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Report No. 502
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On an electrical instrument for the acoustical or optical determination of the incidence of knock.

Synopsis: The apparatus described in this report enables one to ascertain the knock condition of gasoline engines; it represents a development of the arrangement recommended in the report No 475 of the Technische Prüfstand. It allows, for example, of registering the knocking excluding underlying noises. Moreover it is controlled automatically; thus for aero-engines with increasing supercharge no readjustment of the amplifier will be necessary.

In conclusion the practical usefulness of the instrument is demonstrated by some comparison curves.

Introduction:

An Apparatus for the knock condition of engines has been described in the report No. 475 of the Technische Prüfstand. Its main drawback is that apart from the knocking proper one always observes a basic noise depending on the engine conditions. This basic noise does not give a good indication of the state of the engine: for a longer series of measurements however, it is very troublesome. This noise also increases with increasing supercharging in the course of supercharge tests; therefore the knocking becomes less distinct then it would be at lower supercharging. The purpose of this further development was the elimination of these drawbacks.

We started from the knowledge gained with the instrument already in existence: that, at the incidence of knock, the engine gives isolated sharp knocks, whereas regular knocking does not occur. It is true that the change from the knock free to the knocking operation is rather sudden; there is however a transition stage during which knocking, if not yet very hard does, occur and is of such a nature that the ear would not have the usual sensation of knocking. This transition, which is always quite rapid, makes it necessary to construct an instrument on electrical principles which distinguishes the knock beats, including those inaudible to the human ear at this transition stage.

Arrangement of the equipment

In the main we kept to the overall arrangement described in the report No. 475 of the Technische Prüfstand. A pick up which transforms the knock impulses transmitted through the engine casing into electrical impulses, transmits the latter to a selective alternating current amplifier. After the important impulses had been amplified the knock condition of the engine was determined by observation of these impulses.

In place of the electromagnetic pick-up which was used formerly, a commercial crystal pick-up was used, the vibrations being communicated to the latter by means of a short steel wire.

The circuit diagram of the amplifier used is shown in sheet 1. In front of the first amplifying stage there is a high pass filter, a condenser chain of the first order. In the first stage there is also a regulating valve AH1, and resonance amplification is employed. The range of frequency is from about 5000 to 12000 Herz. The second stage is an ordinary resistance amplification stage by means of an AF7. The impulses amplified in the two stages are now rectified. Through the filter R_{12} C_{22} impulses are delivered whose magnitude depends on the potentials set up by the pick up. The impulses are now amplified

and then led into the negatively charged grid of a gas discharge valve, so-called thyratron (S1/0.2). If the impulses reach a certain positive magnitude, which is the case when knocking occurs, then the discharge of the condenser C_{26}, which is in parallel with the valve, set in. The thyratron is immediately extinguished, whereupon the condenser C_{26} is recharged through the resistance R_{18}. The knocking thus gives rise to current impulses which may be employed in various ways for the indication of knocking. Some methods are mentioned below.

It has already been mentioned in the introduction that the basic noise increases with greater supercharging. This basic noise consists of vibrations whose frequencies are nearly equal to those of knocking and which arise as a result of the explosion and which are faintly perceptible even when no knocking occurs. Any other vibrations caused by other phenomena need not be considered; they may easily be eliminated by a special cut-out which is coupled with the engine. At greater supercharging the thyratron reacts earlier because of the growing basic noise. The knock limit proper is not really determined. To put this right one would have to turn back the input regulator to compensate for increasing supercharge. This control of the input voltage may however also be achieved by automatic means. It is for this reason that there is one more rectifying valve in the circuit diagram; which provides the regulating voltage for the valve AH1 by way of the filter R_{10} C_{19}. As the incoming amplitudes widen, the potential applied to the grid of the first valve is reduced so that the outgoing amplitudes always remain of nearly the same height. Only sudden and less frequent pulses are not smoothed out by the filter in consequence of the large time constant of the filter. These pulses may therefore be employed to control the thyratron.

Two rectifying valves are used here for the rectification in order to have increased adjustment while using the common AB 2 valve. The regulation may be carried out by means of the potentiometer P_2 without directly altering the height of the impulses.

The current changes caused by the discharge of condenser C_{26} may then be made to register the knocking either acoustically or optically. One may connect an amplifier with loud speaker to the plug labelled correspondingly. Alternatively one may use a pointer instrument, a glow lamp or one can connect a relay to the plug labelled "charge current". The relay may actuate a bell, for example, which would sound at every knock. Further the apparatus allows one to observe the regulated and amplified vibrations by means of an oscilloscope or by connecting a loud speaker one may listen in to the knocking with the basic noise. The apparatus is provided with all the above connections so that as many indicating methods as possible may be tested.

Testing the apparatus on the engine

According to the experimental results available so far the apparatus described is well applicable to both the BMW 132 single cylinder air cooled engine and the water cooled single cylinder engine DB 6001. In particular comparison tests on the BMW 132 are available. Sheet 2 shows the knock limit curves for a fuel, the incidence of knock having been detected by ear and by the method described above. The electrical equipment was adjusted so that while working with the basic noise, coincidence of the listening and the electrical method occurred at one point. The two curves then coincide over practically the whole of their length. The tests were then repeated without the basic noise. The voltage applied to the grid of the thyratron was adjusted so as to give a fair sensitivity to the apparatus. The knock limit curve determined in this way, lies about 1 atm. mean effective pressure lower than the curve determined aurally. About 1-3 knocks per minute are perceptible to the human ear at the knock

limit found thuswhile generally 8 -10 audible knocks denote the onset of detonation. The instruments thus registers knocking before the human ear can detect it. Naturally, by increasing the applied negative potential, the instrument may be made less sensitive so that agreement can be obtained between the two methods. This demonstrates the subjectivity of the adjustment, which therefore calls for standardisation of either a fuel or a condition. Since the curves obtained aurally agree mostly with the curves found elsewhere, they were regarded as authoritative for the present experiments. Of the curves plotted in sheet 3 the curve for the reference fuel Br. 2315 was determined first aurally. The electrical knock detector was then adjusted to give the same curve when working without the basic noise. Without altering the adjustment another two fuels were run according to the two methods. It may be seen from sheet 3 that the two methods give the same curves. It was shown by these and other experiments that for a larger series of measurements and (particularly) for a shorter series, it was sufficient to adjust the instrument at the beginning to agree with the aural method at one point. All curves may then be run without any further adjustment.

It still remains to be seen how well the instrument behaves after use over a long period. It is being used for all current investigations.

Sheet 1 Circuit diagram of the knock detector

Sheet 2 Knock limit curves according to the supercharge method

Engine type BMW 132 N		Compression ratio	1 :6.5
Engine number II		Boost air temp.	130°C
		Ignition timing	30° B.T.C.