COMPARATIVE TESTS OF HIGH VOLTAGE RESISTORS USED FOR VOLTMETER BLEEDERS

by: Carl T. Grauer, June 19, 1944

Purpose of Test

When measuring high DC voltages, it is general practice to use a combination of D'Arsonval milliameter and series resistor. To reduce the power loss in the series resistor to a negligible value, a low reading instrument, generally 1 milliampere full scale is used.

When using the 1 milliampere meter to measure 40 KV, a bleeder resistance of 40 megohms will be required. To calibrate this combination, the instrument alone may be checked against an accurate milliampere standard. The problem then remains to determine accurately the resistance of the 40 megohm bleeder and also to determine whether this bleeder resistance remains constant.

Tests were therefore made for the purpose of determining the accuracy and permanency of various types of high resistance bleeders, and their resistance variation during use over a period of approximately six months.

Equipment Tested

Tests were made on the following types of high resistance bleeders:

(a) Westinghouse Sectional Resistors, Style #1,099,345, Item 4, rated 1000 volts, 1 megohm, 40 units were used in series to give total values of 40,000 volts and 40 megohms.

(b) International Resistance Co., Type MVR resistor, 1 unit, 40 megohms

(c) International Resistance Co., Type MVR resistors, 2 units of 20 megohms each in series. Total resistance, 40 megohms.

(d) International Resistance Co., Type BTS resistors, 100 units of 0.4 megohms each. Total resistance 40 megohms.

(e) Shallcross Mfg. Co., Type KR-5 Taylor High Voltage Resistor (Super

Akra-ohm). Rated 5000-7500 Volts, 5 megohms each. 8 units used in series, Total rating 40-60 KV., 40 Megohms.

(f) Shallcross Mfg. Co., Akra-ohm type tubular resistor 10,000 Volts, 2.5 Megohms each. 4 units used in series, total rating 40 KV and 10 Megohms.

(g) Weston Model 301 D.C. Milliammeters, 0-1 M.A. Six were used, one in series with each bleeder.

(h) Simpson, Model 29. DC Milliammeters, 0-1 MA. Six were used, one in series with each bleeder.

Method of Test

All resistors, as named above, were mounted on an insulated test rack and paralleled on a high voltage bus. A Weston and a Simpson meter were connected in series on the grounded end of each bleeder, and a 10,000-ohm grounding resistor was connected across the two meters for safety purposes.

The high voltage bus, located in the rectifier cage of one of the projects in the area, ensured that each bleeder resistor and its associated milliammeters was reading the same voltage (approximately 34 KV) as supplied to the tank during operating periods.

The resistance of each bleeder was measured regularly and recorded on a time basis. Regular checks were also made on each meter and all values plotted to show variations from their original values.

Results of Test

The actual resistance values, in Megohms, for each of the six different types of bleeder, are shown in Curve Sheet #1. A megger was used to measure the resistance, output voltage being approximately 600 Volts.

Resistance measurements were also made on these six units by means of direct reading instruments using 2800 volts D.C. and applying all instrument corrections. This voltage was obtained from a full wave rectifier circuit having adequate

filtering, and a very steady output voltage which could be varied over a wide range.

Various test voltages were applied to these resistors, the current drain being measured carefully and then the calculated resistance recorded on Curve Sheet #2.

Variations in the accuracy of the Weston Milliammeter are shown on Curve Sheet #3. It is, of course, obvious that where the bleeder resistance is higher than its nominal value, the meter connected to it will read low, while if the bleeder resistance is low the meter will read high.

When these individual errors are applied to each unit (Bleeder and Meter) the combined errors are as shown on Curve Sheet #4. It will be noted from Curve Sheet #2, that tests were necessarily interrupted on the Shalleross Taylor Type Bleeder after approximately 2300 hours, because one of the units in this group became open-circuited. Prior to this failure, it had been necessary to replace one of these units after approximately 720 hours of service.

Discussion of Results

Curve Sheets 1 and 2, show that there is a continuous and gradual change in the resistance of all six bleeders, greatest changes occurring in the group of 100 BT2 cartridge type resistors of 0.4 Megohms each. For precision work, this type of bleeder can be considered as unsatisfactory, in view of its 7.5% change in resistance in 3800 hours.

Test results show that these units do not remain within the manufacturer's estimate of "±2.5% average variations with time" for the change is approximately three times that figure. Since these resistors are rated at 2 watts and were operated at only 0.4 watt during test, such a large change in resistance value can be attributed to neither overheating nor overvoltage.

V-273-3

However, where voltage checks with an accuracy of ± 10% are satisfactory, these MT2 resistors provide an easy and economical solution to the high voltage bleeder problem. Total cost of the 100 units would be approximately $18.00, not including mounting facilities.

Considerable variations in resistance occurred in the two 20 Megohm Type MVR units, total variation being from + 2.5% to -2.5%. These figures meet the manufacturers rating of ± 2-1/2%, are low in cost (approximately $20.00 each) and can be easily mounted in fuse clips on stand-off insulators.

There is, however, a large variation in resistance of new units, the manufacturer's tolerance being 15%. In order to obtain a bleeder of some desired value, it is therefore necessary to measure a considerable number of them and select the one which is the nearest to the marked nominal value.

A resistance test made on six of these MVR resistors, all marked 40 Megohms, (Type 3185), showed the following values:

Unit A	39 Megohms	2.5% low
" B	37 "	7.5% "
" C	42 "	5.0% high
" D	41 "	2.5% "
" E	40 "	O.K.
" F	41 "	2.5% high

The temperature error due to self-heating, is kept to a low value by the use of 1 milliampere meters.

Thus at 40 KV, the 40 Megohm bleeder will have a power loss of 40 watts. Since there is a total surface area of 108 square inches, the watts loss per sq. inch of radiating surface is only 0.37 which is well under the maximum of 1 watt per square inch generally allowed for resistor work in the power industry.

V-273-4

The Westinghouse Sectional Resistor, 1 megohm each, showed very steady resistance values for approximately 2400 hours of operation, this variation being less than 1%. At the end of an additional 1600 hours operation, the resistance decreased a total of 2-1/2%.

Apparently the Manufacturer makes no claim for permanency of resistance. The initial accuracy tolerance of 1/2 of 1%, however, is justified since measurements of a considerable number of these units, showed values well within these limits.

A serious objection to the use of these units is their high cost. At $12.50 per section, a 40 megohm bleeder costs $500. It has been found that if these sections are mounted in one continuous string, the mechanical strains imposed on each section tend to cause breaking of the very fine wire with which these units are wound. This condition occurs when the coupled sections are mounted in a horizontal position, wherein a long string of the coupled units will sag in the middle.

A flash-over and burnout actually occurred in this manner, the simple and obvious remedy being to mount these units vertically. A still better method is to break up these long strings into a number of short lengths, say 10 strings of 4 units each. If then the end units are equipped with metal ferrules, as supplied by the manufacturer, each string can be snapped into fuse clips mounted on stand-off insulators.

This arrangement allows horizontal or diagonal mounting without imposing mechanical strains, and has the further advantage that each group can be tested with higher voltage gradient, greater accuracy, and can be easily replaced if found to be defective.

These units are non-inductively wound and hermetically sealed in molded Phenolic cases. They have a low heat-loss rating because each unit is completely sealed off from contact with the outside air, and the phenolic casing is a poor heat conductor.

V-273-5

From a design viewpoint, one of the best high voltage resistors is the Taylor-Type XR-5, as manufactured by the Shalleross Co. These units are wound with Manganin wire (having zero temperature coefficient), are non-inductive, electrostatically shielded and have large curved surfaces to eliminate corona.

They are quite constant in their resistance and have uniform values of initial resistance which check closely with their nominal ratings.

Unfortunately, these excellent design characteristics are nullified by the use of resistance wire which is so small and delicate that these units open-circuit and therefore become useless. New units, just received from the factory, have been found to be "open". During the test run, as described, 2 units in a string of 8 became open-circuited. In another installation, 8 of these units were each tested twice before mounting into a group as a complete bleeder. When the assembly work was completed, it was found on final test that one of these units had open-circuited.

At a cost of $60.00 each for a 5 megohm unit, an assembled bleeder of 40 megohms will cost $480.00 exclusive of mounting supports, labor, etc. An effort is being made to have these units rewound with heavier wire by the manufacturer, as high priced electrical instrumentation can only be justified by reliable accuracy and permanence of operation.

The other Shalleross resistors, the Akra-Ohm units are fairly reliable. Megger measurements indicate a resistance drift of 4% maximum, while tests with the 2800 volt method indicate a drift of approximately 2% over a test period of 3800 hours.

These tubular resistors are rated at 2.5 Megohms each, and in a 40 KV circuit a total resistance of 10 megohms will pass 4 milliamperes. Thus the power loss per resistor unit will be 40 watts, or 160 watts for the entire bleeder. However, since each tube has a total winding area of 61 square inches, the self-heating during operation will be less than 0.7 watts per sq. inch which is a safe value for wire exposed to air cooling.

These units are coated with a black ceramic paint, but here again, the wire is so fine that if the paint is accidentally nicked or chipped, it flakes off the tube surface and takes a small portion of wire with it, resulting in an open circuit. The cost of these Akra-Ohm units is approximately $25.00 each, amounting to $100.00 for the ten megohm bleeder complete.

Since these units are rated at 200 watts, it would be possible to meter the 40 KV voltage by using two of the 2.5 megohm units in series with an 8 ma instrument and thus save the price of two resistors. But when this is done, there is a continuous power loss of 320 watts or 7.7 Kilowatt hours per day of operation per tank. If such a setup were to be used in a large scale operation (500 tanks), this power loss would reach the astonishing figure of 3800 Kilowatt hours per day for voltage indication purposes only. If power is readily obtainable in large volumes at low cost, and if strategic material and manufacturing time is scarce, such operation might be justified.

Conclusion:

These tests have indicated that several choices of high voltage resistors can be made. These are listed in order of desirability:

(1) Westinghouse Sectional Resistors, 1 megohm each, 40 required, mounted in groups of 4 units per section with ferrules on each end. This mounting allows rapid installation, testing and replacement if necessary.

±2% Accuracy - Reliable Operation - High Cost

(2) Shallcross Akra-Ohm Resistors, 2.5 Megohms each, 4 units required. Used with a 4 ma meter to read 40 KV.

±2% Accuracy - Reliable Operation - Reasonable Cost - Considerable power loss

(3) International Resistance Co., Type MVR, 40 Megohms, 1 Unit.

V-273-1

It is necessary to test a group of them with selection of the best one.

±2.5% Accuracy - Reliable Operation - Low Cost.

(4) Shalleross Taylor-Type XR-5 Resistors. 5 Megohms each. 8 Required for use with 40 KV and a 1 ma meter.

±1% Accuracy - Unreliable Operation - High Cost

(5) International Resistance Co., Type BTZ. 100 Resistors of 0.4 Megohm each, for use with 40 KV and a 1 ma meter.

±10% Accuracy - Considerable Variation - Low Cost

If the Shalleross Taylor Type units can be obtained, wound with heavier wire, so that they would become reliable in operation, these units might be given the highest rating.

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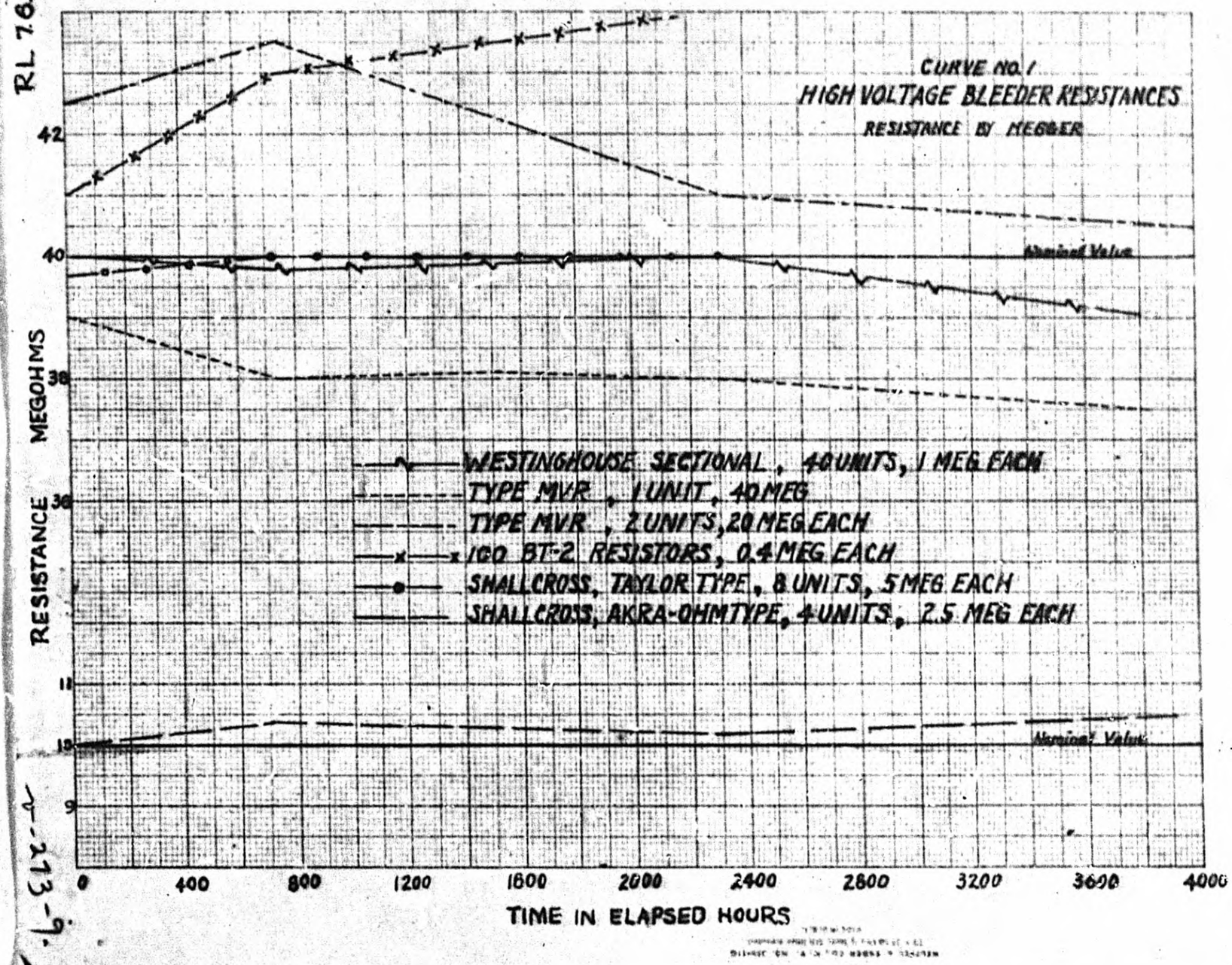
RL 7.6.7

CURVE NO. 1

HIGH VOLTAGE BLEEDER RESISTANCES

RESISTANCE BY MEGGER



RESISTANCE MEGOHMS

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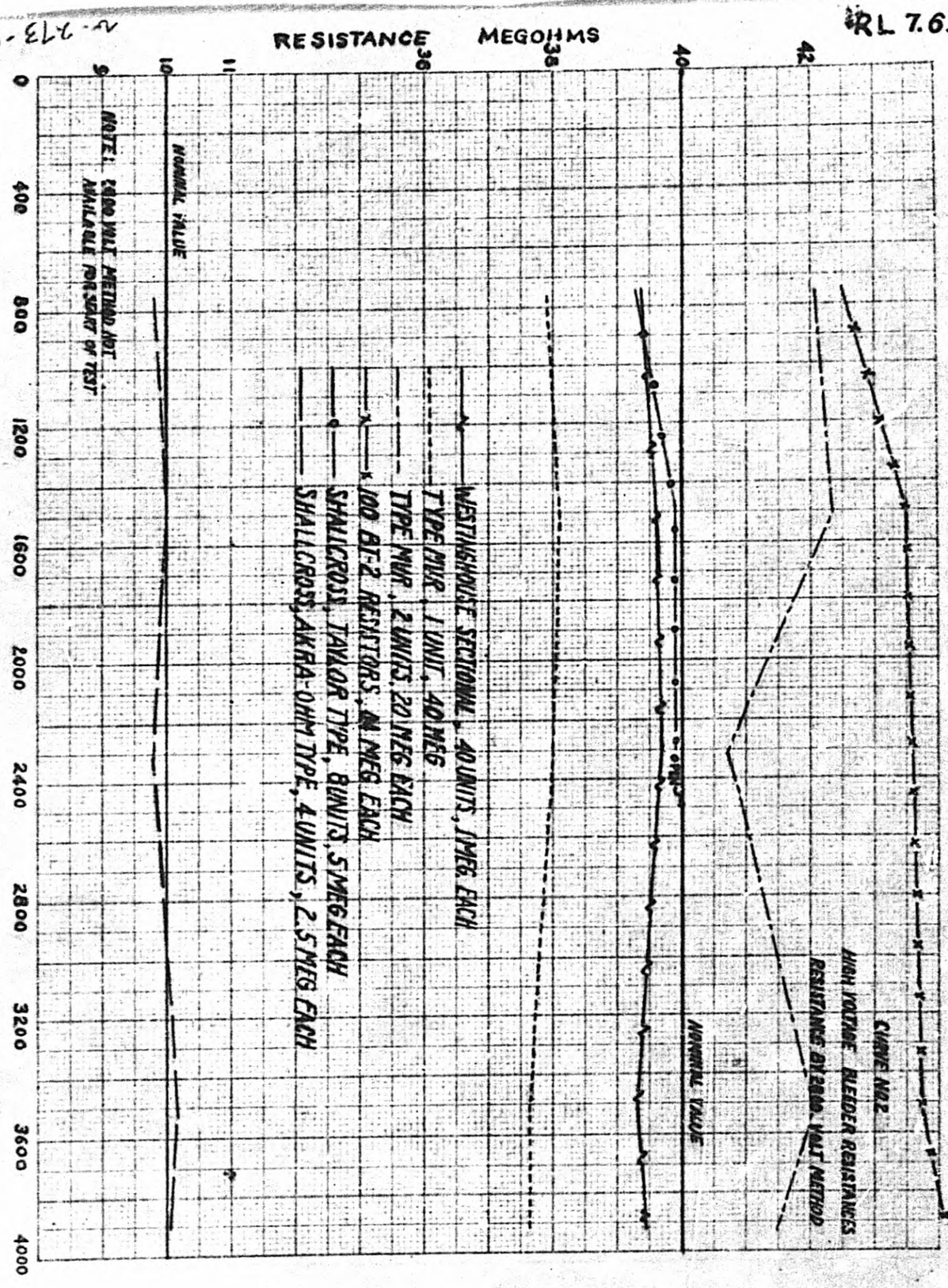
RL 7.6.7



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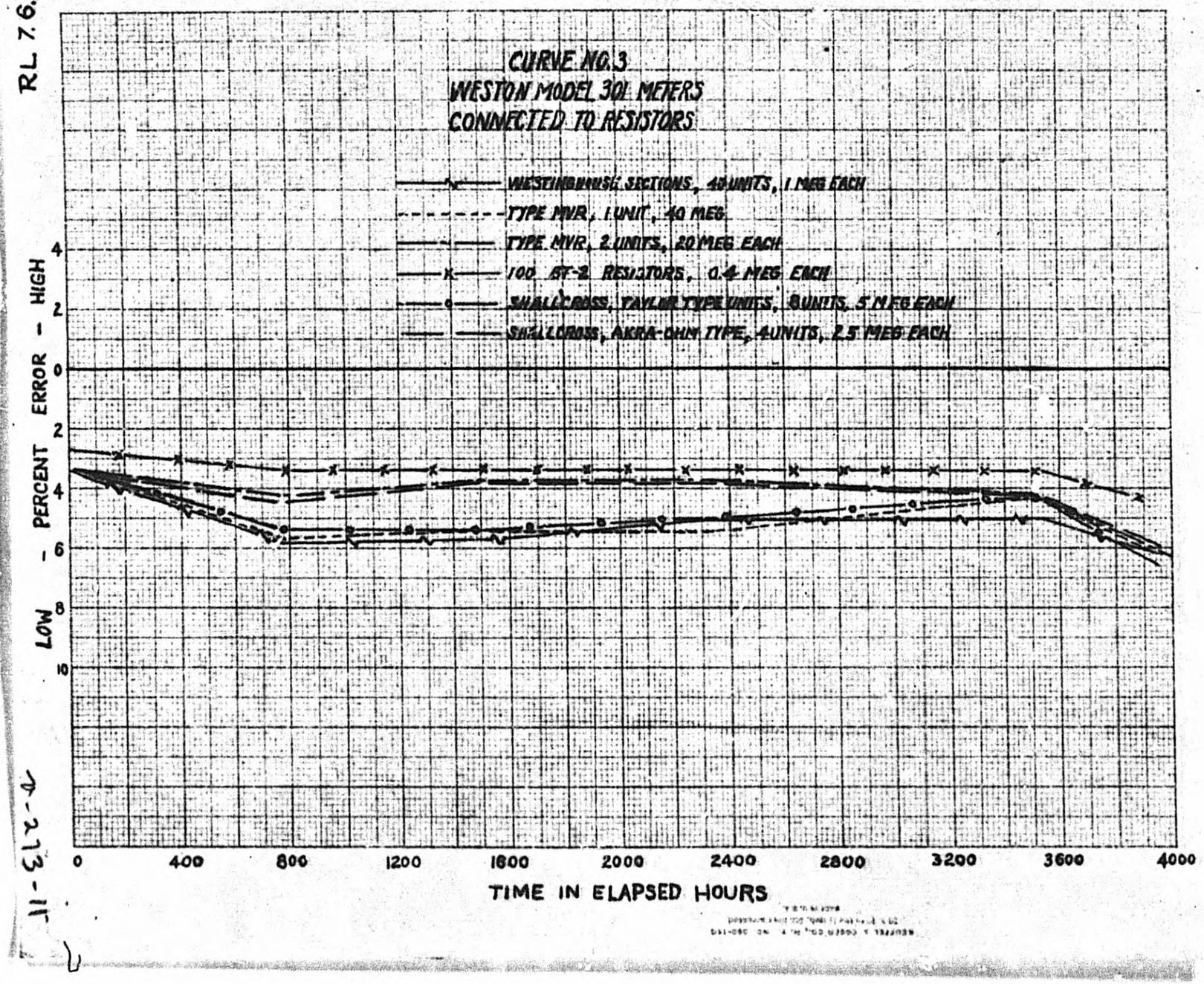

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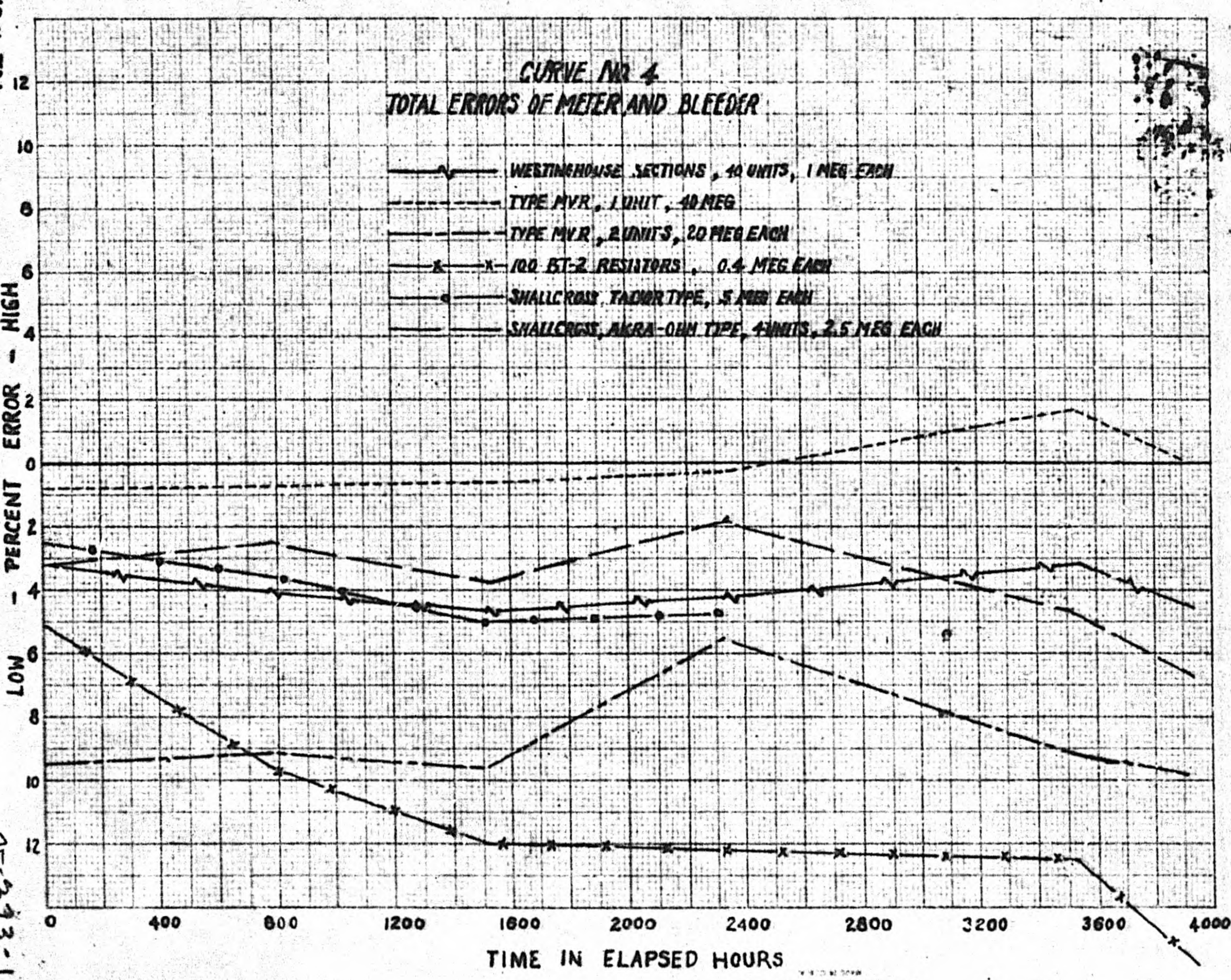

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