Title
Use of the Characteristics of Permalloy in Detecting a Predetermined Value of Magnetic Field or Current in a Time-Varying Electromagnet.

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USE OF THE CHARACTERISTICS OF PERMALLOY IN DETECTING A PREDETERMINED VALUE OF MAGNETIC FIELD OR CURRENT IN A TIME-VARYING ELECTROMAGNET

1/4 Scale Bevatron Operating Model
Magnetic Field Strength-Magnet Current Correspondence

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Purpose of Test:

In programming the sequence of events in the operational cycle of the bevatron, certain devices must be triggered at specific values of magnetic field strength in the gap. It is desirable that the time-jitter, which corresponds to field jitter, of the triggering pulses be small. In the synchrotron this is done with peaking strips which are located in the fringing field of the gap. The rate of rise of the bevatron field is about 5000 gauss/second.

In the bevatron the gap is enclosed. Insertion of apparatus into the gap is done at the expense of available area for the ion current. Therefore, it was thought advisable to program with the current. Because of residual field and eddy current considerations it was not obvious that current and field were in correspondence at all times. The purpose of this test was to establish such correspondence.

Method of Test:

A peaking strip (described in Appendix 1) was placed in the gap of the bevatron model. The purpose of the peaking strip was to indicate the time at which the bevatron field reached a predetermined value. The signal from the peaking strip was amplified and differentiated in the circuit shown in Drawing 2Y1894. The differentiated signal was amplified and used to fire a thyratron. It was found, as shown in Figure 2, that the trailing edge of the peaking strip signal had a steeper slope than the leading edge. The differential curve had approximately constant slope over its height, so any part of it could be used to trigger the thyratron. Amplification of the differential curve inverts it. The positive pip thus obtained is used to fire the thyratron. When the bevatron field decreases a signal of opposite polarity is produced. The bias of the thyratron is such that the small positive pip due to the leading edge of this unwanted signal will not fire it. The thyratron acts as a pulse generator whose sharp output is fed to the oscilloscope.

Peaking transformers were made which linked the magnet current lead in conductor. They are described in Appendix 2. The purpose of the peaking transformers was to indicate the instant at which the magnet current passed through a predetermined value. Their output signals had the same form as that of the peaking strip, and they were handled in the same way. Two peaking transformers were used at one time.

Observations were made with a DuMont Model 248 Cathode Ray Oscilloscope. A triggered single sweep was used. The signal due to one peaking transformer was used to initiate the sweep. The signals due to the other peaking transformer and to the peaking strip were viewed.

Sequence of operation was as follows:

Both peaking transformers were set at approximately the same bias current. The signal from the one being observed was located, using the 1000 μ-sec. sweep, by varying the bias currents in the transformers. The method of doing this was to apply the signal to be viewed to the vertical amplifier. It was great enough to saturate the amplifier for several thousand μ-sec. If the sweep-triggering signal came before the viewed signal, a horizontal line appeared in the middle of the screen. If the viewed signal came first the sweep would go across the bottom of the screen. Bias currents were varied until the saturation occured during the sweep. The signal was then applied directly to the vertical plates and moved to the beginning of the 1000 μ-sec sweep. It was then viewed on the 100 μ-sec sweep and finally on the 25 μ-sec sweep.

After the peaking transformer signal was located on the 1000 μ-sec sweep, the bias on the peaking strip was varied until it was brought onto the same sweep as the transformer. They were kept together and moved to faster sweeps together by varying bias on the triggering transformer. Time markers were placed on the screen and jitter-time was measured with them.

<u>Results of Test</u>:

It was found that the wave-shape of the 4000 turn transformers looked better (steeper slope) when viewed directly, but that they jittered quite badly. This may be due to lack of current regulation, since very small currents are needed.

The 1500 turn transformers were used in conjunction with the peaking strip to check jitter. Sequences of approximately 20 readings were taken. Results:

PS Bias	PT_1 Bias	PT_2 Bias	Jitter PT_1-PT_2	Jitter PT_1-PS	Jitter PT_2-PS	Field Corresponding to Peaking Strip	Current Corresponding to PT_1, Approximate
.175a	.01a	.02a	$<\pm 5\mu$sec	$\pm 5\mu$sec	$<\pm 5\mu$sec	35 gauss	15 amps
.30	.02	.03	± 5	± 8	± 5	50 gauss	30 amps
.40	.03	.04	± 5	± 10	± 5	80 gauss	45 amps
.50	.04	.05	$<\pm 5$	± 10	± 10	100 gauss	60 amps
.60	.05	.06	$<\pm 5$	$<\pm 5$	± 5	120 gauss	75 amps
.78	.06	.075	$<\pm 5$	± 5	$<\pm 5$	156 gauss	90 amps

It was impossible to go higher with the peaking strip due to heating. The peaking transformers were taken on up.

PT_1	PT_2	Jitter	Corresponding Field	Corresponding Current
.10	.11	$<\pm 5$	180	150
.20	.21	± 5	360	300
.30	.30	$>\pm 10$	530	450

There was often drift superimposed upon the jitter. This is believed to be a temperature effect caused by resistance change of the bias windings due to heating. It could be corrected by using a current-regulated supply.

The rate of rise of 5000 gauss/second means that a $\pm$ 10 microsecond time jitter corresponds to a field jitter of $\pm$0.05 gauss, approximately. This is well within the tolerance desired for the bevatron.

Appendix 1
Peaking Strip

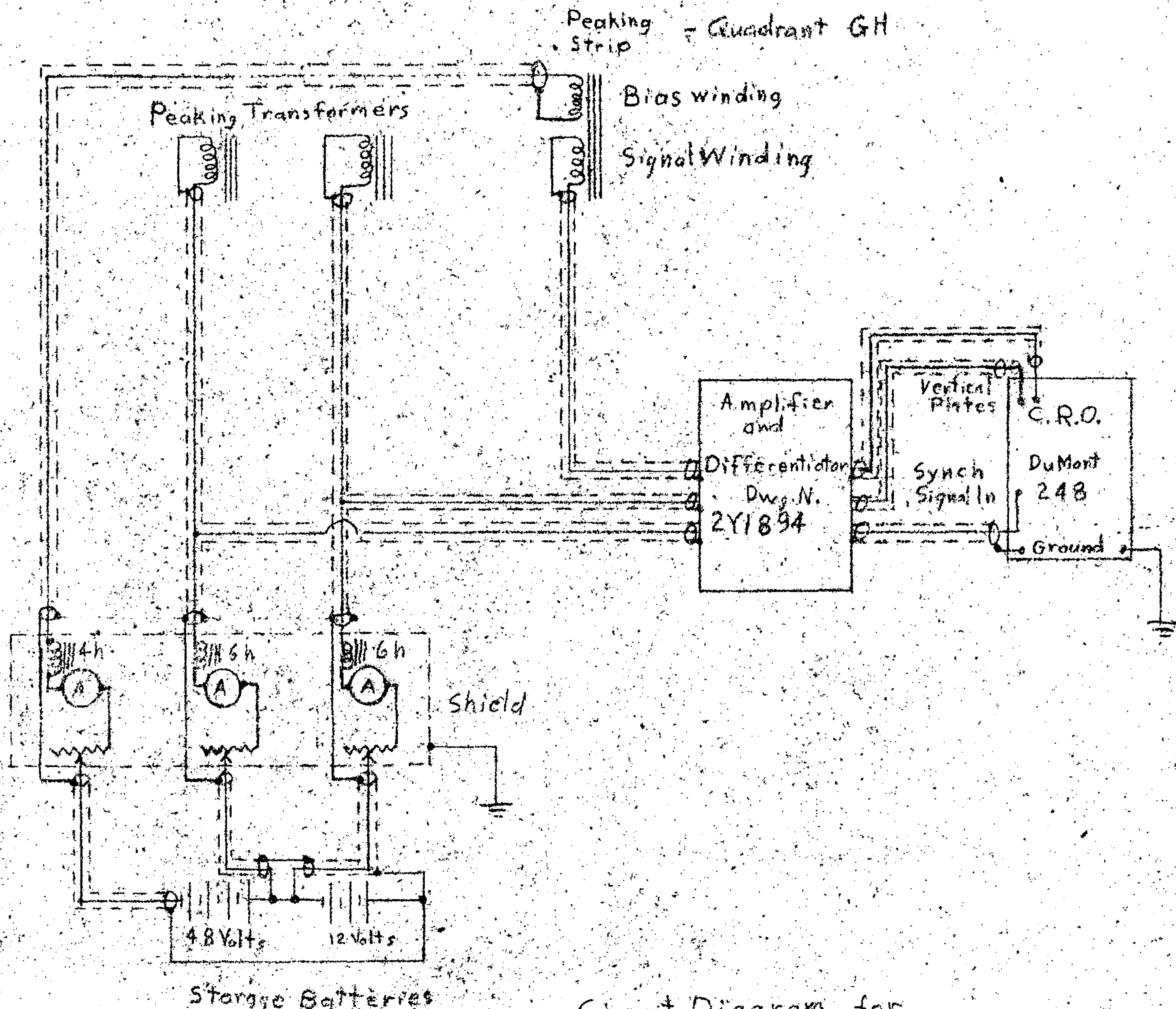
The peaking strip consists of 20 layers of 0.001" x 1 cm x 12" S.G. Permalloy strip wound for 6 cm. of its length with #37 enamelled wire. This is approximately 500 turns. The Permalloy is mounted upon a 2.1 cm x 12" strip of bakelite, which is placed within a 12" long solenoid wound upon 7/8" I.D. Bakelite tubing. The solenoid consists of 8 layers of #26 cotton covered wire, which gives approximately 4800 turns and corresponds to 400 turns/in. The bias field will be approximately 200 gauss/amp. Bias current flows in this solenoid, causing the Permalloy to be saturated. Direction of the bias current is such as to give a field in opposition to the bevatron field. See Figure 2. When the bevatron field reaches a value equal to the bias field, the Permalloy passes through zero field on its B-H curve. As the bevatron field continues to increase, the Permalloy saturates in the opposite direction. When the saturation of the Permalloy reverses, the flux linking the signal winding on the Permalloy changes by twice the saturation flux. This gives the output signal which is proportional to $-\frac{d\phi}{dt}$.

Since Permalloy saturates at less than one oersted, the length of the entire signal, expressed in terms of oersteds, is not more than two oersteds. The trailing edge of the signal occupies much less than this. The output signal of the thyratron is then an indication of some H within 1 or 2 oersted, if the hysterisis, eddy currents, or some other factors do not cause jitter.

Appendix 2
Peaking Transformers

The cores are of 0.001" by 1 cm S.G. Permalloy, wound in a ring with inside diameter of 5 cm. and radial thickness of 0.3 cm. Since Permalloy work-hardens very easily, these were made by unwinding layers from the saturable reactors of S.G. Modulators for some SG shipborne radar. The core was left unworked by this process. A toroidal winding of formex covered copper wire was used. The 4000 turn transformers were wound with #32 wire and the 1500 turn transformers with #26 wire. The signal was taken from the bias winding. A series choke was used to prevent shorting of the signal through the battery circuit. The output signal is formed and handled in the same manner as that of the peaking strip. The measured field, instead of being the field in the bevatron gap, is the field linking the current lead of the bevatron.

Since $\int H \cdot dl$ around any closed path is proportional to the number of amperes turns linked, the ratio of bevatron current to bias current is simply the number of turns of the peaking transformer.



Circuit Diagram for
Hrs. I Correspondence Tests
$\frac{1}{4}$ Scale Operating Model
Bevatron

Fig. 1

3-4-49 R.E. [signature]

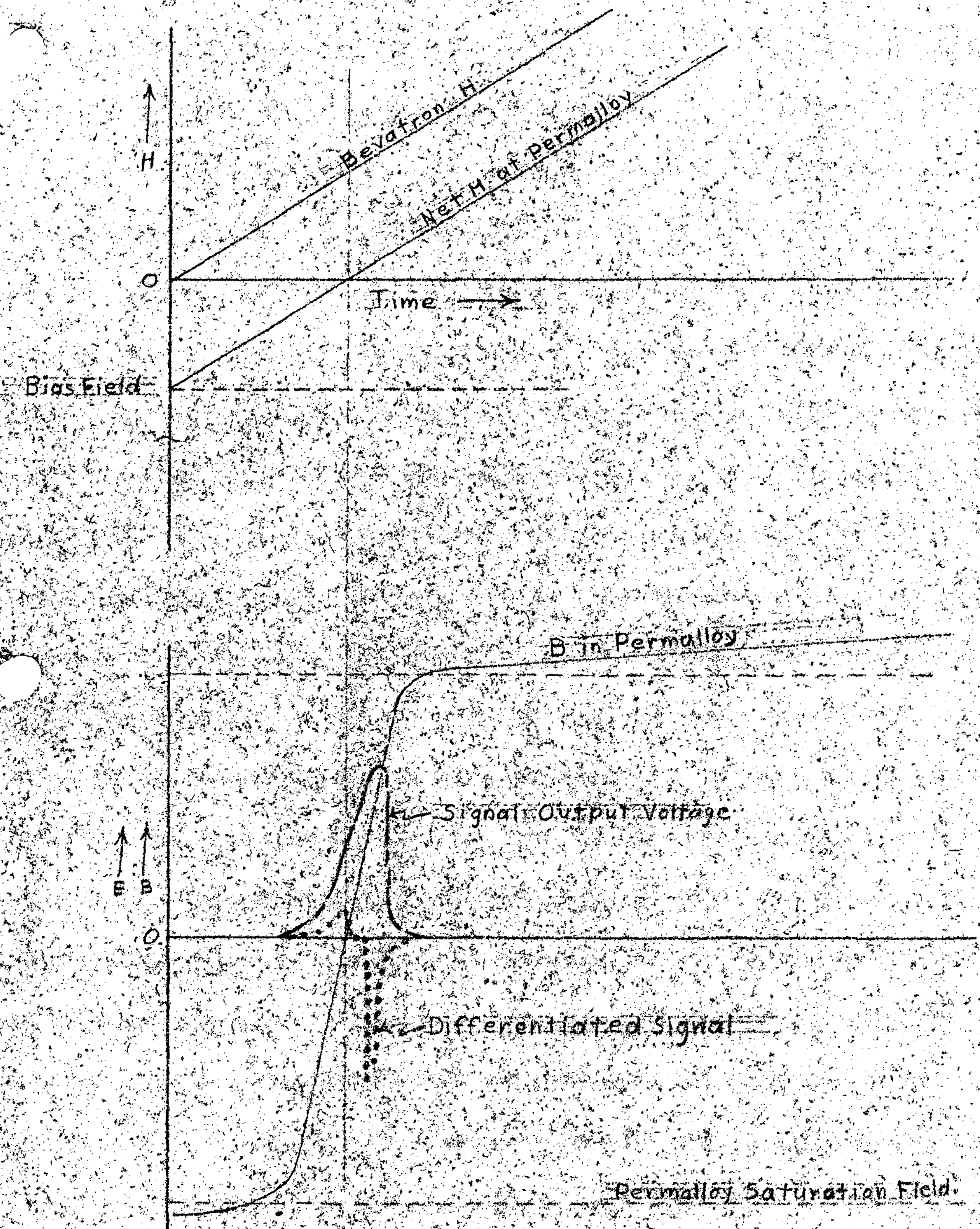


Figure 2

3-24-49 RE Richardson

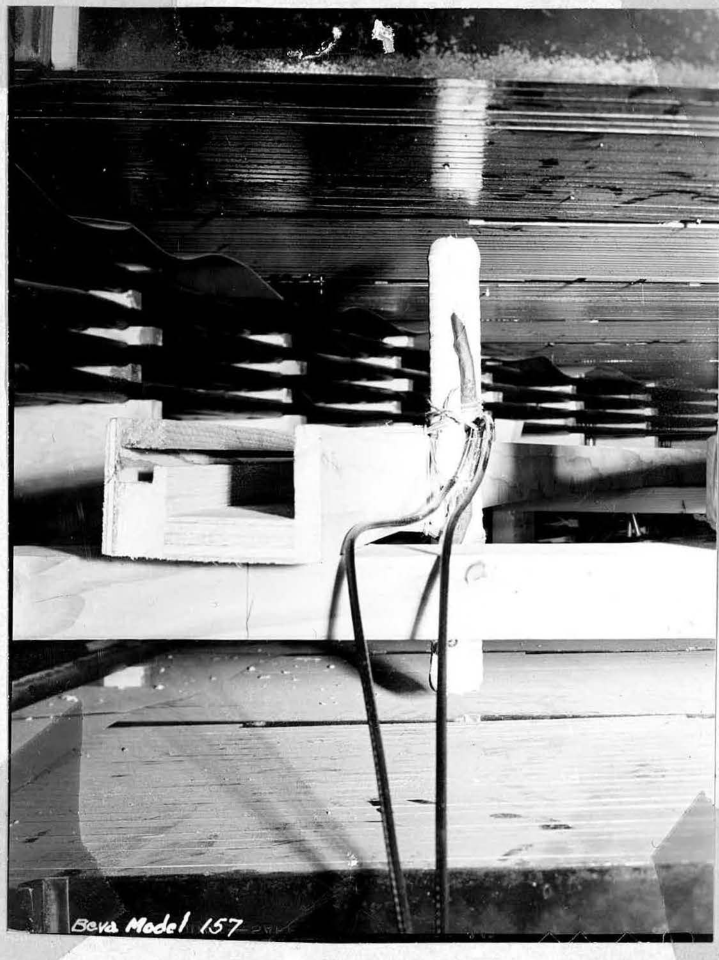


FIG. 3 - Peaking Strip Mounted in
Quarter Scale Bevatron Model Gap

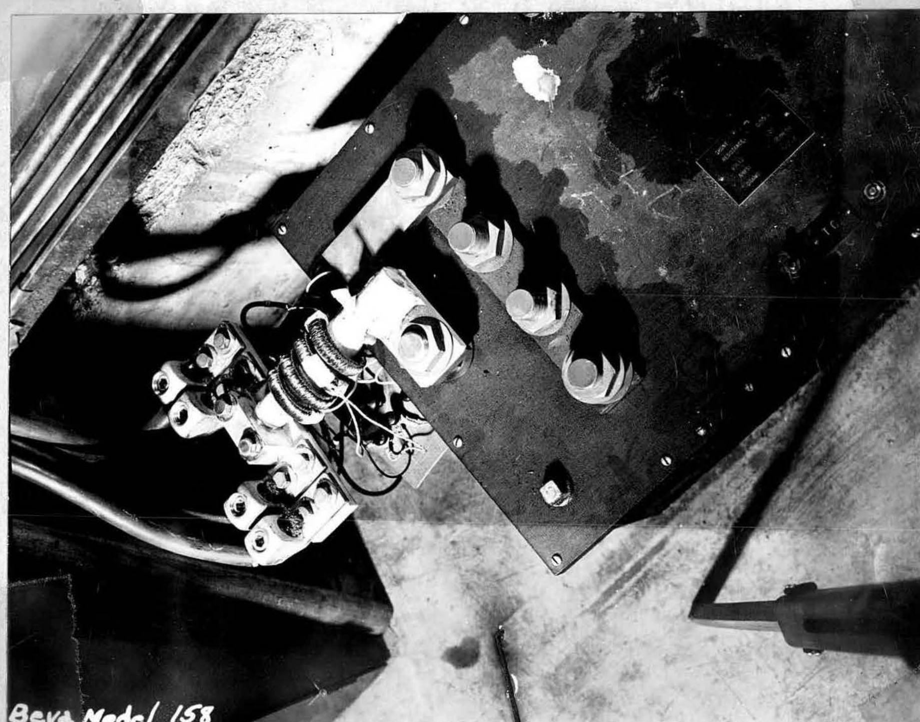


Fig. 4 - Peaking Transformers Mounted on Current Lead at the Shunt

QUARTER SCALE BEVATRON
PEAKING STRIP & PEAKING TRANSFORMER
PULSE AMPLIFIER — SCHEMATIC

FIRST USED ON 184-11	RADIATION LABORATORY UNIVERSITY OF CALIFORNIA–BERKELEY
ROUGH FINISH / FINE FINISH	DRAWN BY JWS / CHECK BY / DATE 1-7-49
GOOD FINISH / GRIND G FINISH	APPROVED BY
TOLERANCES WHERE NOT OTHERWISE GIVEN ±.010	DRG. NO. 2Y1894B
DATE REQ'D / MAKE	SCALE NONE

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