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TECHNIQUES FOR MAKING GOLD WIRE VACUUM SEALS

by

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ABSTRACT

This memorandum describes in detail techniques for making demountable vacuum seals, bakeable to 450°C. The design is of the double-corner type using gold wire gaskets and has been successfully used for seals up to 16 inch diameter.

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INTRODUCTION

1. To obtain ultrahigh vacuum, without recourse to cryogenics, the outgassing rate of the vacuum vessel walls must be reduced by baking, and consequently the seals used on demountable joints must be capable of numerous reliable baking cycles up to temperatures of 450°C. This memorandum describes the seals used on the ion injection mirror machine experiment, which are of the double corner type with gold wire gaskets. The choice of this particular system was made on account of the extensive development work already carried out by R.C.A.[(1)] and reports of outstanding reliability of the design. In our work the seal size was increased to 16 inch diameter compared to the maximum of 8 inch diameter in the original American work, and a system of standard sizes was evolved covering all applications on the mirror machine.

2. In use the system proved most satisfactory and the few failures could always be attributed to incorrect procedure when either making or fitting the seals. This memorandum sets out in detail the techniques which, if adhered to, result in virtually perfect bakeable vacuum seals.

SEAL DESIGN

3. The main features of the design can be seen from the cross section in Fig.1. The ring of bolts which compress the seal lies between the two gaskets, the inner gasket usually forms the vacuum seal, whilst the outer provides the necessary mechanical support to prevent bowing of the flanges during compression of the gaskets. By suitable design the roles of the two gaskets may be reversed. 0.020 inch gaskets of 99.96% pure gold wire are used on flanges up to 9 inch diameter and 0.030 inch on sizes above this.

4. Details of the standard seal sizes used on the mirror machine may be seen from Fig.1. Both male and female flanges are shown, either of which may be made the detachable flange. The gold wire gaskets are made to fit over the spigots of the male flange shown on the right of Fig.1.

5. It may be seen from Fig.1 that the only really tight tolerance on the flange is in the longitudinal direction, ± 0.0005 inch between the two seal faces; this always ensures that the balancing gasket does not prevent the gasket forming the vacuum seal from being compressed by the correct amount. Since these are corner-type seals, the tolerances on the radial clearances between male and female spigots, e.g. between diameters F and H, Fig.1, are such as to ensure a minimum clearance of 0.002 inch and a maximum of 0.003 inch

on flanges up to 9 inch diameter, with corresponding figures of 0.003 inch and 0.005 inch on flanges up to 16 inch diameter. Surface finish on the gold seal faces is 32 μinch or better. Instructions to the manufacturer should state clearly that no scratches can be tolerated across the diameters forming the vacuum seal. Flanges exhibiting any such scratches should be rejected.

6. In use the gaskets are compressed to about one third of their original diameter and the force required to achieve this is about 1500 lbs/inch of wire for the 0.020 inch gaskets and 2400 lbs/inch of wire for the 0.030 inch gaskets. Special high temperature fasteners, corrosion and heat resistant to 650^{o}C, made to Unbrako specification AD776, with a minimum U.T.S. of 130,000 lbs/in^2, are used to compress the gaskets. The fasteners are designed with a special 12 point head, to fit socket spanners, enabling very high torques to be applied and allowing close spacing of the bolts. (Table I) Several holes are tapped in all detachable flanges for jacking screws, to facilitate removal after baking.

TABLE I

Type of bolts	Pitch of bolts	Gasket size	Torque	Gap
AD 776-04-04	¾ inch	0.020 inch	180 lb/inch	0.007 - 0.008 inch
AD 776-06-04	1 inch	0.030 inch	570 lb/inch	0.010 - 0.012 inch

METHOD OF SEAL MAKING AND FITTING

7. For each size of gasket a jig is required, consisting of a 1½ degree tapered steel ring, used for both making and fitting the gasket. This jig always ensures correct size and corner location of gasket. Fig.2 shows details of a jig used for the outer gasket on a 5 inch diameter flange.

8. The following procedure should be adopted to make the seals.

(a) The correct length of gold wire is obtained by wrapping the wire round the top of the tapered jig, (Fig.3) and cutting with a sharp tool. The ends of the wire are then filed square by hand.

(b) The two ends of the wire are held square in a small jig, made from a pair of 5 inch calipers and two crocodile clips, (Fig.4). A gap of 0.0015 inch is left between the wire ends to allow for expansion of the wire during joining.

(c) The gasket is formed by heating the ends of the wire in a finely adjusted oxygen-gas flame, until welding occurs (Fig.5). Necking of the wire or formation of a bead must be avoided. With care and experience perfect gaskets may be formed with one pass of the flame.

(d) The gasket is annealed at 600°C for one hour in a flat oven designed for this purpose. Note that the gasket is annealed laid flat in a circle.

(e) After annealing the gasket becomes very soft and must be carefully handled to prevent work-hardening. The outer gasket is fitted first by placing it over the outer tapered ring and pressing down gently with a circular motion, using a tool made of P.V.C., (Fig.6). When the gasket is within ⅛ inch of the bottom of the jig, it is now sitting on the straight portion of the jig, and is the correct size to be snapped over the spigot, under very slight tension. This ensures a good corner location on the seal face. Fig.7 shows the gasket in its final position.

(f) The inner gasket is then fitted in the same manner described in (e). Fig.8 shows the gasket in its final position.

(g) Before bringing the two seal faces together, they are inspected for extraneous material, i.e. fibre-glass splinters or hairs, and finally wiped over with paper tissues soaked in acetone.

(h) The two seal faces are brought together carefully making sure they are parallel, (Fig.9). For the larger flanges this operation is greatly facilitated by the use of tapered dowels, tipped with S.R.B.P. to prevent damage to seals.

(i) All bolts are inserted and pulled up finger tight, until the gap between faces R and S, Fig.1, is the same as the gasket wire diameter being used. The seal faces are pulled together squarely, gradually increasing the applied torque on the bolts, using a feeler gauge frequently to check the gap. The required gap between faces R and S and the torque required are given in Table I. Any discrepancy noticed between torque settings and gap size as compression proceeds must be investigated, as this indicates that the gaskets are incorrectly fitted or seal faces incorrectly mated. Tightening further under these circumstances will result in damage to the seal faces.

TESTS ON SEALS

9. To test the gold wire seals a vacuum chamber was built incorporating all the seal sizes to be used on the mirror machine. This chamber has a volume of 170 litres and is pumped by an oil diffusion pump fitted with a double chevron type baffle. The pumping speed of this assembly measured above the baffle is 4000 ℓ/sec. for hydrogen. With the top baffle cooled to -40°C pressures of a few times 10^{-10} Torr were consistently achieved after baking to 450°C.

10. The test chamber was used to develop the methods of making and fitting the seals and also to test components under ultrahigh vacuum conditions. Some of the gold seals were thermally cycled up to 450°C, as many as twenty times. No failures were encountered in seals which were leak free on assembly. These results confirm the more extensive re-cycling test reported(1).

EXPERIENCE IN USE

11. On the 16 inch diameter flanges used on the mirror machine it was found that after repeated use movement occurred on the female spigots, decreasing their diameters by about 0.005 inch (Fig.10), thus preventing correct mating of the flanges. To rectify this an adjustable jig carrying a small air driven grinding wheel, was designed. The removal of the metal from both spigots took about 8 man-hours to complete.

12. On one occasion a 16 inch diameter seal was badly damaged due to failure to observe the correct fitting procedure, para 8(i). The damage however was not irreparable and was made good by use of the above jig and hand grinding.

13. During the course of the many sealing operations carried out on the mirror machine and test chamber, three of the smaller diameter 12 point fasteners were sheared. In the light of this experience we would recommend using the larger fasteners, i.e. AD 776-06-04, on flanges above 5 inch diameter.

COSTS

14. Most of the cost of the double corner type seals is in the machining of the flanges. Gold wire, 99.96% pure, costs 10d. per inch for the 0.020 inch diameter and 2s. per inch for the 0.030 inch diameter. The two gaskets required for a 16 inch diameter seal would thus cost £9. 14s. 0d., most of which is recoverable in the scrap value of the gold. Table II gives recent costs of machined flanges, steel jigs and special fasteners.

TABLE II

Item	Cost
12 point fasteners:-	
AD 776-06-04	£120 per 100 or £600 per 1000
AD 766-04-04	£ 50 per 100 or £260 per 1000
16 inch female flange, machined on an existing vacuum chamber	£107
16 inch male blank flange:-	
Material	£ 25
Labour	£184
Tapered jigs for 16 inch seals	
Outer jig:- Material	£ 34
Labour	£ 42
Inner jig:- Material	£ 30
Labour	£ 37
5 inch female blank flange:-	
Material	£ 2
Labour	£ 26
Tapered jigs for 5 inch seals	
Outer jig:- Material	£ 3
Labour	£ 13
Inner jig:- Material	£ 2
Labour	£ 10

CONCLUSIONS

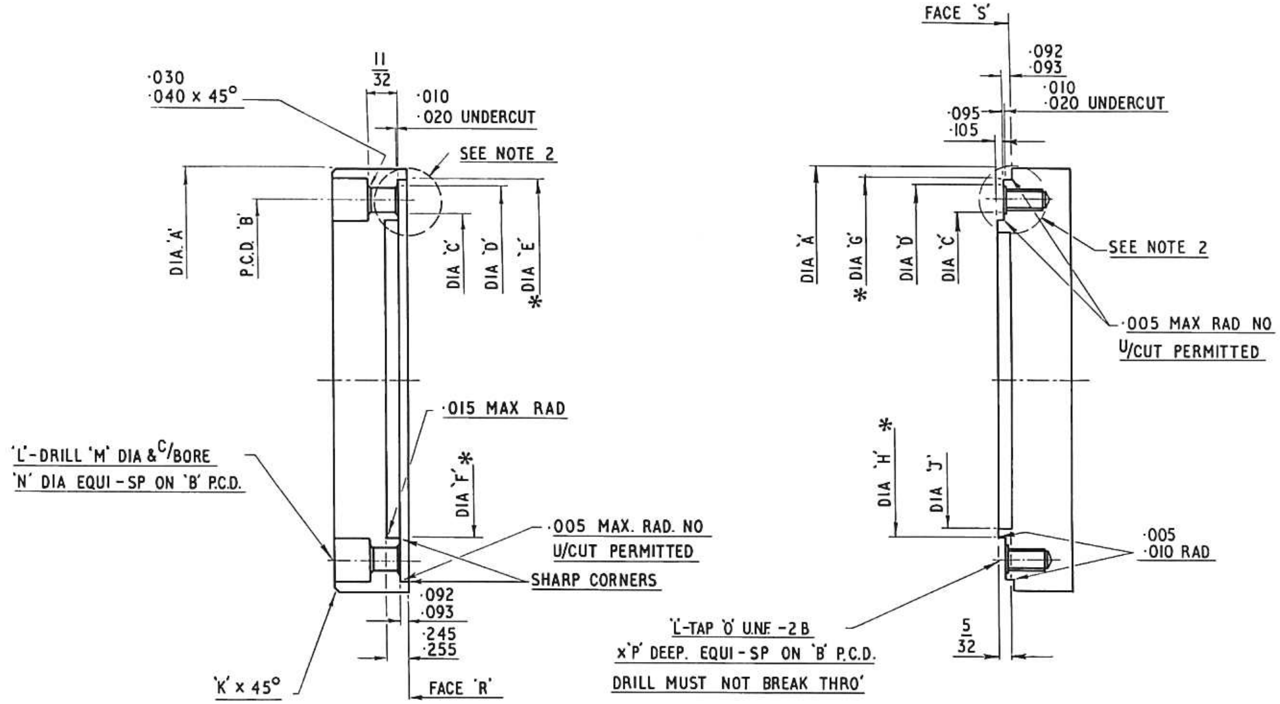
15. The double corner seal using gold gaskets has been found a completely reliable system of making demountable vacuum seals and has been tested up to 16 inch diameter. There appears to be no reason why the size should not be increased further if required. It has been found possible to make in situ repairs to quite serious damage on seal faces. The relative complexity of the system and its appreciable initial cost is adequately compensated by the ability to make consistently reliable seals which can stand repeated baking cycles.

ACKNOWLEDGEMENTS

The work described here is based on the original designs of K.R. Gamlen. The techniques have been evolved from many contributions by individual members of the Mirror Machine group. The encouragement received from Dr A.E. Robson to write this memorandum is gratefully acknowledged.

REFERENCES

1. DREYER, K. and MARK, J.T. Ultrahigh vacuum system developments for the Model C-Stellerator. R.C.A. Rev. (U.S.A.) vol.21, no.4, p.508 - 546. December, 1960.



GENERAL NOTES

1. IN ALL CASES SCREWS ARE TO BE UNBRAKO TYPE AD 776
2. NO ROUGH SPOTS, PITS INCLUSIONS OR SCRATCHES IN THIS AREA
3. GOLD SEAL DIAS MARKED THUS * MUST BE MEASURED AT BETWEEN 60 & 70°F.
4. ALL DIAS MUST BE CONCENTRIC
5. ON NO ACCOUNT MUST ABRASIVE OF ANY KIND BE USED
6. PROTECT FINISHED VACUUM FACES WITH 1/8 THICK HARDBOARD TAPED OVER

NOTE

'Q'- HOLES TAPPED 'O' U.N.F. 2B EQUI-SP ON 'B' P.C.D. & EQUI-DISTANT BETWEEN ANY TWO CLEARANCE HOLES ARE REQUIRED IN ALL FEMALE FLANGES

GOLD SEAL SIZE DIA.A	DRAWING NUMBER	GOLD WIRE DIA	P.C.D. B	DIA C	DIA D	DIA E	DIA F	DIA G	DIA H	DIA J	DIM^N K	NO OFF L	DIA M	DIA N	DIA O	DIM^N P	NO OFF Q	GOLD SEAL CONES INNER	GOLD SEAL CONES OUTER	APPROX BOLTING TORQUE	FLANGE GAPS (FACE R TO FACE S)
3 1/4	DC 321730/1	·020	2·505 2·495	2·193 2·183	2·817 2·827	3·000 3·001	2·000 2·001	2·996 2·995	1·996 1·995	1·750 1·751	1/16	12	9/32	9/16	1/4	7/16	3	AC 316604	AC 316603	180 lb. ins.	·0070
3 3/4	DC 321730/2	·020	3·005 2·995	2·693 2·683	3·317 3·327	3·500 3·501	2·500 2·501	3·496 3·495	2·496 2·495	2·250 2·252	1/16	15	9/32	9/16	1/4	7/16	3	AC 304039	AC 304038	180 lb. ins.	·0070
5	DC 321730/3	·020	4·255 4·245	3·943 3·933	4 557 4·567	4·750 4·751	3·750 3·751	4·746 4·745	3·746 3·745	3·500 3 502	1/16	18	9/32	9/16	1/4	7/16	3	AC 301317	AC 301318	180 lb. ins.	·0070
9	DC 321730/4	·020	8·192 8·182	7·880 7·870	8·495 8·505	8·688 8·689	7·688 7·689	8·684 8·683	7·684 7·683	7·437 7·440	1/16	36	9/32	9/16	1/4	7/16	4	BC 301315	BC 301316	180 lb. ins.	·0070
11 1/4	DC 321730/5	·020	10·067 10·057	9·385 9·365	10·740 10·760	11·000 11·002	9·125 9·127	10·994 10·992	9·119 9·117	8·875 8·878	1/16	40	9/32	9/16	1/4	7/16	4	BC 298461	BC 298460	180 lb. ins.	·0070
16 11/16	DC 321730/6	·030	15·505 15·495	14·822 14·802	16·178 16·198	16·438 16·440	14·562 14·564	16·434 16·432	14·558 14·556	14·3125 14·3160	1/8	48	13/32	13/16	3/8	5/8	6	CC 301313	CC 301314	48 lb. ft.	·0100

Fig. 1 Details of the standard male and female flanges used on the mirror machine (CLM-M57)

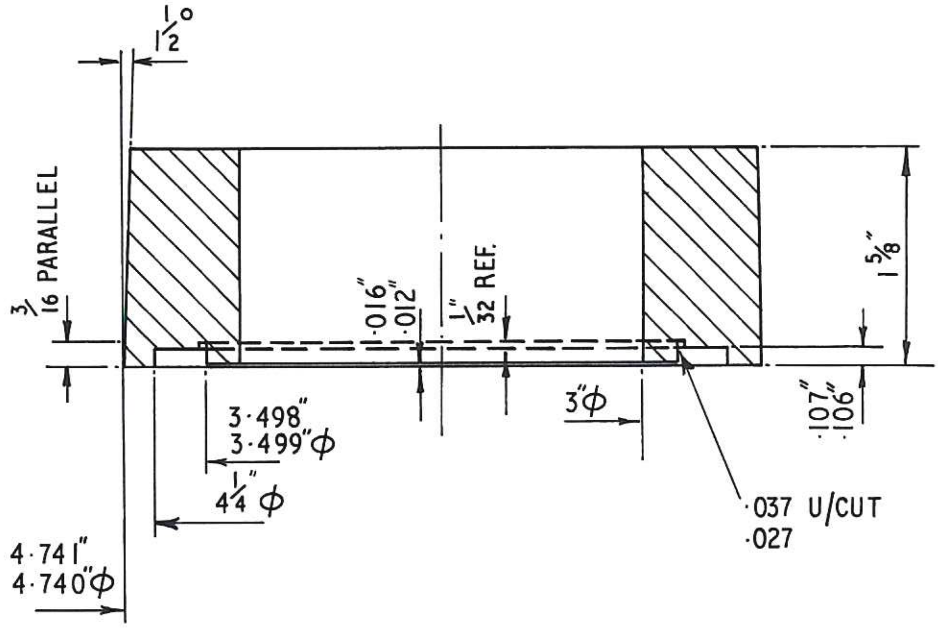


Fig. 2 (CLM-M57)
Details of jig for making and fitting the outer gasket on a 5 inch diameter flange

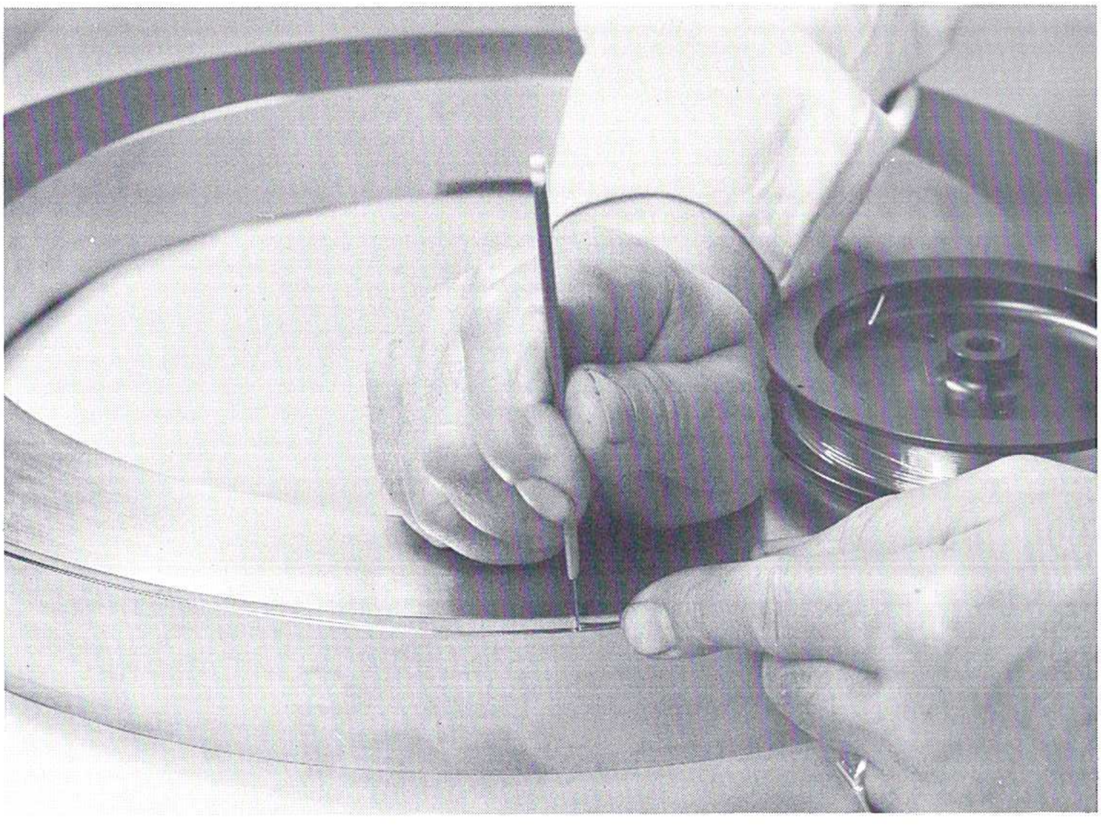


Fig. 3 (CLM-M57)
Using a jig to obtain correct length of gold wire for gasket making

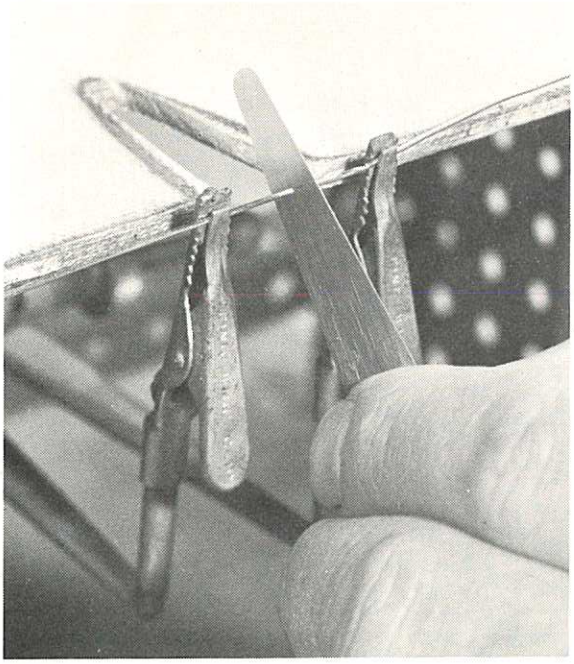


Fig. 4 (CLM-M57)
Gasket ends being set up in preparation for welding

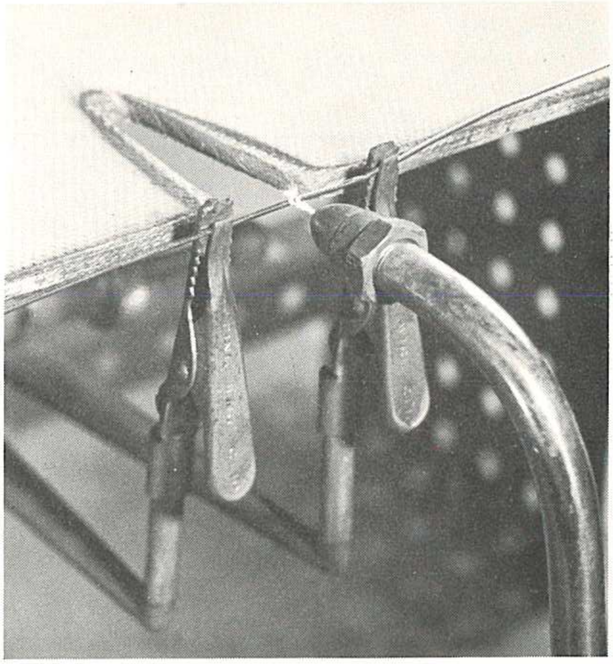


Fig. 5 (CLM.M57)
Gasket being welded in a finely adjusted oxygen-gas flame

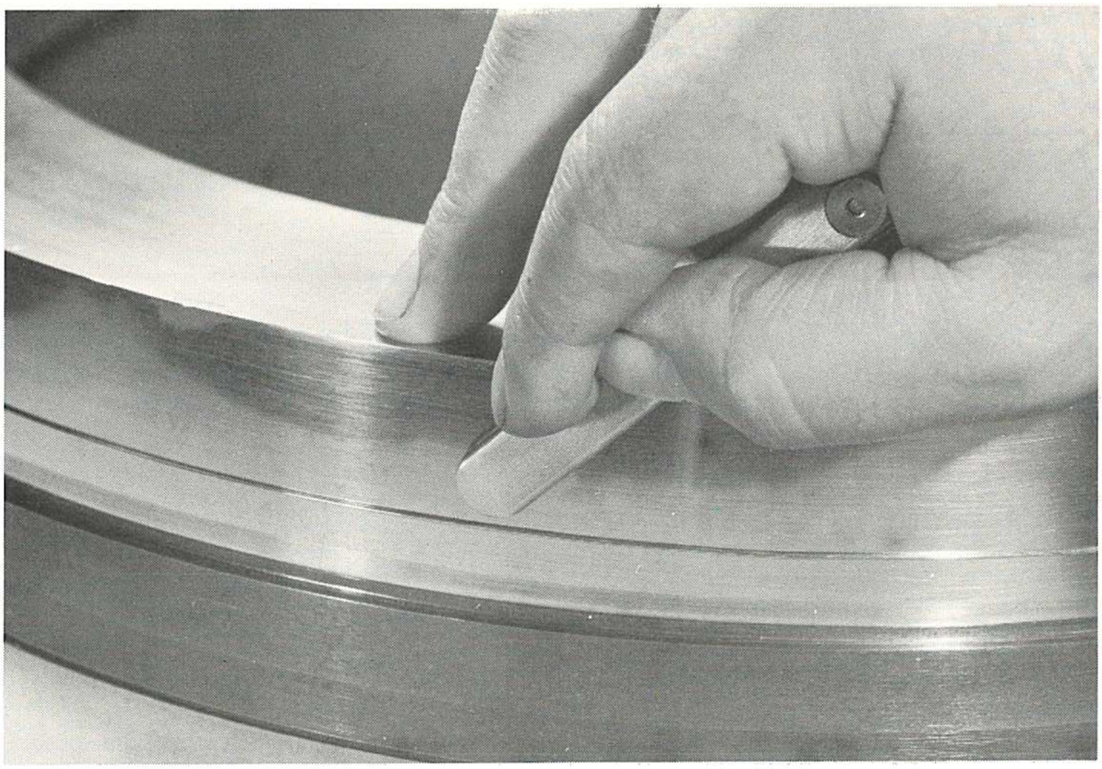


Fig. 6 (CLM-M57)
Tapered jig being used to fit an outer gasket on a 16 inch diameter flange

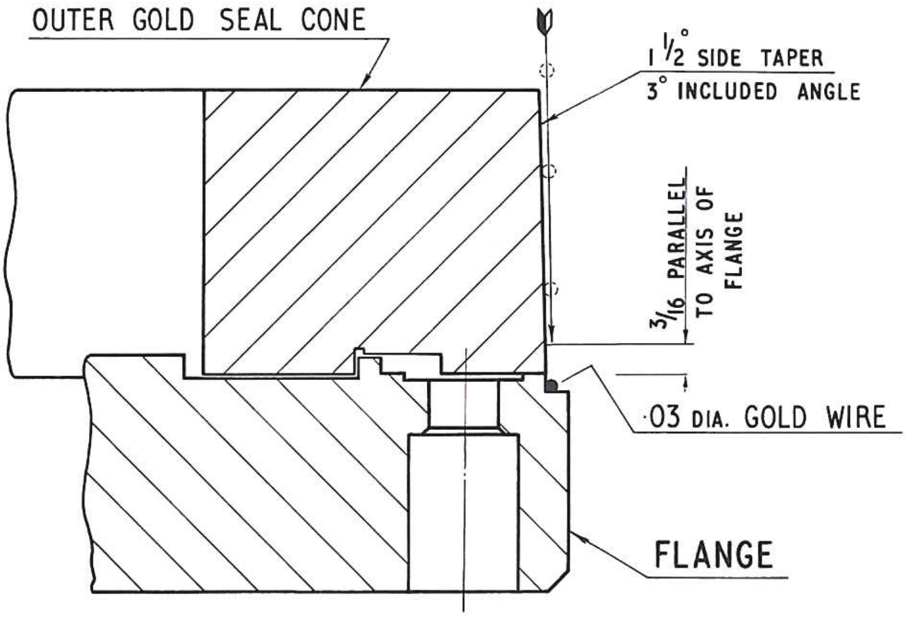


Fig. 7 (CLM-M57)

Cross section of flange and outer tapered jig, with outer gasket in its final position

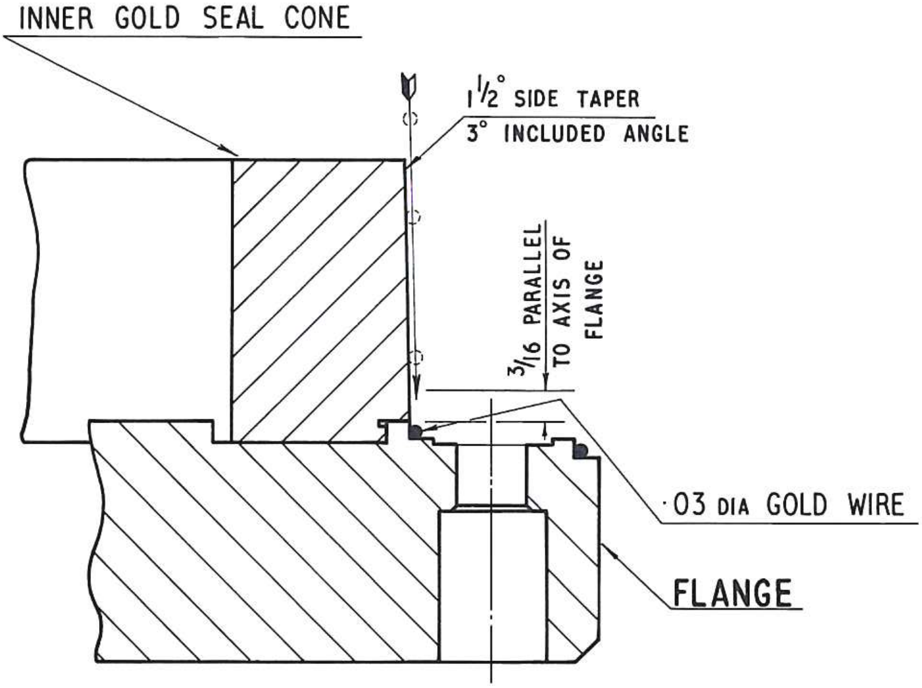


Fig. 8 (CLM-M57)

Cross section of flange and inner tapered jig, with both gaskets in their final positions

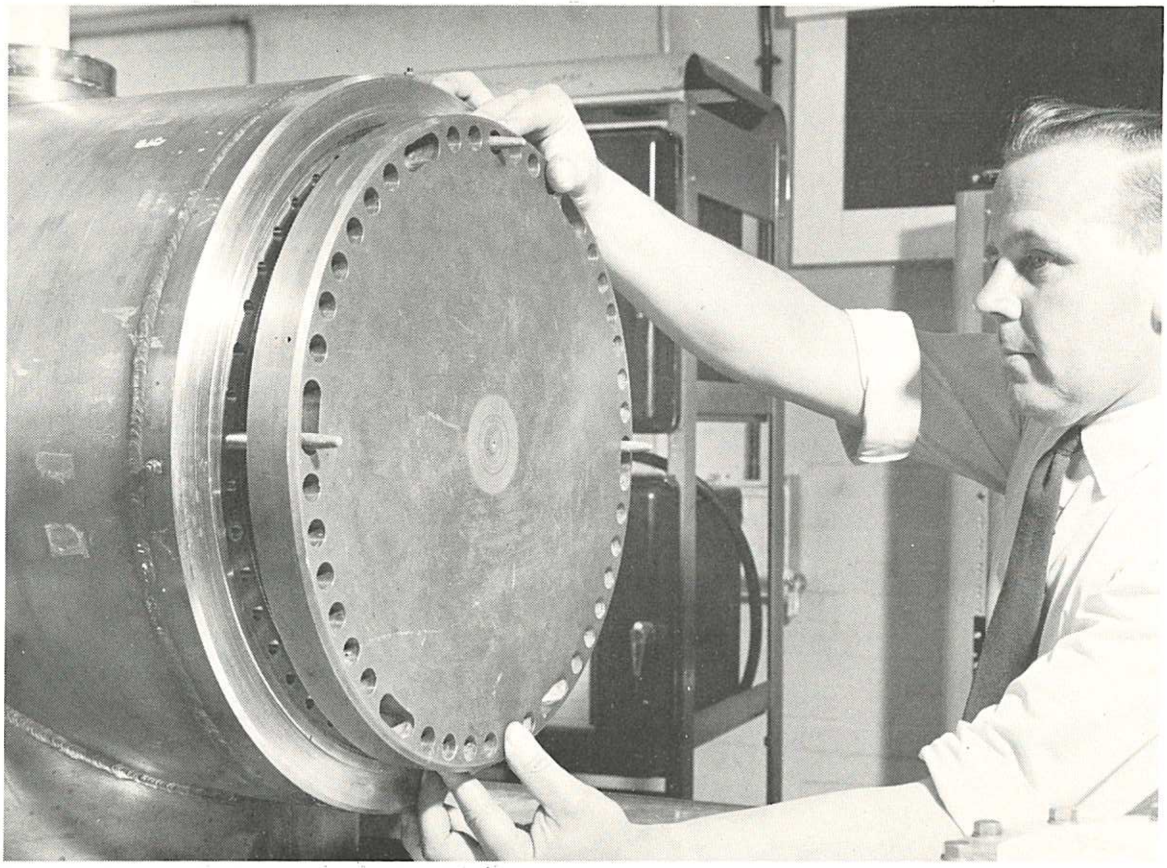


Fig. 9 (CLM-M57)
16 inch diameter male and female flanges being brought together parallel on tapered dowels

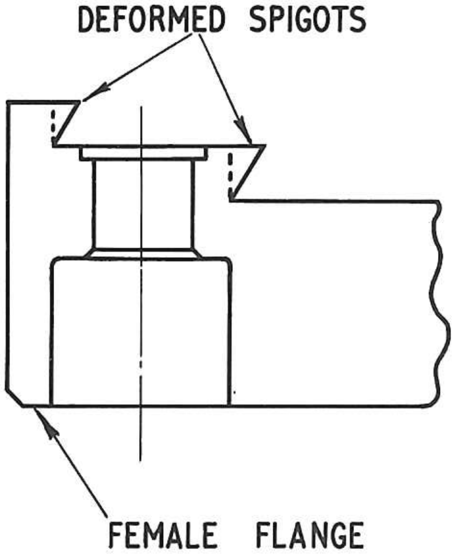


Fig. 10 (CLM-M57)
Cross section of a female flange exaggerating the distortion of the spigots after repeated use