TS-SSC 90-062
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DSO-312 COLLARING EXPERIMENTS
(STAGE 1)

Introduction

Magnet DSO-312 was used to resolve several problems related to collaring SSC dipole magnets. A three stage experiment was planned to resolve the following issues.

Stage 1: Does the Tevatron collaring press, which is used for collaring short SSC magnets, have the capacity to collar magnets with the required prestress?

Do tooling shims have any effect on collaring a coil? And if so, what size shim should be used?

Do the long SSC and Tevatron collaring presses apply the load in an identical manner? In other words, can results drawn from collaring short magnets in the Tevatron press be applied directly to the long SSC press?

Can outputs of wedge capacitor gage and strain gage collar packs be correlated to each other and to the press pressure?

Stage 2: Should Teflon, Molybdenum disulfide, or any other material be added to the ground insulation as a slip plane?

Stage 3: What is the appropriate amount of Kapton to add to the poles when collaring a magnet? The answer to this question will tell ultimately how large to mold the coils to achieve the correct prestress.

Procedures and results of the first stage of DSO-312 collaring experiments are discussed below. The second stage experiments are now in progress and will be reported on when completed.

Procedures & Results

The first part of the stage 1 experiments with DSO-312 was to examine the press capacity for collaring the magnet with the required prestress. The maximum press capacity for collaring is 3,250 tons at 10,000 psi hydraulic pressure. Theoretically, at approximately 8,000 psi hydraulic pressure on the short collaring press, collars should be closed such that the keys could be inserted by hand. Figure 1 shows the cross section of the tooling set up for collaring the magnet. In these experiments, upper tooling was used for both top and bottom. Dial indicators were used to measure the tooling and collar lamination deflections. Two separate attempts were made to key the collars at 9,400 psi hydraulic pressure, which was the maximum pressure that the pump could achieve. Keys could not be fully inserted into the key slots of the collar packs except for those at either end of the assembly. This un-inserted portion of the keys (the portion that remained outside of the key slot) was measured at the middle of each collar pack. Figure 2 shows a plot of the un-inserted portion of the key as a function of position. On the horizontal axis of the plot, position 1 is the lead end collar pack and position 6 is the return end collar pack. Positions 2 and 3 refer to strain gage and capacitor gage packs respectively. A curve fit program was used to connect the data points for better illustration and comparison of the trends. As indicated in the plot, key insertion at the ends of the magnet is a lot more successful than the middle. This "end effect" consistently appeared in all of the experiments with DSO-312. It is also evident that keys could be further inserted into the capacitor gage pack than the strain gage pack. This trend also remained consistent throughout all experiments. The clear indication at this point was that the short magnet collaring press (Tevatron press), used in the manner explained above, does not accommodate hand insertion of the keys. However, with some modifications such as addition of tooling shims, the process could possibly be altered to accommodate keying the collars.

The second part of the first stage of DSO-312 experiments was to examine the effects of tooling shims on collaring a coil. The tooling laminations that were used to assemble the existing tooling for both short and long collaring presses, were originally designed for NC9 magnets. There is a 3 mil radial clearance between the I. D. of these tooling laminations and the O. D. of the current C358 magnet collars. Therefore, the profile of magnet collars do not perfectly conform to that of the tooling laminations. To eliminate this problem, a radial shim could be place between the collars and the tooling laminations to alter the pressing process. Figure 3 illustrates the addition of shims to the press tooling. Figures 4 through 10 show plots of the un-inserted portion of the keys at each collar pack for various radial and vertical shim thicknesses and combinations. These Figures also illustrate the effects of the strain gage and capacitor gage packs on the key insertion. Steps of this part of the experiment are outlined below.

The collaring process was repeated without shims. Capacitor gage and strain gage packs were both replaced with regular collar packs to examine the effects of these packs on key insertion. Figure 4 shows a plot of the data for this experiment. As indicated in the graph, the "end effect" was still present, with nearly the same magnitude as in the last experiment. However, keys could be further inserted into the collar packs over the entire length of the magnet.

This was more evident for the capacitor gage pack and to a lesser extent for the strain gage pack. As in the last experiment, collar packs in the middle of the assembly appeared to show more resistance to key insertion.

The collaring process was repeated with a 3 mil and later with a 6 mil radial shim. Figure 5 shows results of the experiments and makes a comparison of the effects of various radial shims. Clearly, the 6 mil radial shim significantly improves the key insertion process. Figure 6 makes a comparison of the experiments, including the case without capacitor and strain gage packs. Again, the 6 mil radial shim shows the highest degree of key insertion. As in the previous experiments, key insertion into the middle collar packs proved to be worse than ends.

An attempt was made to improve key insertion at the middle collar packs of the magnet. This was done by placing a 7 mil thick, 20 inch long shim between the press platen and the upper tooling over the middle of the magnet. In the figures, this shim is referred to as the vertical shim. As indicated in Figures 7, 8, and 9 key insertion was significantly improved by adding the vertical shim. However, the "end effect" was still present. Figure 10 compares the effects of various radial shims and the gage packs coupled with a 7 mil vertical shim. It is evident that a 6 mil radial and 7 mil vertical shim combination improves key insertion more than any other combination.

To better understand the effects of tooling shims and their contribution to improve the key insertion, it was decided to survey the press platens and inspect the height of the stop blocks. Stop blocks, shown in figure 1, are placed throughout the press, between the upper and lower platens, in order to close the entire press to the same height. In other words, the collaring press is always closed to the same height from one end to the other. These blocks are used to avoid over compressing the coils and to prevent bending the press platens. The height of the stop blocks was calculated to accommodate keying the collars with the required prestress. Inspection of stop blocks indicated that all blocks essentially had the same height (within 1 mil of each other). Laser survey equipment was used to examine deformation of the press platens. As illustrated in figure 11, both platens are permanently deformed. The survey results also indicated that the upper platen was longitudinally twisted in a random fashion. At this point, it was discovered that a few years ago while collaring a short magnet, the stop blocks were not placed throughout the press. The incident resulted in severe deformation of press platens. The lower platen was removed from the press and was repaired. The upper platen, however , was not removed from the press. Instead, the lower platen was installed in the press and an attempt was made to straighten out the upper platen by placing steel blocks between the press platens and closing the press.

Up to this point in the experiment, the magnet was placed at the very end of the press for collaring. Considering the survey results, and for more uniform loading purposes, it was decided to place the magnet and tooling assembly at the middle of the press and examine the effects of positioning of the assembly at various locations in the press. Several collaring experiments were performed at the middle and the end of the press using vertical and radial shim combinations. Figures 12 through 19 illustrate results of the experiments. Clearly, placing the magnet and tooling assembly at the middle of the press improves key insertion. Furthermore, increasing the vertical shim thickness to approximately 12 to 19 mils significantly improves the collaring process regardless of position of the assembly in the press, as indicated in figures 16 and 17. More importantly, it was noted that when collaring at the middle of the press with a 19 mil vertical shim, a full and uniform key insertion can be achieved at 8,000 psi hydraulic pressure, as shown in figure 18. This indicated that with the addition of the tooling shims the Tevatron collaring press is capable of collaring the magnet with the required prestress. Figure 19 illustrates a comparison of the best and worst results. As shown, collaring at the middle of the press with a 19 mil vertical shim provides superior results as compared to collaring at the end of the press without tooling shims which is the existing collaring procedure.

The third part of the first stage of the collaring experiments with DSO-312 was to find out whether results drawn from collaring short magnets in the Tevatron press can be applied directly to the long SSC collaring press. This was examined by collaring the magnet in the long SSC collaring press. Keys could not be inserted at 7,000 psi hydraulic pressure, which corresponds to 9,450 psi hydraulic pressure on the Tevatron press for an equivalent coil stress. At this pressure it required a hydraulic pressure of 1,200 psi on the side cylinders to insert the keys. This pressure corresponds to a force of approximately 630 pounds per linear inch on the keys located on each side. This is by far larger than the exerted force when hand inserting the keys, which was the case when using the Tevatron press. Although the laminated tooling for both presses load the collars in the same manner, because of geometrical differences between the lower press tooling, depth of key insertion could not be measured in the long SSC collaring press. It is important to note that the beams of both presses are permanently deformed in a random fashion. Therefore, application of the load to the collar assembly is not absolutely identical for these presses. However, there is a significant result drawn from collaring DSO-312 in the Tevatron press that can be applied directly to the long SSC collaring press. A detailed discussion of this matter is presented in the conclusion section of this report.

In the search for additional methods of determining the prestress on the coils, two types of capacitive output pressure gages have been investigated. These two gages are epoxy gages and wedge gages. For the epoxy gages, the modules of elasticity of the gage depends on the compression of the two layers of Kapton-Epoxy dielectric compressed against an inner stainless steel electrode by two outer electrodes connected in a "Y", as shown in figure 20. Two of these gages were installed in a special collar pack, referred to as the capacitor gage pack, in the same position as the strain gages in the transducer collar packs. The second type of capacitive gage is referred to as the wedge gage. The coil wedges are electrically "floating", but have very uniform dielectric material composed of layers of Kapton and fiber glass tape. The theory under investigation is that the general uniformity of the dielectric layers, the large surface area of the wedge, and the fact that the wires connected to the wedge bars could be twisted with voltage tap wires to form an electrically quiet cable would all lead to a pressure transducer. This highly predictable pressure transducer would indicate the average pressure over the length of the wedge and therefore the coil. Further experiments are required to investigate the capacitive pressure gages. Results of these experiments and a comparison of capacitive and strain gages will be discussed in a separate report in a near future.

Conclusions and Recommendations

Experiments with DSO-312 have provided a great deal of insight to many ambiguities related to the collaring process. What has been learned from these experiments not only will improve the collaring process for developing the remaining 40 mm design magnets, but also will better prepare us for the 50 mm dipole magnet program at Fermilab.

The first issue that these experiments attempted to resolve was to decide whether the Tevatron collaring press has the capacity to collar short SSC dipole magnets. The Tevatron collaring press has the capacity to collar the magnets. However, the press tooling has to be modified in order to employ the press capacity for collaring purposes. Without any modification, this press can not be used to hand insert the keys, as the theoretical model requires. One possible modification is addition of tooling shims to the press which was the second issue that these experiments attempted to resolve.

Addition of shims between the upper press tooling and the platen (vertical shims) significantly improves the collaring process. The 19 mil vertical shim that was used provided a complete key insertion at 8,000 psi hydraulic pressure. It is more important, however, to understand how this shimming scheme contributes to correct the key insertion process. As described earlier, the Tevatron collaring press is closed to a known stop every time. The stop point is determined by the stop blocks placed between the upper and lower press platens. Figure 21a shows a cross section of the press including the stop blocks, tooling, and the magnet assembly. Figure 21b illustrates how the addition of a vertical shim alters the stop point for the tooling. Clearly, by adding the vertical shims, the magnet assembly is compressed more than it would otherwise. Therefore, it can be concluded that the block height, which was originally determined to provide 5 mils of overcompression, is approximately 12 to 19 mils oversized. The oversized blocks keep the magnet assembly from closing to the required dimensions prior to key insertion. This is indeed the most significant conclusion of the first stage experiments. This problem can be easily solved by machining the blocks to reduce their height by 12 to 19 mils, and therefore lower the stop point. The fact that addition of only a vertical shim is sufficient to correct the key insertion problem leads to another important conclusion. As pointed out earlier, the collaring press tooling laminations are radially 3 mils larger than the magnet collar laminations. Therefore, it can be concluded that the tolerances for the I. D. of tooling laminations can be approximately within 3 mils of the O. D. of the magnet collar laminations. In other words, the tolerances for the I. D. of tooling laminations can be loosened more to ease the manufacturing process for these laminations.

It was mentioned earlier that there is a significant conclusion drawn from collaring DSO-312 in the Tevatron press that can be applied directly to the long SSC collaring press. This conclusion also involves the height of the stop blocks. The tooling laminations for the long SSC collaring press were designed so that the magnet assembly would close to the same dimensions as the stop blocks provided in the Tevatron press. In other words, the same oversized stop blocks were built in the existing tooling laminations for the long SSC collaring press. However, when this tooling was assembled in the press, a 7 mil thick shim was placed between the upper tooling and the press platen. Although an improvement, as indicated earlier, the 7 mil shim is still not enough to significantly correct the key insertion problem. That is why the side cylinders of the collaring press have to be used to force the keys in for complete key insertion. It is recommended to add vertical shims to the long SSC collaring press to improve the key insertion process. Correcting dimensions of the collaring press tooling laminations for the 50 mm design magnets is an important consideration that has to be investigated in more detail to avoid problems such as these.

It is recommended to place the tooling and magnet assembly in the middle of the press when using the Tevatron press for collaring short coils. However, it seems to be more advantages to collar both short and long magnets in the long SSC collaring press. This will eliminate the need for shimming the tooling for both presses. There is a general disadvantage associated with using a long press for both short and long magnet assembly process such as coil collaring. The disadvantage is that there is always a possibility for severely damaging the press tooling when using it for assembly of a short magnet, as it happened with the Tevatron collaring press. A solution to this problem is to provide easily accessible shut off controls for multiple banks of press cylinders. The cylinders that are not needed for short magnet applications can be deactivated, in addition to placing the stop blocks between press platens, to minimize the potential for damage. Use of travellers that call for checks and double checks can also help to prevent incidents such as those mentioned earlier in this report.

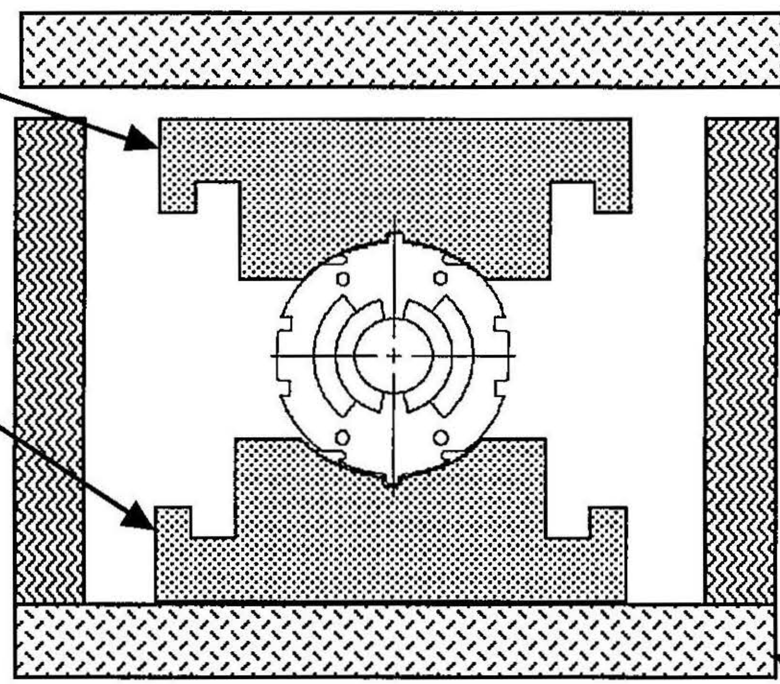

Figure 1 : Tooling set up for collaring DSO-312

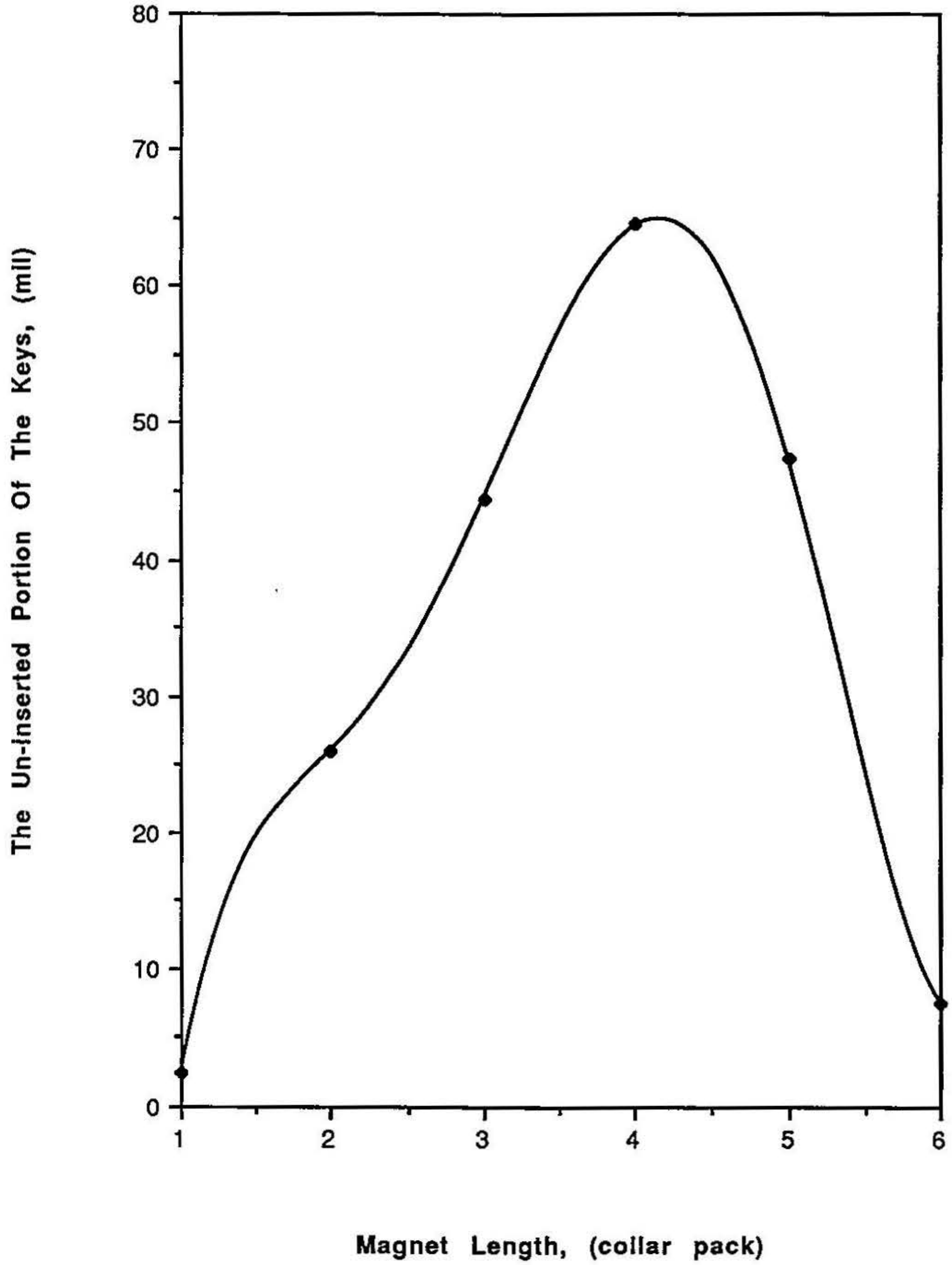

Figure 2 : Collaring at 9400 psi hydraulic pressure

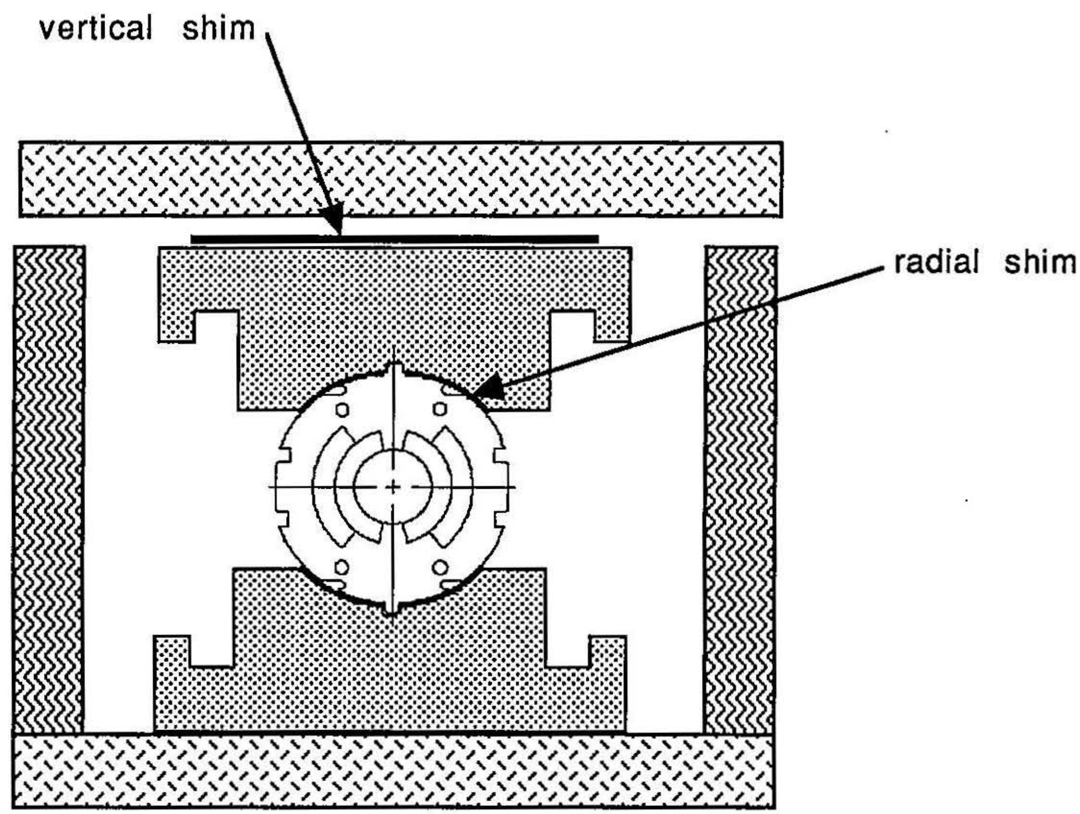

Figure 3 : Radial and vertical shims

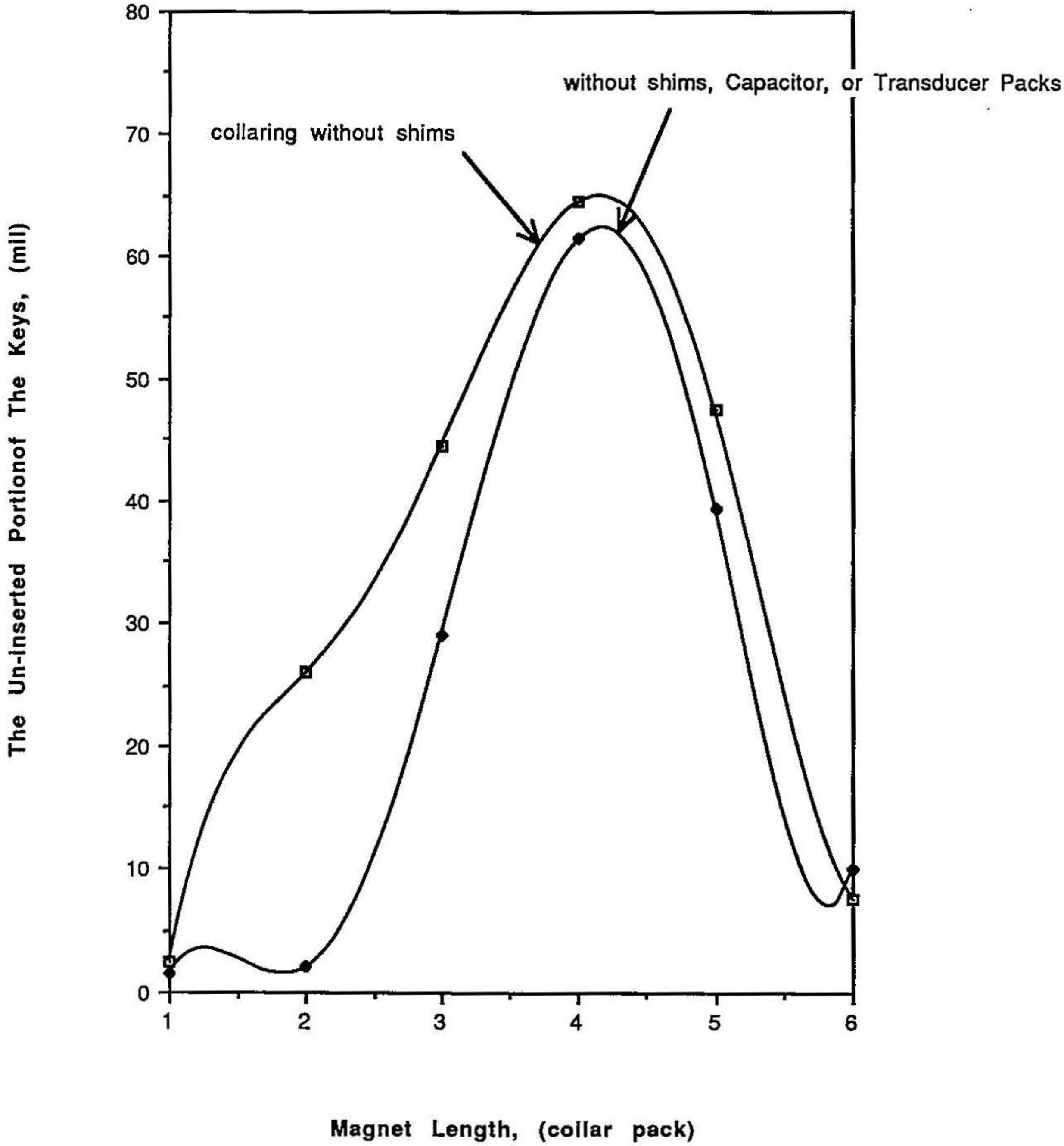

Figure 4 : Collaring without radial shims, at 9400 hydraulic psi, checking for the effects of removing the transducer & capacitor packs.

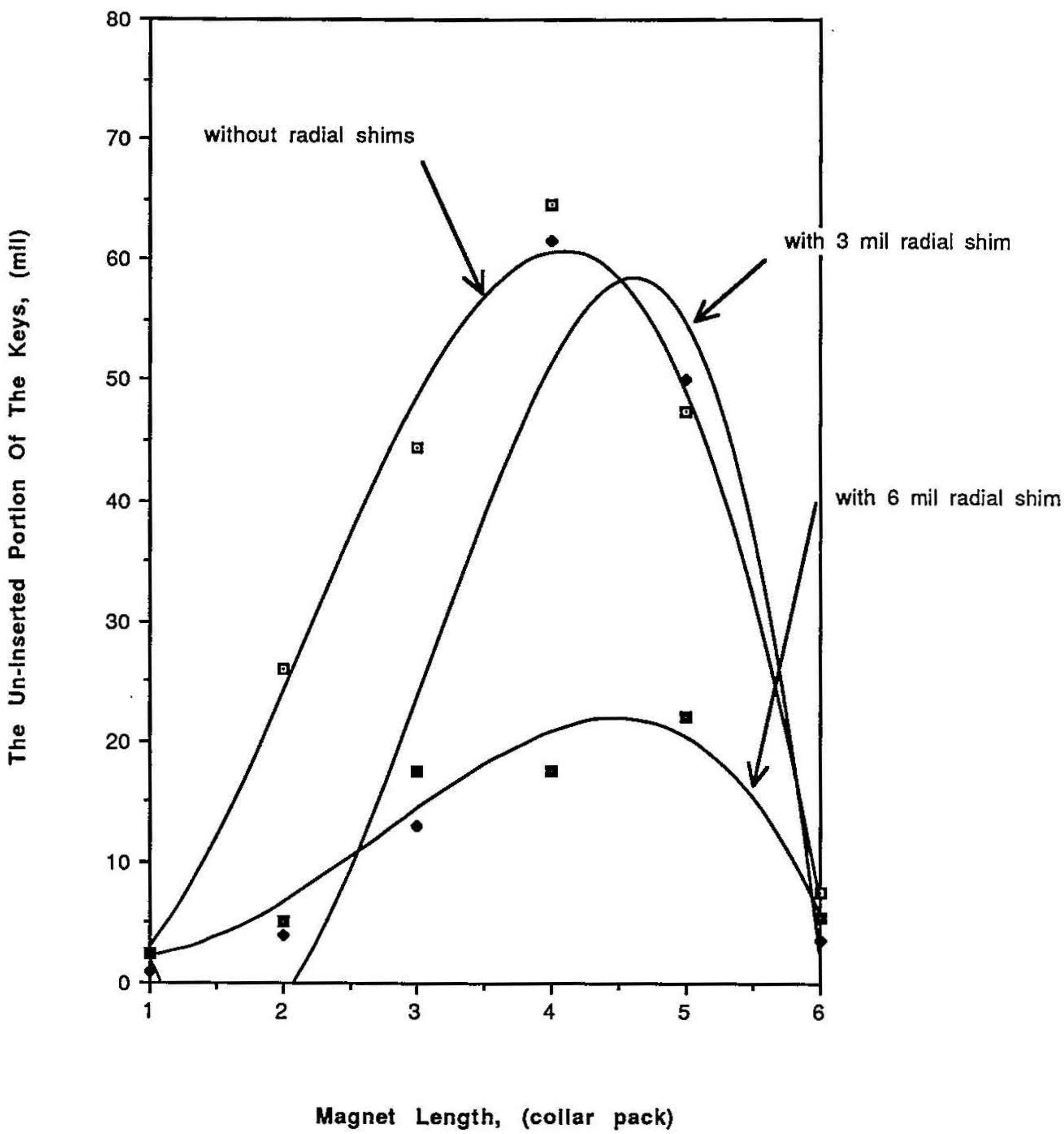

Figure 5 : Comparing the effects of different radial shims

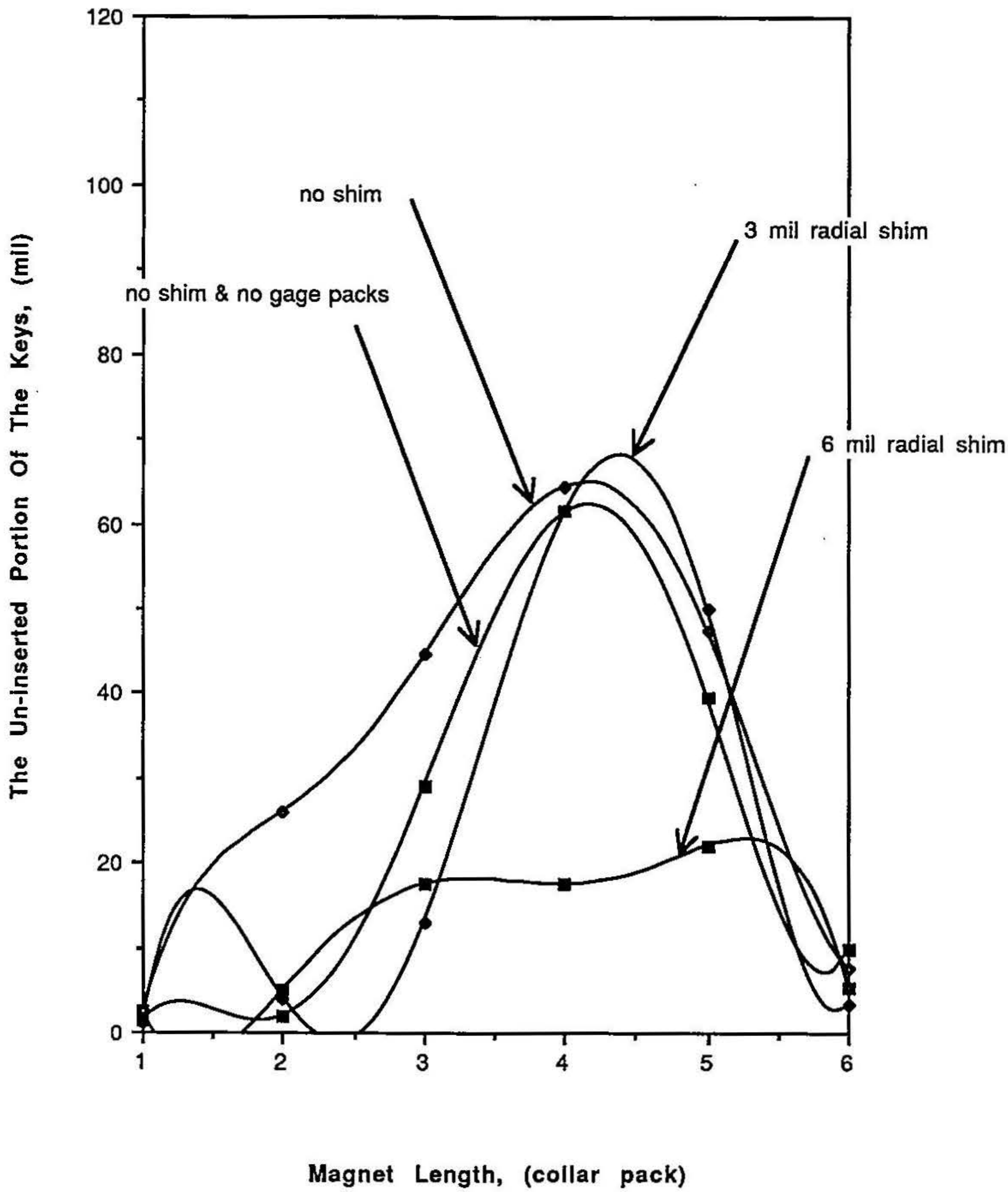

Figure 6 : Comparing effects of radial shims & transducer packs

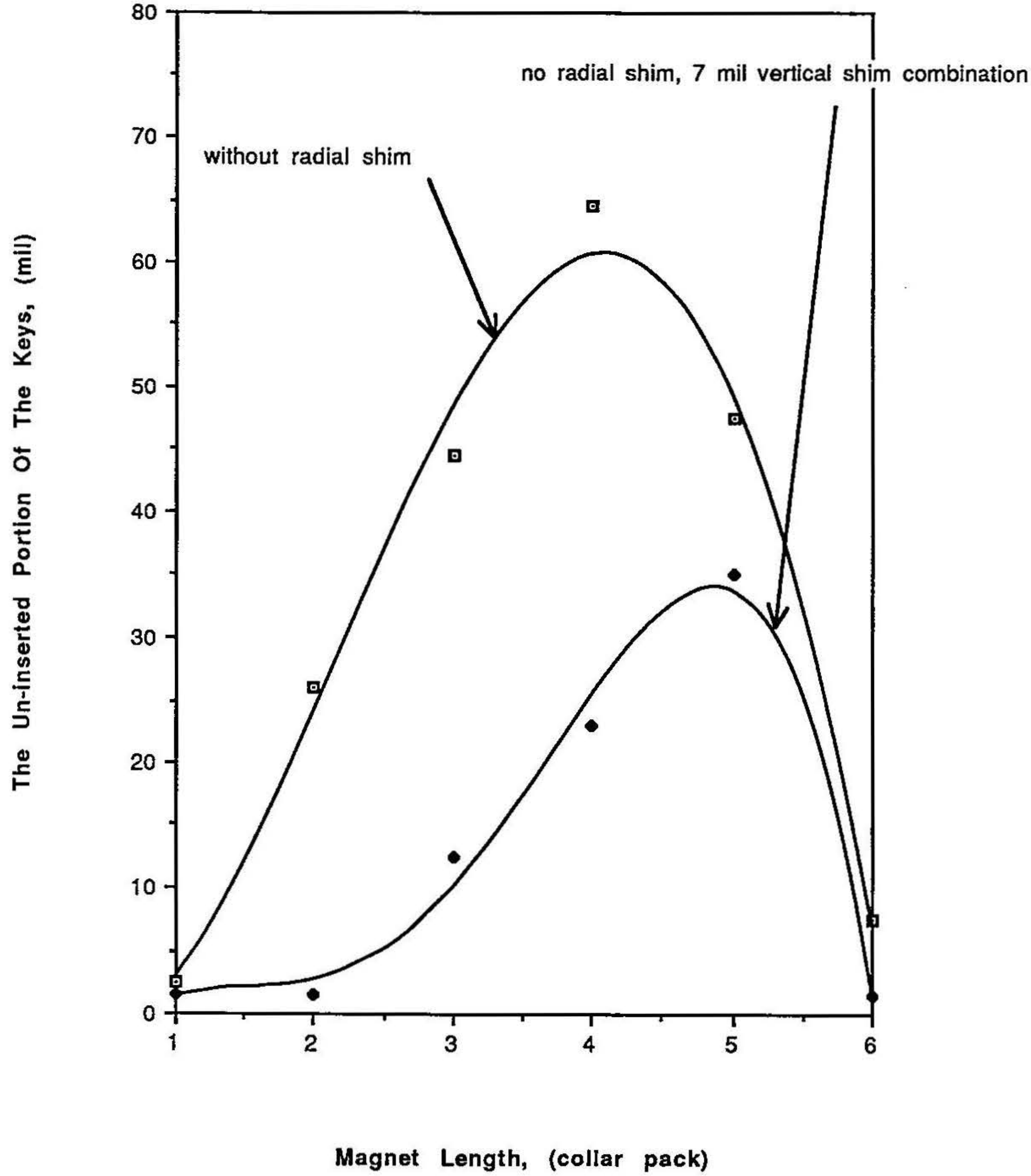

Figure 7 : Collaring without radial shims, checking for the effects of a 7 mil vertical shim

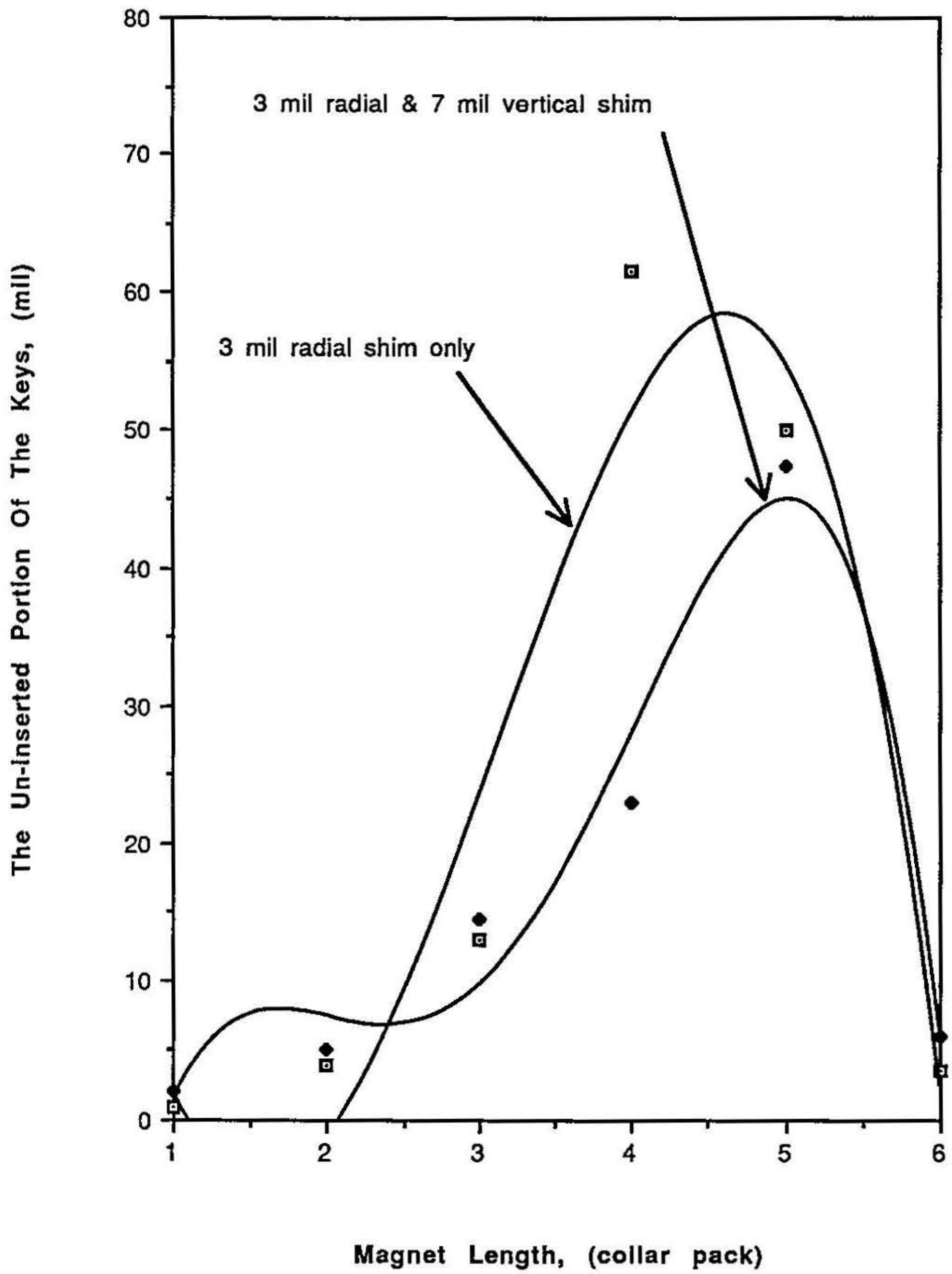

Figure 8 : Collaring with 3 mil radial shims, at 9400 hydraulic psi, also checking for the effects of a 7 mil vertical shim.

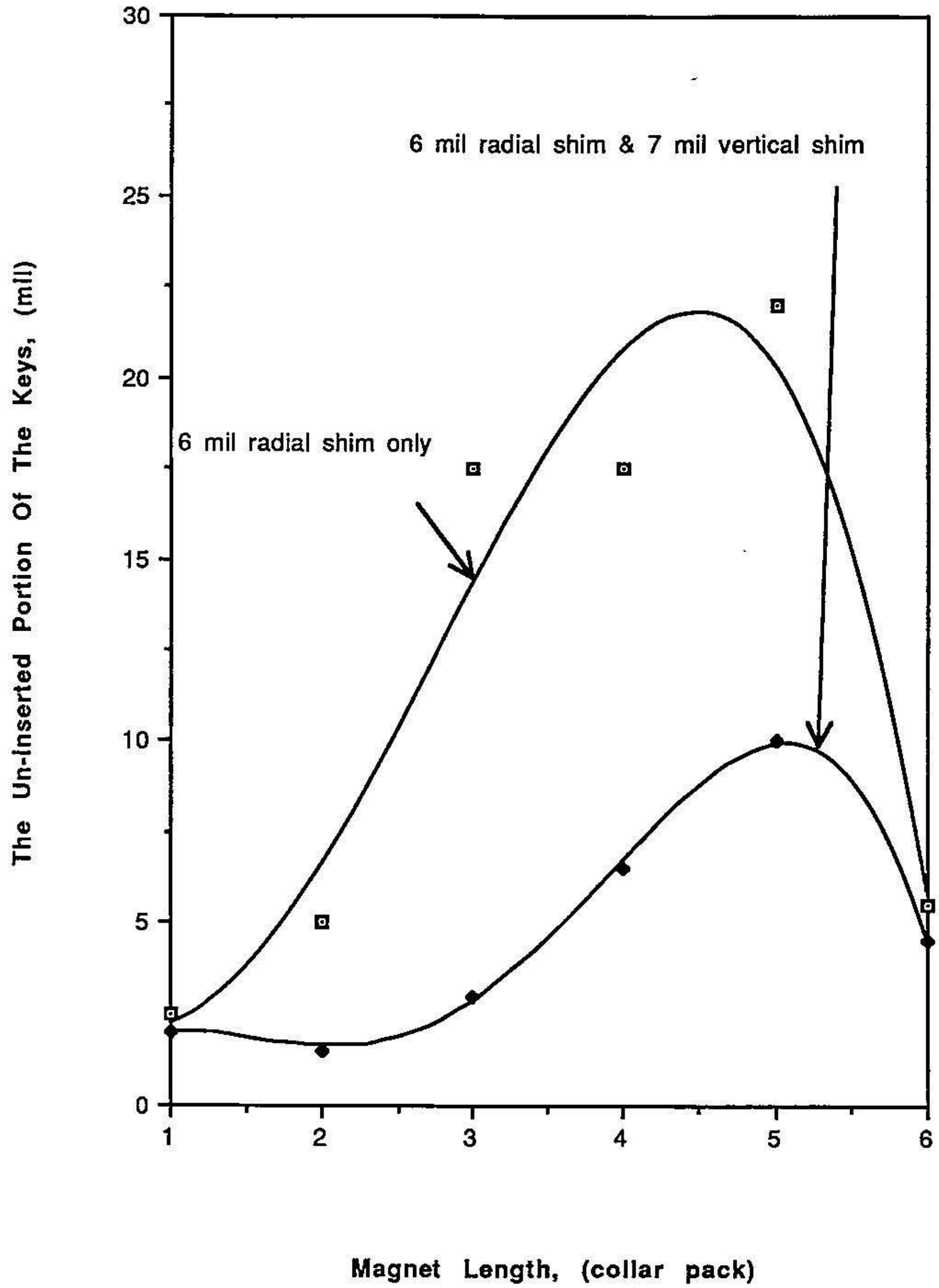

Figure 9 : Collaring with 6 mil radial shims, at 9400 hydraulic psi, also checking for the effects of a 7 mil vertical shim.

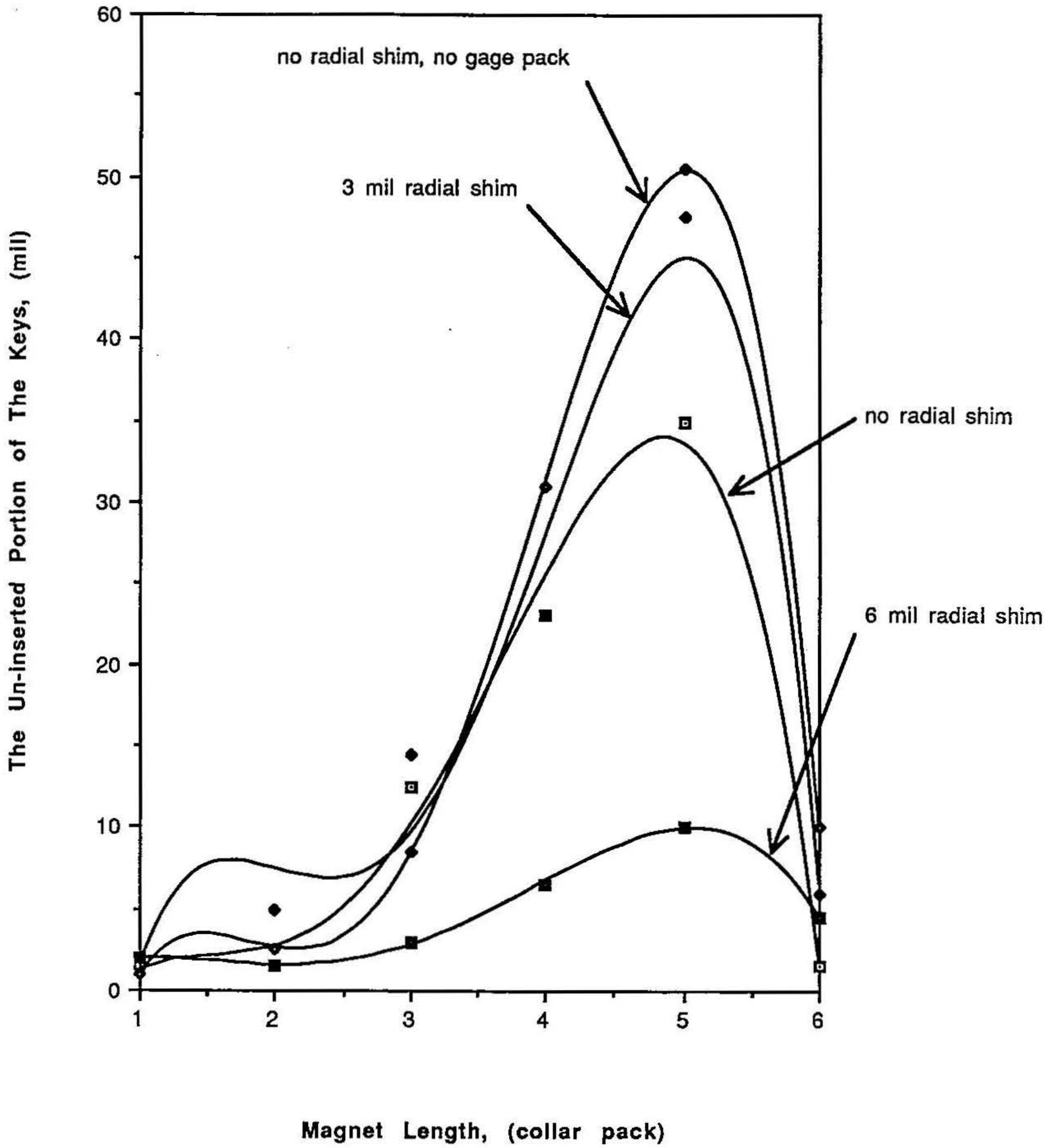

Figure 10 : Collaring with a 7 mil vertical shim, at 9400 hydraulic psi, checking for the effects of different radial shims & transducer packs.

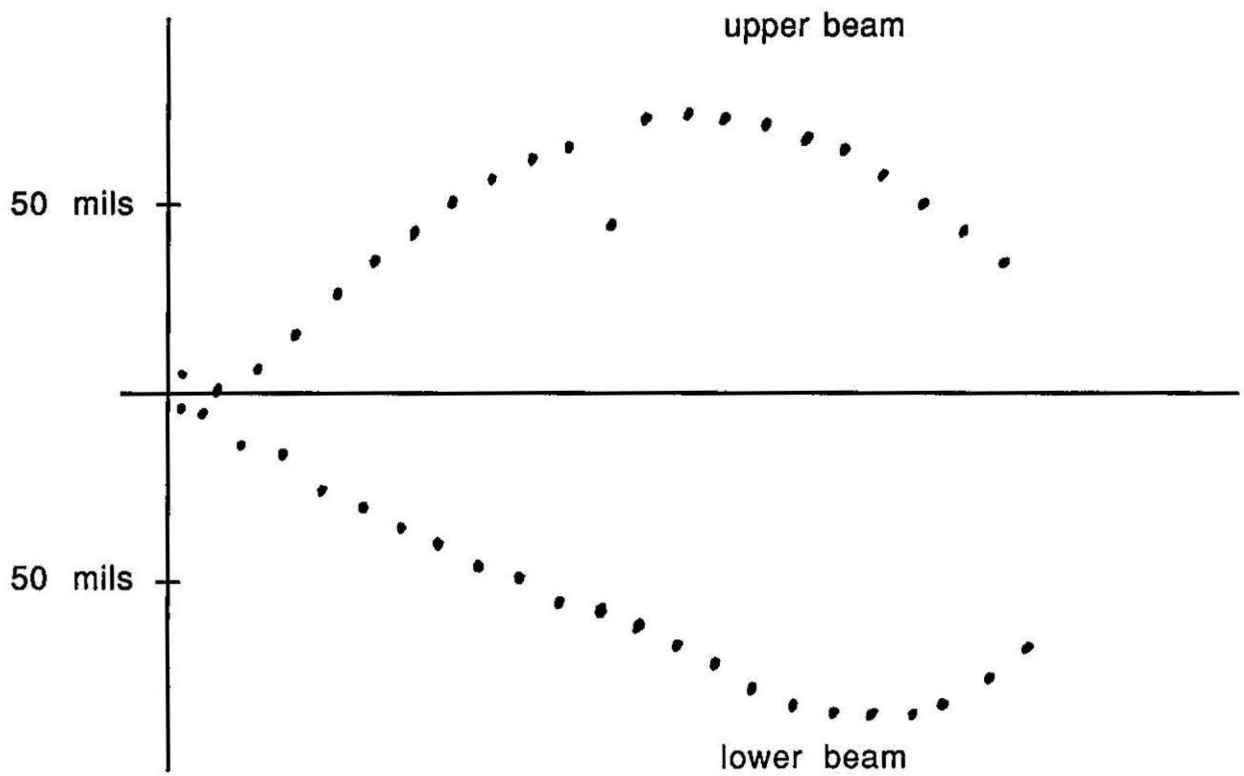

Figure 11 : Upper & lower beam laser survey results

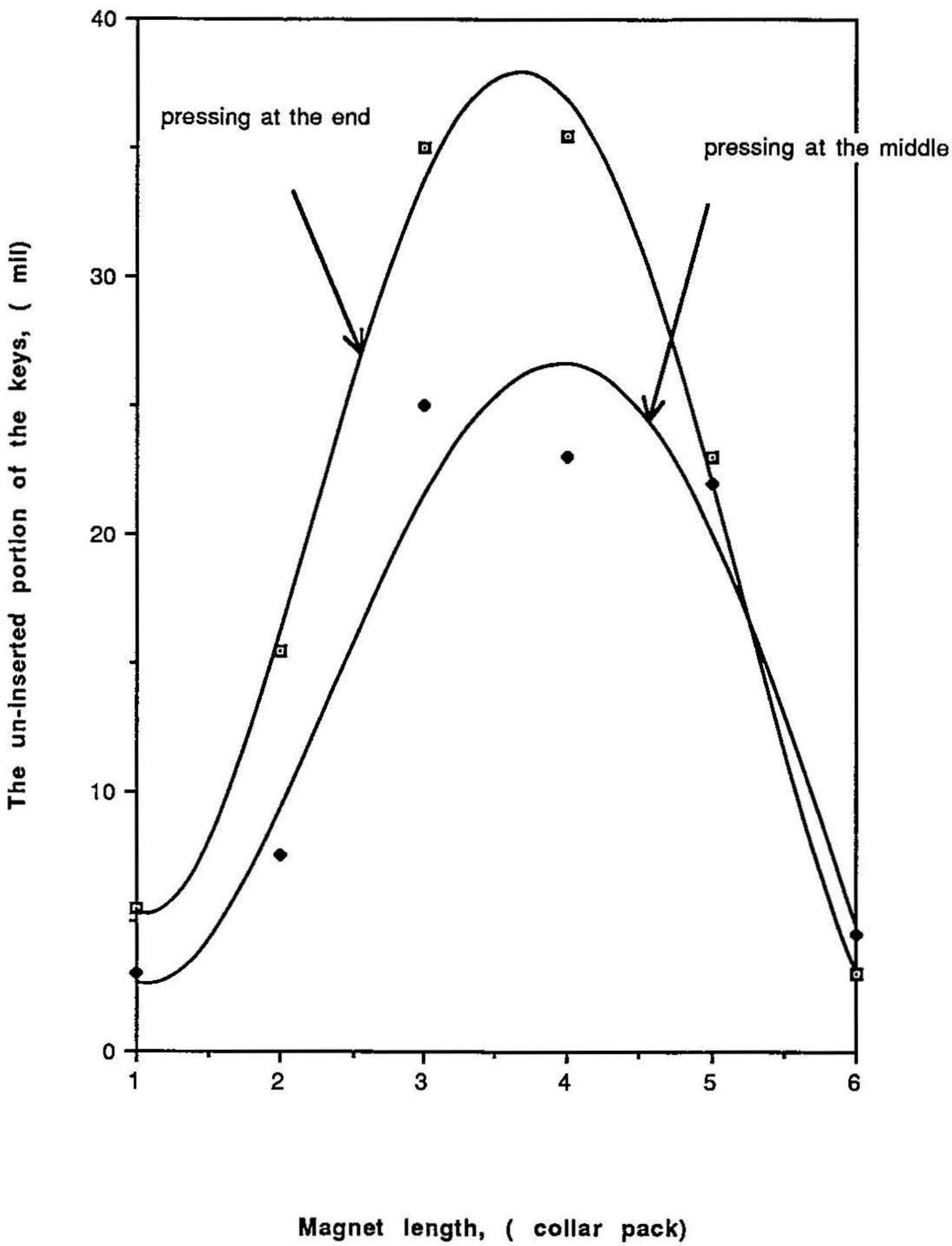

Figure 12 : Collaring at the end & middle of the press without shims

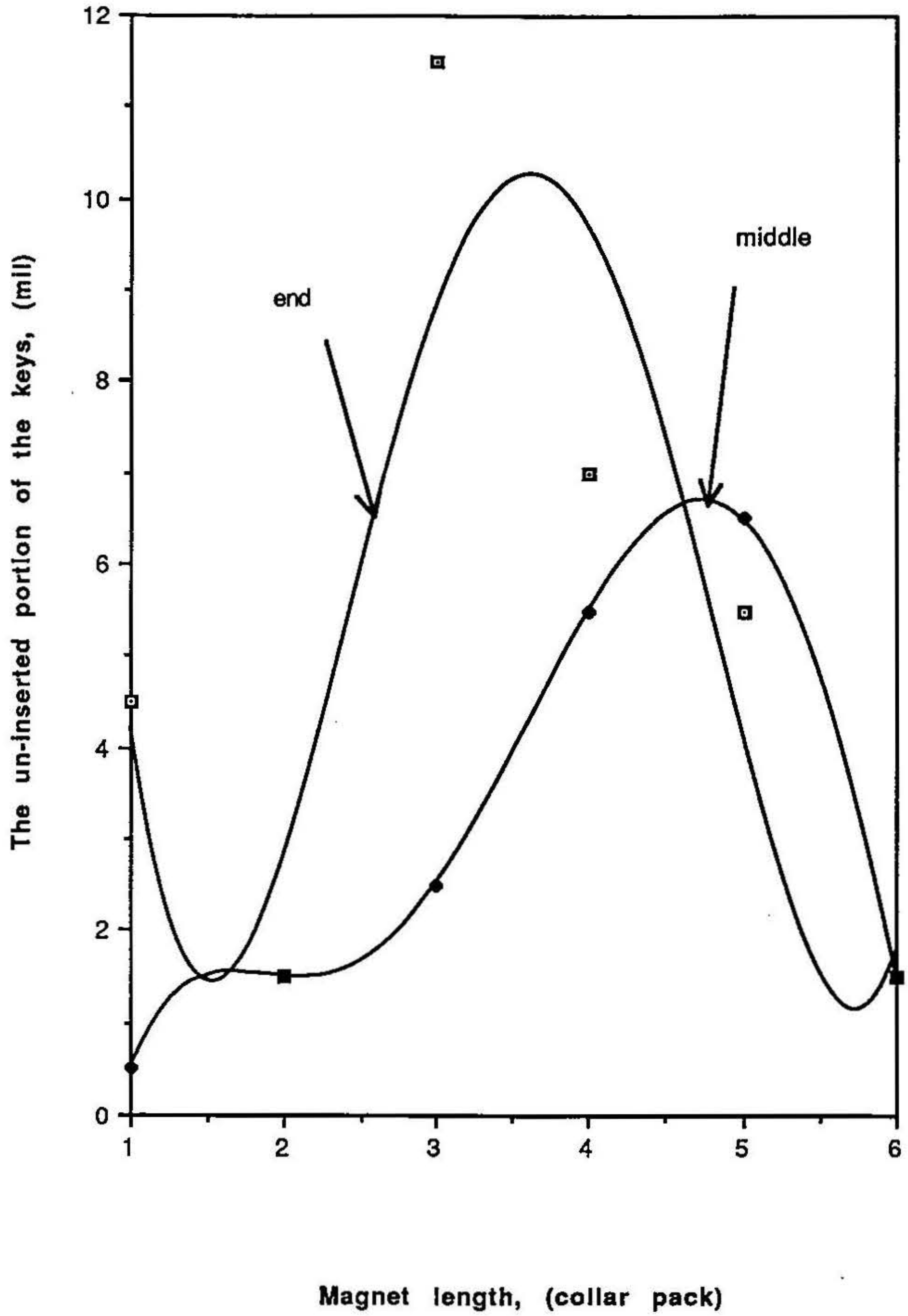

Figure 13 : Collaring at the end & middle of the press with 7 mil vertical shim

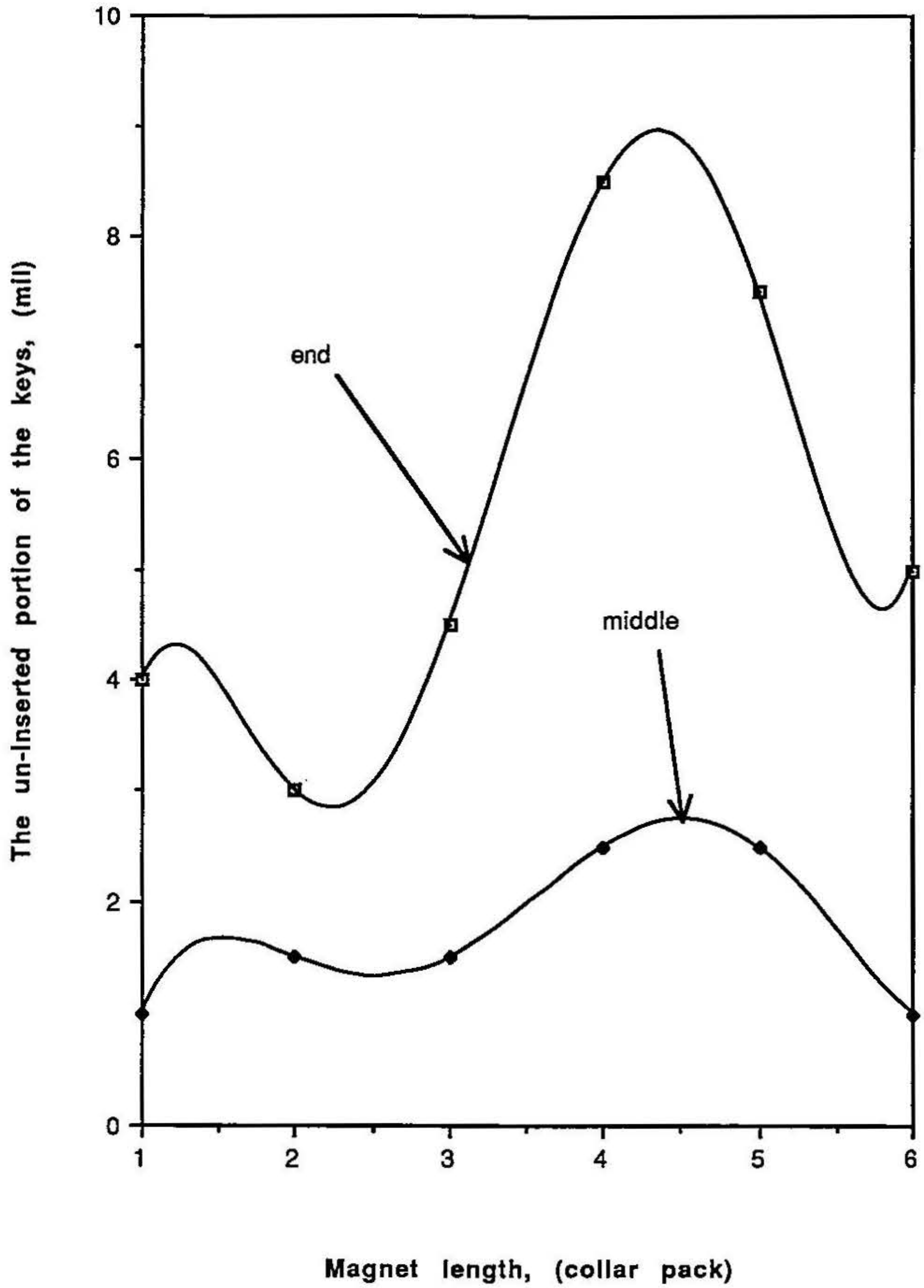

Figure 14 : Collaring at the end & middle of the press with 12 mil vertical shim

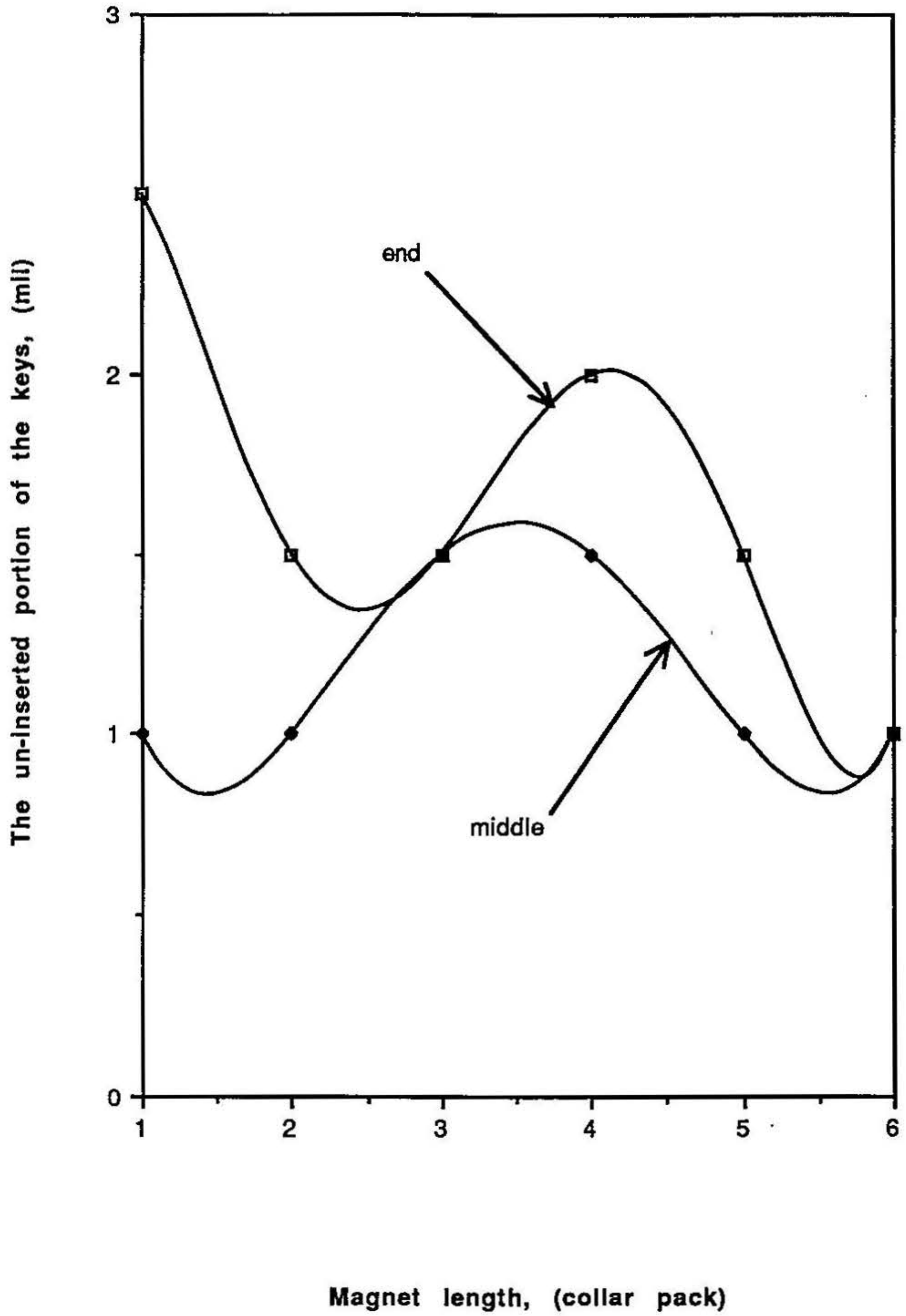

Figure 15 : Collaring at the end & middle of the press with 19 mil vertical shim

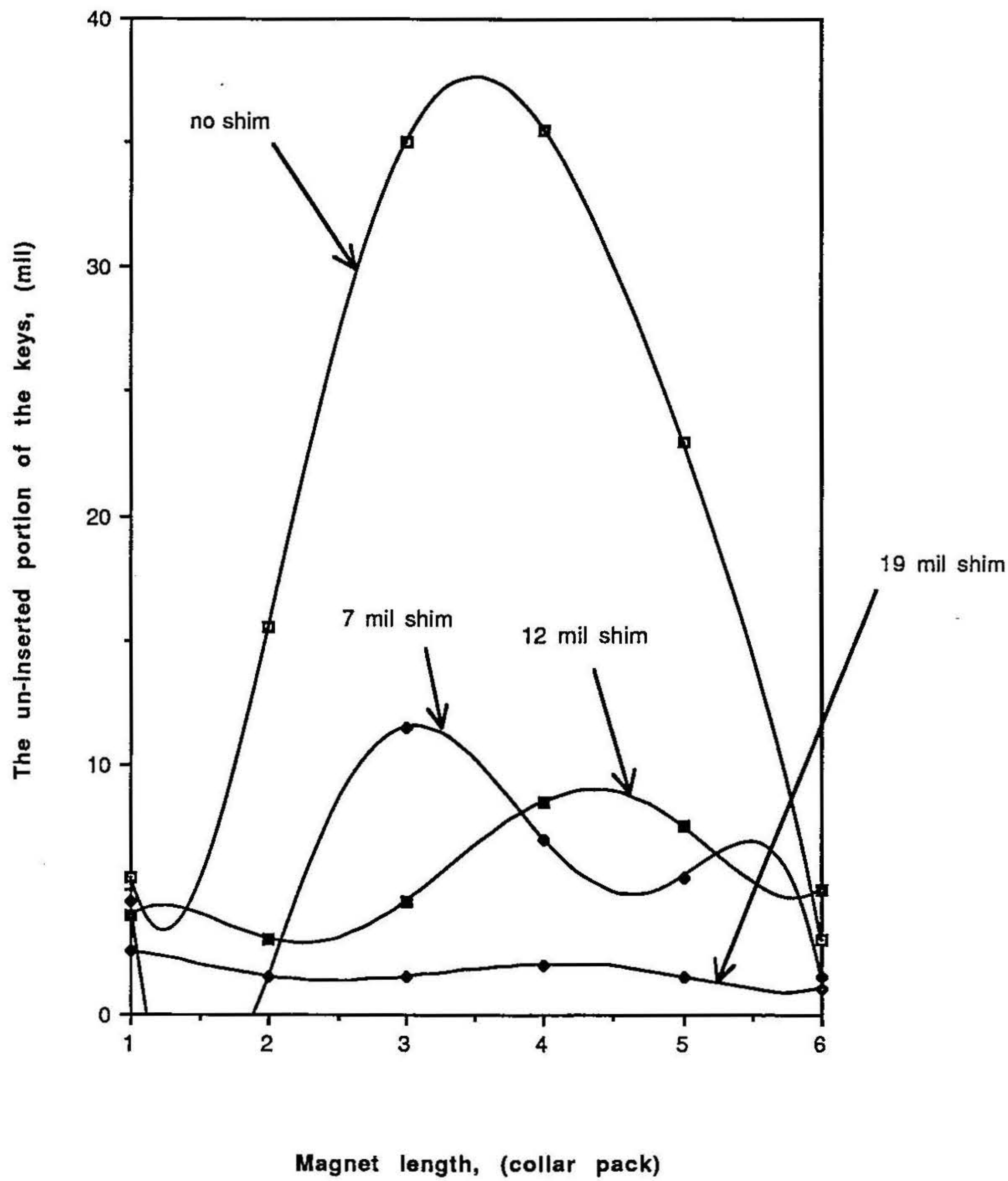

Figure 16 : Collaring at the end of the press, with various vertical shims

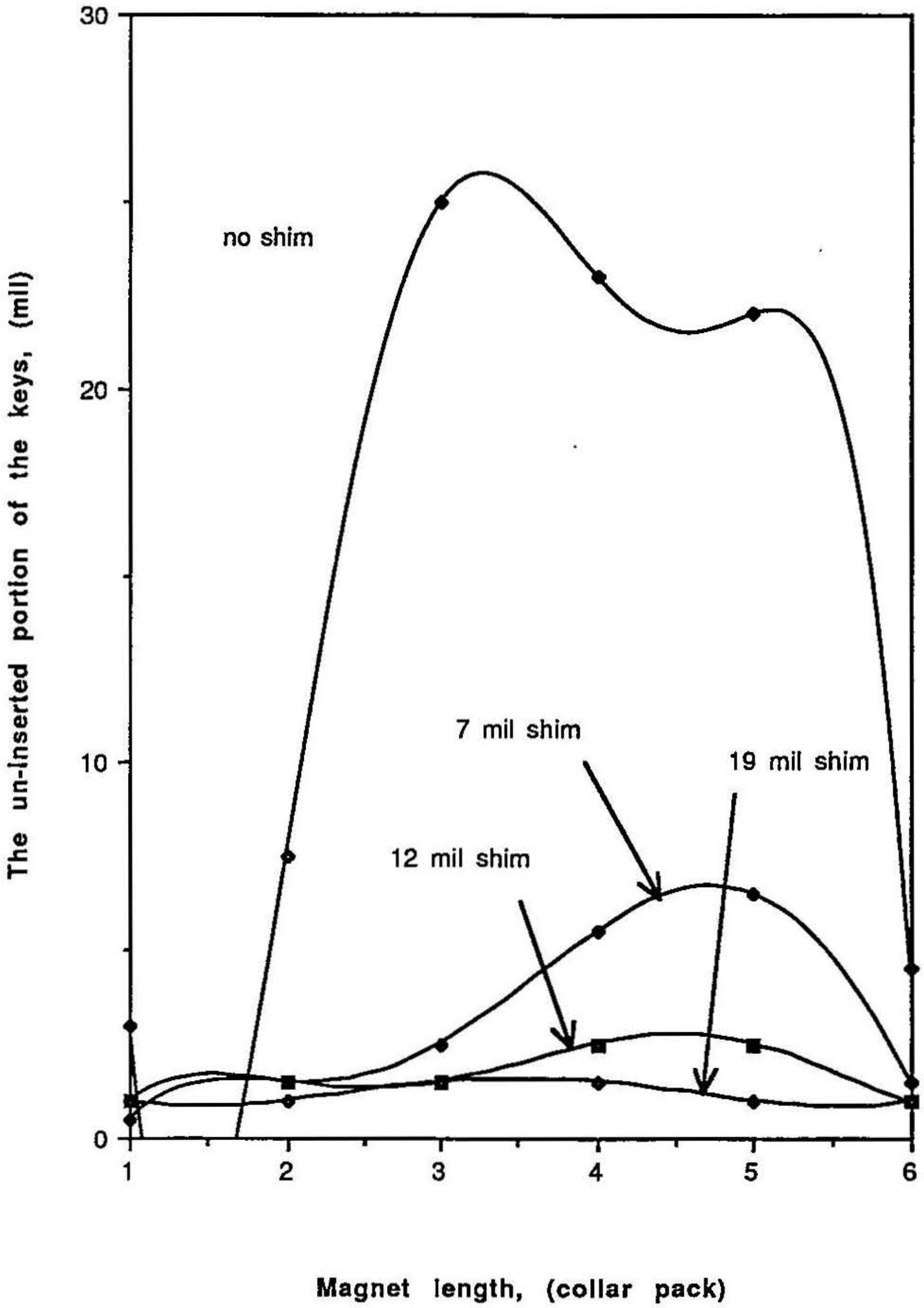

Figure 17 : Collaring at the middle of the press with various vertical shims

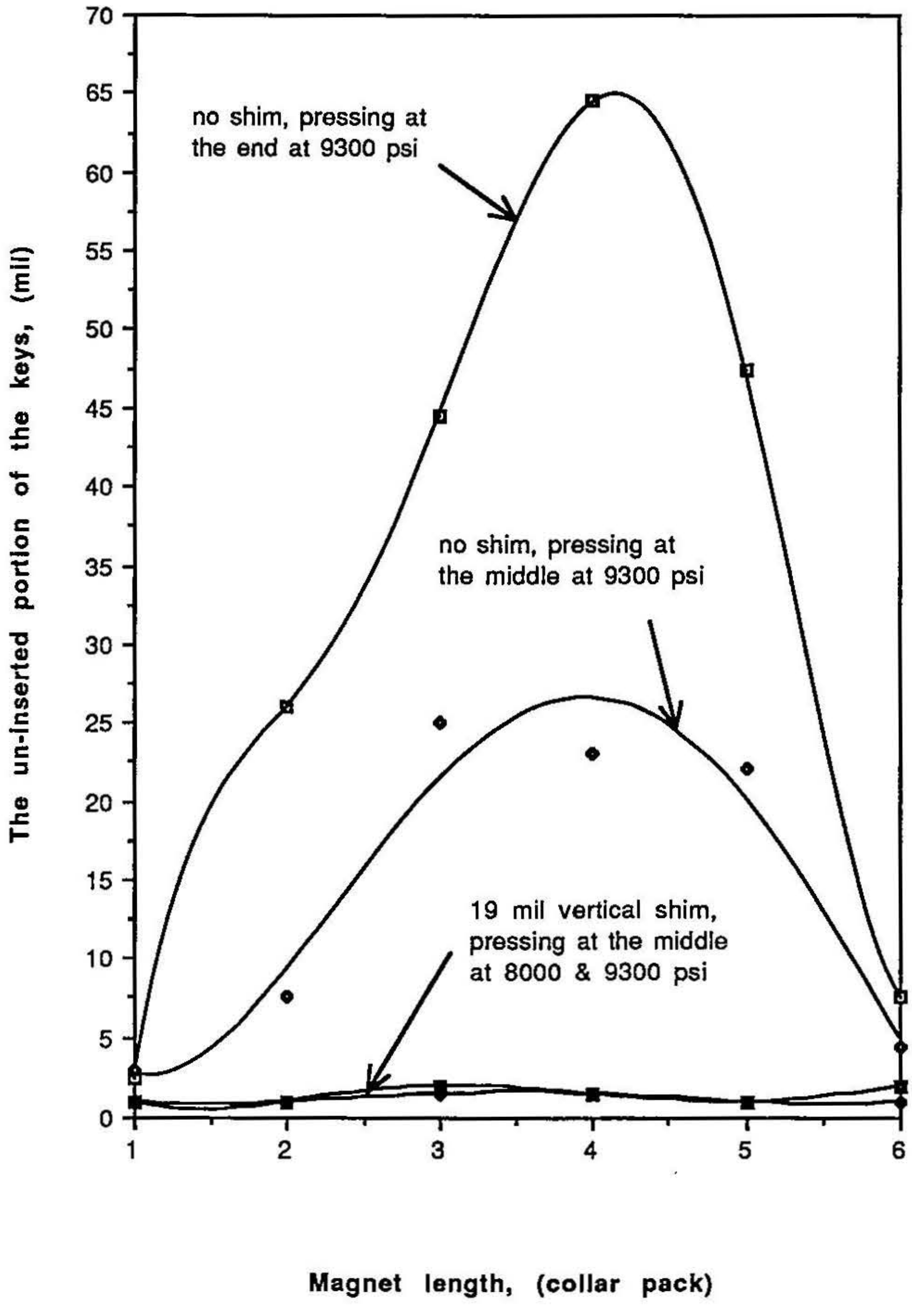

Figure 18 : Collaring at different press positions & pressures

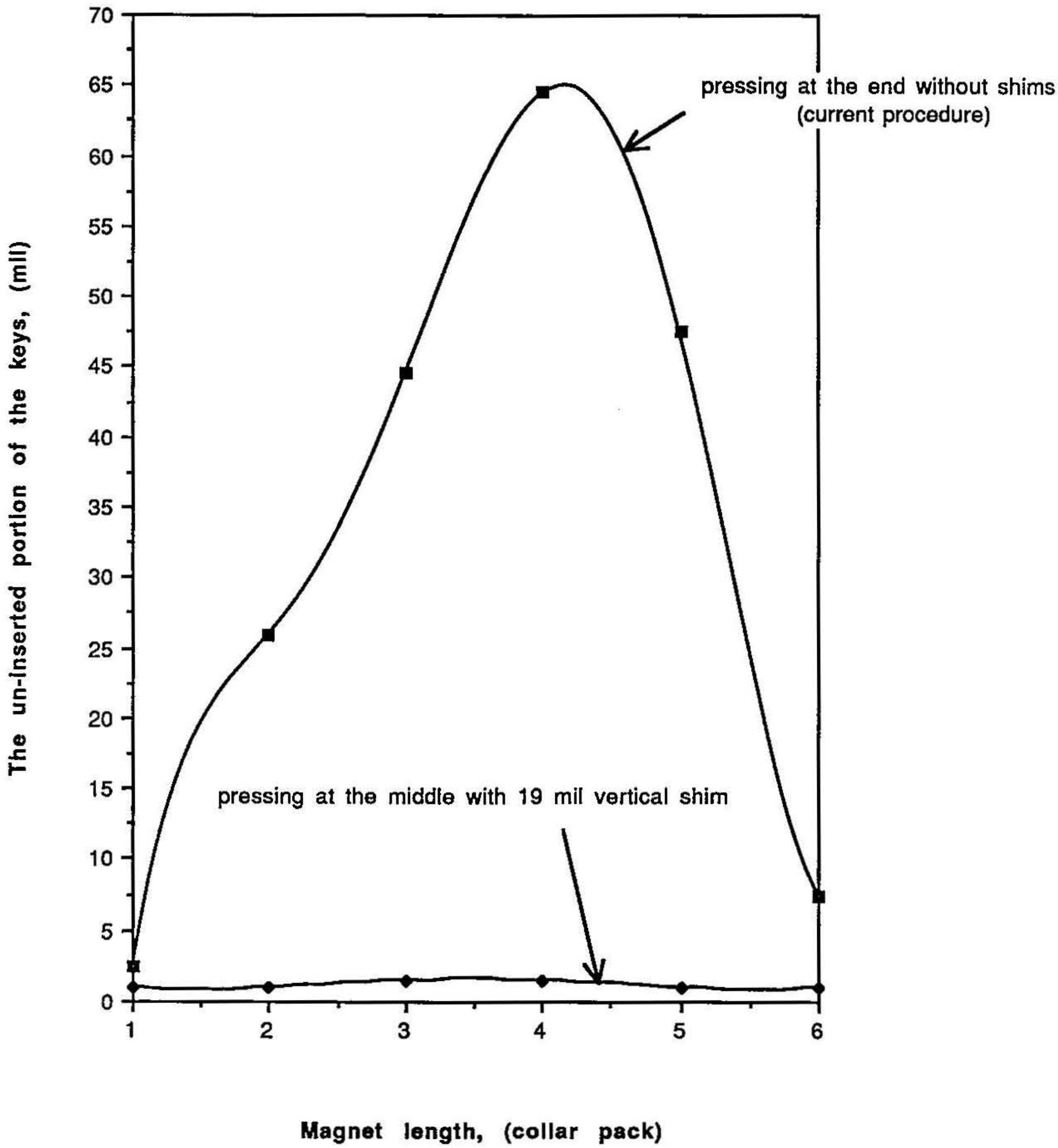

Figure 19 : Comparing the worst & the best results

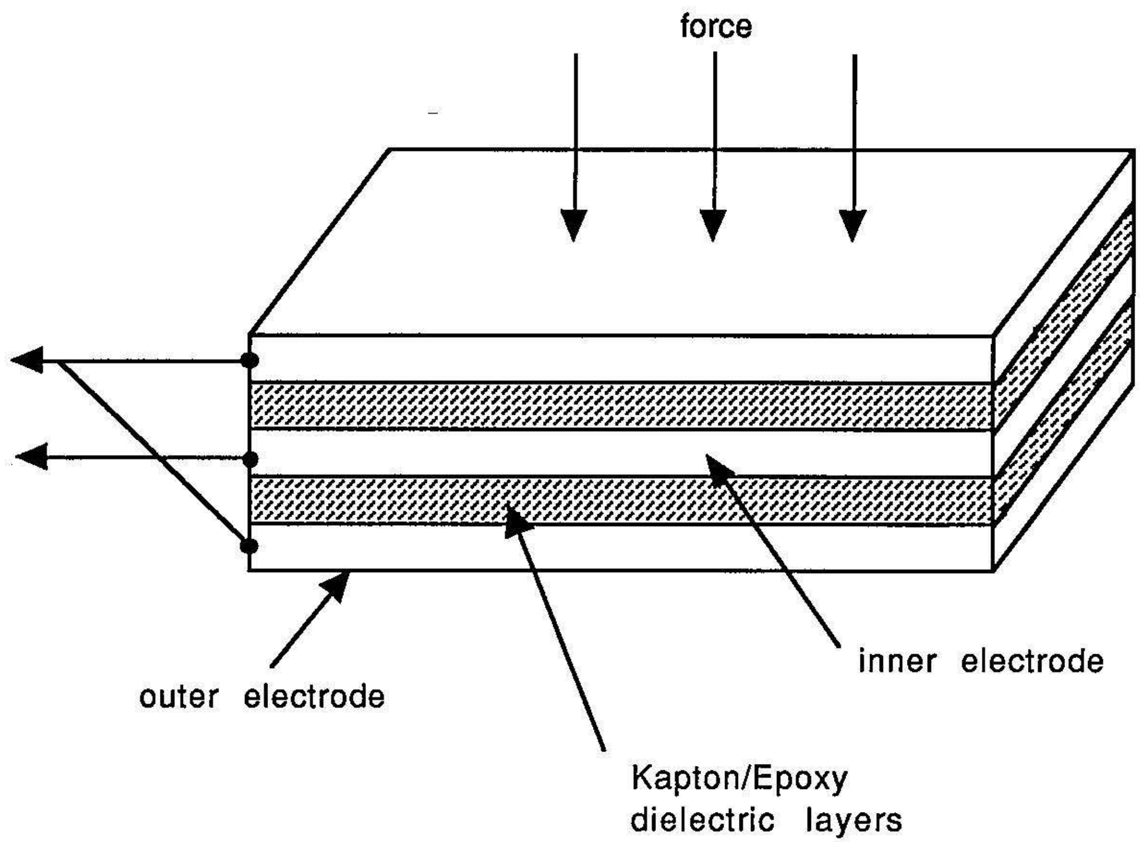

Figure 20 : Kapton-Epoxy gage

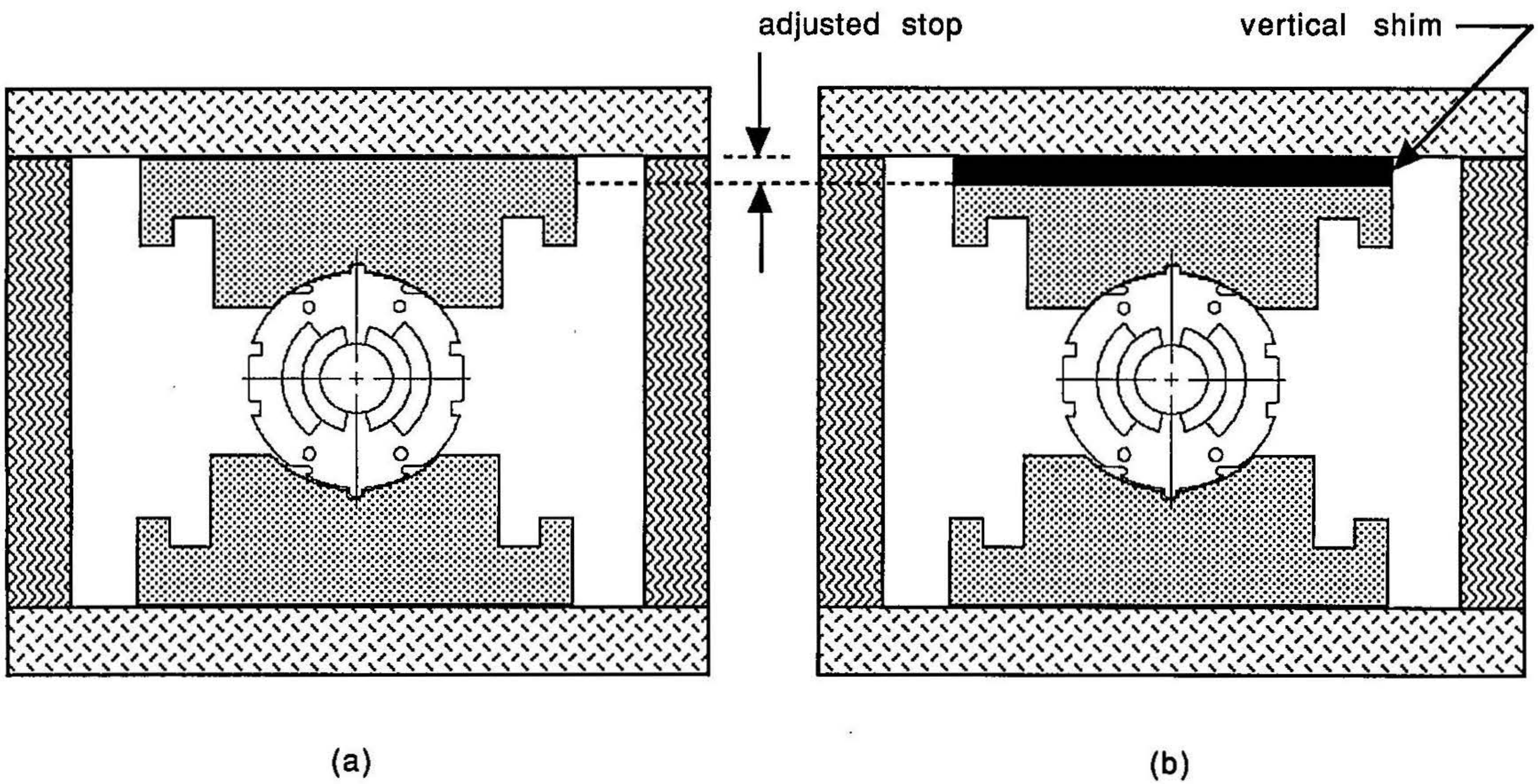

Figure 21 : Vertical shim altering the tooling stop point