NATIONAL RADIO ASTRONOMY OBSERVATORY
Charlottesville, Virginia

ELECTRONICS DIVISION TECHNICAL NOTE NO. 156

Title: **FABRICATION OF MILLIMETER-WAVEGUIDE SHORT-CIRCUITS USING EDM**

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Date: July 5, 1989

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FABRICATION OF MILLIMETER-WAVEGUIDE SHORT-CIRCUITS USING EDM

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As discussed in Electronics Division Technical Note No. 147, Electric Discharge Machining has a number of attractive features as a procedure for fabricating millimeter waveguide components. The low cost, ~$35 per hole, and 1-2 week turnaround are competitive with electroforming.

Fabrication of very small sliding short circuits ("backshorts") for millimeter-wave mixers has been a problem for many years, and has never been satisfactorily accomplished using slitting saws. As EDM seemed well suited to this job, we sent some beryllium copper backshort blanks to EDM specialist Rudolf Albinsky (1108 High Country Road, Towson, MD 21204 (301-828-5002)).

The blanks were made as shown in Figure 1, but without the transverse 0.004"-wide slot (and with the finger tips not rounded). The transverse slot was formed by EDM. Two approaches were used: (i) the blanks were made from material of the desired thickness (0.010") and the slot positioned as centrally as possible, and (ii) the blanks were made of oversize material (0.0125" thick), and were lapped to the correct thickness after the EDM operation. The aim of approach (ii) was to allow correction of unequal finger thicknesses resulting from an off-center slot.

Results

(i) EDM with 0.010" Blanks

The finished backshorts were examined with a measuring microscope. The measured results are summarized in Table I. For a given backshort, T1a and T2a are the thicknesses of the two fingers seen from one side (see Figure 1), and T1b and T2b are the thicknesses of the fingers seen from the other side. All thicknesses are measured near the midpoints of the fingers. The most critical aspect of the ED machining is the centering of the 4-mil transverse slot, which governs how nearly equal the finger thicknesses are. Unequal finger thicknesses result in unequal contact pressures between the fingers and waveguide walls. The thickness of the fingers, nominally 3 mils, is shown in Graph 1. The EDM'ed slot widths, nominally 4 mils, are shown in Graph 2. Five of the ten samples had the transverse slot centered well enough to give finger thicknesses differing by less than 1 mil. In only two cases were the finger thicknesses within 0.6 mil.

(ii) EDM and Lapping of 0.0125" Blanks

Similar measurements were made on these samples. The measurements are shown in Table II, which also includes the backshort thickness D after lapping, and the slot runout X (relative to the direction of propagation in the waveguide) which appeared greater in these samples than in the 0.010" blanks. The thickness of the fingers, nominally 3 mils, is shown in Graph 3. The EDM'ed slot widths, nominally 4 mils, are shown in Graph 4. Eight of the twelve samples had the transverse slot centered well enough to give finger thicknesses differing by less than 1 mil. In four cases the finger thicknesses were within 0.6 mil, although one of these (#11) had a large slot runout. Graphs 5 & 6 show the final backshort thickness H after lapping, and the slot runout X.

Some of the fingers appeared slightly bent, probably during lapping, and the tips of the outer fingers were significantly rounded. This is in contrast with the 0.010" samples ((i) above) in which the fingers were in perfect condition after EDM.

Conclusions

For this particular backshort design, the success rate using method (i) was ~50%, which is superior to that obtained with conventional machining. Compared with transverse slots machined using a 4-mil slitting saw, slots made by EDM were much cleaner, more uniform, and much more parallel to the centerline of the backshort. Furthermore, EDM completely eliminated the tendency for the fingers to be twisted during machining of the transverse slot. Method (ii) gave slightly better slot centering, but some minor damage to the fingers probably occurred when the parts were lapped to the desired thickness.

EDM should be used in future for fabricating backshorts of dimensions similar to these. The small improvement in yield using method (ii) (starting with oversized blanks) appears insufficient to justify the additional labor of this approach.

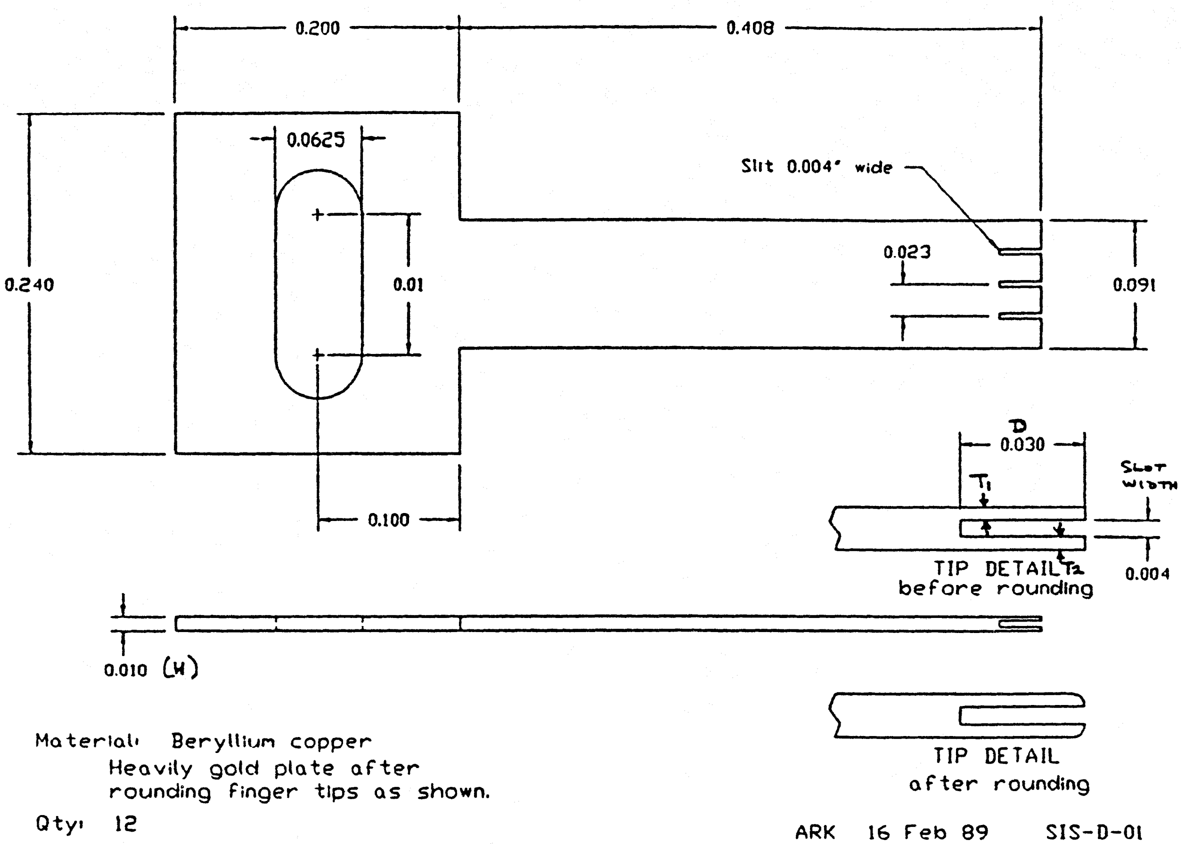


FIG. 1

EDMBS01.WK1 **TABLE I** 5 Apr 89

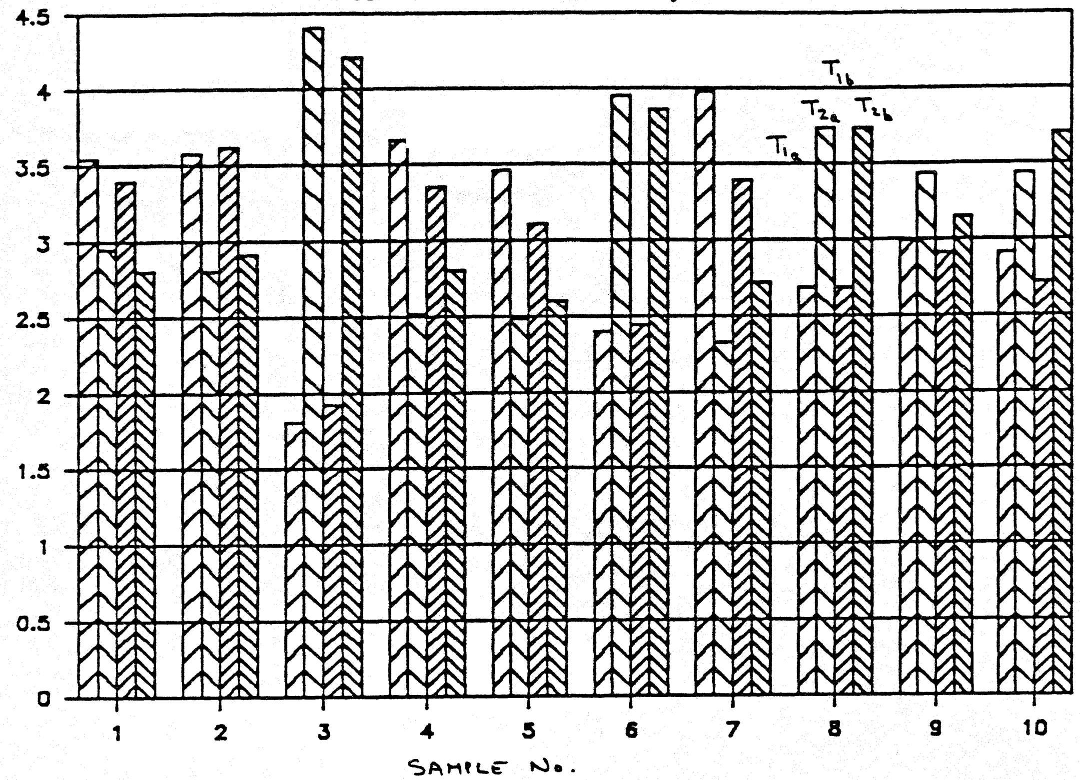
Measured dimensions of WR-10 quarter-height contacting backshorts
EDM'ed by Rudolf Albinsky.

Thicknesses T1a & T2a were measured on one side of the fingers
and T1b & T2b were measured on the other side.

B/S #	Slot depth D	Finger thickness T1a	Finger thickness T2a	Difference T1a-T2a	Finger thickness T1b	Finger thickness T2b	Difference T1b-T2b	Slot width 10-T1a-T2a
1	27.8	3.54	2.95	0.59	3.39	2.80	0.59	3.51
2	25.9	3.58	2.80	0.78	3.62	2.91	0.71	3.62
3	28.4	1.81	4.41	-2.60	1.93	4.21	-2.28	3.78
4	28.7	3.66	2.52	1.14	3.35	2.80	0.55	3.82
5	29.3	3.46	2.48	0.98	3.11	2.60	0.51	4.06
6	27.8	2.40	3.95	-1.55	2.44	3.86	-1.42	3.65
7	26.5	3.98	2.32	1.66	3.39	2.72	0.67	3.70
8	28.7	2.68	3.74	-1.06	2.68	3.74	-1.06	3.58
9	26.4	2.99	3.43	-0.44	2.91	3.15	-0.24	3.58
10	28.2	2.91	3.43	-0.52	2.72	3.70	-0.98	3.66

GRAPH 1

FINGER THICKNESSES Nominally 0.003"



GRAPH 2

SLOT WIDTH Nominally 0.004"

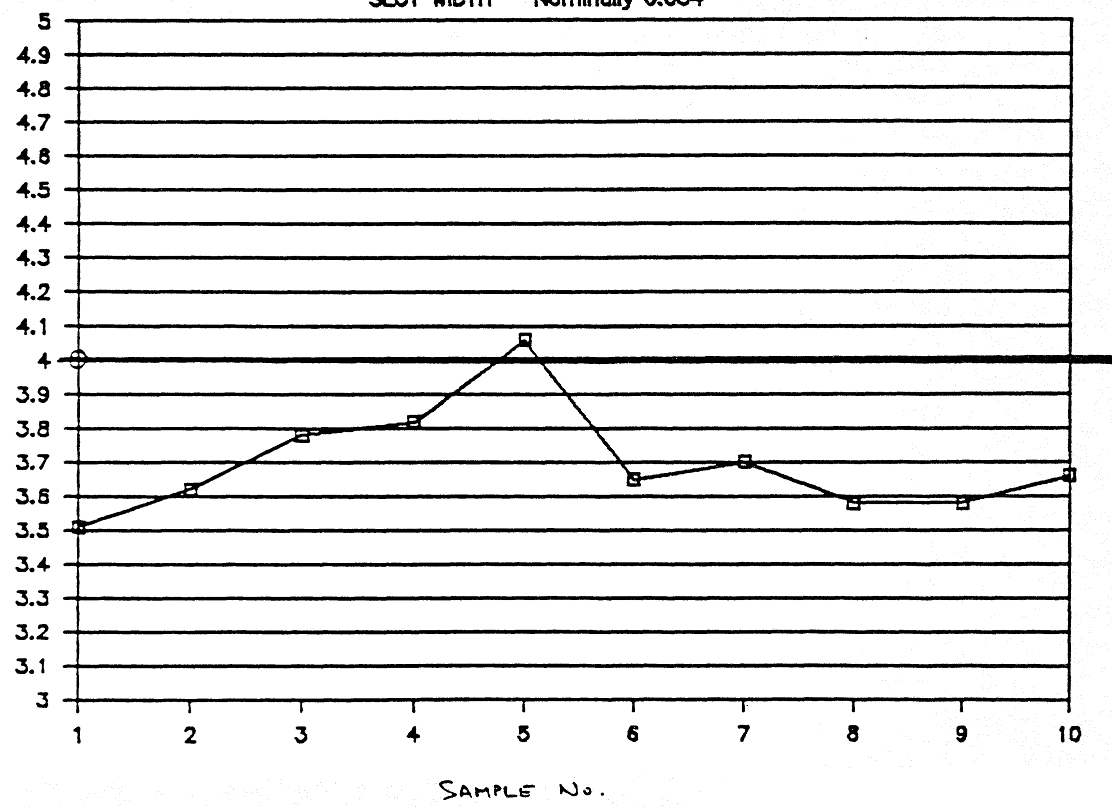


TABLE II

Measured dimensions of WR-10 quarter-height contacting backshorts.
Parts were fabricated from 0.0125" BeCu. Transverse slot was made by EDM,
after which the part was lapped to 0.010" thick so as to center the transverse slot.

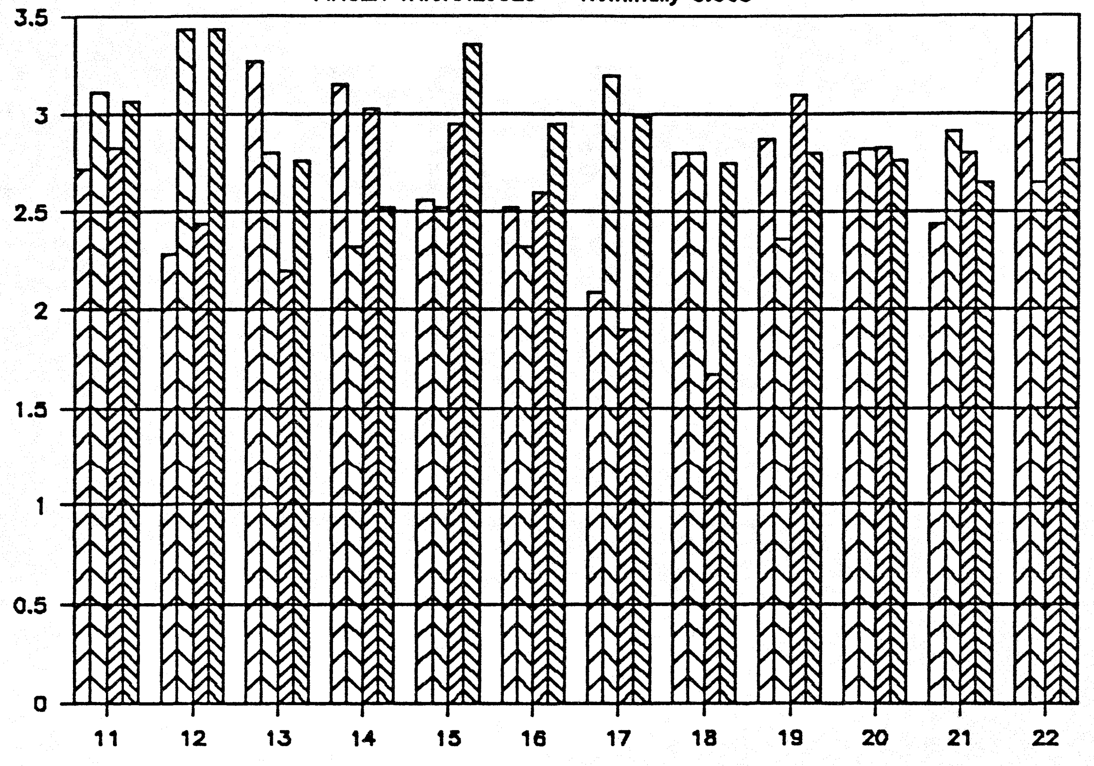
Thicknesses T1a & T2a were measured on one side of the fingers
and T1b & T2b were measured on the other side.

Slot runout X is the degree to which the transverse slot is not exactly parallel
to the backshort centerline.

B/S #	Slot depth D	B/S thickness H	Finger thickness T1a	Finger thickness T2a	Difference T1a-T2a	Finger thickness T1b	Finger thickness T2b	Difference T1b-T2b	Slot width 10-T1a-T2a	Slot runout X
11	30.68	10.20	2.72	3.11	-0.39	2.83	3.07	-0.24	4.17	0.50
12	29.41	10.60	2.28	3.43	-1.15	2.44	3.43	-0.99	4.29	0.00
13	29.19	10.50	3.27	2.80	0.47	2.20	2.76	-0.56	3.93	0.15
14	30.20	9.60	3.15	2.32	0.83	3.03	2.52	0.51	4.53	0.00
15	29.76	10.00	2.56	2.52	0.04	2.95	3.35	-0.40	4.92	0.20
16	27.36	9.57	2.52	2.32	0.20	2.60	2.95	-0.35	5.16	0.20
17	28.50	10.40	2.09	3.20	-1.11	1.90	2.99	-1.09	4.71	0.15
18	28.58	9.50	2.80	2.80	0.00	1.67	2.75	-1.08	4.40	0.15
19	30.35	10.40	2.87	2.36	0.51	3.10	2.80	0.30	4.77	0.00
20	27.85	10.45	2.80	2.82	-0.02	2.83	2.76	0.07	4.38	0.00
21	27.56	10.70	2.44	2.91	-0.47	2.80	2.65	0.15	4.65	0.00
22	30.20	10.45	3.50	2.65	0.85	3.20	2.76	0.44	3.85	0.15

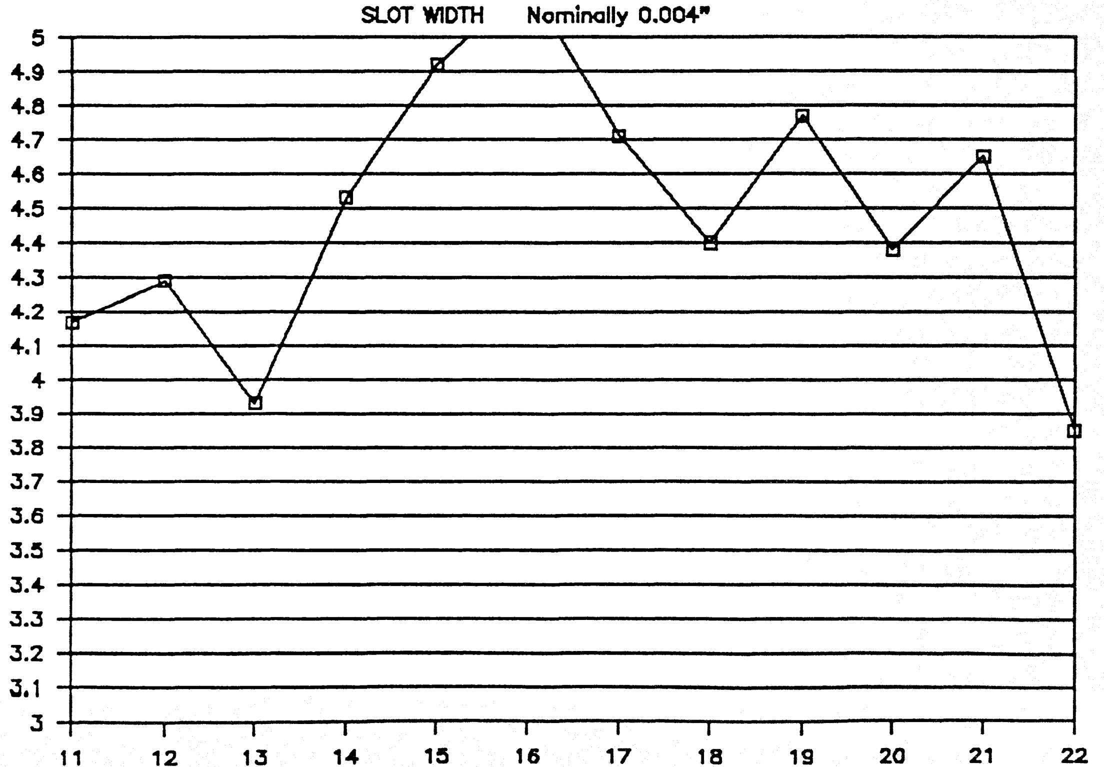
GRAPH 3

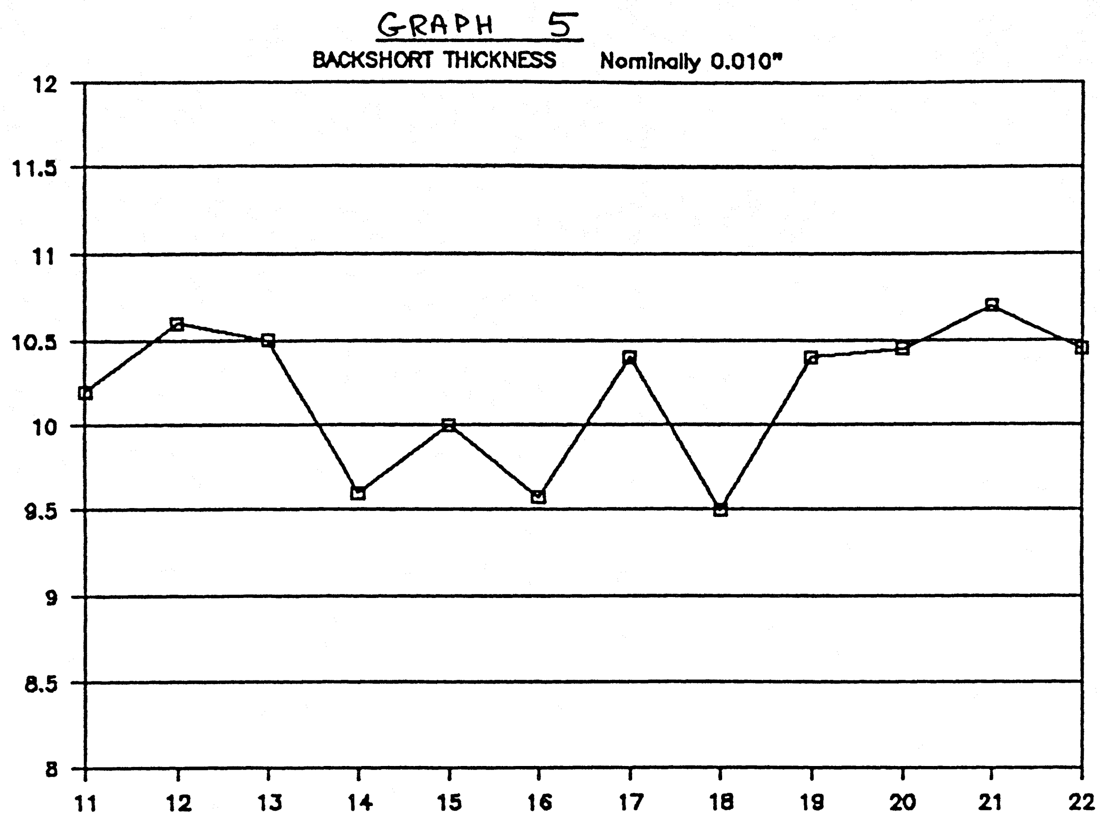
FINGER THICKNESSES Nominally 0.003"

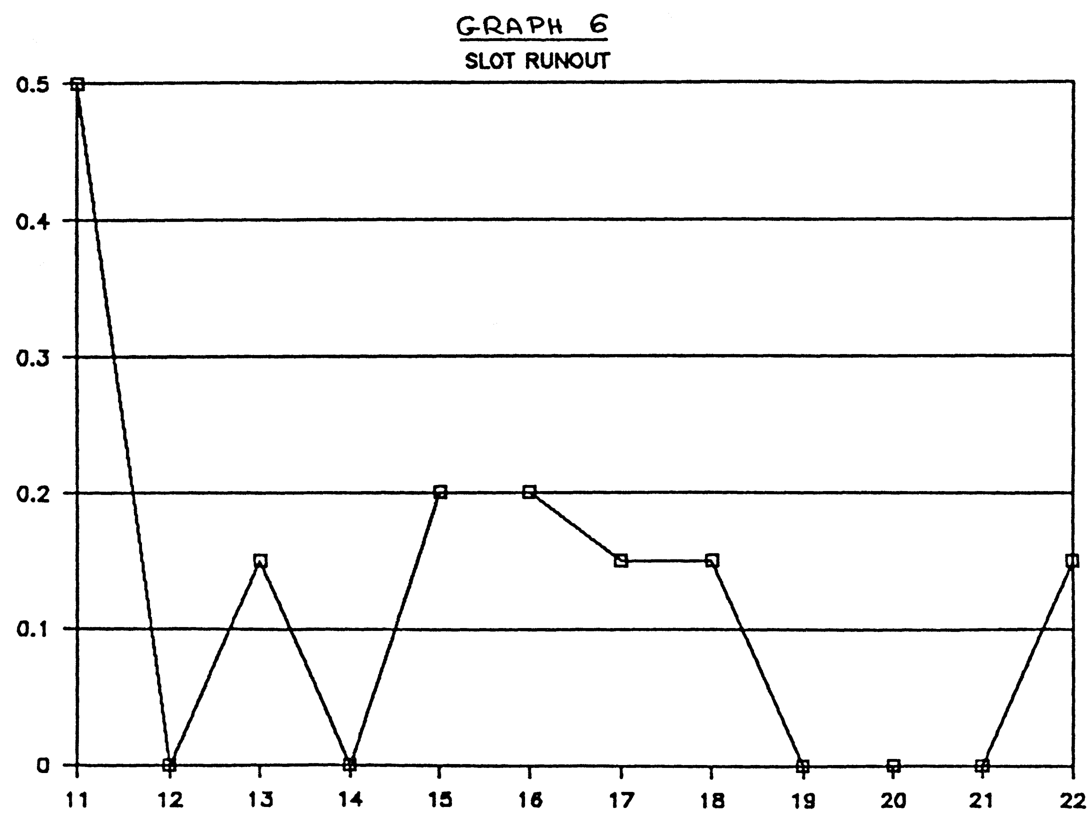


GRAPH 4

SLOT WIDTH Nominally 0.004"




GRAPH 5
BACKSHORT THICKNESS Nominally 0.010"
12
11.5
11
10.5
10
9.5
9
8.5
8
11 12 13 14 15 16 17 18 19 20 21 22


GRAPH 6
SLOT RUNOUT
0.5
0.4
0.3
0.2
0.1
0
11 12 13 14 15 16 17 18 19 20 21 22