PS / RF / Note 90-11
12-07-1990

IMPROVING THE RELIABILITY OF THE 114 MHZ CAVITY (ESPECIALLY SHORTING SWITCH AND RF-WINDOW)

R. Hohbach

1. INTRODUCTION

In the past, faults in the electromechanical shorting switch (Figs. 1 and 2) of the 114 MHz cavity [1, 2] caused long breakdowns, ranging from hours to days.

The reason for this delay is that a repair requires a breaking of the vacuum followed by a reconditioning of the cavity by slowly raising RF.

The weak points were up to now vacuum leaks caused by premature end of bellows life or destroyed Al-joint from excessive driving forces when adjusting the device (oscillations).

Other leaks were caused by heat cycling (by RF-power) at an uncooled stainless steel flange with an Al-joint and by a cracked RF-window (by raising the voltage too quickly in the run-in-period).

Recent improvements and investigations should greatly reduce breakdowns caused by this shorting-switch within its scheduled 1 year continuous operation (equivalent to 2 million movements).

No electronic, or coupled damper can compete with this near ideal switch, with its low ON-resistance and low RF-losses, especially important in our high Q cavity.

2. IMPROVEMENTS MADE

ACTION	RESULT
2.1. In PS - ring	
2.1.1 Installation of a second cavity.	Quick switch-over to spare cavity (< 30 min.) for electrical mechanism or starting up vacuum faults.
2.1.2 Installation of a sector valve between the two cavities .	Repair possible at one cavity, keeping the other conditioned.
2.2. Shorts	
2.2.1 Construction of a cover box to tighten a leak at the bellows.	Leak can be reduced by use of a prevacuum pump and other cavity or short can be used for acceleration.
2.2.2 Use of only one of the two installed per cavity.	Second shorting switch always available as a spare part.
2.2.3 Independent vibration monitor, cutting the power to the drive electronic for excessive arm acceleration (by a relay = slow).	Avoids bending of shorting bar and leaks from moving Al-joint, may also increase lifetime of bellows.
2.2.4 Installation of a fast electronic overcurrent protection.	Protects as above, but very fast (ms) and avoids oscillations during adjustments.
2.2.5 Revision and new adjustment of the drive electronic (all cards found to be in a different state due to different fabrication dates).	Optimized movement and less oscillation.
2.2.6 Use of new printed circuit boards for drive electronic, with easier and more reliable adjustment possibilities	Should avoid wrong settings and give possibility of faster arm movement (foreseen for September 1990).
2.2.7 Cooling of flange	No more leaks after high RF-power cycling.

2.3. Nose cone : higher water-flow.	No more leaks after power cycling and less frequency drift.
2.4. RF window	
2.4.1 Protection ring at brazing.	Increases high voltage behavior and life.
2.4.2 Blind flange to close a leak.	Leak removed, second cavity may be used.
2.4.3 Electronic protection by a fast RF power cut-off when pressure is rising.	A discharge inside the cavity is no longer destructive.
2.5. Higher Mode Dampers: copper plating and better cooled parts.	Reduction of multipactor and heating, causing drift in tuning.
2.6. Piston tuners : copper plating.	Reduced drift in tuning due to less heating and lowered risk of vacuum leaks from heat cycling.

3. TESTS AND INVESTIGATIONS

3.1. Lifetime of Bellows (History)

In the design of the drive mechanism, the bellows were considered as having infinite lifetime due to over-dimensioning and this was guaranteed by the manufacturer.

Bellows tests at CERN, with vacuum inside or outside confirmed this in over 20 million non-destructive cycles of movements.

Unfortunately, we achieved only 100,000 movements in operation (a week of operation in these pre-LEP-days).

A new construction with a lighter arm, a reduced diameter of the bellows with the vacuum inside and a reduction of the angular movement (+ 15° down to + 12°) increased the operational lifetime to 1 million (a few months at LEP cycling).

While in the old construction, the bellows were heated (up to 50°) by RF-currents, the new version with improved RF-shielding stays at ambient temperature (but heating certainly did not determine end of life).

However this short operational lifetime was often preceeded by uncontrolled stresses from self oscillation of the arm in adjustment periods, probably weakening the bellows.

We also cannot trace back, if all the bellows had their obligatory CERN heat treatment up to 600°, under vacuum.

3.2. Bellows Damage Investigation

In the first version, with the vacuum outside, the bellows cracked in the middle of its length.
In the present version with vacuum inside (Fig. 3), it cracked close to its ends, at the inner welding (Fig. 4).

Observation on our new bellows-test-set-ups showed that the bellows moved angularly were deformed by side forces from the atmospheric pressure (differential pressure to vacuum) [3] (Fig. 5].
This opens the first and last folded sections much more leading to cracking, while in the middle they are more compressed (and less stressed).

So, the bellows crack because the stresses are not uniform along its length under vacuum.

Recent tests showed, that the bellows are less deformed by side forces, if they are HARDER, SHORTER AND MORE COMPRESSED.

Going too far in mounting the bellows under compression, jumping of the middle part of the bellows (0.1 mm) was observed (like in a Micro switch).

3.3. Calculation of Stresses

Stresses in the folds of the bellows are composed by forces from the atmospheric pressure and from the pulling force (spring constant) [4, 5].

In our soft bellows, the stresses from the atmosphere to vacuum forces are 7 times higher (35 kg/mm2) than from the angular movement (5 kg/mm2) in air.

If we increase the material thickness, the stresses from atmosphere to vacuum drops with the square and stresses from pulling forces increase linearly. The sum drops to a minimum at 0.25 mm (Fig. 7) and rises slowly afterwards.

The sum of both stresses open the bend at the inner welding (cracking) and reduces the angle at the outer weld (safe !).

In addition to this, there is a shearing force, depending on the angle of movement, trying to cut the weld at the first bends. It is due to the difference of projected surfaces at the top and bottom of the bend bellows under atmosphere to vacuum pressure (16 Kg/mm2). In a simplified drawingP (Fig. 6) it is shown that if the middle parts stay compressed [as observed), the folds at the extremes have to carry the full angular movement and nearly all at the inside weld.

3.4. Proposals for modification to increase bellows lifetime

Based on the above observation and on stress calculations, thicker bellows (0.13 mm instead of 0.1 mm) should be used and installed with distance rings (5 mm) on both sides to keep the movement more in the compression range.

The increased material thickness of 0.13 mm should raise the expected lifetime by a factor 4, (following lifetime curves for IWKA-bellows) due to reduction of the sum of stresses.

On our test stand, life tests have been run with new bellows made of material thickness of 0.1 mm, 0.13 mm and with reinforced ends, up to 20 million bending cycles, without destruction.

3.5. Investigation to Reduce Vibration on the Arm

Further work is going on to damp the mechanical resonance of the arm tips (40 Hz) causing phase and amplitude modulation of the acceleration voltage (short in open position).

Application of a mechanical damper should reduce the Q of the arm resonance and shorten the ringing time.
Presently the ringing amplitude falls to half in approximately 1 sec. (0.1 sec. is desired).

Reducing the weight of the arm front end leads to higher frequency (> 50 Hz), a lower amplitude of vibration (presently approximately 0.1 mm at the tip) and an easier control by the drive- feedback electronic system is expected.

3.6. Reduction of Wear in Vacuum Joints

AL- diamond-shaped joints at locations heated by RF or under mechanical stress should be replaced by C-shaped joints which keep their elasticity, while the AL joints are plastically deformed.

4. CONCLUSION

Availability of RF for LEP should have been strongly improved and also personal stresses reduced for our vacuum, mechanical and RF crew (reducing night call-outs for immediate repair) .

Electronic and human faults which may cause much damage are reduced by fast interlocks depending on pressure rises and excessive in acceleration on the shorting arm.

Long operation without vacuum leaks will be assured by modifications in the bellows position and joints.

Quality of the RF with more definition in timing and reduction of phase and amplitude modulation may be achieved by electronic improvements for the shorting switch.

ACKNOWLEDGEMENTS

Construction and improvements on the Shorting switch were made by S. Talas and are now being continued by M. Corcelle.

Mechanical tests for bellows were done by G. Baud. Improvements of Dampers and Tuners were made by G. Serras. Numerous leak-tests and improvement on our test set-up and cavity were made by the vacuum specialists under A. Burlet.

Information concerning bellows improvements were collected in discussions with M. Van Rooy, R. Matet and S.E. Milner.

Thanks to their effort, the reliability for PS and LEP could be considerably improved.

REFERENCES

1. "The 1 MV 114 MHz Electron accelerator system for the CERN- PS", Proc. of the IEEE Particle Accelerator Conference, Washington D.C., March 16-19th, 1987, p. 1901.
2. "The Shorting switch", R. Hohbach (note in preparation).
3. "Bellow tests", R. Hohbach (collection of measurements).
4. "How to calculate bellows", W. Richter, MPS/ML Note 69-21 and "Consigne de construction SPS/SME DO".
5. "Etude en vue d'améliorer la durée de vie des soufflets", J.M. Dalin, SB 85/SB/AC/CQ/3133/gp, juin 1985.
6. "The Conditioning of the 114 MHz cavity (Multipactor)", R. Hohbach, PS/RF/Note 90-10.

LIST OF FIGURES

Distribution :
RF Group Staff
PS Group Leaders
A. Burlet
R. Matet
S.E. Milner
M. Van Rooy

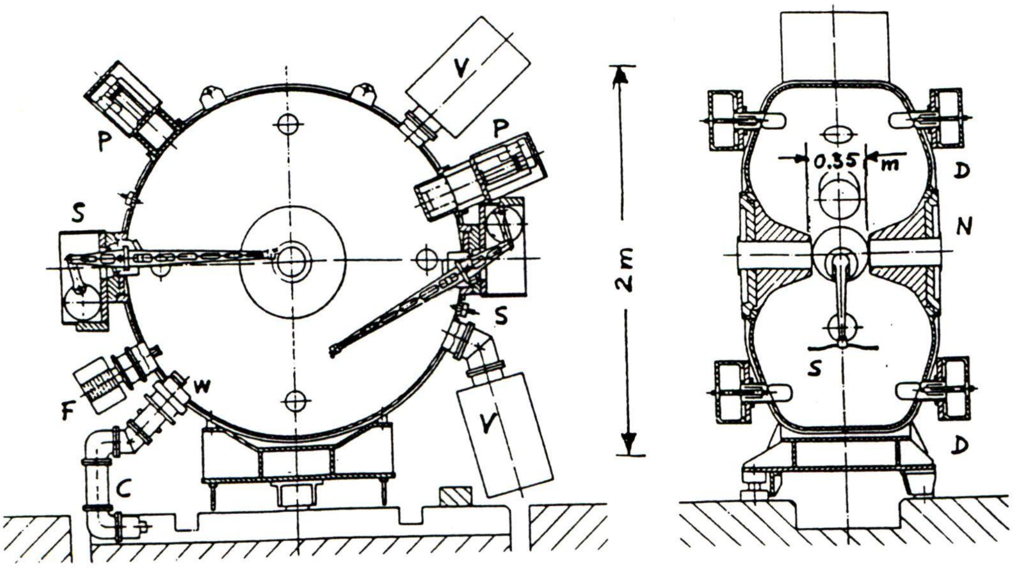


Fig. 1

The 114 MHz cavity

N = nose cone
D = damper
W = RF window
C = cable to amp.
F = ferrite tuner
S = short
P = piston tuner
V = vacuum pump

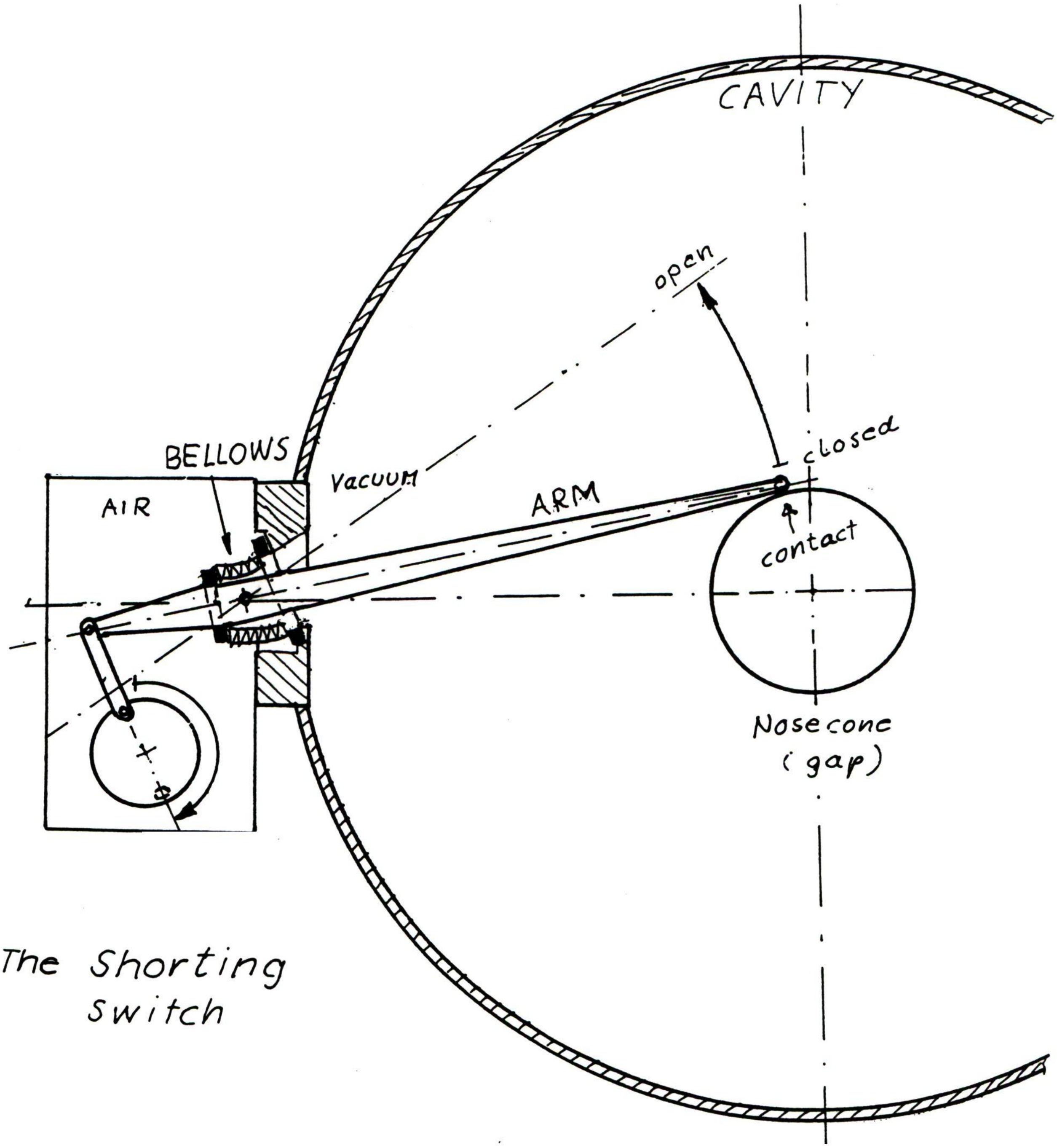
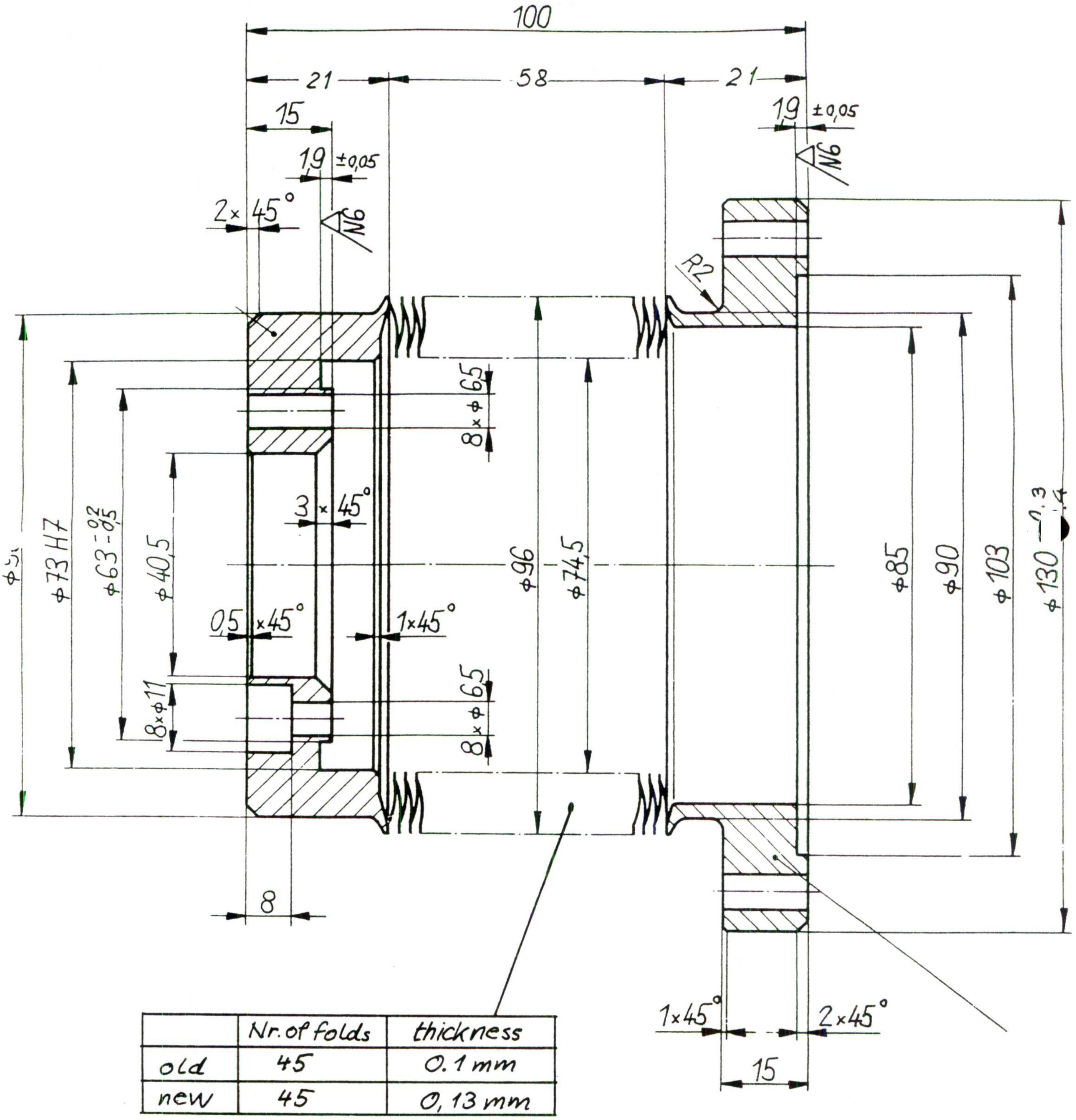


Fig 2

The Shorting Switch



	Nr. of folds	thickness
old	45	0.1 mm
new	45	0,13 mm

1 : 1 scale

FIG 3a

The BELLOWS

made by **Mecatest**/Genève

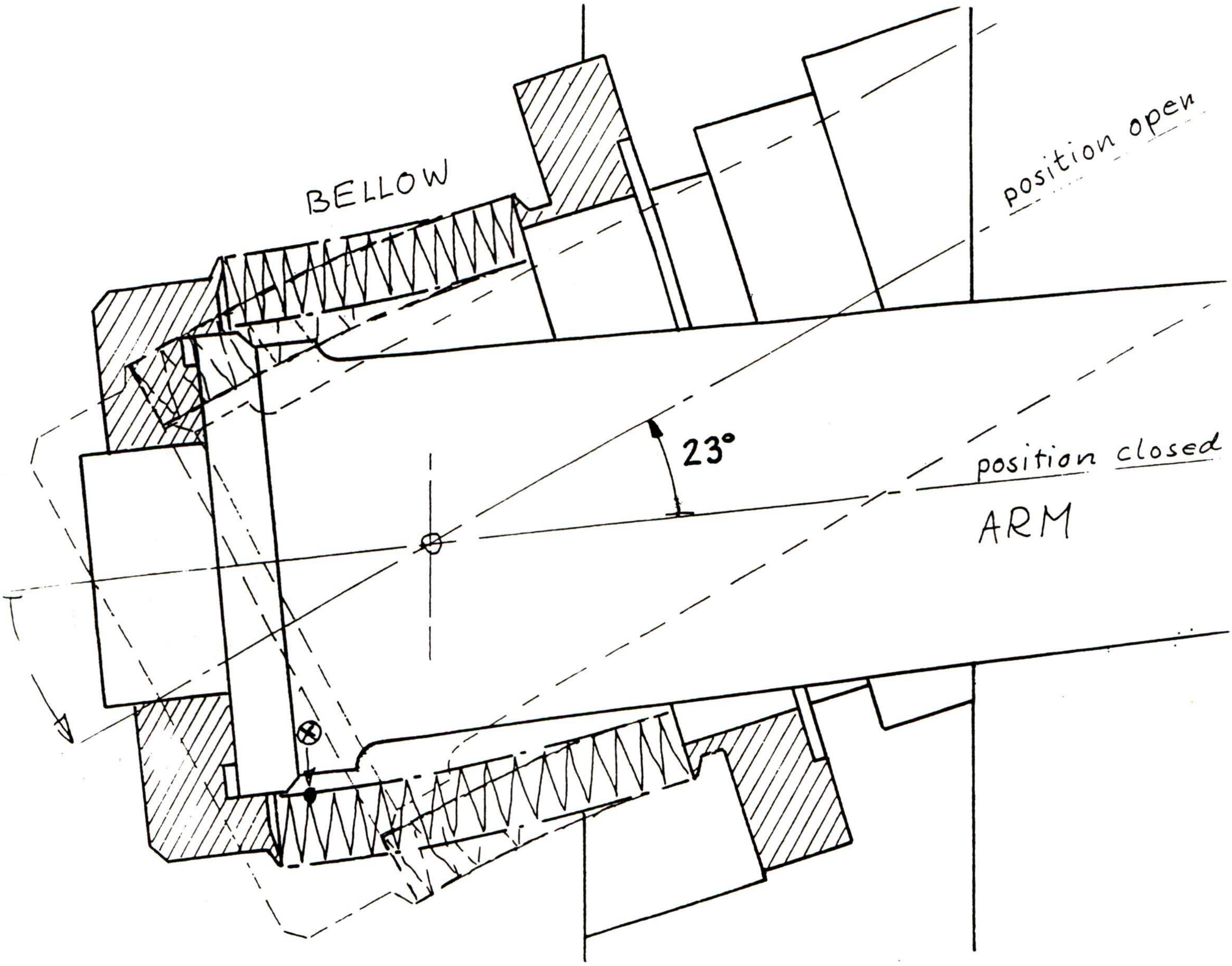
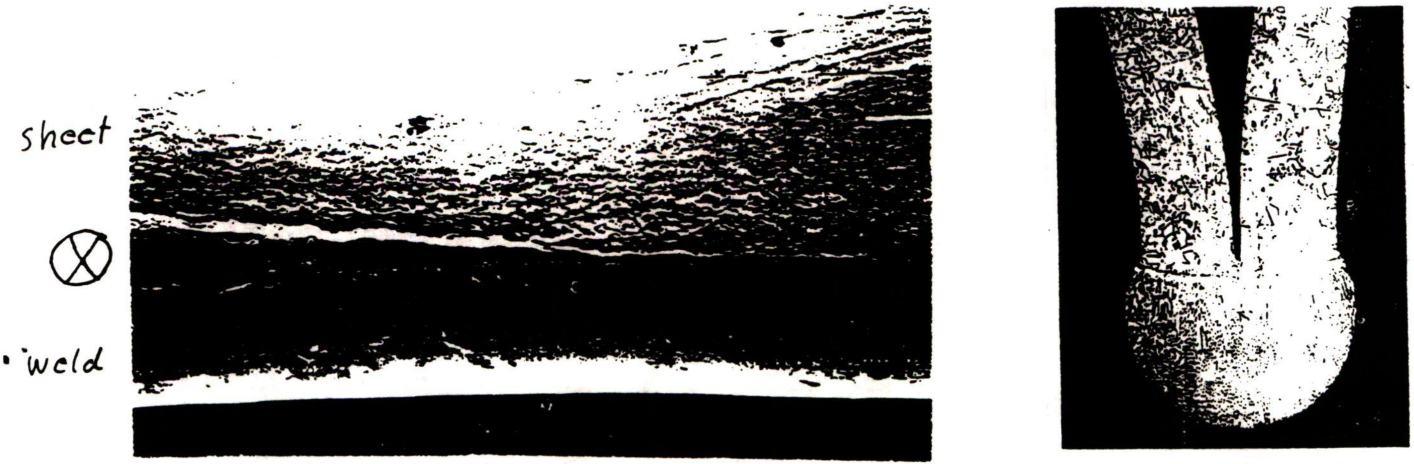


Fig 3b The Bellows (1:1 scale) in open or closed position

⊗ position of cracked welding (see Fig 4)



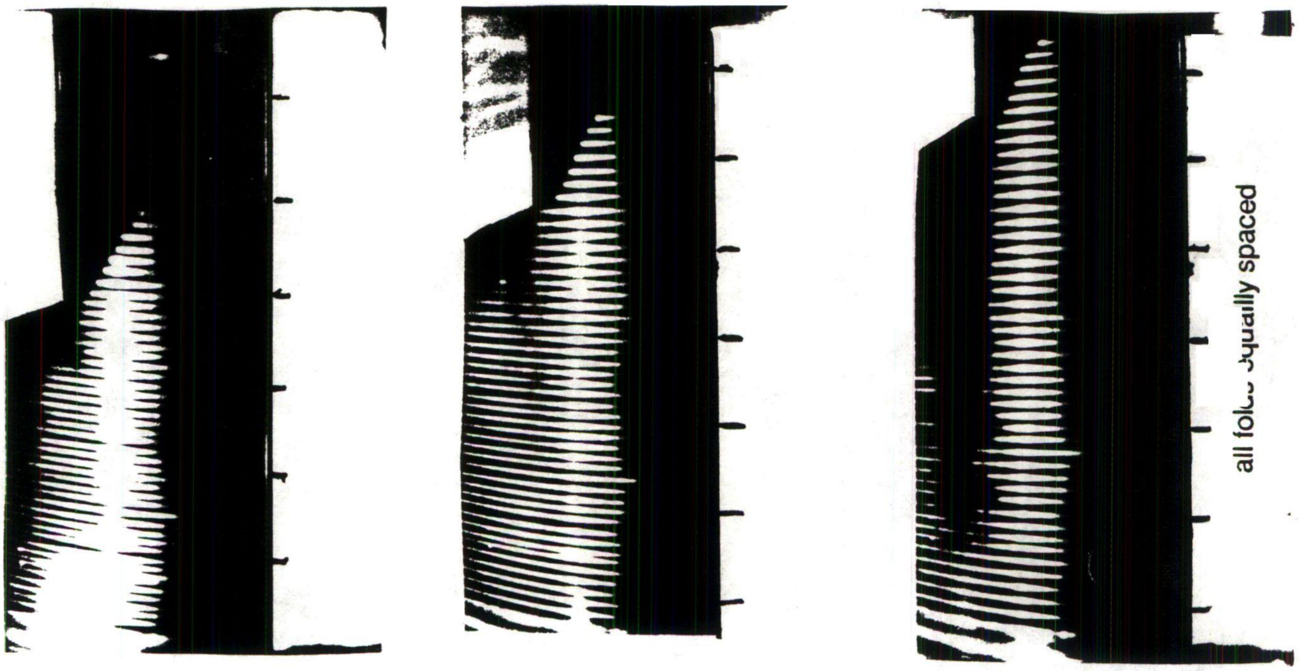
side view

crossection of fold (close to crack)

Fig 4 Bellow's end of life (magnification 100 x)

FIG. 5 Bellows deformed by side forces (approx. 1 : 1 scale)
Thin bellow (0.1 mm) in test set up, bending 12 deg.

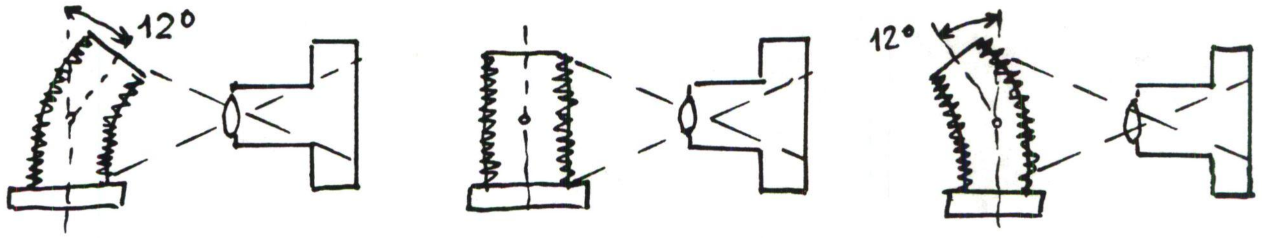
(90-04-12)

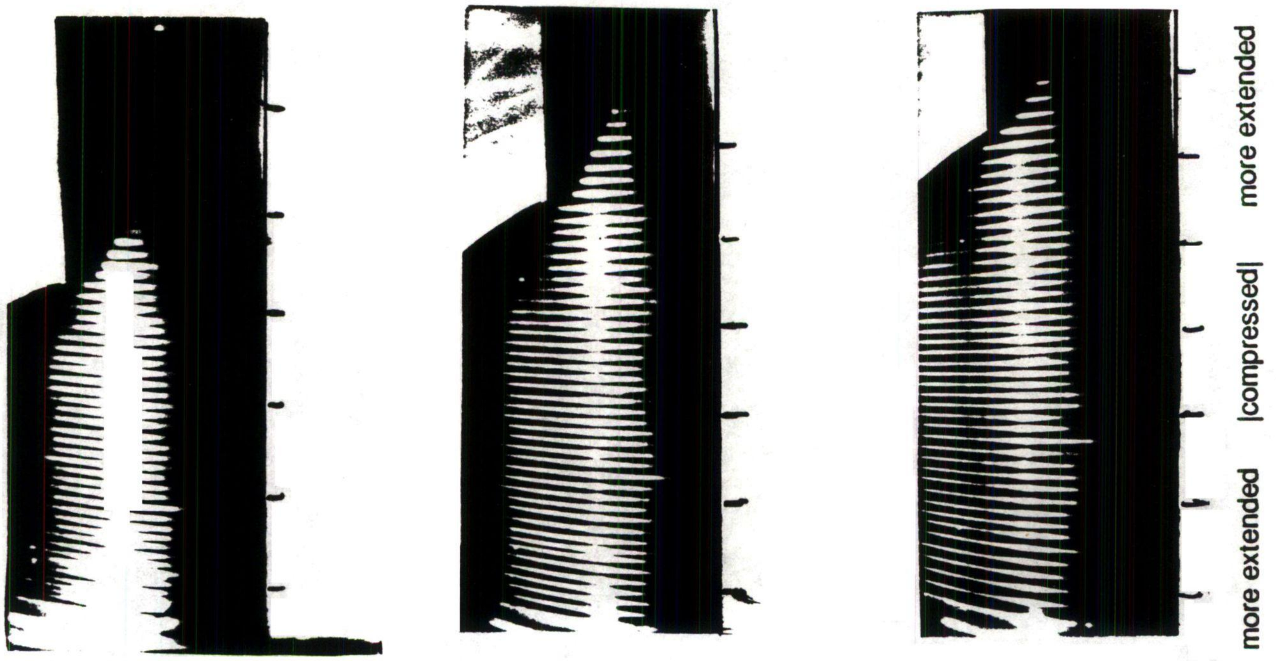


compressed side
no vavuum

straight
no vacuum

extended side
no vacuum





compressed side
vac. inside

straight
vac. inside

extended side
vac. inside

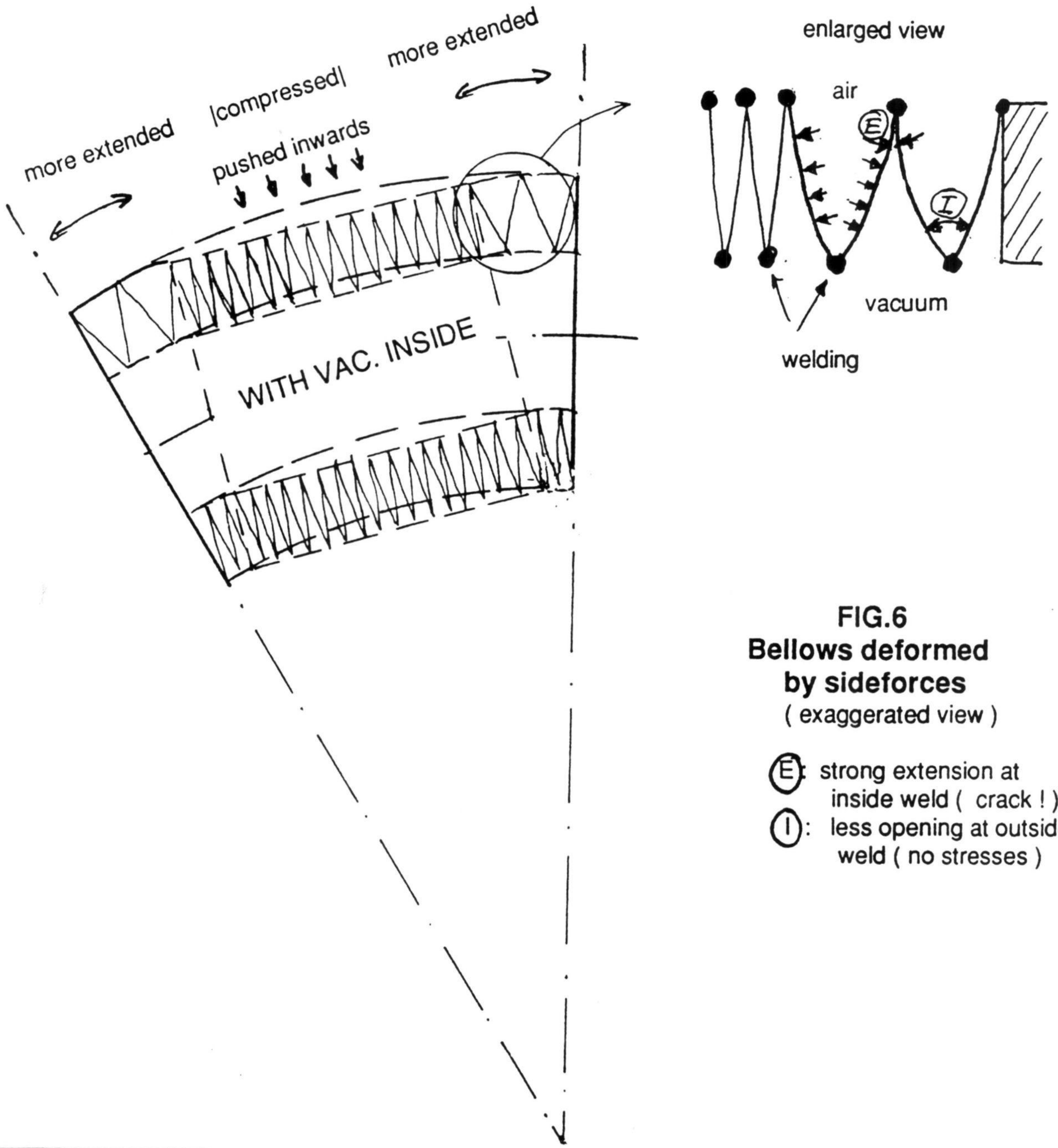


FIG.6
Bellows deformed by sideforces
(exaggerated view)

Ⓔ: strong extension at inside weld (crack !)
Ⓘ: less opening at outside weld (no stresses)

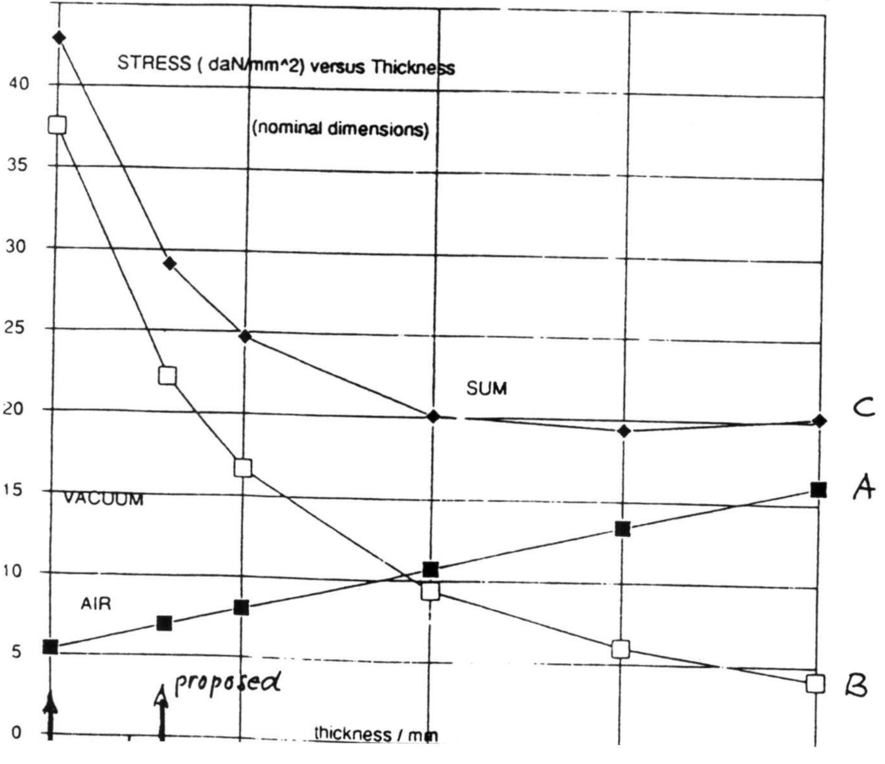


FIG. 7
Stresses in the bellows versus thickness of material
(for bending of 12 deg.)

A: same pressure inside, outside
B: from vacuun inside
C: sum of A and B