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CLINTON ENGINEER WORKS - TENNESSEE EASTMAN CORPORATION

Process Improvement Division

Technical Report

TITLE : THE AVERAGE Q METER

ABSTRACT : The average Q meter is an instrument which averages the Q over short periods of time, thus taking into account non-productive moments due to sparking and other factors, giving a truer measure of production than the present instantaneous meters. Embodied in this report are its methods of operation, reasons for its use, and descriptions of various physical types of the average Q meter.

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METHOD OF OPERATION

It has been customary throughout the plant to consider the sum of the instantaneous Q readings to be the production figure. This figure multiplied by the hours of operation and by appropriate conversion factors should give the quantity of material received at the E. It has been known for sometime that this quantity differs from that actually recovered by a large percentage. It has been found that most of this discrepancy arises from neglecting the effects of sparking (Ref. 1). Each spark causes the E voltage to drop; this drop is followed by a slow rise of voltage to the operating value. During this 3 or 4 millisecond period production is zero. In Alpha-II these short periods of outage account for about 17% of the total production time.

In addition to sparking, high drains operate an overload mechanism for a short interval (3 seconds) which is also non-productive. In Alpha-II this outage is about 4%.

Operating technique has considerable effect on spark outage (Ref. 1) and hence on production. While other factors affect outage G voltage is perhaps the most important. Figure 1 shows spark outage as a function of G voltage. The normal operating point is shown at P. A slight increase beyond this point results in a heavy increase in sparking and instability. Instantaneous Q (Figure 2) increases linearly with G voltage and maximum apparent output is just below the point of instability. However, the true output is shown by the solid curve in Figure 2. This curve is obtained by multiplying the instantaneous Q by the percent innage. This procedure is impractical from the operations standpoint. An instrument can be used which reads effective Q directly. Oscillograms of Q current show in general two values: the instantaneous value shown on the standard meter, and zero. The zero values produced by sparking and breaker operation occur at random. If the Q function is averaged over a period long enough to obtain a representative sampling, the average will be equal to the effective Q .

Figure 1

Figure 2

Any direct current meter because of its construction reads an average current. The period over which this average is taken is a function of the damping of the meter. Any averaging period may be obtained by proper adjustment of the damping. Electrical as well as mechanical damping may be used for this purpose. With a damped instrument the needle moves in response to a step function rapidly at first and then more slowly, the velocity being an exponential function. The "time constant" for this type of movement is the time required for the needle to travel 63% ($1 - \frac{1}{e}$) of the distance from starting to final value.

The time constant must be great enough to obtain a representative sample of the Q but short enough to show effects of cubicle adjustments. It has been found that time constants of one or two minutes are desirable in averaging Q in Alpha-II equipment.

From Figure 2 it can be seen that maximum production is not achieved by the present method of operation, but by a reduction of G voltage. In a recent test an increase of 12% was obtained through the use of average Q meters. Since the production curve shows a rather broad maximum (2 or 3 kilovolts) considerable leeway in G voltage is permissible. Since many equipment failures can be traced directly to sparking, resulting from too-high voltages, the lowest possible G voltage consistent with maximum production should be used.

HISTORY

The average Q meter was first designed and built in February, 1945. The first instrument, an electronic device with a time constant of one minute, was used in studying the effects of spark outage on production and the operator's part in the elimination of outage.

By the first of May measurement of production by means of integrating Q meters was receiving considerable attention and interest was revived in an instrument which would indicate production continuously. Efforts were directed towards electronic means for averaging Q current. An average Q meter attachment was added to the integrating Q meter by K. G. Macleish and E. K. Proctor. Several electronic instruments were also built by the High Voltage Transient Group, but it was soon decided that electronic methods were not suitable. To provide a stable and accurate instrument complicated circuits must be used, requiring a long building time and considerable maintenance.

A resistor-capacitor damped meter was tried but sufficient time constants could not be obtained because of other restrictions on the instrument. With an oil damped meter early experiments indicated that it might be practical and that it was susceptible to extremely heavy damping. Its limitations were not too severe. By the first of June production of these instruments was under way.

A test on 18 production cubicles showed a definite increase in production resulted from the average meter and a large scale test involving 96 cubicles was planned. Oil damped meters were to be used again since they could be built in the plant. A shortage of parts made it necessary to scale down the test to 48 cubicles. Due to a mix up in instructions and the closing of the Alpha plant the test was not carried out as planned. The limited amount of data accumulated indicated the benefits of the average meter were well worth the expense involved in making this meter the standard for all cubicles.

Except for several capacitor damped meters installed in Alpha-I by the Electrical Division staff this experimenting has been confined to Alpha II equipment. Plans at present are to test this meter in Beta.

DISCUSSION OF POSSIBLE TYPES OF AVERAGE Q METERS

There are many types of instrument which may be used to read average Q. Time constant is the important consideration since physical limitations usually place the upper limits on this quantity. In Alpha-II a time constant of at least one minute is necessary. While no experiments have been carried on in Beta, it is thought that 30 seconds will be sufficient. The instrument must be stable and accurate and require no more attention than the present Q meters. Cost and/or difficulties of construction make simplicity necessary. The voltage drop between the Q electrode and ground must also be kept to a minimum, probably below 1 volt.

Capacitor-Resistor Method:

Figure 3 shows a resistor circuit arranged for averaging Q current. A resistor in the Q lead gives a voltage proportional to the current, which is then fed through an R-C filter to a meter. The time constant of such a circuit is

Fig. 3

$$TC = \frac{R_1 R_2 \times C}{R_1 + R_2}$$

R_2 in this case includes the resistance of the meter. If the voltage across r is limited to 1 volt and a 100 μ a meter is used, R_1 plus R_2 cannot be greater than 10,000 ohms, and permissible leakage through the capacitor limits it to about 4000 MFD. The maximum time constant is, therefore, $2500 \times 4000 \times 10^{-6}$ = 10 seconds. This may be satisfactory for Beta operation but it is too short for Alpha. In addition it requires large capacitors and sensitive meters, neither readily obtainable.

Electronic Methods:

By the use of amplifier tubes, it is possible to achieve long time constants with small capacitors, eliminate sensitive meters, and permit small voltage drops in the Q circuits. The fundamental difficulty is that it involves direct current with a small input signal (compared to grid potentials). Methods by which a d.c. amplifier of this sort may be stabilized require additional equipment and lead to complex circuits, difficult to build and maintain.

Fluid Damping Method:

Fluid damping may be used to average the mechanical motion of the meter needle. The meters used in making the oil damped instrument were 500 ma G.E. type D058 milliammeters, identical with the standard total Q meters. The meter cases were sealed with Bakelite cement leaving two holes for admitting oil. After the oil was introduced these holes were closed by screw plugs. The operation is simple and be performed quickly on a semi-mass production basis. Since the whole meter case is filled with oil the entire meter movement including the needle acts as a dash pot; surface tension forces do not exist because all moving parts are submerged. The degree of damping depends on the viscosity of the oil. It was found that a wide range of time constants could be had with oils which were easily obtainable. The oil must be clear so that needle and scale may be seen through it plainly, must not attack any of the meter components or the sealing cement, and must have a viscosity that is constant from batch to batch and reasonably constant with temperature. The viscosity of Nujol and similar mineral oils may vary considerably between bottles and, therefore, not be adapted to mass production. The table below shows the various oils tested and the time constants associated with them. These time constants apply only to the G.E. type D058 meter since configuration greatly affects damping.

OILS USED FOR FLUID DAMPING

Type	Viscosity Saybolt Seconds at 100°F	Time Constant Seconds
Transil Oil	55	4
Nujol	200	20
Castor Oil + 10% CCl ₄	740	50
Castor Oil	1300	130

Information on the oils and some of the oils themselves were supplied by T/4 C. B. Yantis of the Lubricating Engineering Department.

That fluid damping, at least with the oils listed above, is equivalent to electrical damping was demonstrated by applying current step functions to the instruments. The major limitation of the present design of the oil damped meter is that it must be operated in a horizontal position. The type D058 instrument has an aluminum needle made from a hollow tube of

small cross section. This needle is balanced in air by a small brass weight opposite the needle. When the meter is immersed in oil the buoyant forces on needle and weight are different and hence the movement is no longer balanced. This unbalance arises partly due to air entrapped in the hollow needle. This unbalance will cause an error in reading unless the plane of the needle movement is horizontal, in which position the unbalanced forces are perpendicular to the direction of motion. This difficulty may be overcome by use of standard meters rebalanced under oil, or by the use of meters so constructed that air is not entrapped and the needle and counterweight are of the same material. The latter is the most practical method since oil balancing is tedious and messy.

Maintenance on some 80 of these meters, some of which have been in operation more than three months, has been negligible. No difficulty has been encountered with oil leaking out. If a manufacturer can be persuaded to build these meters, they would probably be the cheapest method of obtaining long time constants.

Thermal Damping Method:

The thermal damping method using a thermocouple type meter, suggested by the General Electric Company, with a thermal resistance between the heater and couple and/or a thermal capacitance at the couple is used. It is not known how difficult it would be to produce such a meter, but it would seem to have good possibilities. It is not a true averaging meter, however, because the deflection is a function of the r.m.s. or heating value of the signal.

Magnetic Damping:

The Tripplett Electrical Instrument Company submitted models of magnetically damped meters. A 50 μ a movement was shunted with a 500 ma shunt to provide a nearly zero resistance loop, and a strong cobalt magnet was used. Some damping was obtained but the time constant was only about 1 second. It seems doubtful if a time constant of one or two minutes can be built into an ordinary meter in this way.

CONCLUSIONS

The average Q meter is a useful instrument in measuring production and in aiding the operator to maintain maximum output with minimum damage to equipment wherever heavy sparking is encountered. Its use in testing new equipment is imperative since it is the only instrument which allows the operator to achieve maximum production. Instances can be cited where units thought to be good because of high instantaneous Q current were relatively poor because of excessive sparking. The electronic method of damping can be eliminated because of its complexity; the magnetic can probably be eliminated also due to the extreme difficulty of obtaining sufficiently long time constants. The thermocouple meter looks promising although it is not truly an averaging meter and considerable development would be necessary

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before it could go into production. For time constants up to 10 or possibly 20 seconds the capacitor-resistor instrument is practical and easily built but rather expensive due to the sensitive meter and large capacitor. Where longer time constants are necessary the oil damped meter seems to be the best solution. Cost of this instrument would probably be low in the quantities required.

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