CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

OTTAWA

MINES BRANCH INVESTIGATION REPORT IR 72-6

EFFECT OF COLD WORK ON THE MAGNETIC PERMEABILITY OF SHERRITT GORDON'S HIGH-PURITY NICKEL STRIP

by

C. F. DIXON AND N. S. SPENCE

PHYSICAL METALLURGY DIVISION

COPY NO. 0

FEBRUARY 10, 1972

Mines Branch Investigation Report IR 72-6

EFFECT OF COLD WORK ON THE MAGNETIC PERMEABILITY OF SHERRITT GORDON'S HIGH-PURITY NICKEL STRIP

by

C. F. Dixon* and N. S. Spence**

- - - -

ABSTRACT

The effect of from 0 to 15% cold reduction on the microstructure, hardness, and magnetic permeability of Sherritt Gordon's SGM nickel strip was investigated. No change in the equiaxed grain structure of the strip was observed as a result of the cold reduction, but there was a decrease in magnetic permeability that appeared to be directly related to an increase in hardness. Different starting and finishing gauges had no effect on the hardness or magnetic permeability.

---

* Physical Scientist and ** Head, Nuclear and Powder Metallurgy Section, Physical Metallurgy Division, Mines Branch, Department of Energy, Mines and Resources, Ottawa, Canada.

INTRODUCTION

Part of the study by the Royal Canadian Mint Committee on New Coinage on factors involved in minting pure nickel coins revealed that small variations in the magnetic permeability of nickel could be important in the design and operation of sophisticated electronic coin-testing units for vending machines and that the magnetic permeability was related to the cold work introduced during the production of coin blanks and struck coins. The relationship between magnetic permeability and cold work was therefore investigated to provide information for possible use in establishing production and quality control over the minting of nickel coinage.

In a previous report (1), the magnetic permeability of Sherritt Gordon's SGM cold-rolled nickel strip was shown to be inversely proportional to the hardness, and the greatest magnetic permeability and hardness change occurred within the first 20% of cold reduction. This report deals with the magnetic permeability and hardness of nickel strip cold-rolled, in small increments, up to 15% cold reduction. The microstructure of the strip was also examined.

MATERIAL

The material examined was Sherritt Gordon's SGM 99.9% Ni strip produced by the roll compacting of nickel powder, sintering at 980°C (1800°F) and hot rolling to 0.180-in. and 0.090-in. gauge strip. Material of each gauge was cold-rolled to intermediate gauges, annealed in a hydrogen atmosphere for 30 min at 900°C (1650°F) and cold-rolled to 0% (annealed), 2%, 4%, 6%, 8%, 12%, and 15% reduction to produce 0.051-in. and 0.036-in. gauge strip. This resulted in four series of cold-worked strip as shown in Table 1.

TABLE 1

Nickel Strip

Series	Starting Gauge (in.)	Final Gauge (in.)
I	0.180	0.051
II	0.180	0.036
III	0.090	0.051
IV	0.090	0.036

The grain sizes and hardness of 0% cold-reduced samples for each series, as supplied by Sherritt Gordon, are listed in Table 2.

TABLE 2

Grain Size and Hardness of SGM Nickel Strip

Series	Condition	Grain Size (microns)	DPH
I	0% CR	15-20	81.4
II	0% CR	15-20	78.4
III	0% CR	15-20	71.8
IV	0% CR	20-25	65.2

CR - Cold-Reduced.

PROCEDURE

Samples, 1/2 x 2 in., were cut from nickel strips in each metallurgical condition. These samples were sectioned into three specimens as shown in Figure 1.

The three surface planes identified as X, Y, and Z were polished and etched for metallographic examination and hardness determinations as described elsewhere (1).

Superficial Vickers hardness tests using a 5-kg load were done on polished sections of specimens mounted in diallyl phthalate.

The magnetic characteristic of the nickel strips was determined by a Magne Gage (American Instrument Company). Values are indicated on an arbitrary scale and are directly proportional to the magnetic permeability.

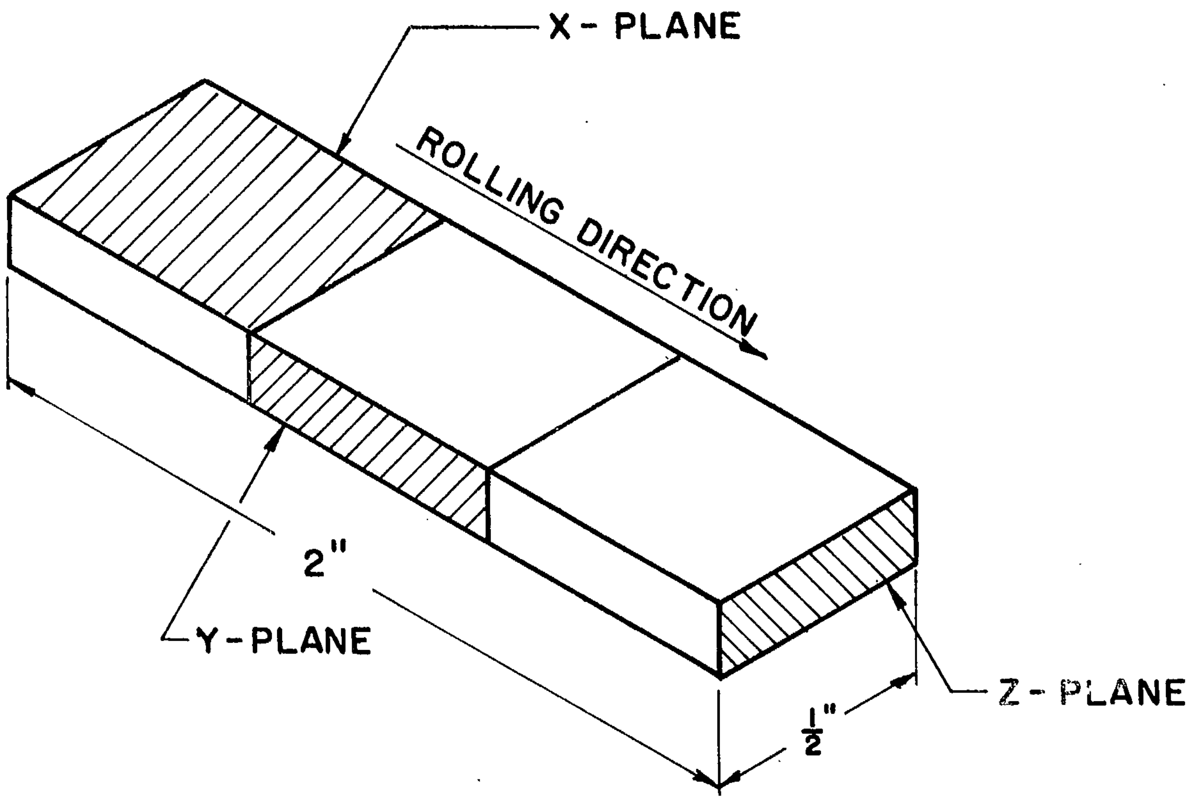
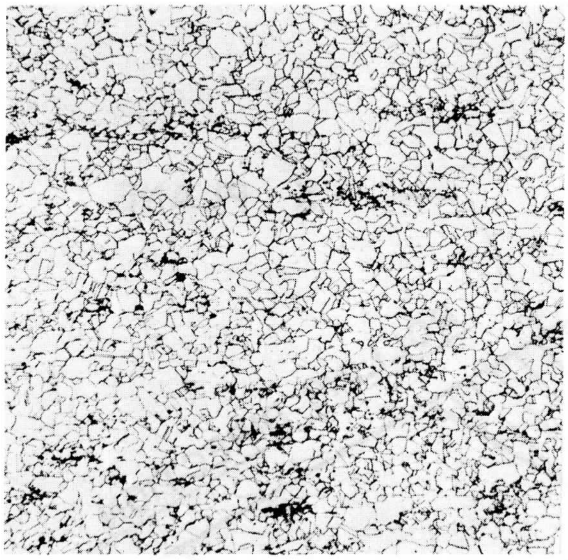


Figure 1.   Nickel Sample

RESULTS AND DISCUSSION

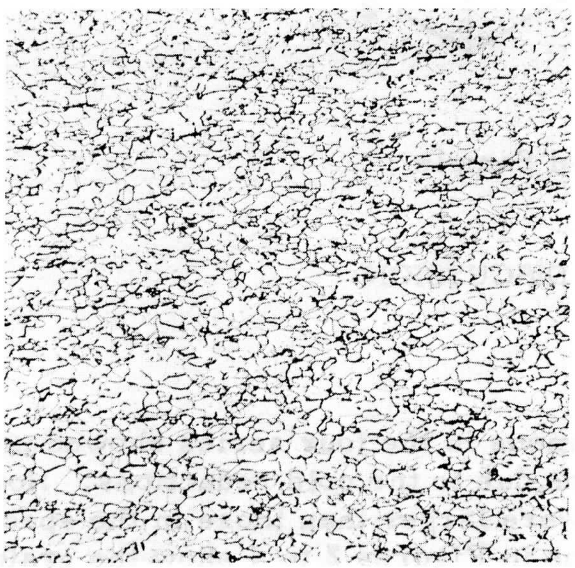
Grain Structure

Microexamination of the specimens in the four series showed no change, in the equiaxed grain structures, due to the cold reductions. However, the grains in specimens in Series III were larger than those in the specimens in the other series. Photomicrographs in Figures 2 to 4 show the grains, in the X, Y, and Z planes of the specimen in Series II, cold-reduced by 6%; these are typical for all specimens in Series I, II, and IV. Figures 5 to 7 show the grains in the three planes of the specimen in Series III cold-reduced by 6%. This difference in grain size evidently results from the metallurgical histories of the strips prior to annealing. The grain sizes supplied by Sherritt Gordon Mines Limited (Table 2) show Series IV to have the larger grains. The reason for this conflict is not known.



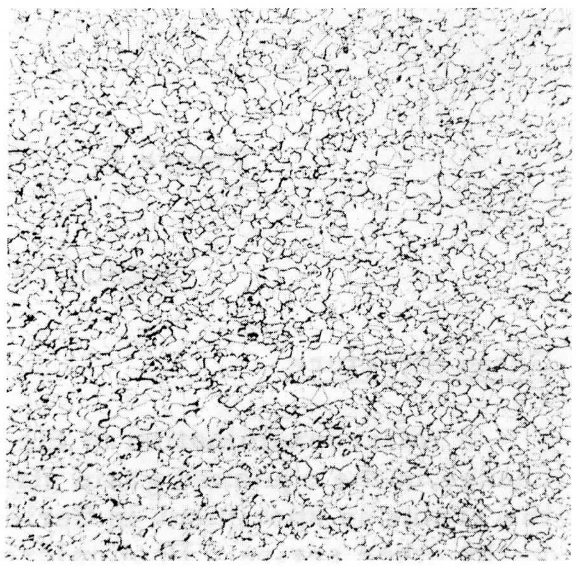
X100

Figure 2. SERIES II
X-Plane, 6% CR



X 100

Figure 3. SERIES II
Y-Plane, 6% CR

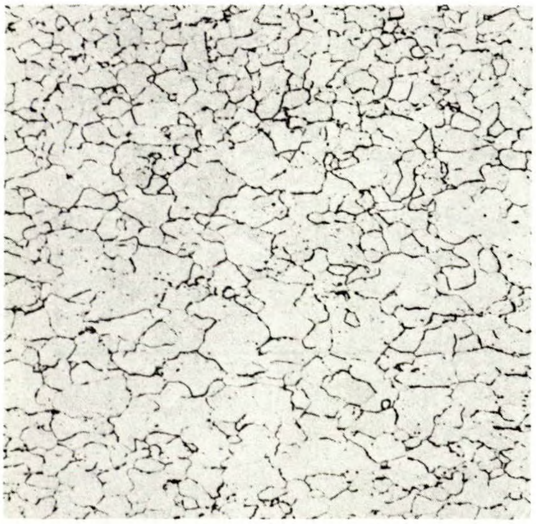


X100

Figure 4. SERIES II
Z-Plane, 6% CR

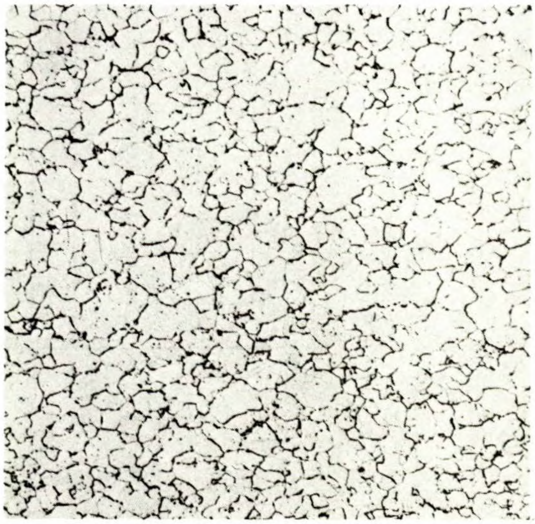
X100

Figure 5. SERIES III
X-Plane, 6% CR



X100

Figure 6. SERIES III
Y-Plane, 6% CR



X100

Figure 7. SERIES III
Z-Plane, 6% CR

Superficial Hardnesses

Results of the superficial Vickers hardness tests for the X-. Y-, and Z-planes of all the specimens in Series I, II, III, and IV are listed in Table 3. Average values for the three planes in each specimen are plotted against the per cent cold reduction, Figure 8, and the line graph for the points in Series I is drawn in. There is some scatter of the hardness for each increment of cold reduction but the four series of samples showed the same trend.

TABLE 3

Vickers Hardness Numbers (5-kg load)

SERIES	PLANE	% Cold Reduction						
		0	2	4	6	8	12	15
I	X	86	100	114	124	128	141	149
	Y	72	92	115	125	131	147	154
	Z	78	93	118	128	131	146	156
II	X	81	97	113	125	128	131	152
	Y	72	95	113	125	128	137	148
	Z	73	101	113	124	129	136	152
III	X	88	108	120	125	129	150	152
	Y	72	102	119	120	130	151	147
	Z	71	102	121	118	131	150	147
IV	X	85	98	113	143	146	151	157
	Y	71	88	105	139	144	151	156
	Z	71	90	108	140	146	152	156

Magnetic Properties

Magne Gage readings for all specimens examined are plotted against per cent cold reduction and against Vickers hardness in Figures 9 and 10, respectively. In the latter, values obtained in this investigation as well as values , from previous work (1), for nickel strip cold-reduced up to 70% fall within the range indicated. These graphs show that the magnetic permeability of nickel strip is inversely proportional to the per cent of cold reduction and to the hardness, and it appears that either could be used to indicate the degree of magnetic permeability.

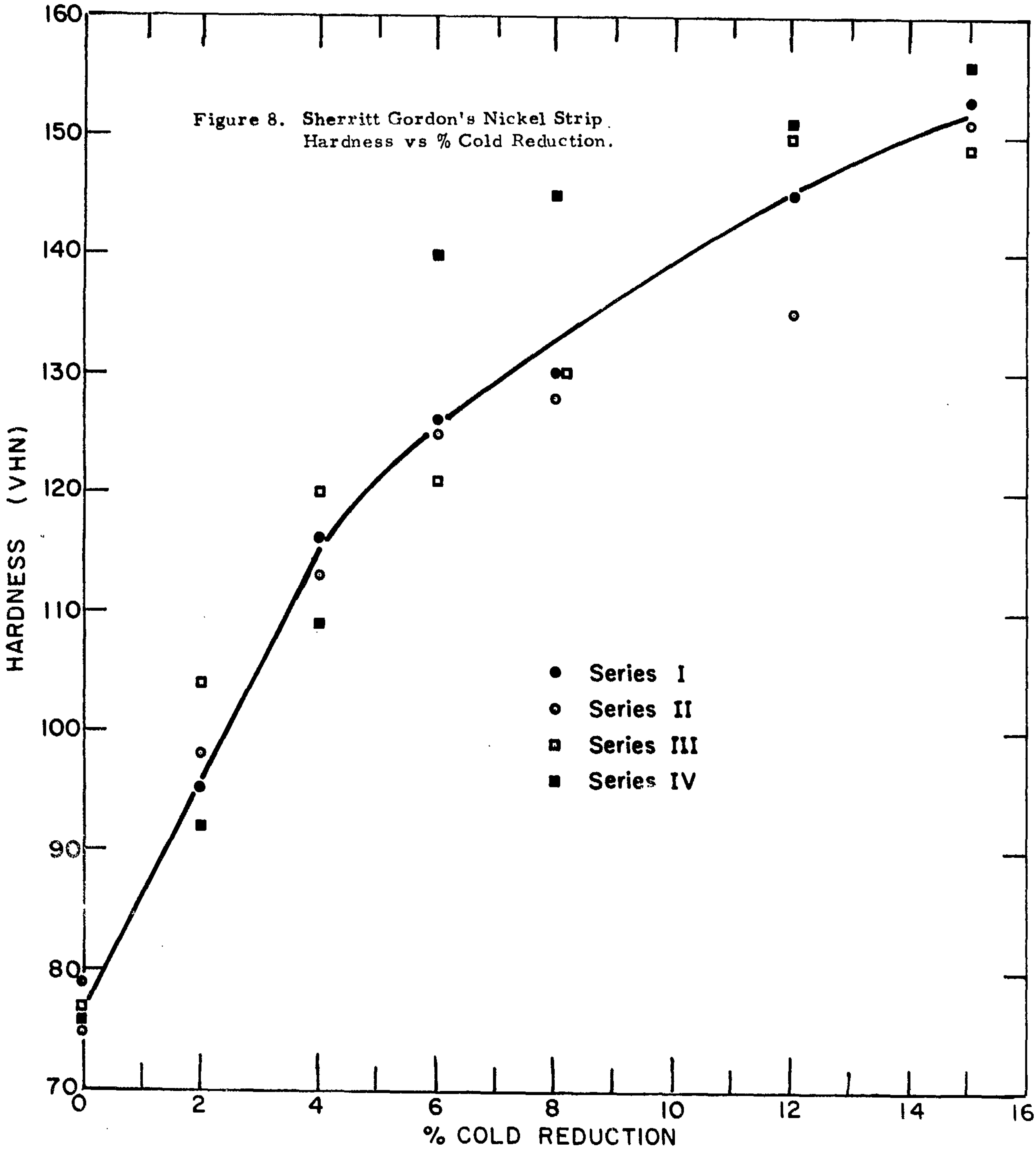


Figure 8. Sherritt Gordon's Nickel Strip
Hardness vs % Cold Reduction.
HARDNESS (VHN)
160
150
140
130
120
110
100
90
80
70
0
2
4
6
8
10
12
14
16
% COLD REDUCTION
Series I
Series II
Series III
Series IV

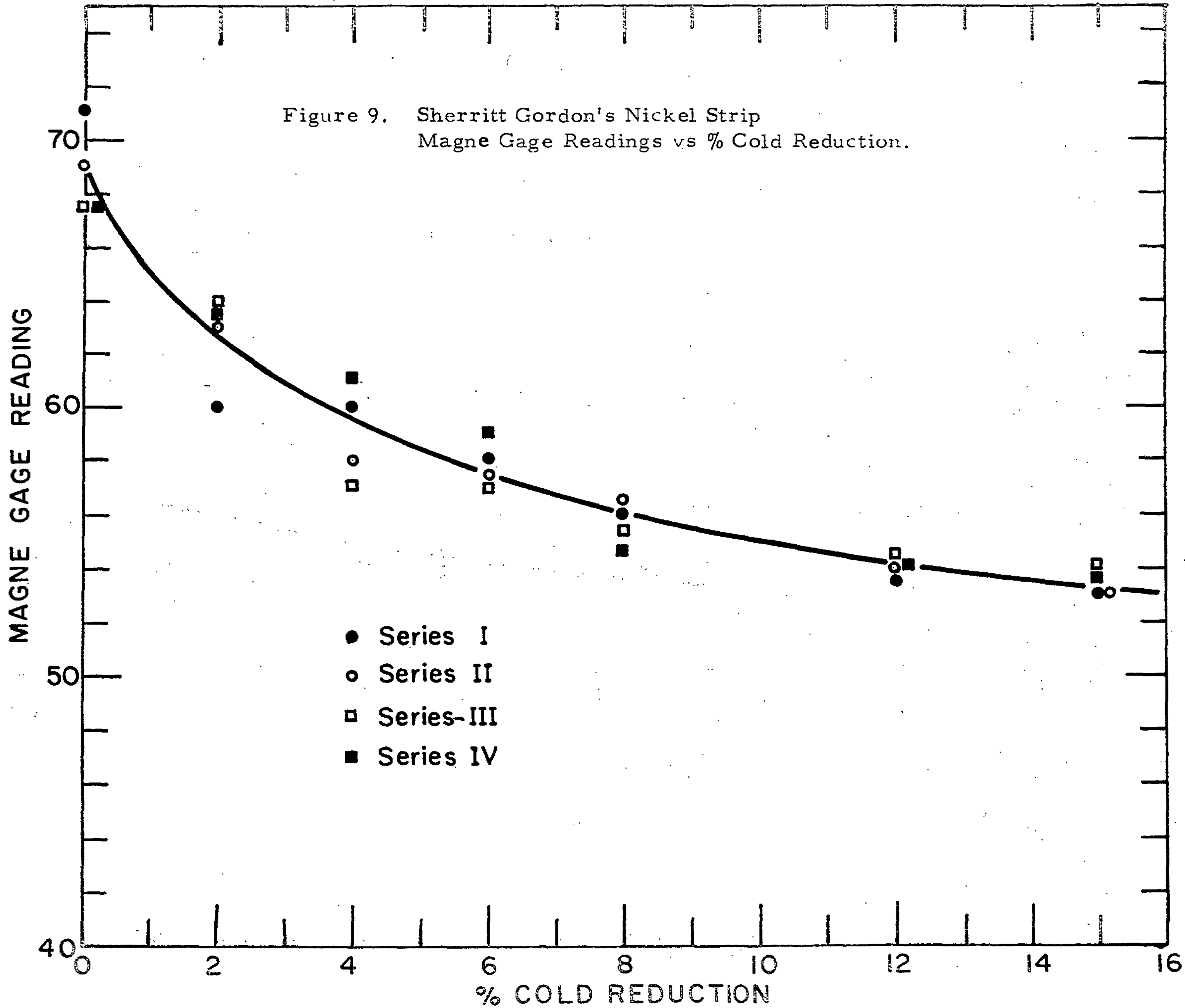


Figure 9. Sherritt Gordon's Nickel Strip
Magne Gage Readings vs % Cold Reduction.
MAGNE GAGE READING
70
60
50
40
0
2
4
6
8
10
12
14
16
% COLD REDUCTION
Series I
Series II
Series-III
Series IV

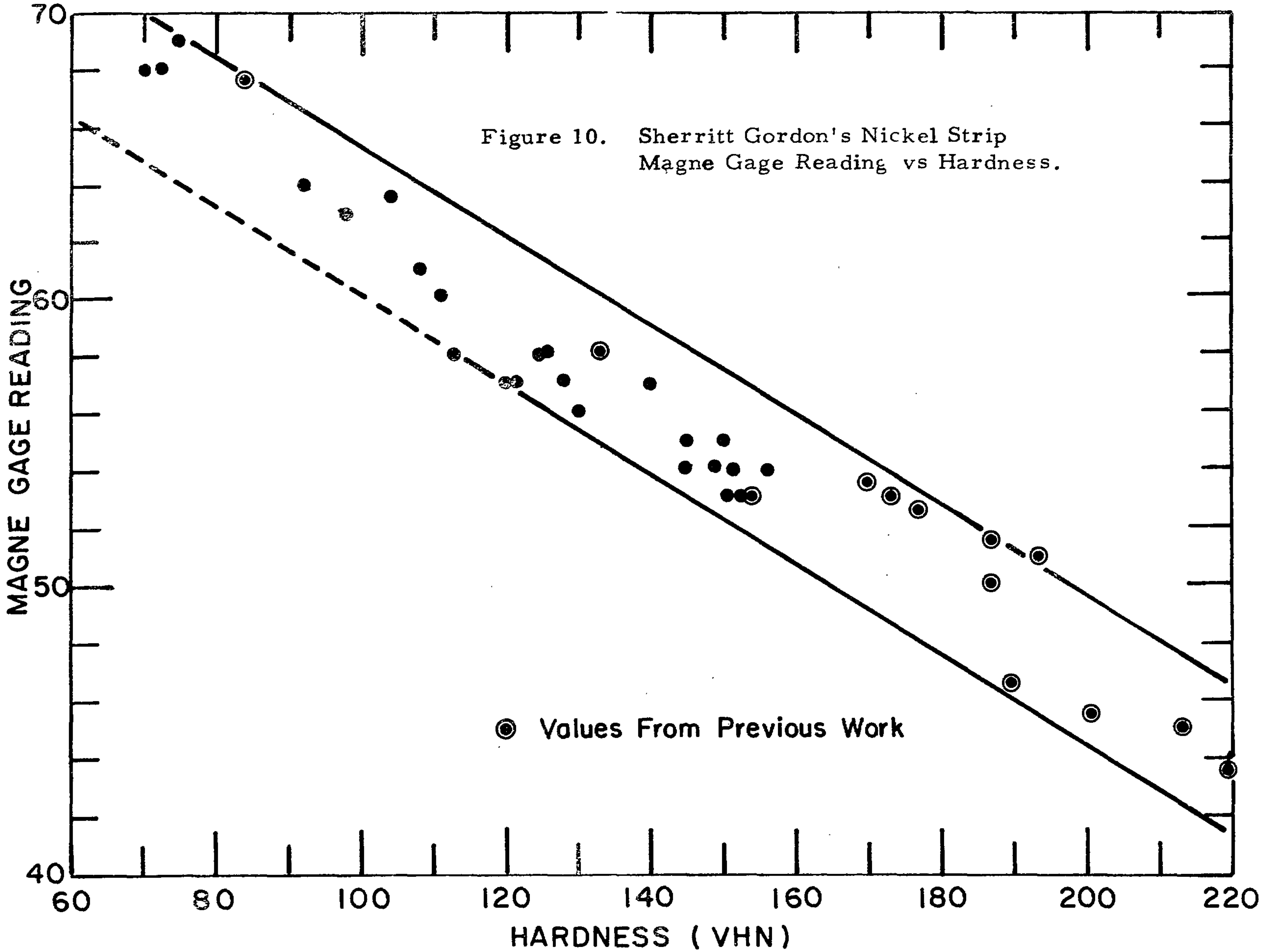


Figure 10. Sherritt Gordon's Nickel Strip Magne Gage Reading vs Hardness.

However, prior investigation of nickel strips with metallurgical histories similar to the strips in Series I and II but cold-reduced by as much as 50% and 70%, respectively, showed that the magnetic permeability is not consistently related to the per cent of cold reduction. This is illustrated in Figure 11 (reproduced from previous work[1]) which shows two separate graphs for the magnetic permeability of the above nickel strips when plotted against per cent cold reduction. The hardness on the other hand does appear to be directly related to the magnetic permeability. The scatter in the values in Figure 10 probably could be reduced by more accurate measurements of the magnetic permeability by means of a sophisticated measuring instrument such as a Hysteresisgraph.

The large grains in Series III and the thickness of the nickel strip had no noticeable effect on Magne Gage readings.

SUMMARY

1. Larger grains in the microstructure of the nickel strip in Series III have little, or no, effect on hardness or magnetic permeability.

2. Neither hardness nor magnetic permeability of the nickel strips is affected by different starting or finishing gauges.

3. The magnetic permeability of Sherritt Gordon's nickel strip is directly related to its hardness. The scatter in values in the graph, hardness versus magnetic permeability, probably could be reduced by using a Hysteresisgraph to measure the magnetic permeability.

REFERENCES

1. C. F. Dixon and N. S. Spence, "Examination of Cold-Rolled High-Purity Nickel Produced by Sherritt Gordon Mines Limited, for Coin Production", Mines Branch Investigation Report IR 71-51, Department of Energy, Mines and Resources, Ottawa, (Aug. 5, 1971).

- - - -

CFD/NSS/gm

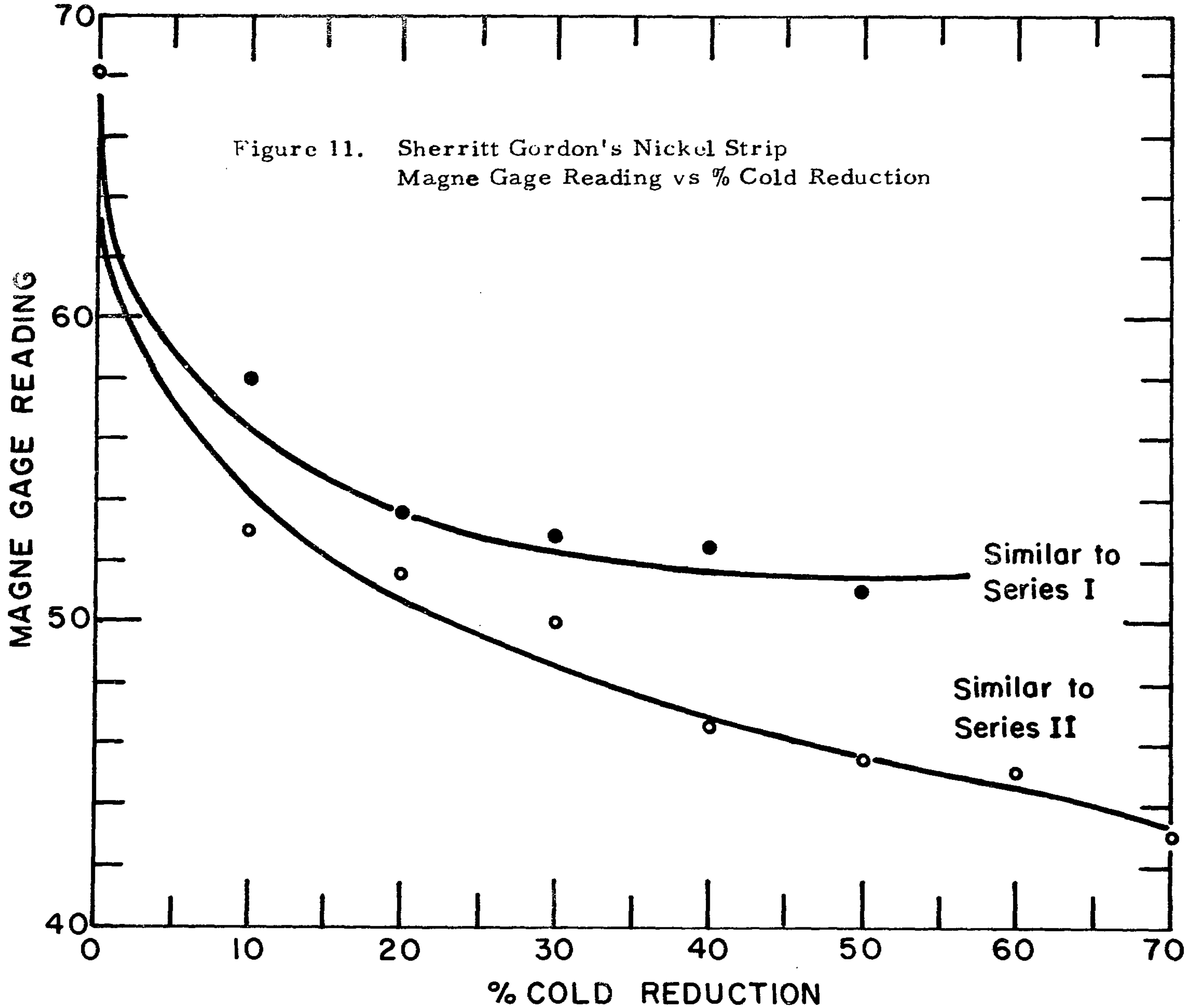


Figure 11. Sherritt Gordon's Nickel Strip
Magne Gage Reading vs % Cold Reduction
MAGNE GAGE READING
70
60
50
40
0
10
20
30
40
50
60
70
% COLD REDUCTION
Similar to
Series I
Similar to
Series II