Fermilab

June 1, 1990

TO: E. G. Pewitt

FROM: G. R. Kobliska

SUBJECT: SSC Steel Requirements

On May 9, 1990, John Zweibohmer, Eric Larson, and myself visited J & L Steel at their Midland, PA. plant. The purpose of the visit was to discuss material that they might supply for magnet collar material and the precision skin program.

The current scenario has been to have Armco Steel provide their 90,000 lb. yield strength Nitronic 40 to meet our needs, with Armco essentially being a single source. In an effort to develop a second source, we have been working with J & L Steel to provide a material with the proper strength and magnetic requirements. J & L Steel proposes to furnish some material of a grade UNS-219 (21-6-9), which is essentially a generic equivalent to a Nitronic 40. They made three heats in their laboratory, with their heat number V958 being the one that would ultimately meet our needs. Attached, you will find a detailed report which they presented to us. The only additional comment that I might make is that the other potential suppliers for SSC collar material, namely Armco and Kawasaki, have performed their own tests which have not been performed with any uniformity. It is my intention to have Anter Laboratories and the Mellon Institute perform tests for us on Armco and Kawasaki steel that we would furnish them.

With respect to precision skin (magnet outer shell) materials, J & L's proposals for increasing the yield strength were primarily centered around cold working the material. The problem with that option is that the welding which we will do, produces localized annealing which would return the yield strength back to an annealed condition. It seemed that the most viable solution was to go to a 21-6-9 grade (same as collar materials) which would yield a 60,000 PSI yield strength in the annealed condition.

It is important to note that increasing the thickness of the skins would necessitate going to a plate stock. As such, we would no longer be able to obtain the smooth finished condition for a bearing surface that we are presently accustomed to. If we did have to go to a thicker plate and a subsequent polishing operation on the material to obtain a bearing quality surface, we would lose a lot of control on material thickness, which would effect our accuracy in roll forming. And while we are on the subject of roll forming, I must caution you that significant increases in yield strength, will have significant effects in roll forming. Such effects could well be significant enough to cause the roll forming tooling to be redesigned, or inhibit the process. Careful thought must be given as to exactly what material strength is needed.

If you have any questions or need additional information, please feel free to contact me.

attachments

c: R. Bossert
J. Carson
E. Larson
P. Mantsch
T. Nicol
J. Strait
J. Zweibohmer

MAGNET OUTER SHELL MATERIALS

A. AVERAGE CHEMISTRY

helps in welding

increase yield

Grade	C	Mn	P	S	Si	Cr	Ni	Mo	Cu	Co	N_2
304	.058	1.69	.029	.011	.57	18.23	8.10	.24	.28	.10	.059
304LN	.022	1.63	.030	.016	.56	18.37	8.57	.26	.29	.11	.126
316LN	.027	1.68	.029	.018	.56	17.42	10.27	2.43	.34	.12	.114
201LTM	.026	6.24	.033	.011	.52	16.36	5.09	.20	.50	.05	.15

B. AVERAGE MECHANICAL PROPERTIES

Material	Finish	Hardness	Yield Strength psi	Tensile Strength psi	Elongation %
T304, .185" (~ 7 coils)	2B	88 Rb	49,600 ±5, 48-52	91,700	55
T304	1/8 HD	25 RC	87,500	114,000	34
T304	1/4 HD	28 RC	97,500	124,500	26
T304LN	2B	90 RB	50,000	92,000	52
T316LN	2B	90 Rb	50,000	92,000	50
T201LTM	2B	93 Rb	53,000	101,500	50
T201LTM	3/8 HD	28 RC	96,000	124,000	30

roll forming should increase yield by 5KPSI

2684L

21-6-9 is a good option 60KPSI yield in the annealed cond.

May 8, 1990

21-6-9 DEVELOPMENT

1. Compositions
2. Delta Ferrite in Austenite Structure
3. Mechanical Property Data
   - annealed and cold reduced condtions
4. Magnetic Permeability Data at 4.2 Kelvin
   - vibrating sample magnetometer, 1000 Oe

   force used was 5000 oe
5. Thermal Contraction Data

SUMMARY:

1. Material composition and processing need to be controlled
   - avoid delta ferrite in final materials
   - cold reduce to provide 90 ksi min yield strength
2. Very low (1.0040 to 1.0065) magnetic permeability values at 4.2 Kelvin are possible
   - literature data report 1.0012 to 1.005 for Nitronic 40 and Kawasaki KHMN30L at 4.2 Kelvin. These are about the same considering the technique used and variability or lower due to different techniques and especially low strength magnetic field

J&L Specialty Products Corporation

varied purposely

TABLE I

CHEMICAL ANALYSES OF COMMERCIAL AND LAB 21-6-9 MATERIALS

Material	C	Mn	P	S	Si	Cr	Ni	Mo	Cu	Co	N_2	Delong * % Ferrite
Armco 21-6-9 Heat 980043	.033	9.30	.030	.002	.54	19.90	7.03	.30	.41	.16	.278	- 9.4
Armco 21-6-9 Heat 677093	.035	9.20	.024	.004	.62	19.93	7.00	.19	.28	.12	.288	- 9.9
Lab 21-6-9 Heat V956	.029	9.46	.023	.006	.58	19.92	7.42	.26	.30	.17	.199	- 4.6
Lab 21-6-9 Heat V957	.033	9.47	.025	.008	.58	20.76	7.10	.26	.30	.17	.220	- 3.0
Lab 21-6-9 Heat V958	.038	9.46	.024	.006	.59	19.70	7.14	.27	.30	.17	.307	-12.7

made @ JPL

*or "austenite stability" factor

TABLE II

DELTA FERRITE

Heat	Material	Condition	Magne Gage % Ferrite	Est. Delong % Ferrite	Metallographic Ferrite
V956	Lab Ingot	As-cast	5.0	- 4.6	Yes
V957	Lab Ingot	As-cast	6.5	- 3.0	Yes
V958	Lab Ingot	As-cast	1.5	-12.7	No
677093	Armco strip .064"	2400°F-3 hrs. water quenched	1.0	- 9.9	Trace at mid-thickness
980043	Armco strip .037"	2400°F-3 hrs. water quenched	1.0	- 9.4	None
677093	Armco strip .064"	Final gauge, cold rolled & annealed materials	None		None
980043	Armco Strip .037"	Final gauge, cold rolled & annealed materials	None		None
V956	Lab heat, Strip .065"	Final gauge, cold rolled & annealed materials	$<1\%$		Yes (trace)
V957	Lab heat, Strip .065"	Final gauge, cold rolled & annealed materials	None*		Yes (trace)
V958	Lab heat, Strip .065"	Final gauge, cold rolled & annealed materials	None		None

* Not sensitive enough.

TABLE III

MECHANICAL PROPERTY DATA FOR COMMERCIAL AND LAB 21-6-9 MATERIALS

Sample	Material	Condition	Gage (in)	Hardness R30T	Hardness Rb	Hardness Rc	Yield Strength (psi)	Tensile Strength (psi)	Elongation (%)
A	Armco Ht. 980043	As annealed	.035	72			68,800	116,570	42
1	Armco Ht. 677093	As annealed	.0642		98		62,330	107,860	43
2	Armco Ht. 677093	1.4% cold reduction	.0633		100	22	76,400	113,300	38
3	Armco Ht. 677093	6.2% cold reduction	.0602			25	88,500	121,200	33
5	Armco Ht. 677093	8.6% cold reduction	.0587			27	98,600	125,600	30
4	Armco Ht. 677093	9.0% cold reduction	.0584			28	103,400	126,900	30
6	Armco Ht. 677093	11.3% cold reduction	.0569			29	114,000	131,930	27
7	Armco Ht. 677093	16.2% cold reduction	.0538			32	130,100	146,800	21
8	Lab Ht. V956	As annealed	.0681		95		46,410	90,480	45
9	Lab Ht. V956	6.2% cold reduction	.0639		96		64,530	98,500	47
10	Lab Ht. V956	10.9% cold reduction	.0607		100	19	87,680	100,300	37
11	Lab Ht. V956	14.1% cold reduction	.0585			21	91,470	111,950	32
12	Lab Ht. V956	22.5% cold reduction	.0528			30	115,810	129,760	19

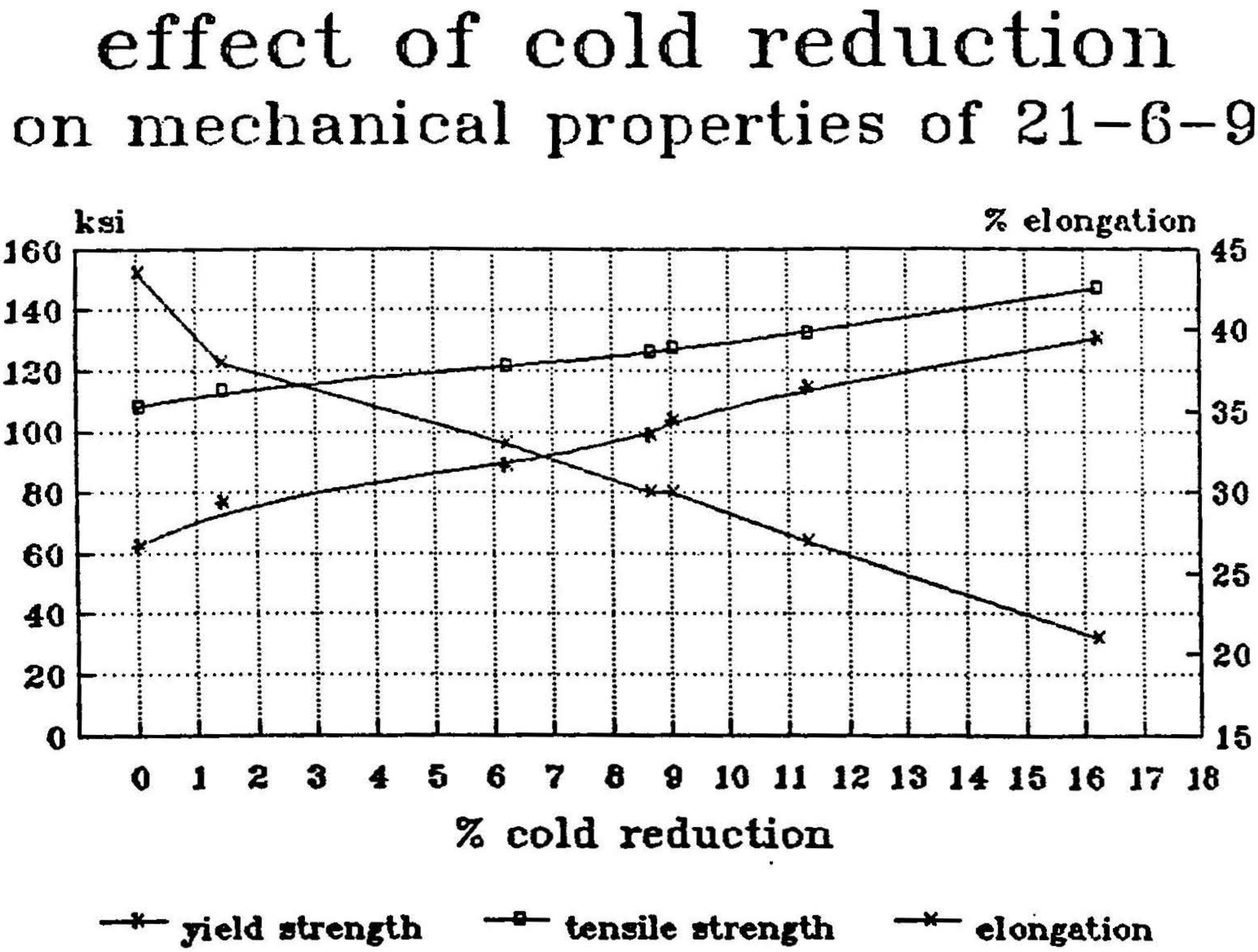
Continued.....

TABLE III (continued)

MECHANICAL PROPERTY DATA FOR COMMERCIAL AND LAB 21-6-9 MATERIALS

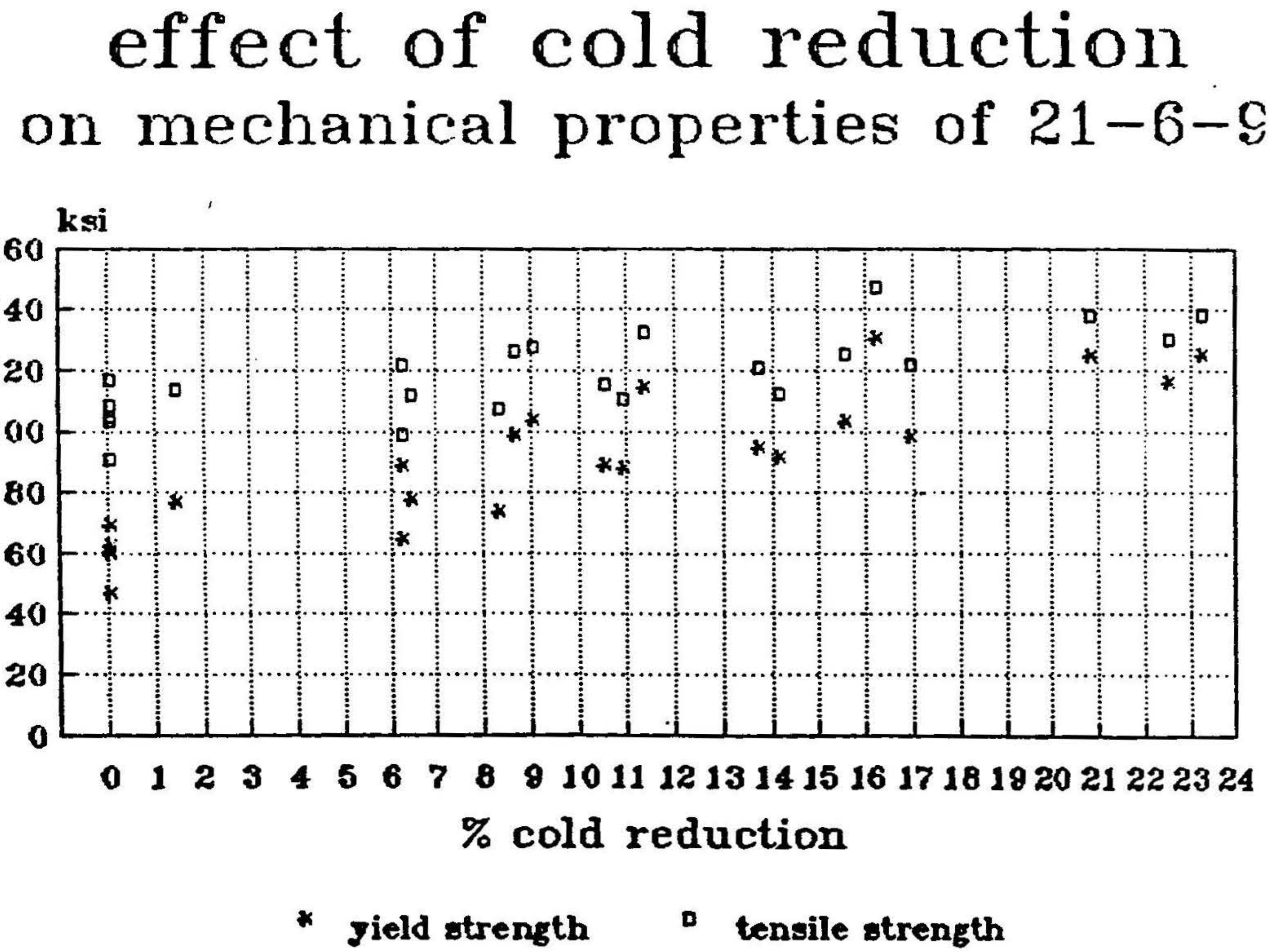
Sample	Material	Condition	Gage (in)	Hardness R30T	Hardness Rb	Hardness Rc	Yield Strength (psi)	Tensile Strength (psi)	Elongation (%)
13	Lab Ht. V957	As annealed	.0689		98		59,570	102,950	44
14	Lab ht. V957	8.3% cold reduction	.0632		98		73,160	106,870	41
15	Lab Ht. V957	10.5% cold reduction	.0617			23	88,410	114,960	37
16	Lab Ht. V957	15.5% cold reduction	.0582			27	103,100	124,960	25
17	Lab Ht. V957	23.2% cold reduction	.0529			30	124,700	137,870	21
18	Lab Ht. V958	As annealed	.0692		99	19	60,250	104,060	45
19	Lab Ht. V958	6.4% cold reduction	.0648			21	77,180	111,310	45
20	Lab Ht. V958	13.7% cold reduction	.0597			24	94,550	120,280	33
21	Lab Ht. V958	16.9% cold reduction	.0575			26	97,900	121,280	32
22	Lab Ht. V958	20.8% cold reduction	.0548			31	124,400	137,640	24

FIGURE 1



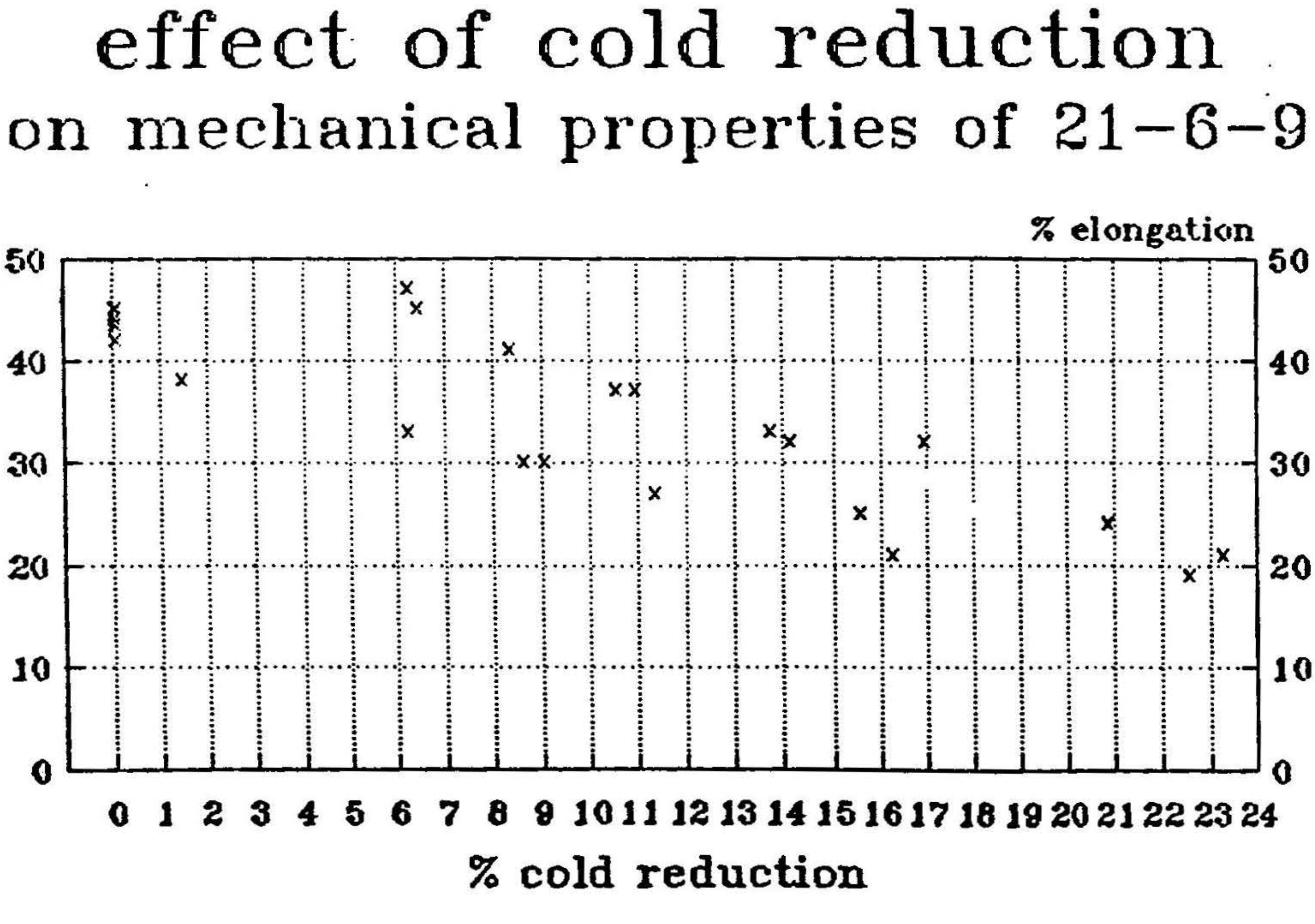
commercial armco material

FIGURE 2



ommercial and lab materials

FIGURE 3



commercial and lab materials

See mechanical property data page for identification

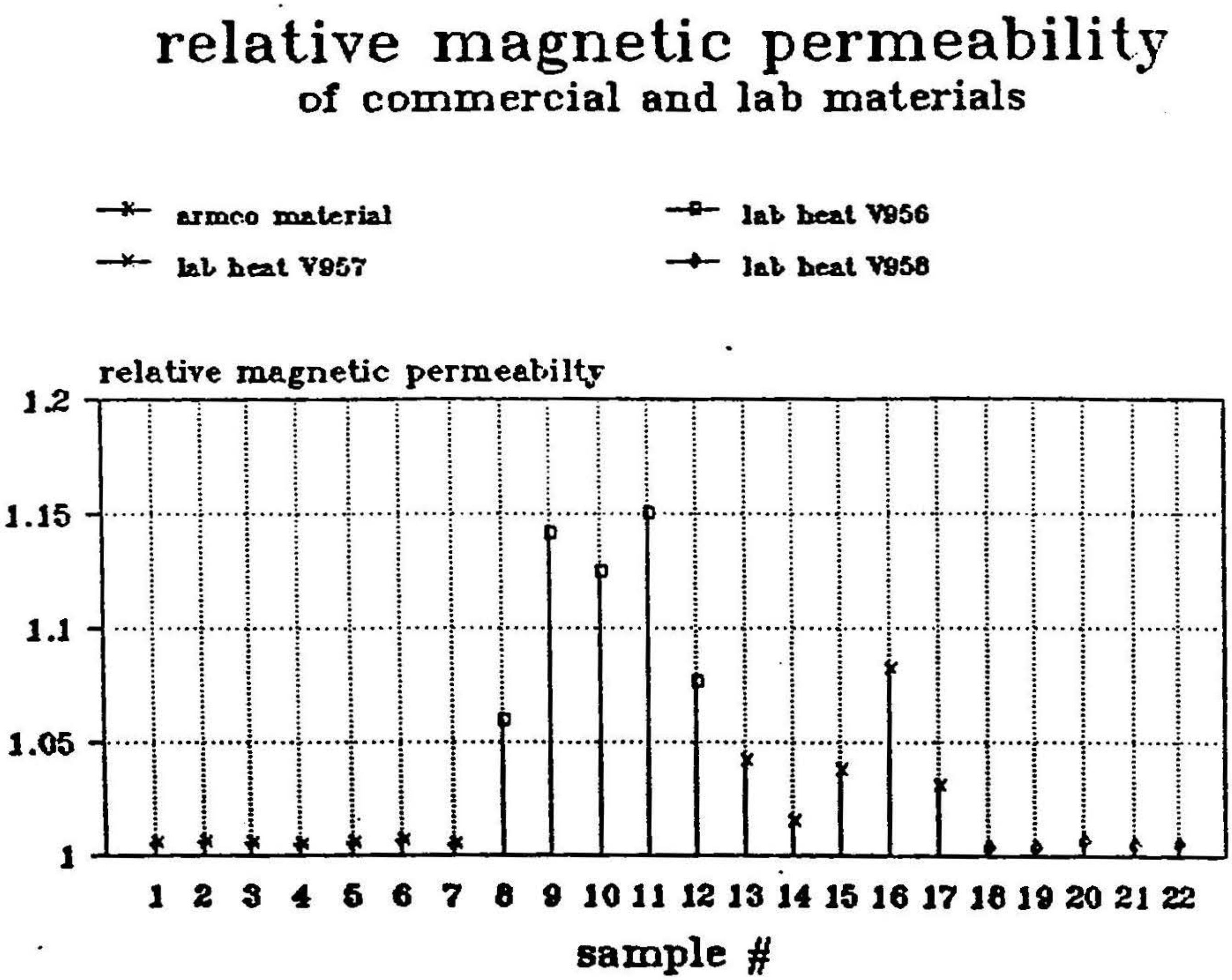
TABLE IV

MAGNETIC PERMEABILITY

DATA AT 4.2° KELVIN

ample #	μ	H(kOe)	M(emu/cc)	M(emu)	weight(gm)
1	1.0055	0.9287	0.4031	0.0048	0.0932
2	1.0060	1.0533	0.5009	0.0057	0.0899
3	1.0056	0.8907	0.3952	0.0044	0.0874
4	1.0051	0.8880	0.3598	0.0043	0.0941
5	1.0056	1.0218	0.4520	0.0046	0.0833
6	1.0065	0.8757	0.4550	0.0046	0.0787
7	1.0051	1.2913	0.5265	0.0049	0.0734
8	1.0596	1.1299	5.3617	0.0656	0.0958
9	1.1412	0.8240	9.2596	0.1038	0.0877
10	1.1245	0.9841	9.7473	0.0976	0.0784
11	1.1501	0.9179	10.9654	0.1174	0.0839
12	1.0762	1.0879	6.5995	0.0661	0.0784
13	1.0423	1.0150	3.4147	0.0462	0.1060
14	1.0151	1.2238	1.4689	0.0147	0.0782
15	1.0382	1.1412	3.4667	0.0357	0.0807
16	1.0820	1.1619	7.5808	0.0825	0.0852
17	1.0313	1.0158	2.5280	0.0242	0.0751
18	1.0040	1.1383	0.3629	0.0046	0.0994
19	1.0040	1.3128	0.4214	0.0048	0.0890
20	1.0064	0.7191	0.3668	0.0041	0.0884
21	1.0049	1.2251	0.4742	0.0050	0.0819
22	1.0054	1.0108	0.4357	0.0048	0.0859

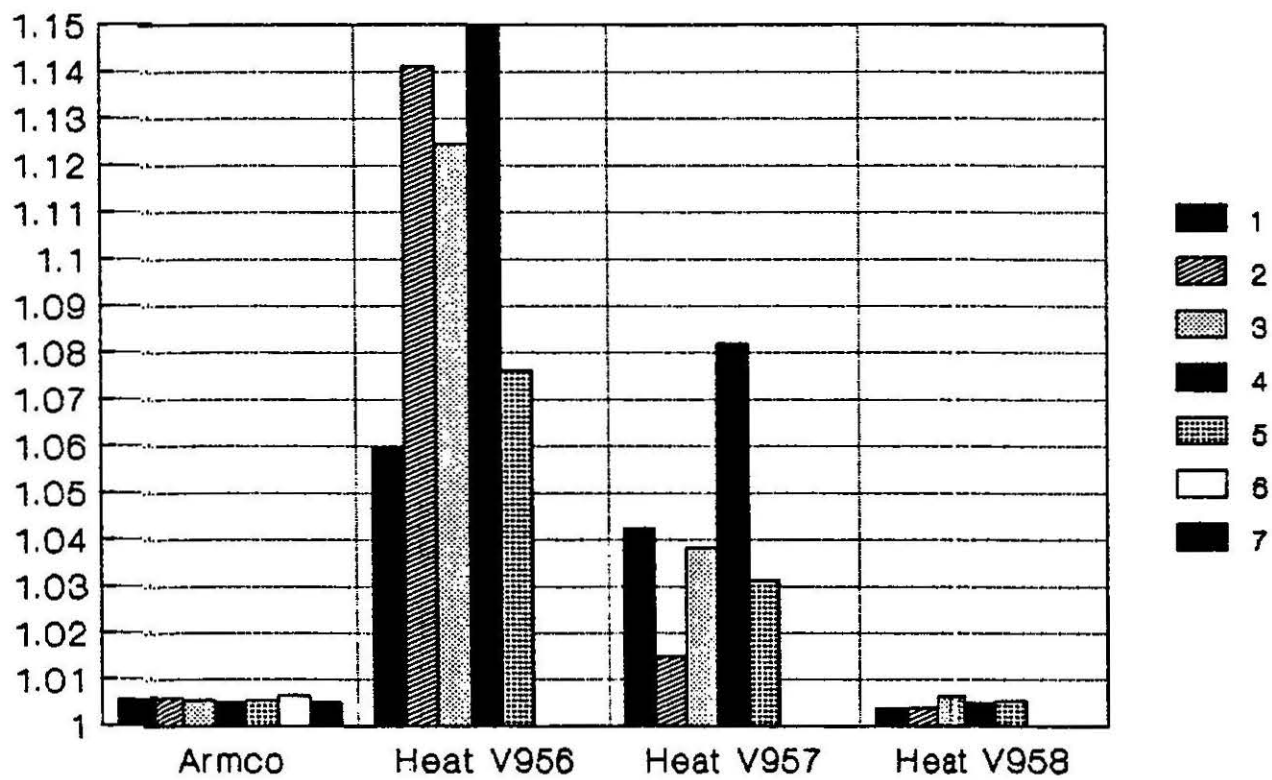
FIGURE 4



at 4.2 degrees Kelvin

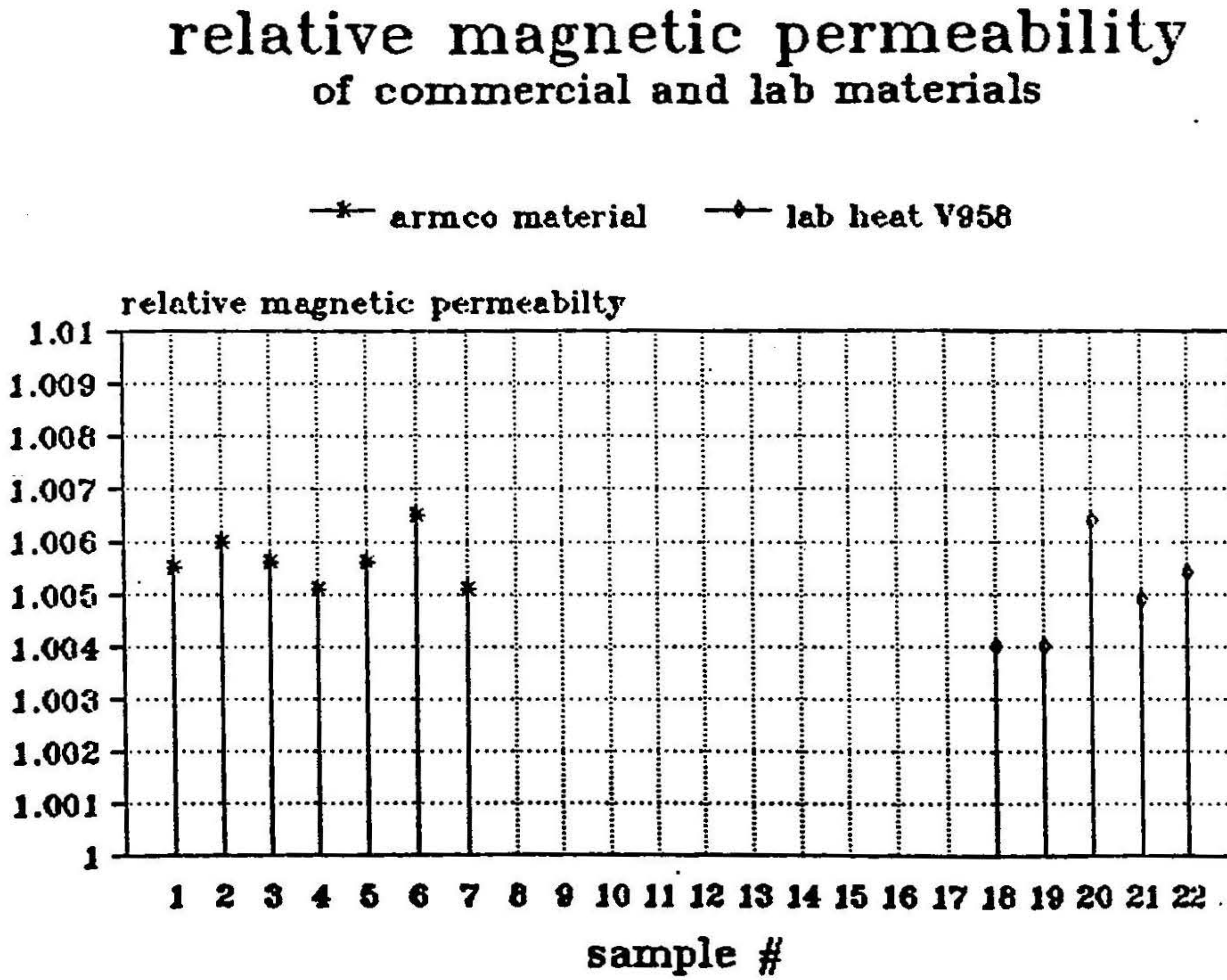
Figure 4

Relative Magnetic Permeability
of commercial and lab materials



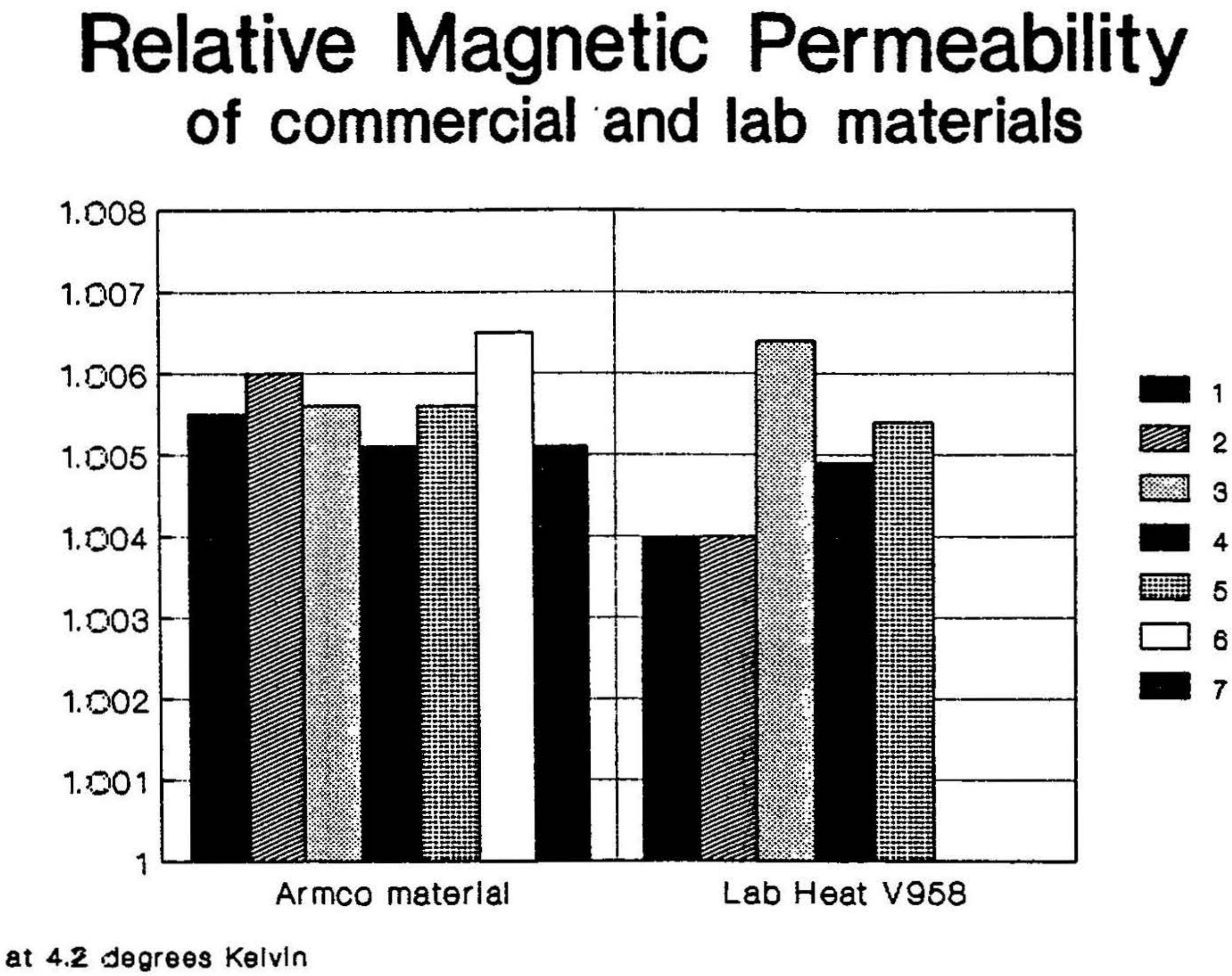
at 4.2 degrees Kelvin

FIGURE 5



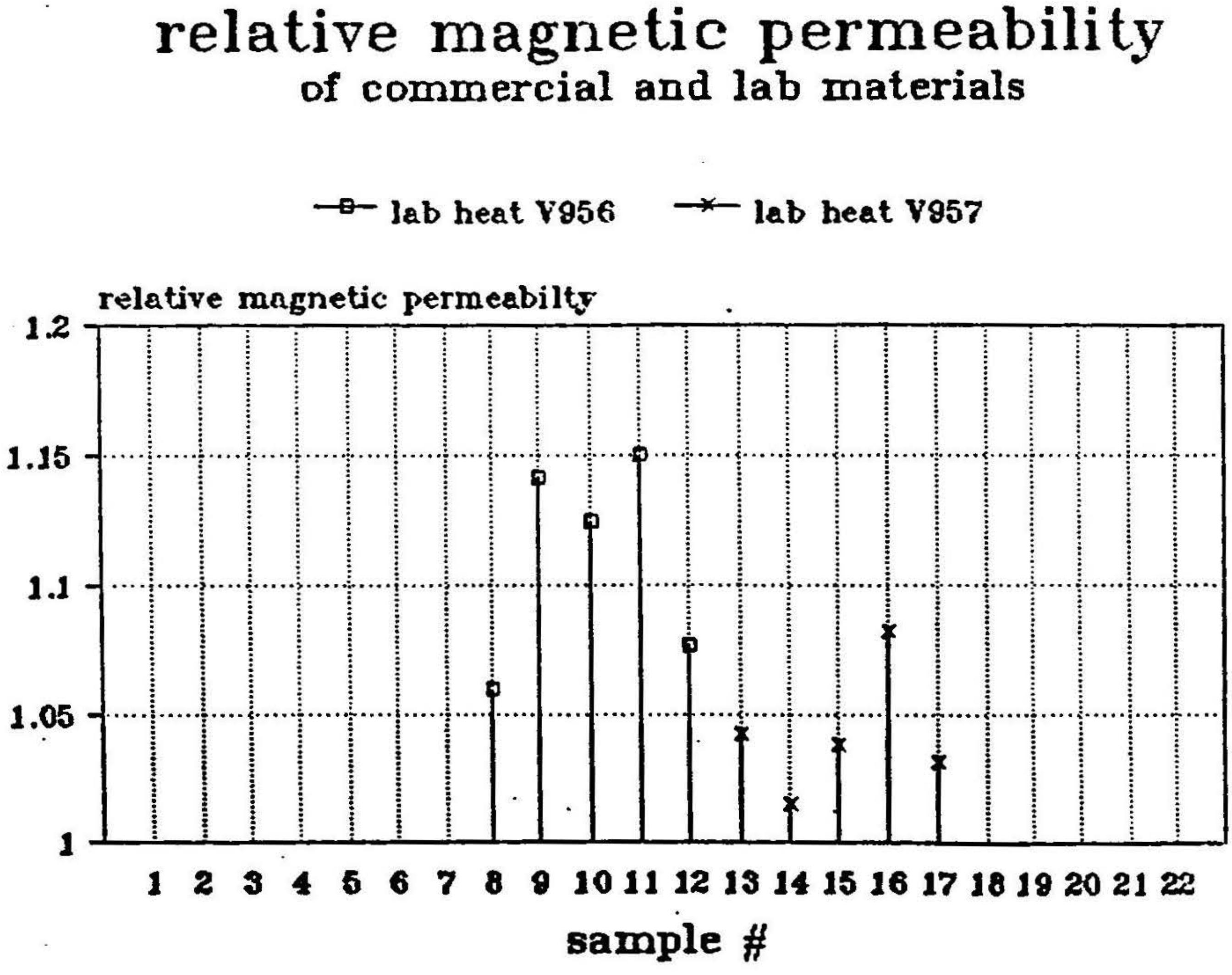
at 4.2 degrees Kelvin

Figure 5



Relative Magnetic Permeability
of commercial and lab materials
1.008
1.007
1.006
1.005
1.004
1.003
1.002
1.001
1
Armco material
Lab Heat V958
1
2
3
4
5
6
7
at 4.2 degrees Kelvin

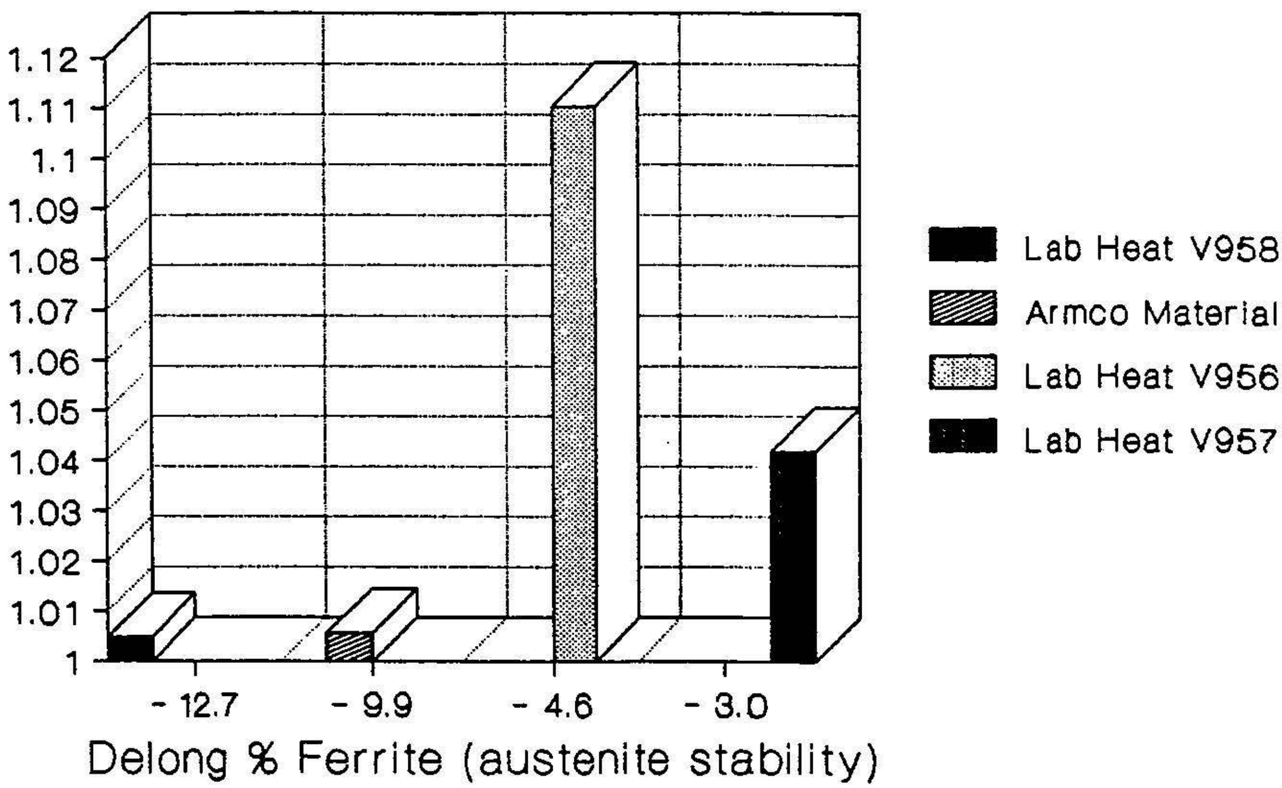
FIGURE 6



at 4.2 degrees Kelvin

Figure 7

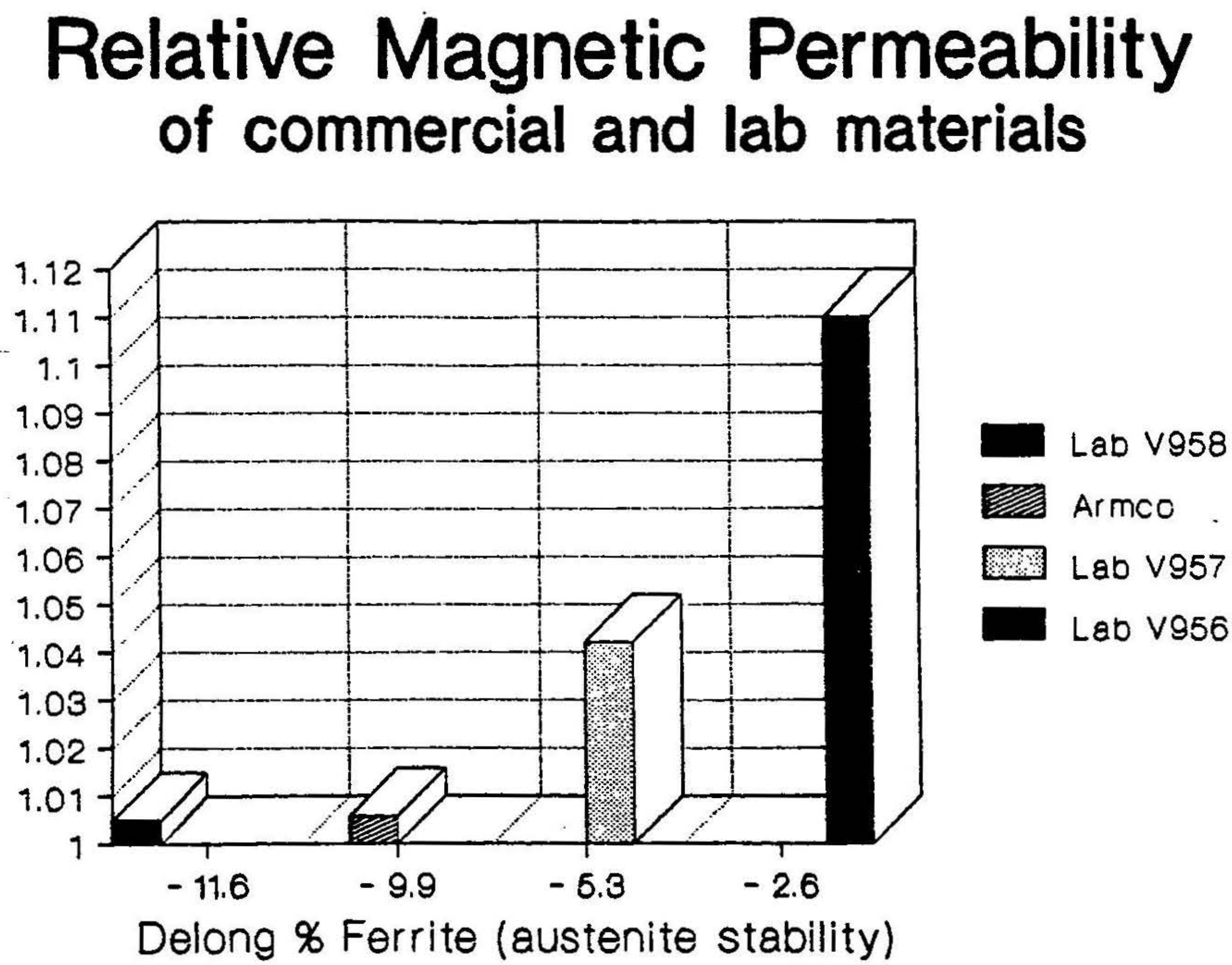
Relative Magnetic Permeability
of commercial and lab materials



at 4.2 degrees Kelvin

based on original lab heat analysis

Figure 7



at 4.2 degrees Kelvin

based on product check analysis at hot band and final gauge

21-6-9

COEFFICIENT OF THERMAL CONTRACTION

SAMPLE	Average CTE (in/in/°C x 10^{-6})	Average CTE (in/in/°F x 10^{-6})
1. Heat V958, hot band annealed & pickled, .131"	15.3	8.5
2. Above + 11.5% cold reduced, .116"	15.3	8.5
3. Heat V958, cold reduced 13.5%, .0575"	15.0	8.3
4. Armco, annealed & pickled, .0645"	15.3	8.5
5. Above + 7.8% cold reduced, .059"	15.6	8.7

From 20°C to -150°C

ANTER LABORATORIES, INC.
1700 UNIVERSAL ROAD
PITTSBURGH, PA. 15235 USA

May 8, 1990

J&L SPECIALTY PRODUCTS CORPORATION
12th Street and Midland Avenue
Midland, PA 15059

ATTN: Mr. Jay M. Mehta, Senior Product Metallurgist

RE: PO# 342113 Coefficient of Thermal Expansion Testing

Thermal Expansion testing of your samples is complete. Each sample has been tested for the Average CTE (Coefficient of Thermal Expansion) from 20 C to -150 C as per your request. Calculations are based on a reference temperature of 20 C.

SAMPLE CODE	Average CTE (in/in/C x 10^{-6})	Average CTE (in/in/F x 10^{-6})
1	15.3	8.5
2	15.3	8.5
3	15.0	8.3
4	15.3	8.5
5	15.6	8.7

Accuracy: ±0.3 in/in/C x 10^{-6}. ±0.2 in/in/F x 10^{-6}
Resolution: ±0.2 in/in/C x 10^{-6}. ±0.1 in/in/F x 10^{-6}

All measurements are traceable to NIST (National Institute of Standards and Technology) Fused Silica References.

Graphical results will be forwarded as soon as available.

Please call if you have any further questions.

Sincerely,

Mark A. Cirucci

Mark A. Cirucci
Supervisor, Testing Services

MAC/alp

TEL (412) 795-6410 FAX (412) 795-8225

MELLON INSTITUTE

MATERIALS CHARACTERIZATION CENTER

Report on

MAGNETIC PERMEABILITY OF TWENTY TWO (22)
STEEL SAMPLES AT 4.2°K

Submitted to

J. Mehta
J&L Specialty Metals
12th & Midland Avenue
Midland, PA 15059

SUMMARY

Twelve (12) samples are magnetically pure, one (1) is slightly impure, and the remaining eight (8) are magnetically impure.

JOB NO 9002036

March 2, 1990

Prepared by: S. G. Sankar

Job No. 9002034

Objective: Determine the magnetic permeability of twenty two steel samples at 4.2 K.

Samples: The 22 samples supplied by the customer were coded as follows:

1 through 7 : Competitive
8 through 12 : Lab Heat V956
13 through 17: Lab Heat V957
18 through 22: Lab Heat V958
Please see the attached sheet for more details.

A small portion (about 100 mg) of the sample was cut with a diamond blade far away from the sheared edges. The samples thus cut were cleaned in an ultrasonic cleaner to remove any impurity.

Test Procedure:

As per the instructions of J and L, Mr. Greg Kobliska at the Fermi Lab was contacted. Upon his instructions, Dr. Ghosh at the Brookhaven National Laboratory was contacted. It was agreed by Dr. Ghosh that magnetic permeability measurements may be made with a vibrating sample magnetometer in an external magnetic field of approximately 1000 Oesterds.

The sample was loaded into a vibrating sample magnetometer. It was cooled with liquid helium. The sample temperature was maintained at 4.2 K throughout the measurements. An external magnetic field of approximately 5000 Oe. was applied in the superconducting magnet. Magnetization was measured as the field was lowered to zero field using an automated data acquisition system. The magnetic permeability was determined from these results at an external field of approximately 1000 Oe. This procedure was repeated for all samples.

In the calculations, a density of 7.83 g/cc was used for all of the samples, as per J and L's instructions.

Magnetic permeabilty was calculated using the formula:

$$\mu = 1 + (4\pi M/H)$$

where H is the external field and M is the measured magnetization per cubic centimeter.

Job No. 9002034

Results:

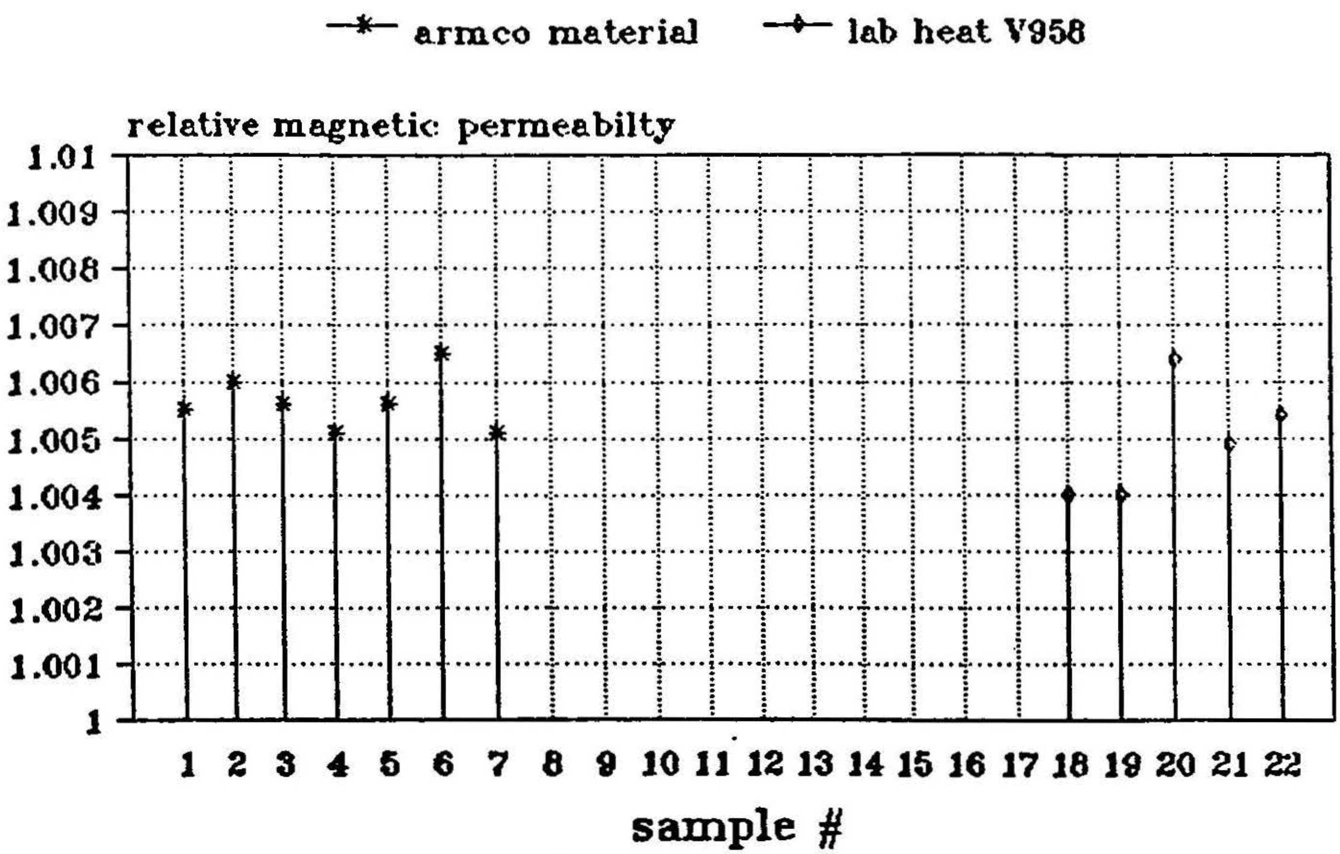
The results are presented in the table and figure enclosed. The table identifies the weight of the sample (Column 6), measured magnetiztion in emu (Column 5), magnetization per cc (Column 4) and the value of the external field (Column 3). The calculated permeability is given in Column 2 for the 22 samples.

Discussion:

Samples 1 through 7 and 18 throgh 22 exhibit a permeability of nearly 1.005 at 4.2 K. Sample 14 shows a permeability of 1.015, indicating the presence of a trace magnetic impurity. The remaining samples have large amounts of a magnetic impurity.

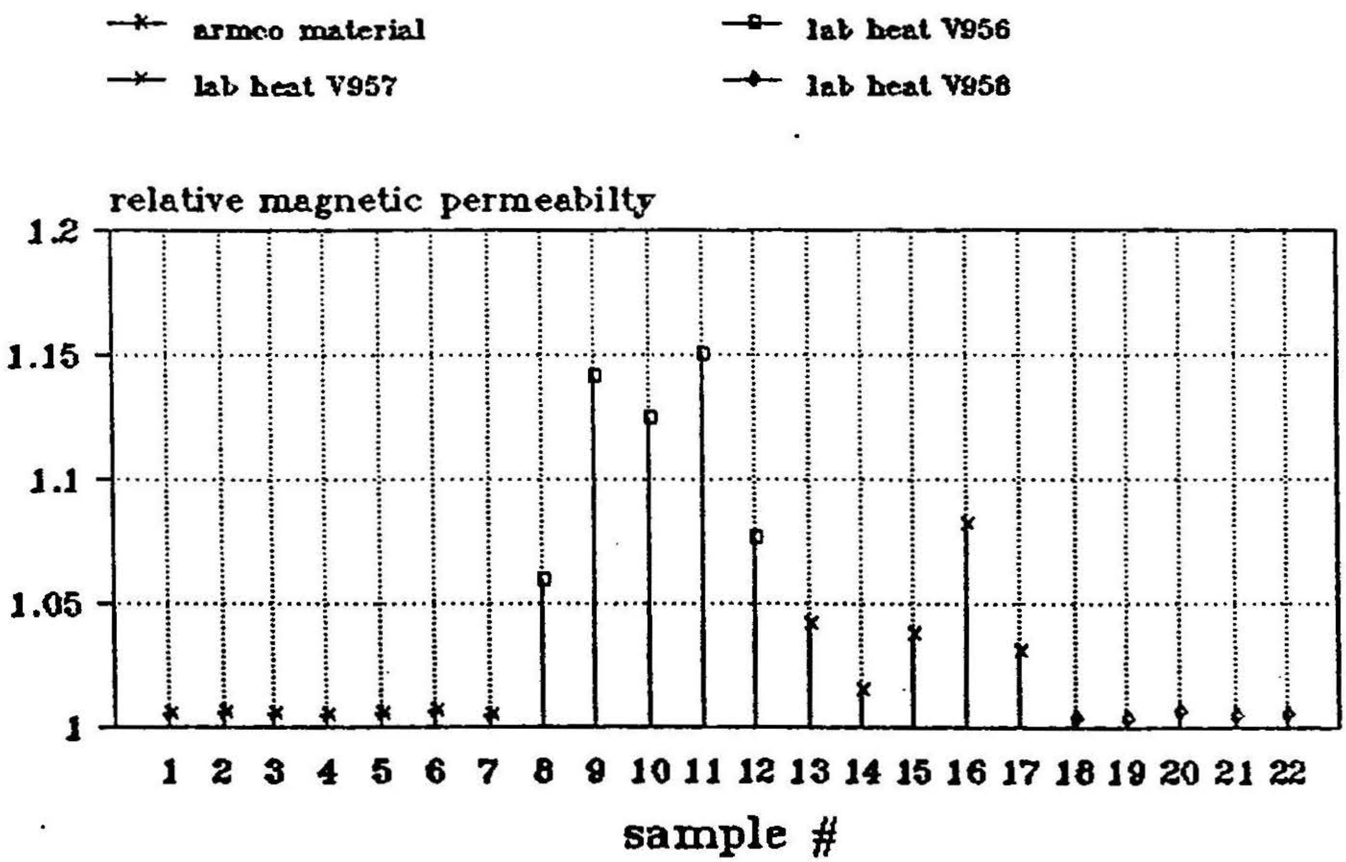
mple =	µ	H(kOe)	M(emu/cc)	M(emu)	weight(gm)
1	1.0055	0.9287	0.4031	0.0048	0.0932
2	1.0060	1.0533	0.5009	0.0057	0.0899
3	1.0056	0.8907	0.3952	0.0044	0.0874
4	1.0051	0.8880	0.3598	0.0043	0.0941
5	1.0056	1.0218	0.4520	0.0048	0.0833
6	1.0065	0.8757	0.4550	0.0046	0.0787
7	1.0051	1.2913	0.5265	0.0049	0.0734
8	1.0596	1.1299	5.3617	0.0656	0.0958
9	1.1412	0.8240	9.2596	0.1038	0.0877
10	1.1245	0.9841	9.7473	0.0976	0.0784
11	1.1501	0.9179	10.9654	0.1174	0.0839
12	1.0762	1.0879	6.5995	0.0661	0.0784
13	1.0423	1.0150	3.4147	0.0462	0.1060
14	1.0151	1.2238	1.4689	0.0147	0.0782
15	1.0382	1.1412	3.4667	0.0357	0.0807
16	1.0820	1.1619	7.5808	0.0825	0.0852
17	1.0313	1.0158	2.5280	0.0242	0.0751
18	1.0040	1.1383	0.3629	0.0046	0.0994
19	1.0040	1.3128	0.4224	0.0048	0.0890
20	1.0064	0.7191	0.3668	0.0041	0.0884
21	1.0049	1.2251	0.4742	0.0050	0.0819
22	1.0054	1.0108	0.4357	0.0048	0.0859

relative magnetic permeability
of commercial and lab materials



at 4.2 degrees Kelvin

relative magnetic permeability
of commercial and lab materials



at 4.2 degrees Kelvin