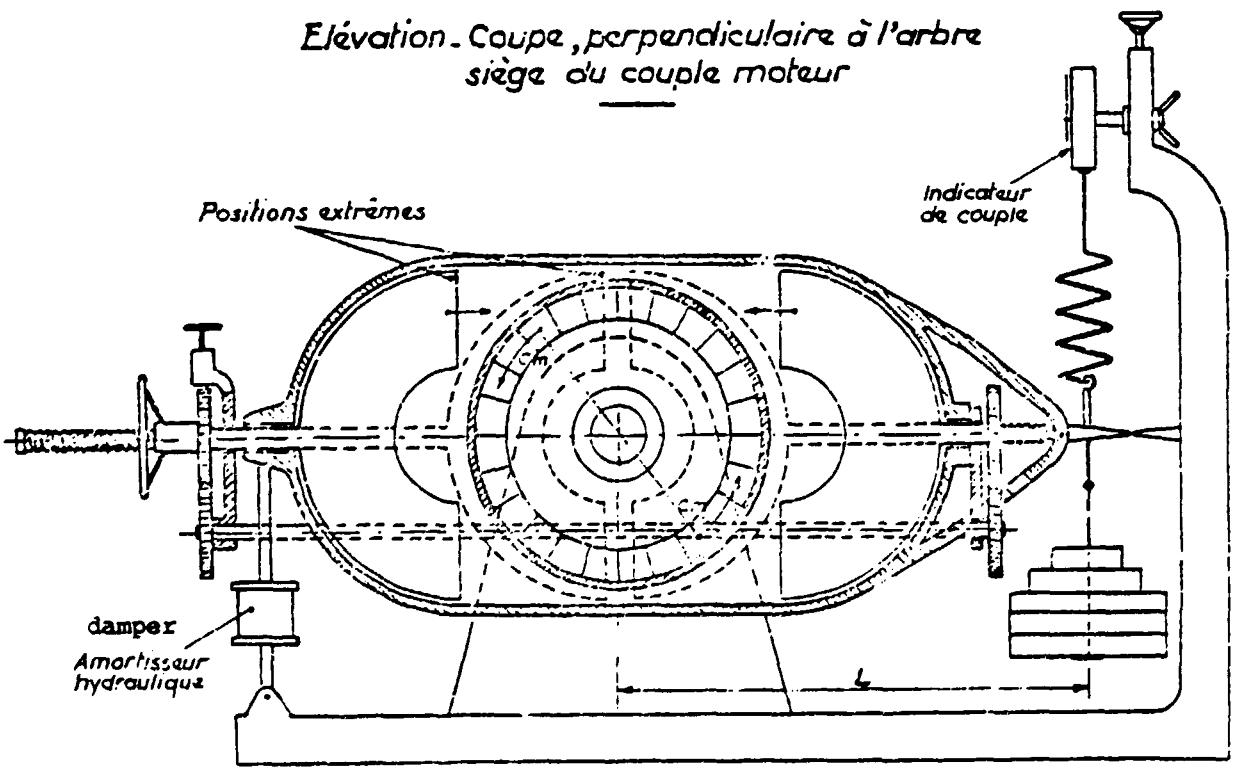
ANNEX 2 : HYDRAULIC DYNAMOMETER SCHEME

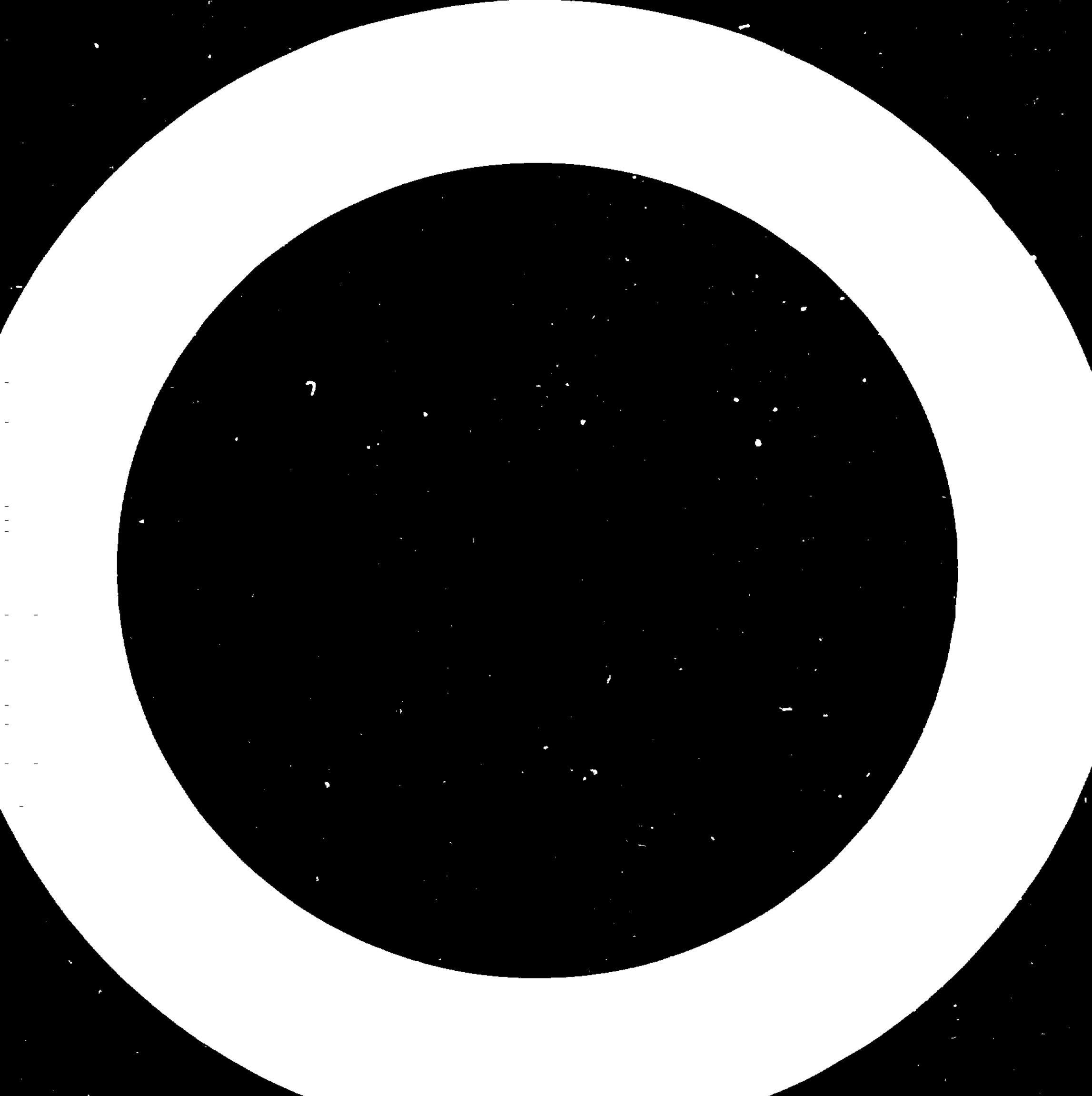
Dynamomètres d'absorption hydraulique HEENAN - FROUDE, Type DPX

Coupe dans l'axe de l'arbre, siège du couple moteur

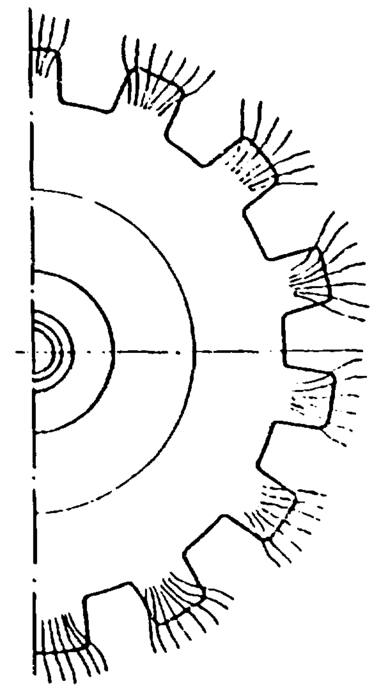


Elévation - Coupe, perpendiculaire à l'arbre siège du couple moteur

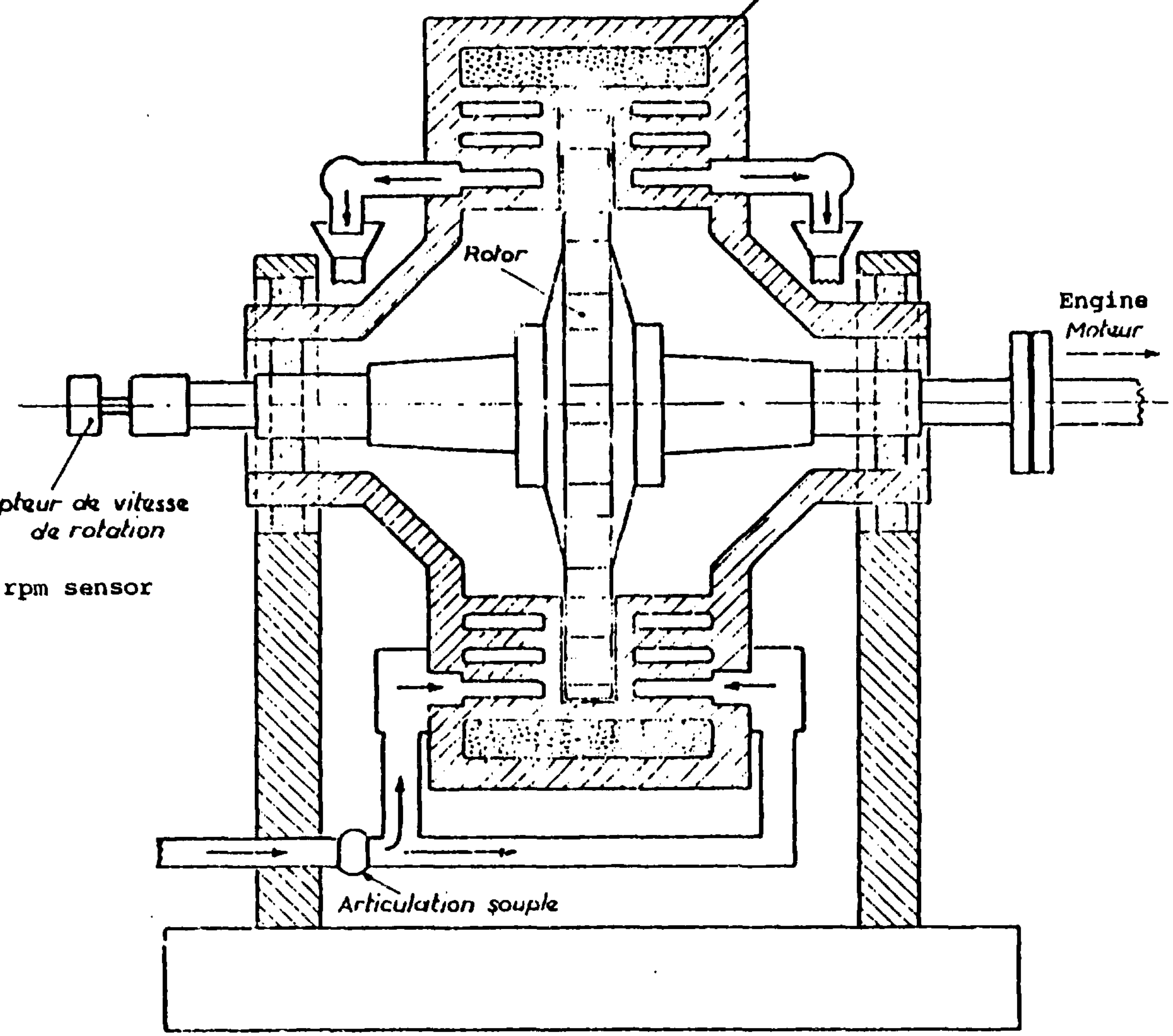




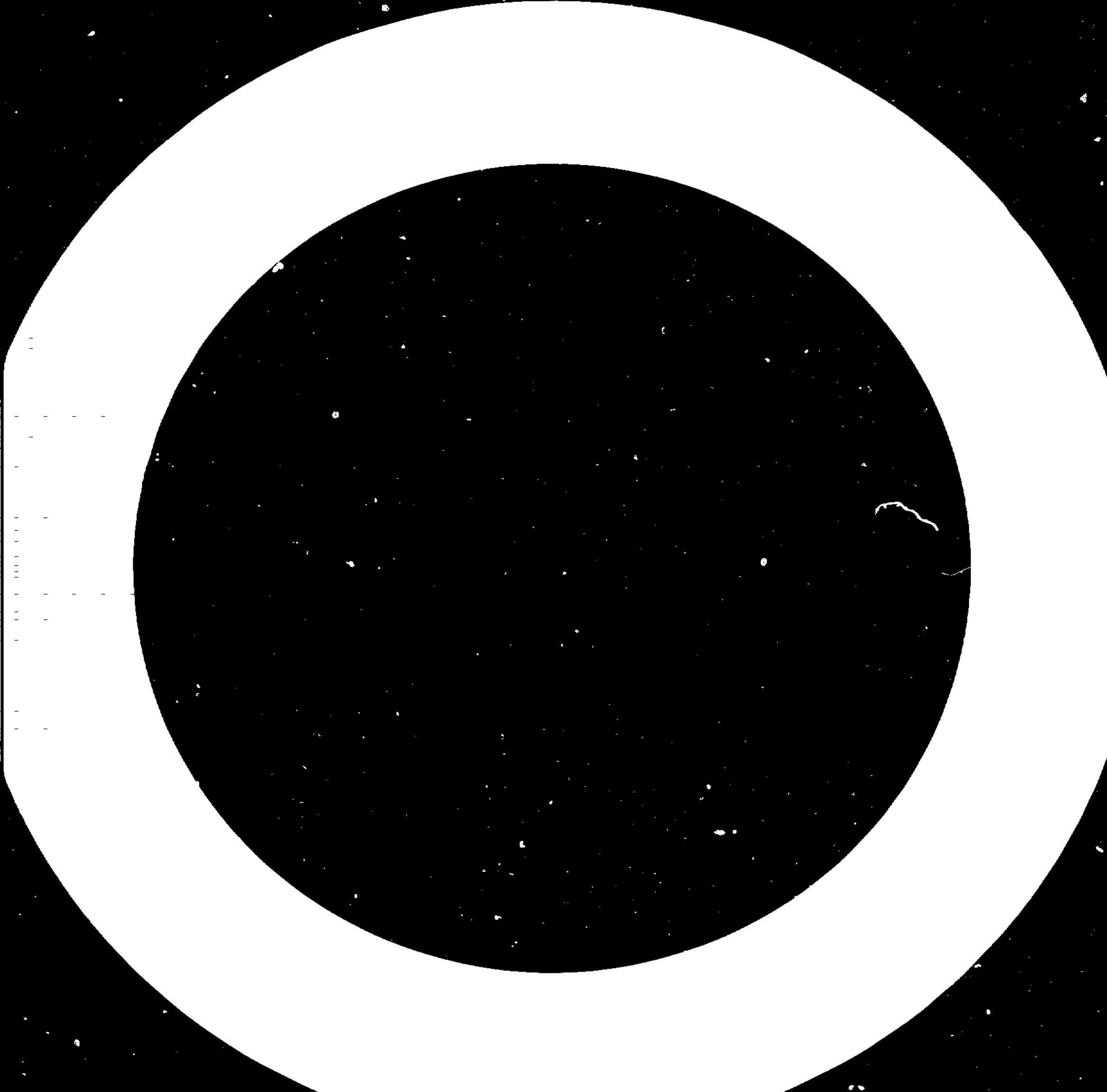
ANNEX 3 : FOUCAULT's CURRENTS DYNAMOMETER



Rotor



Dynamomètres d'absorption à courants de Foucault SCHENCK, Type W



ANNEX 4 : READJUSTMENTS SYSTEMS AND CURVES OF ABSORPTION

Hydraulic and electrical dynamometers can both be equiped with readjustment systems which reduce inaccuracies during the measurement and also enable instantaneous readings to be taken.

Several kinds of re-adjustments are used :

- re-adjustment with constant torque
- re-adjustment with constant speed
- re-adjustment with steep inclination characteristic curves.

The optimum stability of the measurement is when the angle α between the characteristic curves of absorption of the dynamometer and the tested engine torque curve is as near as possible to 90°C (Fig. 1).

The best solution for tractor testing and engines fitted with a governor is to have a dynamometer fitted with two re-adjustment systems :

- re-adjustment with constant speed for readings in the part of the curve where the engine is working at full load (the speed varies a lot, the torque varies a little) (Fig. 2).

- re-adjustment with constant torque when the engins is operating in the pump governor zone of action (the speed varies very little, the torque varies a lot). (Fig. 3).

The whole of the characteristic curve of absorptions (an infinity) makes a "family" whose area is determined by the use of the dynamometer. This area has very precise limits, imposed by the design of the dynamometer and the choice of materials. These limits are shown in Fig. 4. as the perimeter O A B C D.

- the OA section shows the maximum breaking torque that can provide the dynamometer at low speed

- AB : limit upto which the parts of the bench can resit strain (maximum torque)

- BC : limit of heating that the bench can afford (constant power corresponding to the maximum heat)

- CD : maximum speed the bench can turn at (vibrations, mechanical resistance)

- DO : minimum torque given by the bench under which no measurement is possible.

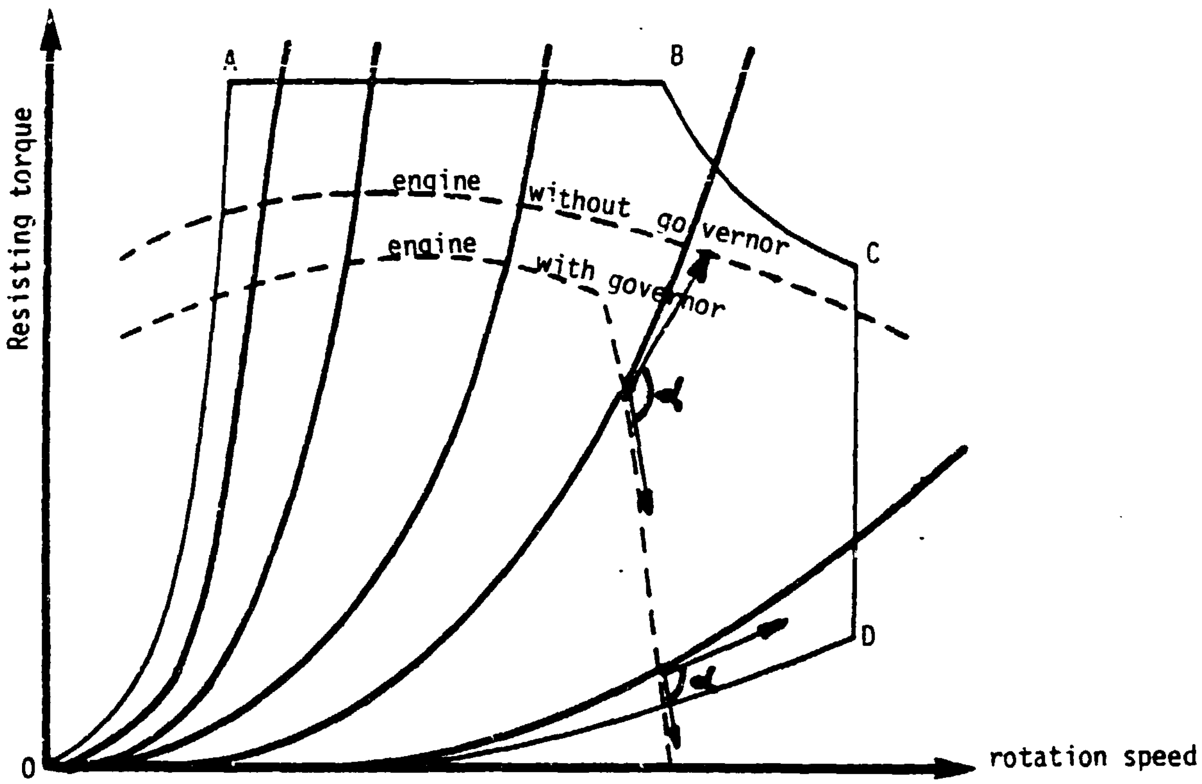


Fig. 1 : Characteristic Curves of Torque Absorption without Re-adjustment.

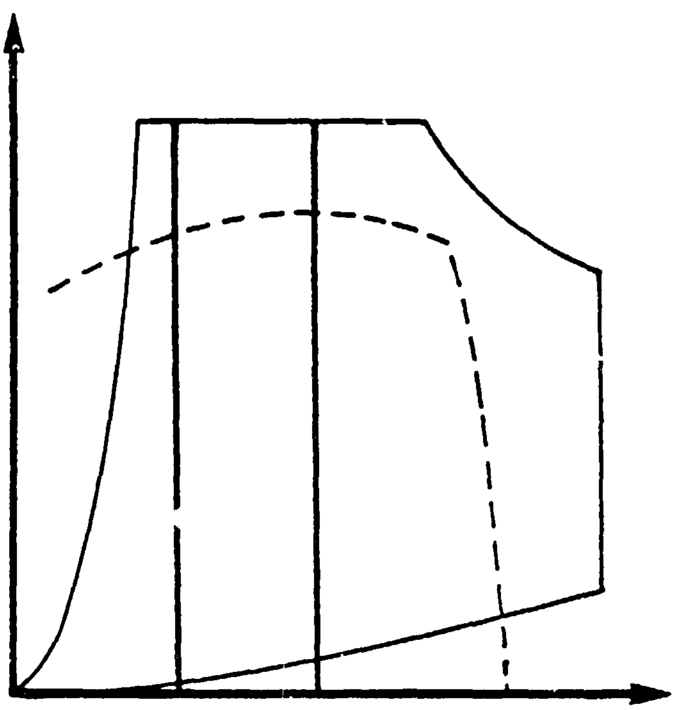


Fig. 2 : Re-adjustment at Constant Speed

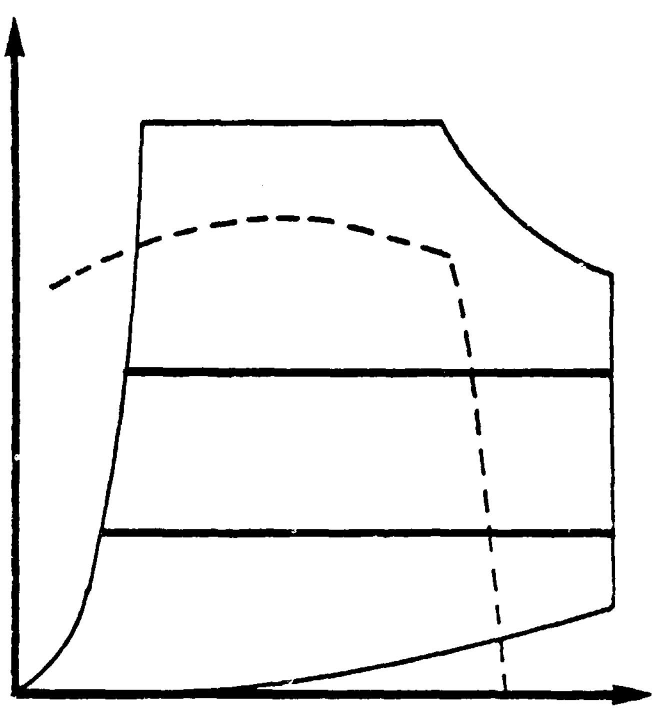
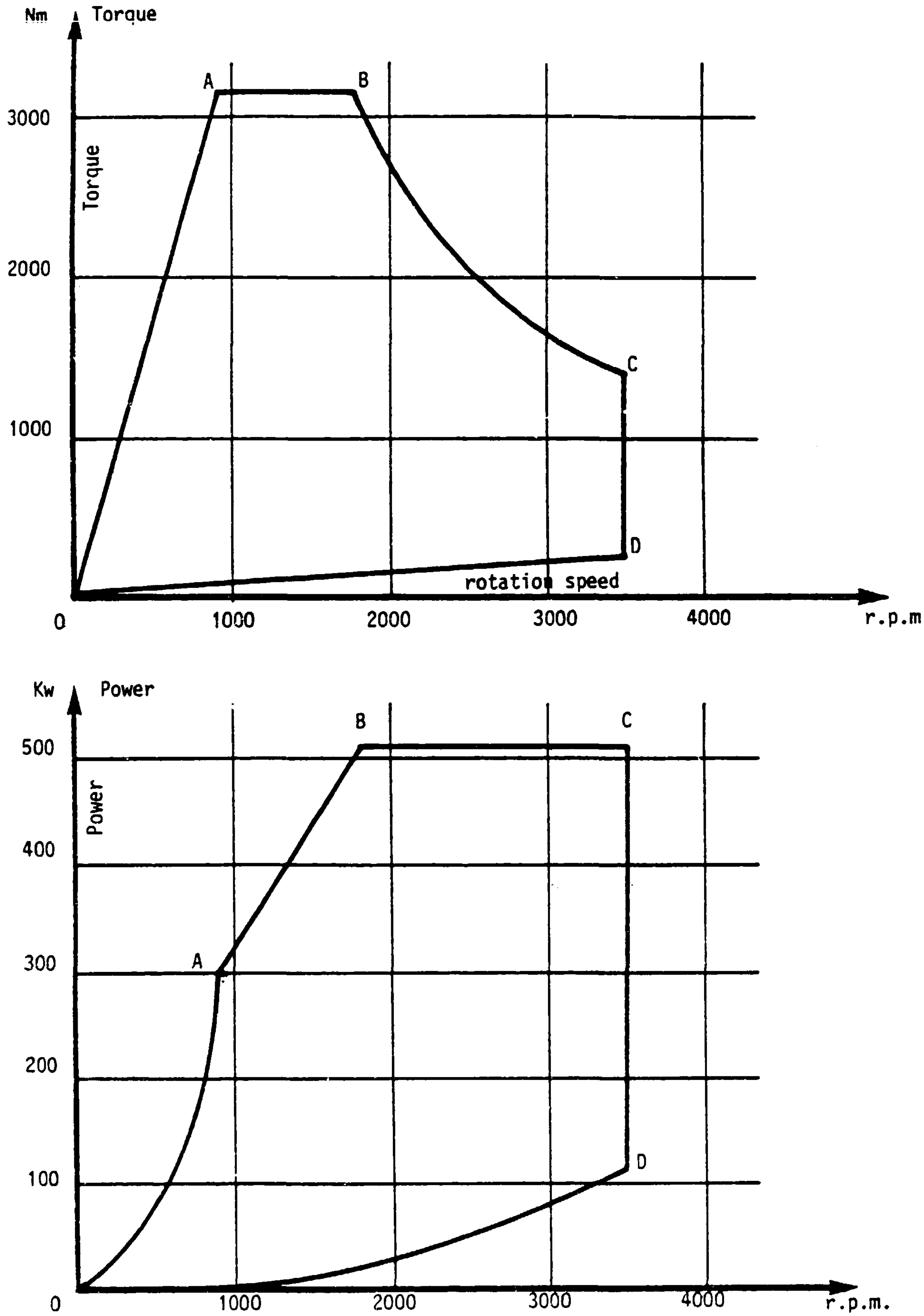
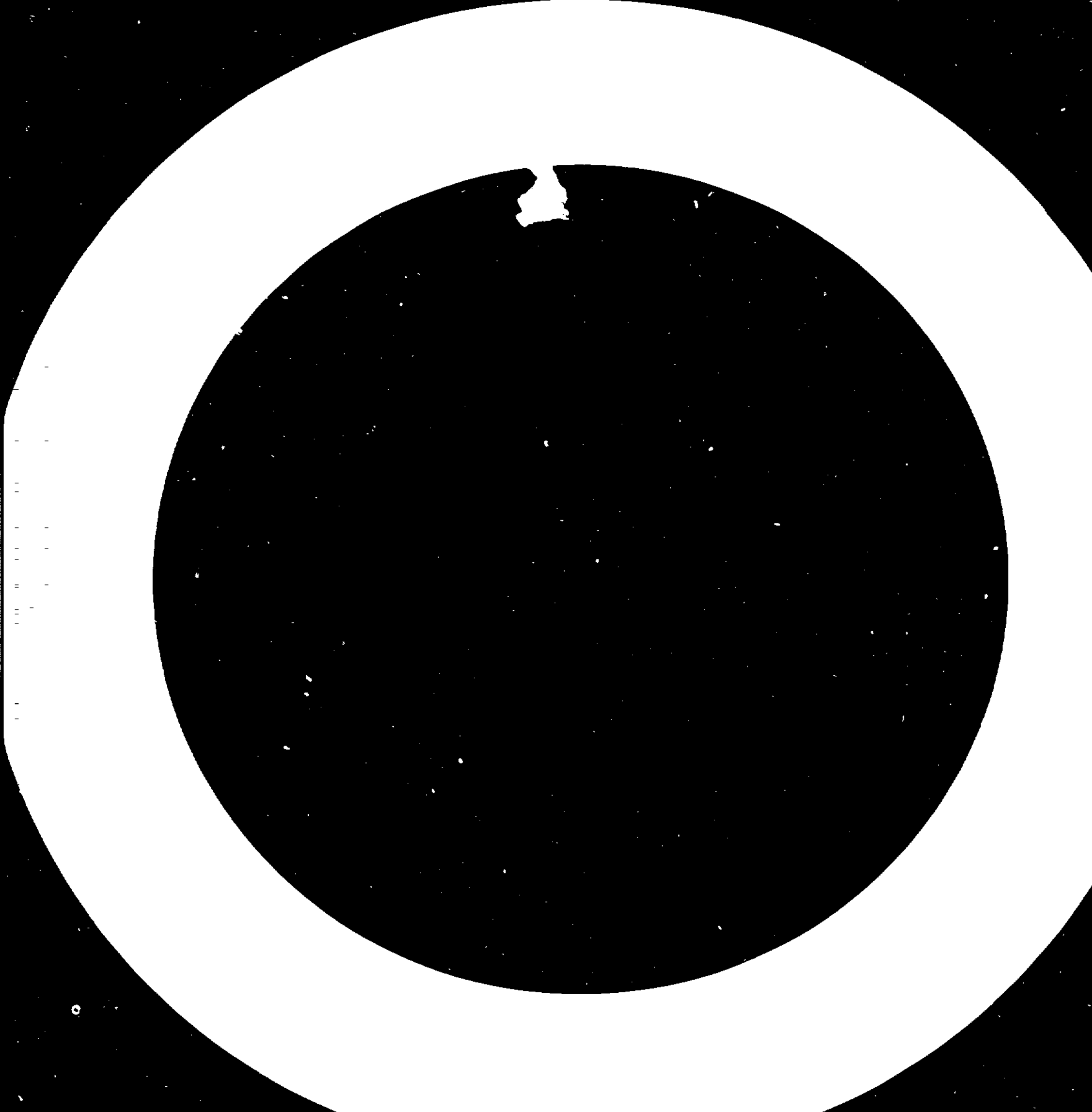


Fig. 3 : Re-adjustment at Constant Torque

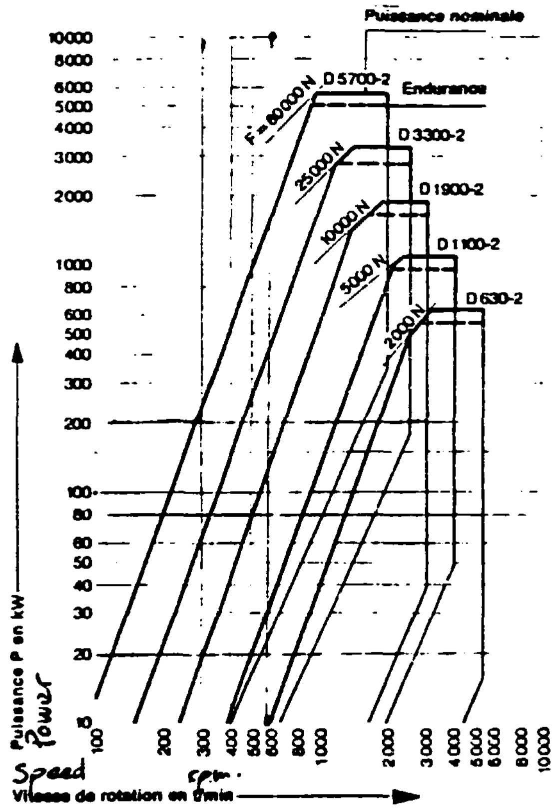
Fig. 4 : Diagrams of Maximum and Minimum Torque and Power given by the HEENAN-FROUDE DP x 5 Hydraulic Dynamometer.



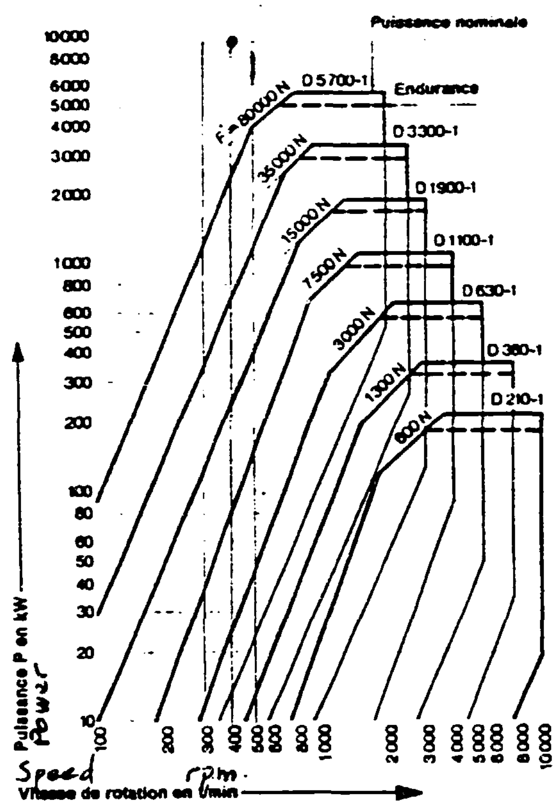
Source : CNEEMA.



ANNEX 5 : SOME DIAGRAMS OF ABSORPTION FOR DIFFERENT MODELS

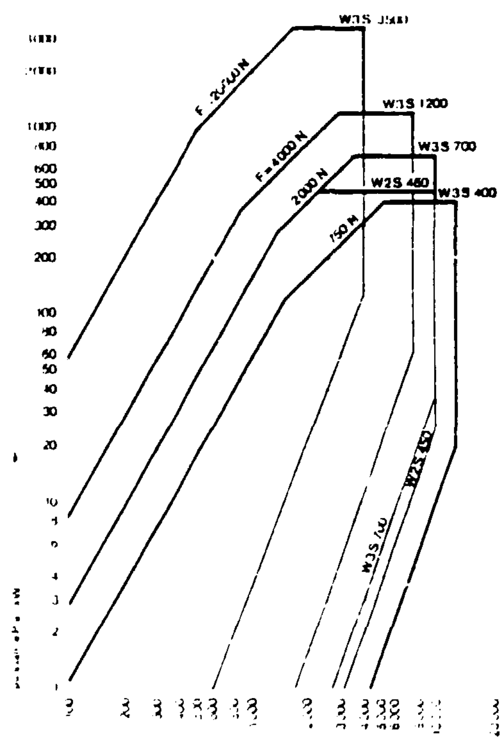


Hydraulic Benches two rev. direction

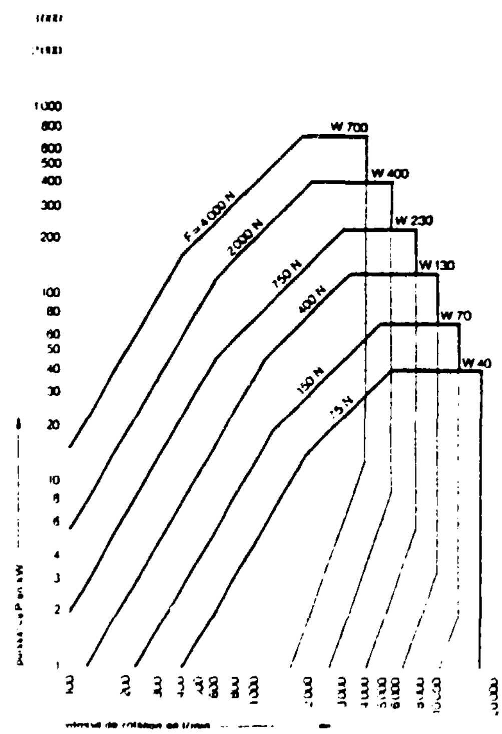


Hydraulic Benches one rev. direction.

1. Hydraulic Benches



gammes de puissance des types de constructions W2S/W3S

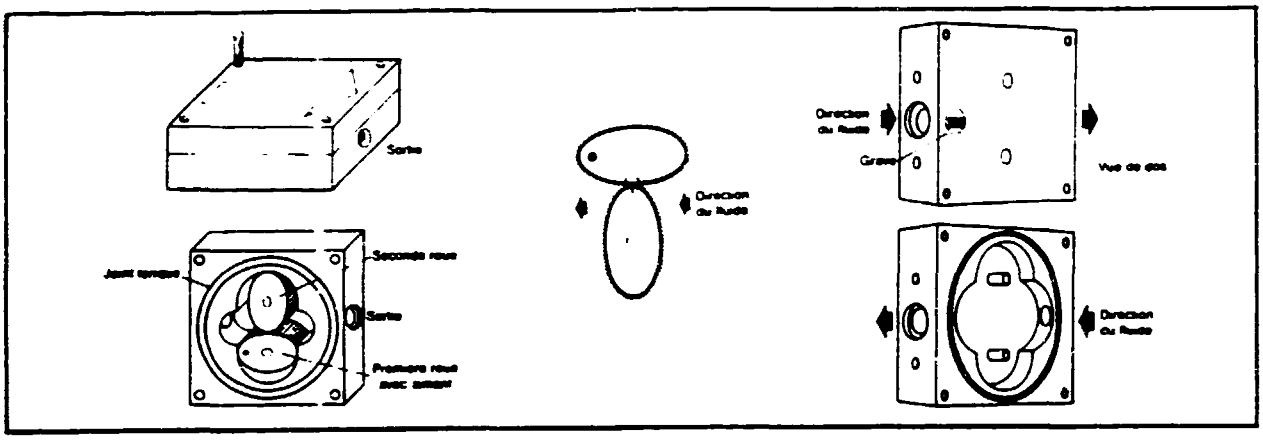


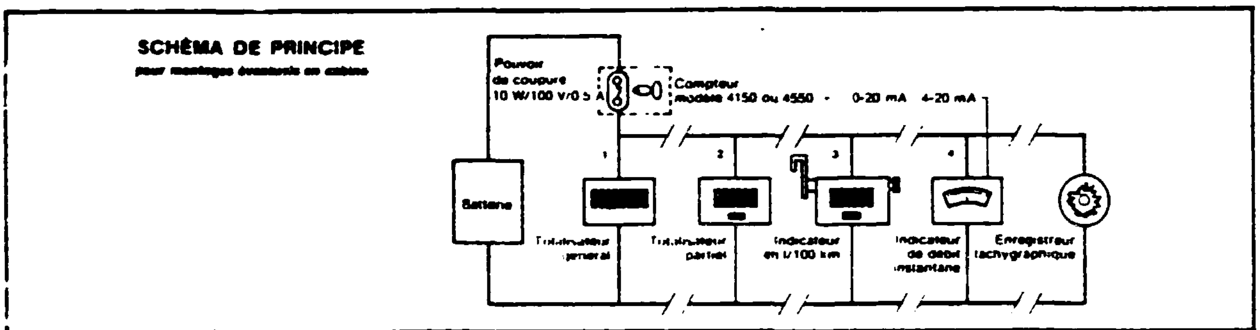
gammes de puissance du type de construction W

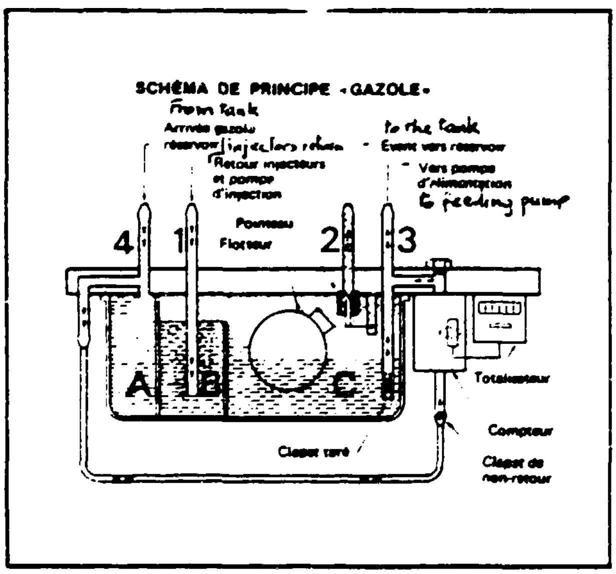
2. Electrical Benches

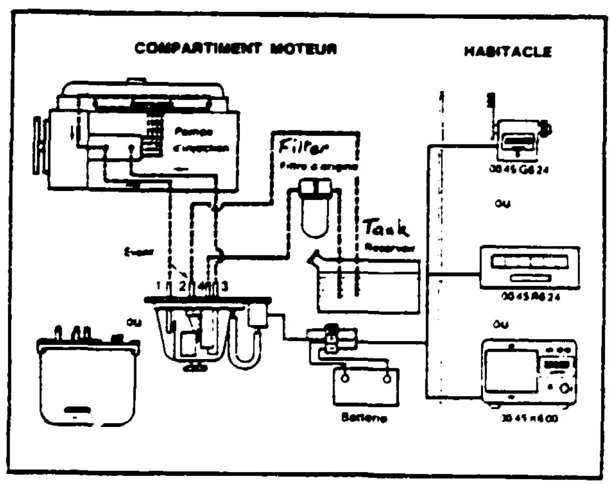
Source : SCHENK

ANNEX 6 : THE FLOWMETER MICRO OVAL SOLEX FOR FUEL CONSUMPTION MEASUREMENTS

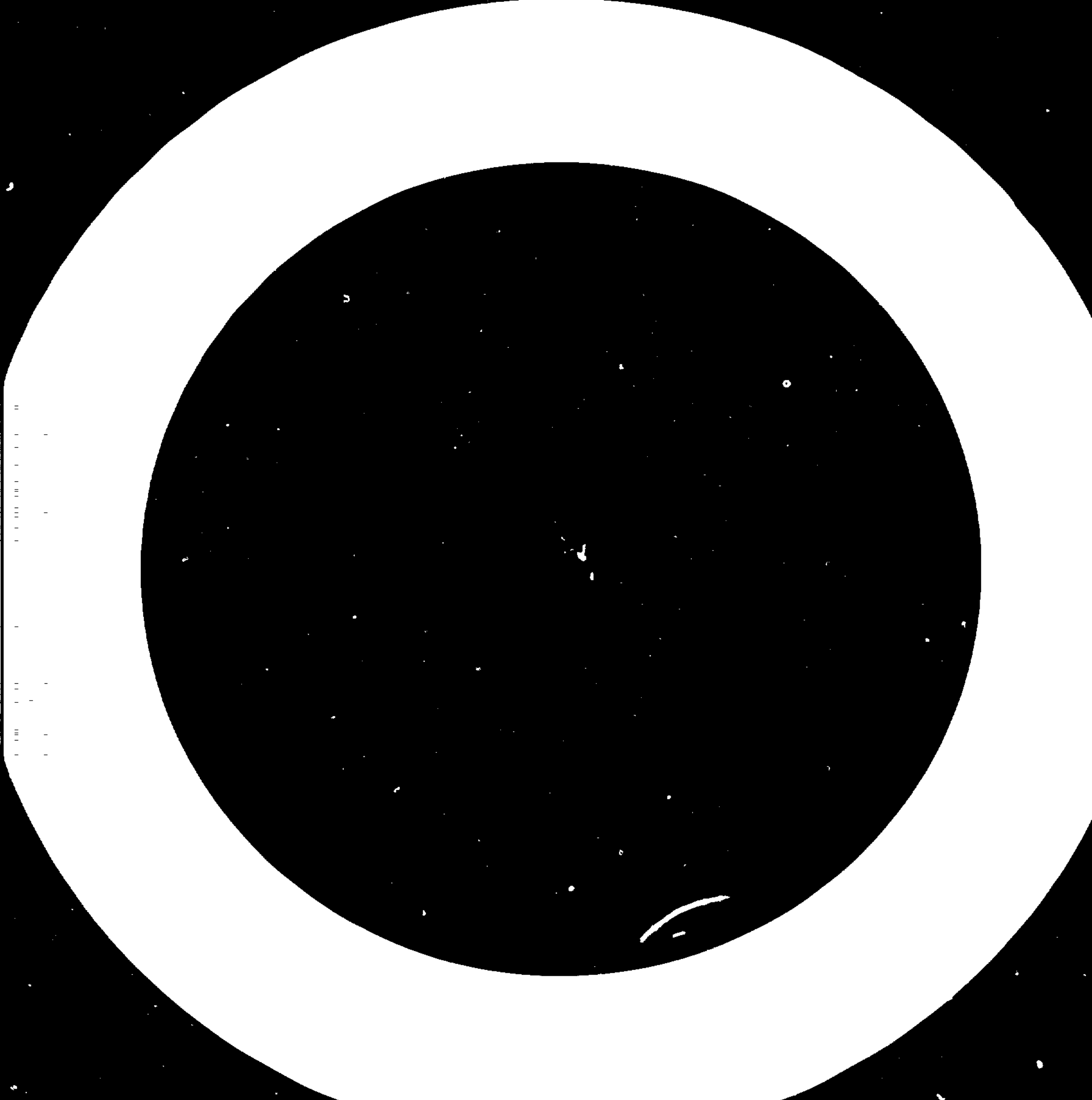




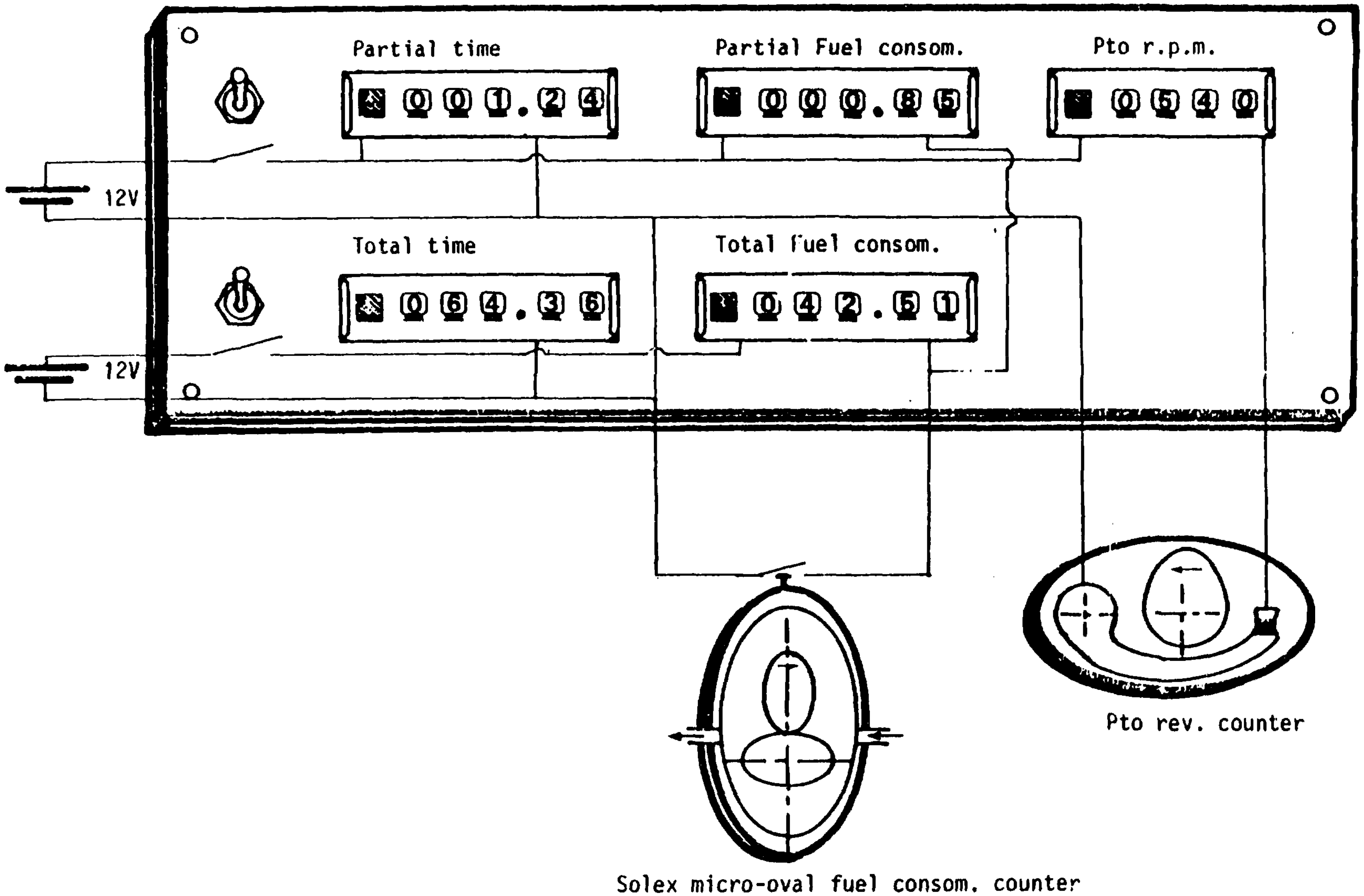


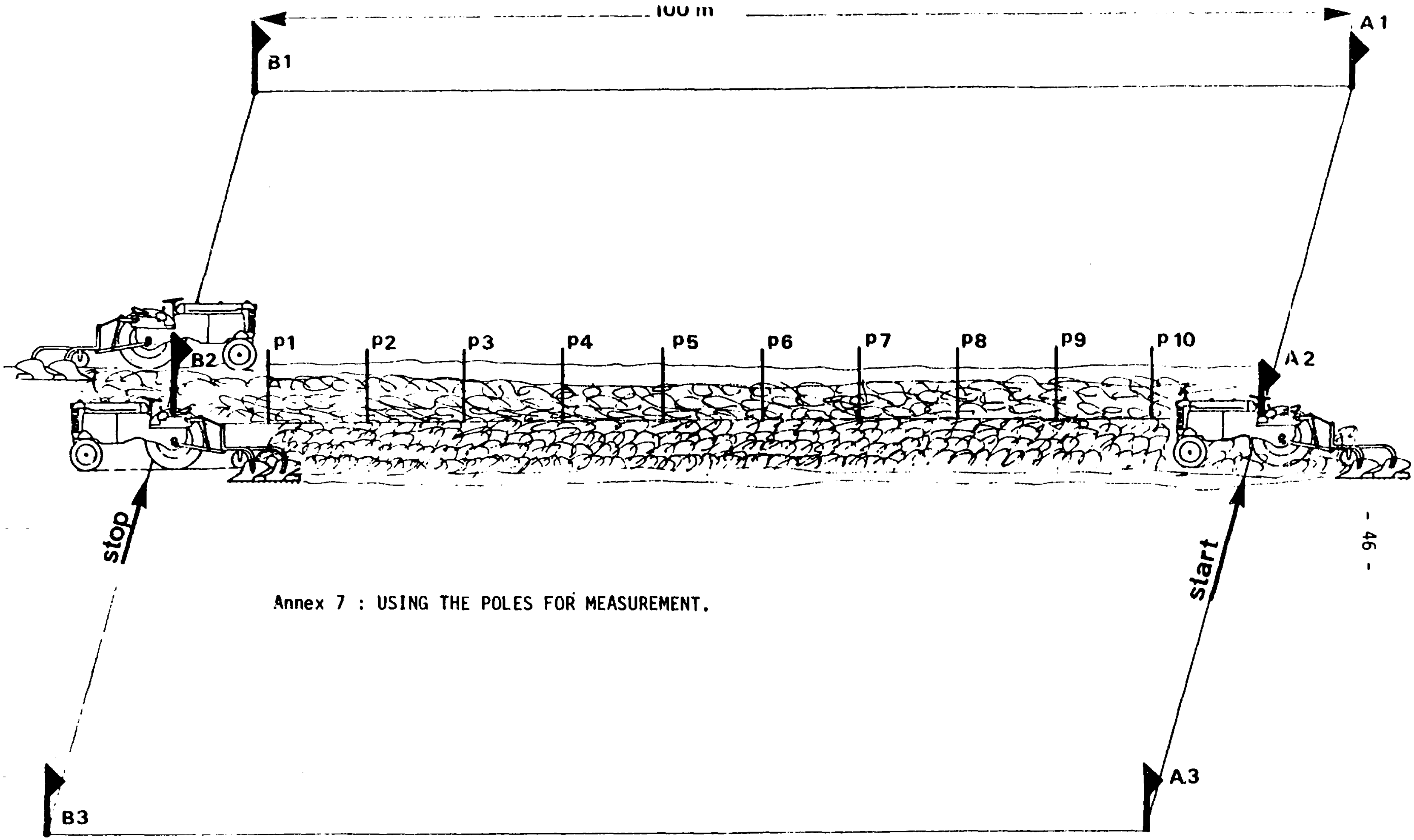


Source : EMERSON-BROOKS - France.



ANNEX 7 : A CHAIN OF MEASURING INSTRUMENTS FOR FIELD TESTS





Annex 7 : USING THE POLES FOR MEASUREMENT.

ANNEX 8 : FIELD TEST FORM MODEL

Date : .... Test Site : .... Tractor : .... Implement : ....

Temperature : ......°C Relative air moisture : ..% Atmospheric pressure : ..... m/bars Altitude : .... m

Soil Conditions : ....
(surface conditions, weeds, trash, moisture, clay content, penetrometer index etc.)

RESULTS

Average pull resistance of the soil Rs = ... $\frac{N}{dm^2}$ Average drawbar pull F = ... N

Average Speed km/h	Average Depth cm	Average Width cm	Total Time hours/ha	Time eff. Spent hours/ha	Fuel Consom. litres/hour	Fuel Cons. litres/ha	Efficiency	Wheel-Slip

OBSERVATIONS : (tractor manoeuvrability, balance, adjustments, breakages, work effected etc.)

TEST FORM (Annex 8)
=========

Row N°		P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	Average	Time eff. Spent	Total Time	Fuel consom.	Pto or Wheel rev
1	W															
	D															
2	W															
	D															
3	W															
	D															
4	W															
	D															
5	W															
	D															
6	W															
	D															
7	W															
	D															
8	W															
	D															
9	W															
	D															
10	W															
	D															
												Average				

W = Width D = Depth

Wheels or pto rev. not ploughing

ANNEX 9 : "WHEEL SLIPPAGE (g) AND DRAWBAR PULL (F)

The adherence ratio is $f = \frac{F}{N}$

F = drawbar pull

N = weight on the driving wheels and load transfer on the driving wheels

The relation between adherence and slippage has been determined experimentally :

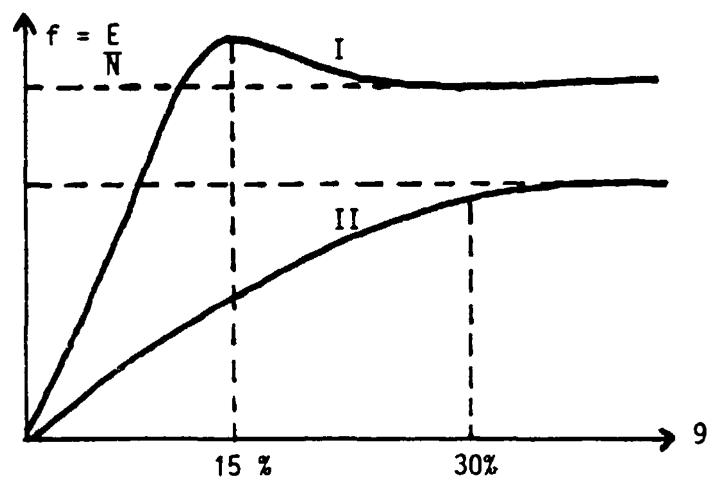


Fig. 1

I : Coherent soils

II : Little coherent soils (sand)

Upto the maximum, the adherence can be said to be proportional to g

$f = kg$

k = (approx.) 0.6 - coherent soils
k = (approx.) 0.3 - little coherent soil (dry clay)

- on a coherent soil the maximum adherence is reached at a relatively low slippage (15 to 20 %). It is then useless to work at higher slip ration.

- on non-coherent soil (sand) the maximum may not be reached before 25 or 30%. It is therefore possible to work with a high slip ration

- what are the factors influencing the adherence ?

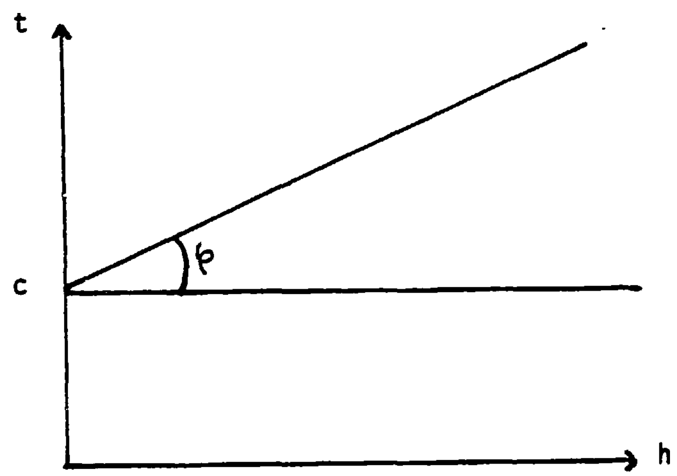
The theoretical Coulomb's equation for this is :

$t = c + h\,tg\,\varphi$ — t = tangential force required to make a layer of soil slide over the next

c = cohesion, characteristic of the soil

h = orthogonal force applied to the soil

φ = "friction angle", another characteristic of the soil



For a driving wheel bearing a weight N and with a soil contacting surface S, this equation gives :

$$t = c + \frac{N}{S}\,tg$$

The drawbar pull given by the wheel at the point where slippage begins is :

$F = ts = cs + Ntg$	(1)
$f = \frac{F}{N} = \frac{C}{P} + tg$	(2)

$P = \frac{N}{S}$ unitary pressure on the soil

ANNEX 10 : LIFE TEST : DAILY FORM

Tractor : ....

Driver : ....

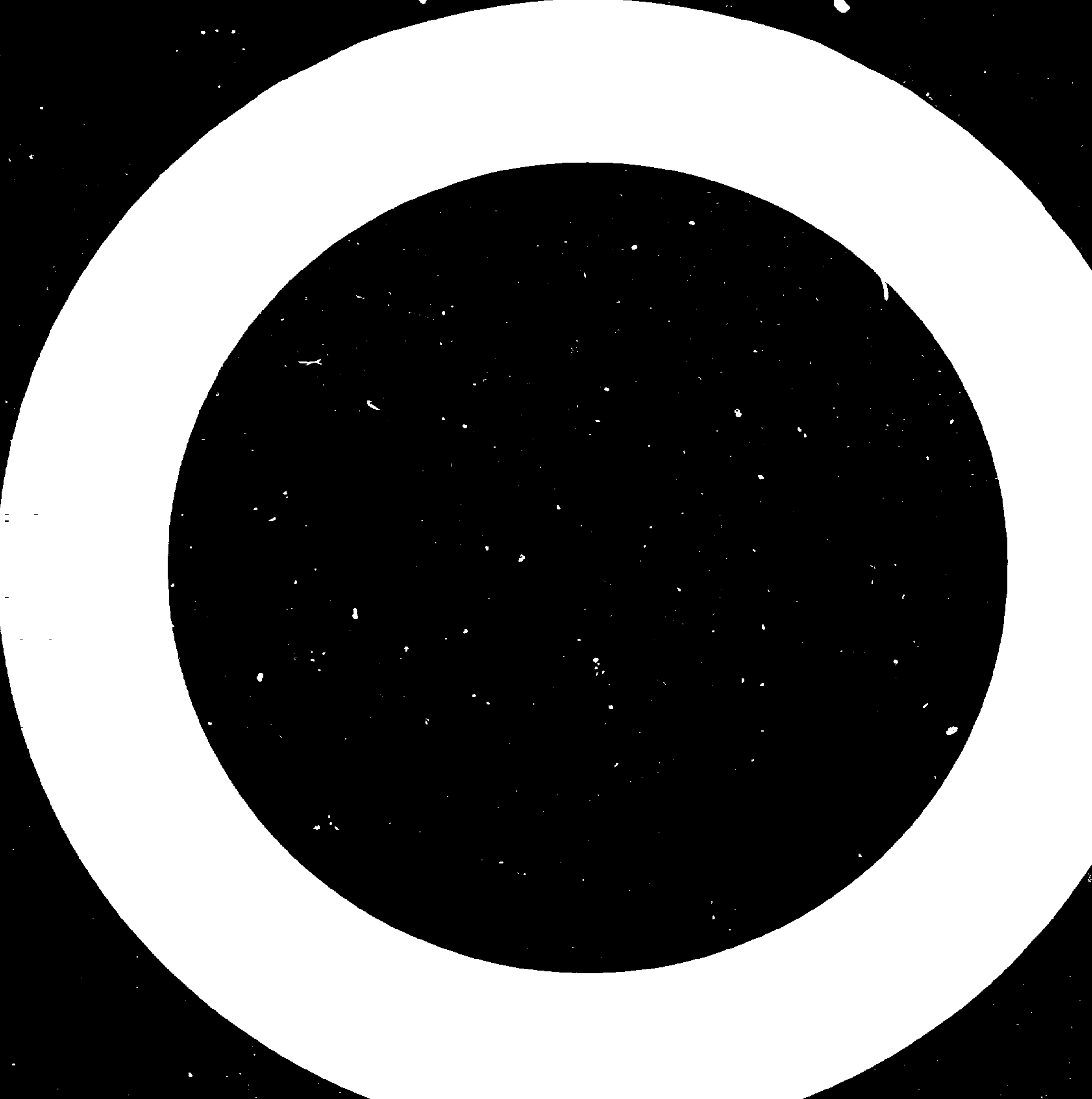
Date :	1st Work	2nd Work	3rd Work
Time of departure			
Time of stop			
Time spent on way from garage to field & back			
Kind of work			
Implement			
Characteristics of the work :			
Width			
Depth			
Others			
Speed of work			
Atmospheric conditions			
Soil conditions			
Fuel consumption			
Acreage			
Time/hectare			
Observations	1st Work		
	2nd Work		
	3rd Work		

Breakages :

Servicing :

	Yes	No
changing oil		
greasing points		
cleaning fuel filter		
cleaning air filter		
battery level		
tyre pressure control		

Others :

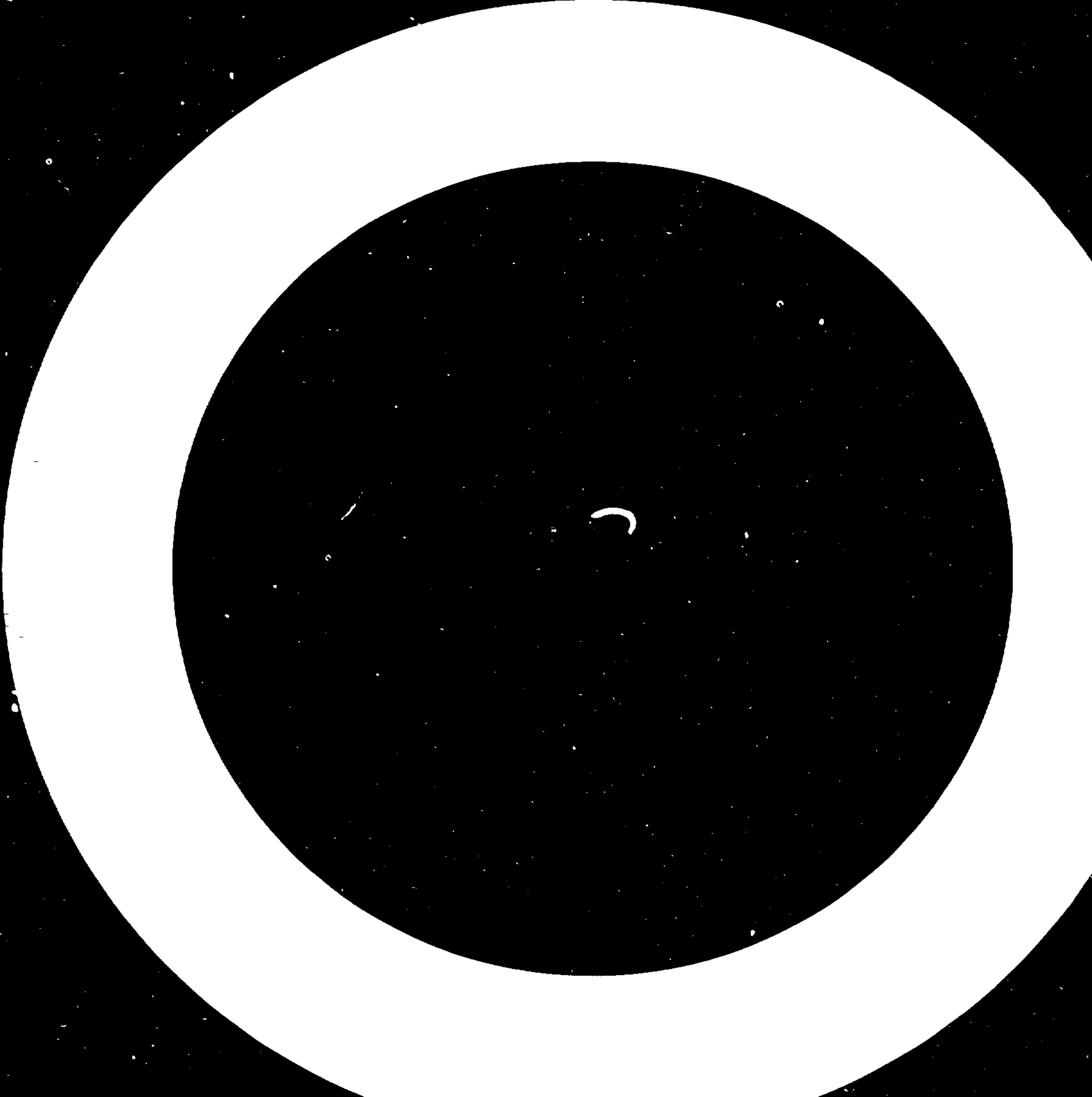


ANNEX 11 : LIFE TEST : MONTHLY FORM

Tractor : ....

Date	Kind of Work Working conditions	Time Spent in the field (hours)	Time for transport (hours)	Fuel Cons. (litres)	Acreage	Breakages Servicing
Total						

	Total Time	Average Time/ha	Total Acreage
Ploughing			
Harrowing			
Planting			
Transport			



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