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GRAVITY MODIFICATION BY HIGH-TEMPERATURE SUPERCONDUCTORS

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ABSTRACT

Claims that the weight of test masses can be changed in non-relativistic experiments have been investigated. Amongst the most prominent reports has been a paper by Podkletnov & Nieminen (Physica C **203** 441, 1992); more recently, Rounds (Proc. NASA Breakthrough Propulsion Phys. Workshop, Cleveland, 297, 1998) used a simpler experimental arrangement. Both of these experiments measure the gravitational field above $YBa_2Cu_3O_{7-\delta}$ (superconducting below $T_c \approx 93K$). Podkletnov & Nieminen specify that the superconductor must be cooled below 70K, magnetically rotated at ~5000 rpm, and simultaneously levitated magnetically using two separate frequency excitations; weight changes of ~1% were reported. Rounds specifies less stringent conditions, mainly that the YBCO is cooled to 77K whilst stationary. The Rounds experiment has been repeated virtually exactly, and the Podkletnov experiment has been investigated by reproducing some of the conditions specified. No measurable gravity modification (within ±0.03%) was observed using the subset of the Podkletnov conditions, (but this does *not* preclude gravity modification arising from the full specified conditions). The Rounds configuration also has not shown any effects reliably ascribable to gravity modification, although there was unusual thermal behaviour.

1. INTRODUCTION

A number of reports recently claimed that the weight of test masses can be changed as a result of using various materials in various configurations and using various excitations. One of the most prominent of these has been that by Podkletnov and Nieminen[1]; as far as the present authors are aware, not only is this the only such paper that has appeared in a peer-reviewed journal, but it is also one of the few that cannot immediately be dismissed as spurious.

The experimental results reported by these authors appear to contradict conventional gravitational theory, because their claims amount to apparent modifications to the gravitational field in a laboratory-based system that – at face value – does not require analysis by General Relativity. This experiment is therefore potentially highly important scientifically because of the enormous technological implications for the design of current transportation vehicles and handling methods for bulk materials if gravity modification (and, in particular, gravitation reduction) were demonstrated to be feasible.

Objections to the Podkletnov and Nieminen experiment have been raised. Podesta and Bull[2] discuss the measurements[1] in terms of buoyancy effects that could be present because of the helium cooling the air surrounding the test weight. Although interesting, the air temperature required to achieve a buoyancy effect of the same magnitude as seen by Podkletnov is 150K which seems to be too low to make this a likely explanation. Unnikrishnan[3] includes a description of static levitation of a large superconducting disk that finds no gravity effect, but is more interesting for its discussion of Podkletnov's claim that the gravitational effects have no dependence on the height above the spinning disk, which appears extremely strange at first sight. This, along with Podkletnov's claims to have seen increases as well as reductions in test mass weight, confirms that the effect claimed must be "Gravity modification" rather than passive "Gravitational shielding".

Pokeltnov's report[1] was therefore selected for particular attention and experimental testing in the present work, along with a subsequent and broadly similar (though smaller) effect reported by Rounds[4]

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using a much simplified experimental arrangement. The experiment due to Rounds[4] has been repeated virtually exactly, and that due to Podkletnov[1] (experimentally much more challenging) has been investigated by examining some (although not yet all) of the conditions reported as necessary for demonstrating gravity modification.

Both of these experiments have in common that they require the gravitational field to be measured above the high-temperature superconductor $YBa_2Cu_3O_{7-\delta}$ (which is superconducting below the critical temperature $T_c \approx 93K$). In the Podkletnov arrangement, the superconductor (in the form of a multiphase circular disk having a minimum diameter 10cm) must be cooled below 70K, and magnetically rotated at high speed (e.g., 5000 rpm) and simultaneously levitated magnetically using two separate frequency excitations; weight changes (in a test mass) of the order of 1% were reported. In the Rounds arrangement, the conditions are much less stringent and mainly require the YBCO to be cooled to 77K in a stationary magnetic field.

1.1 Other claims of gravity modification

Reiss[5] has reported work on the weight of a PTFE capsule containing pellets of various materials including 2212 BSCCO high-T_c superconductor when the capsule is immersed in liquid nitrogen. All of Reiss's measurements showed the apparent weight rising with immersion time to some final figure after about 5 minutes. This rise is a result of the thermal contraction of the holder (giving a steadily reducing buoyancy in the liquid nitrogen) and shows some scatter as well as differences for different materials contained within the holder. However, Reiss's figures indicate that the capsules containing the superconductor have the biggest apparent weight increase (although not markedly bigger). Reiss interprets this in terms of the superconductor gaining weight as the inside of the sample holder cools below his superconductor's critical temperature (~95K). Reiss points out that the variation in the buoyancy drop found for his three non-superconducting materials (alumina, copper and PVC, in order of the lowest to highest drop) does not match variations in their specific heat. However, the variation in buoyancy drop *does* occur in the same order as the thermal expansion of these materials (i.e. alumina has a thermal expansion coefficient smaller than that of copper, which in turn is smaller than that of PVC). The room-temperature expansion coefficient of BSCCO (which shows the largest buoyancy drop) is roughly the same size as that of copper. Reiss's calculations show that the shrinkage of the PTFE capsule should lead to a buoyancy drop three times larger than that seen in any of his experiments; this inconsistency alone throws doubt upon gravity modification having been demonstrated conclusively.

Gravity experiments by Schnurer[6] use a 1" diameter superconducting disk attached to the top of three coils in a triangular arrangement and a metallic test mass is attached to the top of the superconductor. This assembly forms the weight on one end of a balance; the counter weight then sits on digital laboratory scales so that a weight decrease in the superconductor assembly produces an increase in the scales reading. The superconductor assembly is immersed in liquid nitrogen; once it has cooled the scales reading is noted, and power applied to the coils. The scales show an increase proportional to the sample mass. Nitrogen boiling due to the resistive heating by the coils, and possible flexing of the wires supplying the coils, may be possible explanations for these observations.

2. TESTS OF WEIGHT REDUCTION USING ROTATING SUPERCONDUCTORS

2.1 Background

Fully reproducing the Podkletnov conditions[1] is not straightforward. As far as the present authors are aware, no others have demonstrated gravity modification using similar experimental arrangements, though other partial tests[7] have been reported.

The present approach to this experiment was to start by spinning a superconductor at high speed. The basic equipment used in initial tests is illustrated in Fig. 1. A nominal 2" diameter (the die size, not the precise final disk size; where appropriate this is given in mm) granular disk fabricated ten years previously was employed. Although this disk was able to produce significant levitation (~5mm) of a 10g FeCo magnet, it could not levitate a 40g, 1" 0.45T NdFe magnet, nor could it sustainably levitate itself above an array of these magnets. A number of tests where the superconductor was cooled to 77K, spun at up to 5000 rpm, then slowed, and finally tested with a small magnet to ensure that the Meissner effect was still present, never produced any change in the test weight.

2.2 Present Project

In developing this investigation further, it was clear that reproducing the full Podkletnov conditions would take considerable time. Dr. Podkletnov has visited our laboratory to observe our experiments, and has made some helpful comments based upon his own experience[8]. The strategy adopted was as follows:

- to be limited initially to 3" diameter disks,
- to develop a melt texturing process for disk fabrication (Podkletnov partially melt textured his disks to achieve much greater levitation for the same magnetic flux density),
- to develop a new weight measurement system,
- to use permanent magnets to provide levitation and/or rotating fields, and
- to produce low field, high frequency excitation using a 13.56MHz generator.

These points will be discussed in turn below.

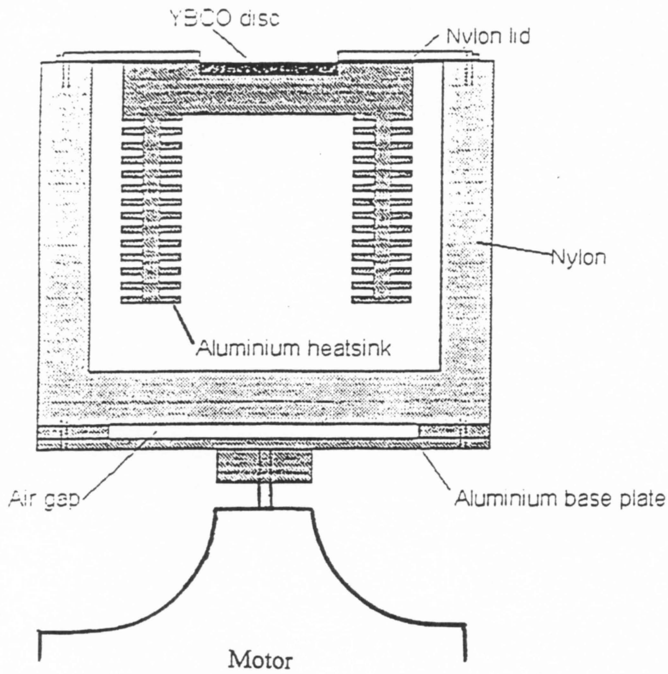


Fig. 1: *The basic gravity test equipment. The aim was to spin the nitrogen container at high speed, while keeping the superconductor below T_c*

2.2.1 Melt Texturing and Disk Fabrication

Melt texturing has been found to improve YBCO's levitation force significantly for a given field and so was developed to produce disks that could self-levitate above NdFe magnets.

When YBCO is raised above 1008°C it begins to decompose according to the reaction:

$$2YBa_2Cu_3O_6(s) \rightarrow Y_2BaCuO_5(s) + \text{copper/barium rich liquid},$$

i.e., the high temperature form of the superconducting YBCO phase decomposes to a liquid that is mostly $BaCuO_2$ and solid green phase YBCO. This reaction is partially reversible, i.e. slow cooling back through 1008°C re-forms the 123 (superconducting) phase with inclusions of the 211 (green) phase and solidified copper/barium material. The resulting YBCO is referred to as "melt textured"; essentially the grain boundaries which limit the bulk superconductivity of a granular sample have been reduced as the grains have melted into each other. Most importantly the crystal axes in a melt textured sample tend to be aligned (usually so that the larger *c*-axis is vertical) so that the sample properties are no longer an average of the good in-plane and poor out-of-plane superconductivity exhibited by YBCO.

One step further than melt texturing is top seeded melt texturing. Seeding is carried out using small 123 phase crystals with the yttrium replaced with neodymium or samarium. This substitution produces a material with the same crystal structure (except that the larger rare earths have a tendency to be disordered because their size means that they can partially substitute for barium) but having a higher decomposition temperature. These crystals when placed on the surface of an YBCO pellet above the decomposition temperature can, on cooling, seed the growth of large single domain pseudo-crystals of 123 YBCO (they are not true single crystals because of the 211 and Cu/Ba inclusions).

Practical problems such as liquid flowing out from the pellet above 1008°C can be controlled by adding extra 211 phase to increase the solid content at high temperatures, but precise temperature control, without significant temperature gradients, is necessary. (Temperature gradients lead to different crystallisation rates across the disks, causing disk cracking.)

The aim of this work was to produce 3" disks with an even distribution of reasonably sized, randomly oriented domains across their surface. Although single YBCO domains up to 70mm across have been demonstrated[9], owing to the level of furnace temperature control currently available to the present work the largest single domain produced was approximately 12mm × 12mm. In addition Podkletnov considered inter-grain junctions to be crucial to the gravity effect and we did not want to eliminate grain or domain junctions entirely.

It was found that attempting to distribute Nd123 crystals across the disk surface did not produce the even domain distribution necessary. Not all of the Nd seeds produced large domains and in any case distributing small seed crystals in a furnace at 1020°C is not an easy process. A disk resulting from multiple top seeding is shown in Fig. 2; it clearly showed visibly uneven crystal distribution, giving a levitation force varying from place to place across the disk.

Fig. 2: Top seeded 3" disk

A better disk was produced not by seeding, but by dropping the post-decomposition temperature from the 982°C used for seeded growth to 975°C. This lower temperature produces self-seeding and smaller randomly shaped but evenly distributed domains resulted (Fig. 3). This 110g disk, following oxygenation between 500 and 200°C for a week, could self-levitate above an array of seven NdFe magnets at a height of approximately 15mm, and could levitate a single NdFe magnet plus a further 80g at 2mm above its surface.

As an alternative to homogeneous self-seeding a new process, heterogeneous self-seeding, was tried. This involves including some Nd211 phase in the Y123/211 mix so that the Nd/Y ratio was 2/98. When the disk was raised to 1100°C (above the decomposition temperature of Nd123) and then cooled to 982°C, Nd123 is able to solidify from the 211/liquid mix first. This is because of its higher decomposition temperature and because the neodymium's similar size to barium makes Nd much more soluble than Y in the melt – enhancing diffusion to a growing crystal surface. The Nd123 crystals formed in this way then act as seeds distributed evenly throughout the disk for the Y123 growth. A disk grown by this method (Fig. 4) had levitation characteristics similar to the homogeneously seeded disk; it is expected that further development of this process would lead to still higher levitation forces.

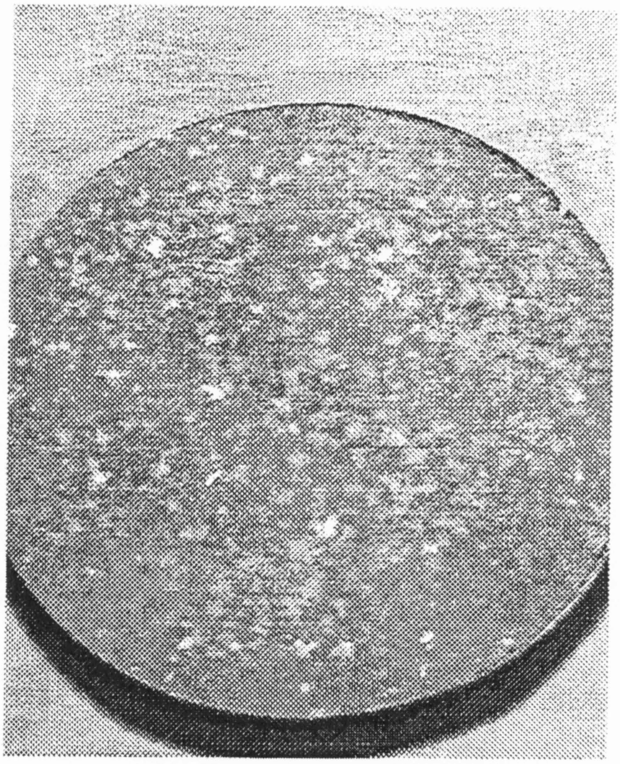


Fig. 3: Homogeneously seeded 3" disk

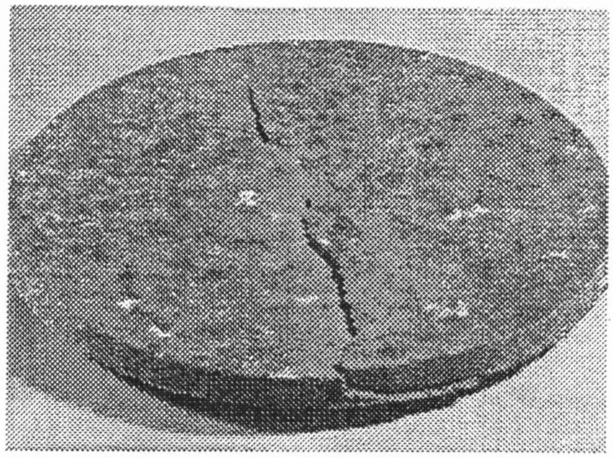


Fig. 4: Heterogeneously self-seeded 3" disk. The crystallisation is more evenly distributed with a more random orientation than the top seeded disk

The chief problem found in this work is that of disk cracking. It was found that any indication of a crack in the unfired disk that had been compacted in a die from the precursor powders using a fifty tonne hydraulic press would lead to catastrophic cracking during firing. Only one in four disks as-pressed was good enough to be fired (although unfired disks could usually be reground and pressed again). One in two that were fired held together, with or without some evidence of cracking, after melt texturing. The extra shrinkage due to the densification that occurs during melt texturing, plus the uneven crystallisation resulting from temperature gradients, puts a big strain on the mechanical stability of the disk.

One final innovation used during disk manufacture was the use of Saffil fabric (Alumina/Silica fibres pressed into a loose fabric/board) between disk and substrate on firing. This served two purposes; the main one was to ensure that disk could be separated from the substrate post partial melting. Secondly, since both aluminium and silicon chemically poison YBCO, incorporation of the fabric into the lower layer of the disk during melt texturing meant that there was a graduated poisoning of the superconductivity from top to bottom. In effect, the disks were bi-layered as specified by Podkletnov[1].

2.2.2 Experimental Apparatus

A beam balance was designed having the necessary resolution (0.004g or better for a 100g test mass, i.e. 0.004%) using a knife-edge pivot. Damping was essential, and was incorporated using a magnet that induced a Lorentz current in an aluminium plate opposing motion in proportion to velocity. The final design is shown in Fig. 5. The balance counter-mass was adjustable to give sensitivities that ranged from 1mm deflection for 0.02g difference, to 5mm deflection for 0.02g difference. The test mass used was 100g in all the tests undertaken as part of the present work, so that the best resolution obtainable was of the order of 0.004%, certainly sufficient for this application.

The cryostat body was made of aluminium and uses chemically-expanding foam as a thermal insulator. An aluminium heat-exchanger, for thermal coupling of the superconductor to the liquid nitrogen refrigerant, was also used.

Tests on this cryostat assembly showed that although it performed better than previous cryostats (fabricated from nylon) in maintaining superconductivity during static tests, after spinning at 5000 rpm and slowing to rest the superconductor had warmed above T_c (determined using the Meissner effect). Over 20 tests were performed using this cryostat (on the basis that the disk would be superconducting for at least some of the time that it was being spun) with the old 2" YBCO disk and various magnet configurations. No balance deflections were seen that could be definitely ascribed to anything except vibration and so using this configuration a gravity effect larger than 0.02% can be formally ruled out.

Following this work a foil liner was added to the cryostat between the liquid nitrogen refrigerant and the foam insulator to reduce the friction on the nitrogen during acceleration. With this liner in place and using a new partially crystallised 2" disk (an early melt-textured sample that could only levitate the NdFe magnets a few millimetres) the superconductor could be consistently accelerated to a top speed of 6000 rpm, stopped, and then still levitate a magnet afterwards.

In this new configuration 32 full runs were performed using a video camera to record any balance deflections. The kinds of magnet configurations used are illustrated in Fig. 6. In some tests the superconductor was cooled through T_c in the presence of a magnetic field ("field cooling") and in others the superconductor was cooled without a field.

One variation (two NdFe magnets held over the edge of the disk, one with north up and one with north down, and the superconductor field-cooled) seemed to show balance deviations that indicated a very small weight loss during disk acceleration and deceleration. However, the vibration produced by the rotating cryostat was such that rotation alone produced balance deviations as large as any possible gravity effect. The movements were not consistent enough to be ascribed gravity effects, which in this configuration can be formally ruled out down to 0.03%.

2.3 Experimental Results from Rotating Field Tests

The aim of this work was to rotate a levitated three inch disk. However, whilst a levitated cylindrical magnet can be freely rotated about its axis in any orientation, levitated superconducting disks resist rotation in a stationary field. Therefore, the superconductor was fixed in place at the levitation height – 10 to 20mm – above a rotating array of NdFe magnets (Fig. 7). If the superconductor was not fixed in these experiments then it tended to rotate unstably with the rotating magnets. If a container was used that only just contained the superconducting disk, then sometimes the disk was seen to rise out of the position in which it had been lodged and rotate slowly when the magnets were rotating fast.

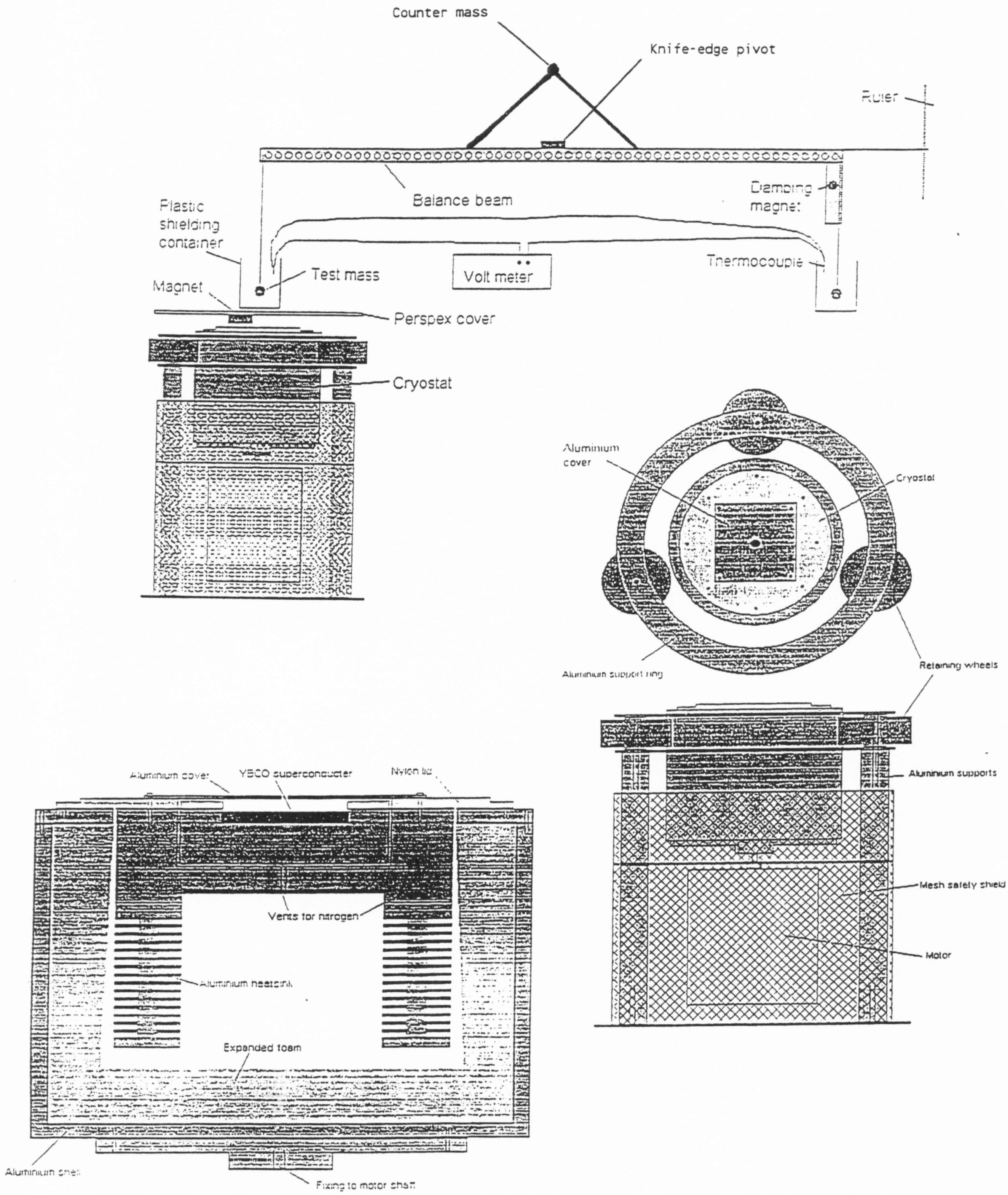
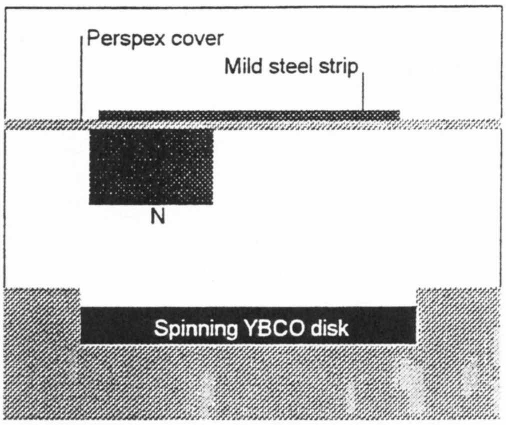


Fig. 5: *The final assembly for the rotating disk tests*



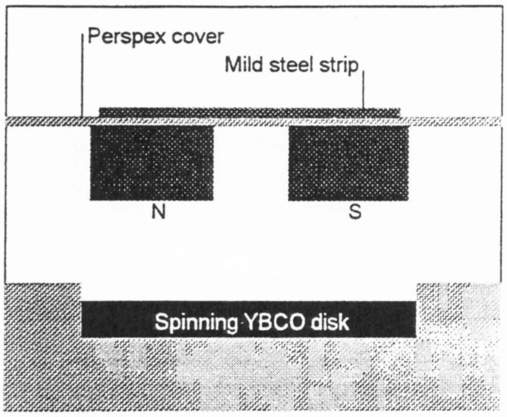


Fig. 6: Sample magnet configurations

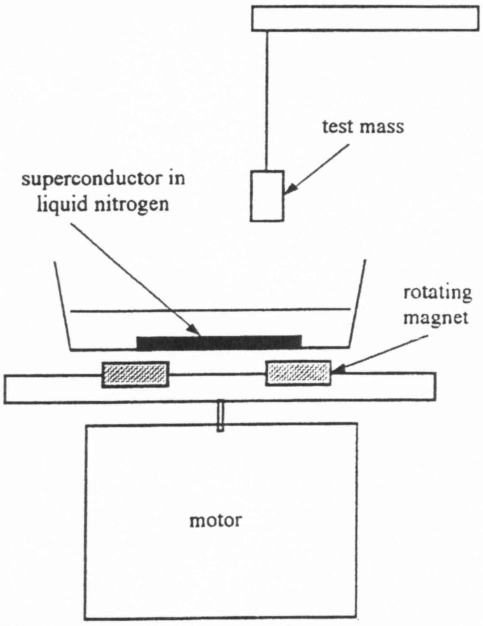


Fig. 7: Rotating field apparatus

If the superconductor was fixed in place and the container was unsecured, then when the magnet rotation speed reached around 2000 rpm the superconductor lifted the whole container with liquid nitrogen, and the container then vibrated violently. This agrees with Podkletnov's observation of his disks rising when rotated[8], but it seems more likely that this is due to Lorentz force rather than a weight loss.

When the superconductor was firmly fixed in position the field linkage between superconductor and magnets meant that at least ~10% more power was required to start the motor turning. If the superconductor was then allowed to warm through T_c with the magnets still rotating below, the motor immediately accelerated, indicating that high rotation speeds do not diminish the torque between superconductor and magnets.

Several magnet arrangements were tried (see Fig. 8). The only noticeable result arising from the different arrangements was that greater variation in the field distribution produced greater rotational stiffness of the superconductor rotating in that field. Both the homogeneously and heterogeneously self-seeded disks discussed in Section 2.2.1 were used with no obvious differences between their behaviour. No balance deflections were seen for magnet rotation speeds of up to 10000 rpm (using three pairs of opposed magnets at this speed is equivalent to a 500Hz levitation field) and a gravitational effect can be ruled out down to 0.01% (these experiments did not require the "see-saw" balance to be moved for each run, giving better resolution).

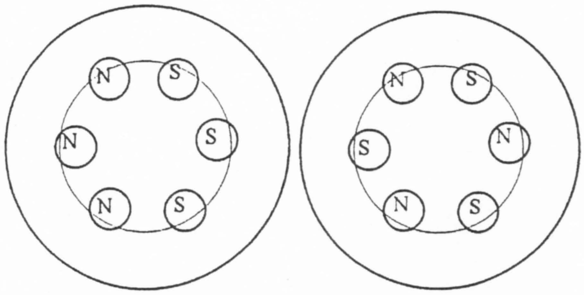


Fig. 8: Two different rotating magnet configurations tried during the present work

A variation on the above was to use four vertical magnets placed around the superconductor (Fig. 9). These magnetically contained the superconductor which was not secured in place mechanically. When the magnets below were rotating at speed the superconductor rotated slowly from the face of one containment magnet to the next. No balance deflections were observed.

Finally, five turns of copper tube were placed around the superconductor and connected through a matching unit to a 13.56MHz r.f. supply. The matching unit was designed for capacitive loads and had very little effect in minimising the reflected power. In fact the generator instrumentation suggested that for 200W forward power only 2W was absorbed by the load. Nevertheless, significant r.f. radiation was present in the vicinity of the superconductor, evidenced by the fact that the magnetic pick-up coil used for measuring rotation speed developed 3V peak to peak at r.f., swamping the output from the small magnets bonded to the rotating assembly. The r.f. had no other effect on the experiment and a gravity effect could still be ruled out to 0.01%.

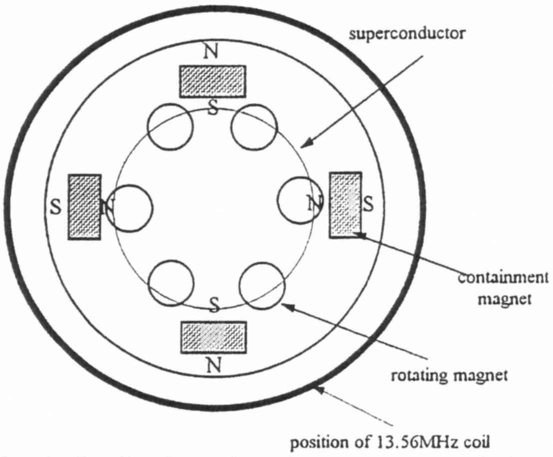


***Fig. 9:** Positioning of containment magnets to prevent the superconductor rotating uncontrollably*

2.4 Discussion

It can be argued that the fact that no effect has been observed in tests such as those described above is that these tests have not fulfilled the specified conditions for a gravity effect. These are:

- A disk with a diameter greater than 100mm
- A disk containing ~ 30% non-superconducting YBCO, preferably organised into two layers
- A disk capable of self-levitation, but still containing large numbers of intergrain junctions
- An a.c. levitation field with a frequency ~10kHz
- A second a.c. excitation field with a frequency of ~1MHz, for disk rotation
- Disk rotation speeds of a few thousand rpm for large (>0.05%) gravity effects (the largest effects (>2%) were reported[1] when the disk was being decelerated at around 3000 rpm).

The difficulties involved in meeting Podkletnov's experimental conditions[1] have already been discussed. In 1999 another team[7] working on reproducing Podkletnov's work followed a broadly similar route to the present work, i.e. using melt textured disks levitated with low frequencies. This group was not able to achieve stable static levitation of large disks at frequencies greater than 600Hz, and with disks that were not melt-textured stable levitation was achieved only with frequencies up to 45Hz. No gravity effects greater than 0.000001% were found.

The present work has investigated melt-texturing technology and produced high quality bi-layer disks with a final diameter of 70mm. There seems no *a priori* reason why this process may not produce larger diameter YBCO samples, particularly if annuli are formed so that larger diameters can be achieved at similar surface areas. An annular sample may also significantly reduce cracking due to shrinkage during the sintering process.

Rotating a melt-textured bi-layer 45mm disk at up to 7500 rpm through small static magnetic fields produced no effects that could be extracted from the system noise. Nor did various arrangements of high quality bi-layer 70mm superconducting disks held at levitation height above magnets rotating at up to 10000 rpm produce any gravity effect. The addition of a small 13.56MHz excitation field did not alter this negative result.

3. ROUNDS'S EXPERIMENT: STATIC SUPERCONDUCTOR

3.1 Introduction

Rounds[4] discussed a series of experiments in which a superconductor in the presence of a permanent magnet and immersed in liquid nitrogen was slowly allowed to warm. Rounds measured the weight of the whole system, reasoning that as the superconductor passed through T_c any weight anomaly associated with the Podkletnov effect would show up as a deviation from the monotonic weight loss as the nitrogen boiled off.

Rounds found deviations from linearity in his weight against time curves for superconducting disks, and less so for copper disks. However, as with the Reiss experiment[5], it is possible to postulate a number of thermal effects that could account for this observation.

Nevertheless, the experiment was interesting and has been repeated. Exactly the same type of superconducting disk and magnet (Edmund Scientific, part numbers CR37-446 and C52-867 respectively) were used, along with a somewhat larger nitrogen container than used by Rounds and also with a thermocouple bonded to the top of the YBCO and copper disks used.

3.2 Results

The results from a typical run with a thermocouple, an YBCO disk and a magnet separated from the YBCO by 10mm of plasticine are shown in Fig. 10, and for a copper sample in Fig. 11. Different ambient conditions along with the larger container meant that our experiments took longer (210s to the prominent inflection in the curve) than those of Rounds[4] (48s) and the initial portion of the weight loss curve shows greater deviation from a straight line. However, the deviation of our weight loss curve from a straight line (Fig. 12) shows behaviour similar to that reported by Rounds, in particular an anomaly at around 20s elapsed time. Unfortunately our results contain too much scatter (probably a result of vibrations in the thermocouple wires) for us to ascribe this anomaly to anything more than noise.

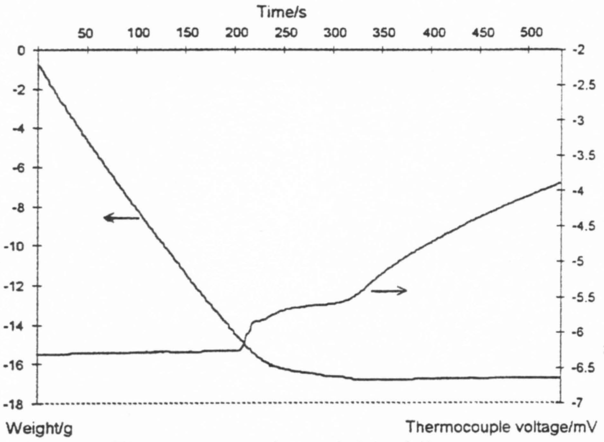


Fig. 10: The changes in weight of the experimental apparatus as nitrogen boils off in the present work

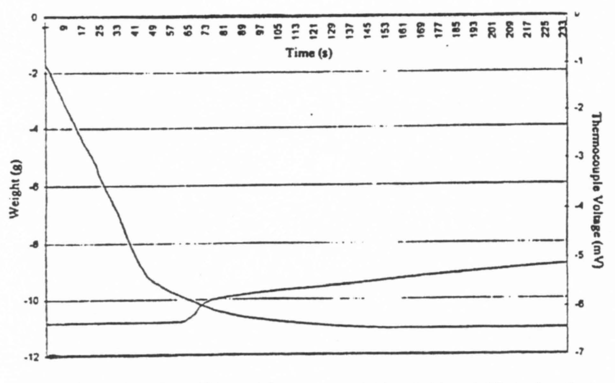


Fig. 11: As for Fig. 10 except that the YBCO disk has been replaced with a copper disk of the same size

However, the inclusion of a thermocouple does allow identification of the point at which the superconductor sample's temperature begins to rise. Inspection of Fig. 13 shows this to be after 205s, i.e. at the same time as the inflection in the weight loss curve. This concurrence can be explained by hypothesising that the heat flux into the experimental apparatus prior to 205s produced only nitrogen refrigerant boil-off, but post-205s was also required to raise the superconductor temperature, thus resulting in a slower boil-off rate.

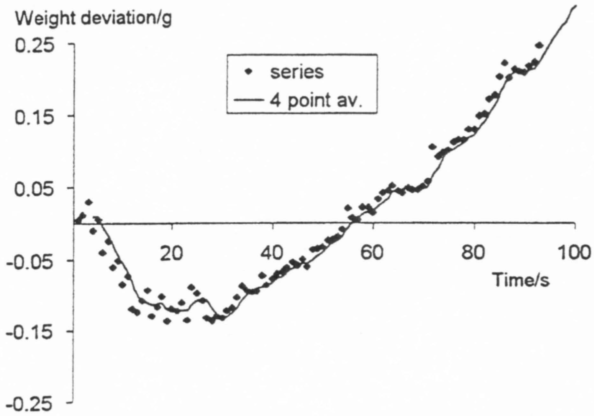


Fig. 12: The deviation from a straight line of the weight changes in Fig. 10

After 220s, as shown in Fig. 13, the rate of increase of temperature slowed dramatically, and the temperature effectively paused for a period of 10s at 93–94K. This is, of course, the critical temperature of the superconductor. Thereafter the rate of increase was slow until after 320s when no further liquid nitrogen refrigerant remained. This behaviour was reproducible using the YBCO superconductor sample but no such temperature pause was seen when the superconductor was replaced with a copper disc of similar dimensions.

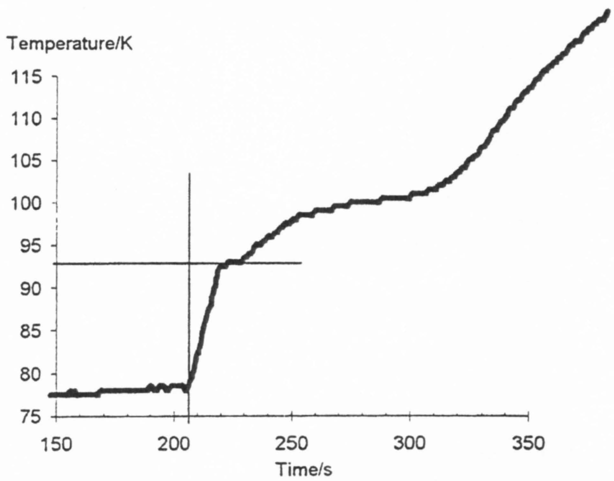


Fig. 13: Graph of thermocouple temperature vs. time in the Rounds-configuration experiment

3.3 Discussion

With the superconductor sample (and to a lesser extent the copper sample), the inflection in the weight loss curve corresponded to the sample starting to warm. A consequence of this (and presumably Rounds's original equipment[4] behaved similarly) is that any anomalies in the weight loss curve before the inflection point occur while the superconductor is at a constant 77K and are therefore most unlikely to be related to modification of gravitation.

Of more interest in the results is the slowing of warming rate at T_c which is reminiscent of a first order phase transition (like, for example, the melting of ice). However, the only first order phase transition reported in high T_c superconductors is flux vortex lattice melting and this has only been observed in small, high quality, flux grown single crystals, not in granular samples like ours[10]. Whilst this is an interesting observation and in need of further investigation, it appears to be a purely thermal effect without any implications for gravity research.

4. CONCLUSIONS

The conclusions from the present work are that the subset of the Podkletnov conditions examined here does not produce gravity modification measurable with our equipment (a resolution of the order of ±0.004%); it remains an open question whether gravity modification can be *repeatably* observed using the full set of Podkletnov conditions. This may, of course, only be a confirmation that not all of the correct and prescribed conditions have been achieved so far and that the present experiments could not be expected to show positive results.

The Rounds configuration also has not shown any effects unequivocally indicating gravity modification. Although some interesting effects have been produced, no effects reliably ascribable to gravity modification have been observed using either experimental arrangement.

From our repetition of the Rounds experiment, it appears likely that Rounds[4] was seeking a gravitational anomaly at an incorrect temperature. There was, however, unusual thermal behaviour in the YBCO results for which as yet there is no adequate explanation. Unusual behaviour around T_c has been found by other authors and it is known that high T_c superconductors with very short coherence lengths can show short-lived superconducting fluctuations up to 15K either side of T_c (the width of the distribution describing these fluctuations is proportional to coherence length). It is not clear that such fluctuations or thermal effects have any relation to any gravity effect.

4.1 Simplified summary of conclusions

Two recent experiments, one in Finland and the other in the U.S.A., have claimed to demonstrate reduction of the earth's gravity in a laboratory. Such observations are potentially of great importance to the future of spaceflight, air travel, and other endeavours in which gravity plays an important part. These experiments are extremely challenging technically and so an exact repetition is difficult; nevertheless, a partial repetition of the specified experimental conditions has been undertaken. No reduction in the earth's gravity has been observed by the present researchers to date. However, this may simply be because the full specified conditions have not yet been met.

5. FURTHER WORK

The next step in this work is to attempt a more complete test of the Podkletnov conditions. Work is already in hand to increase the disk size to 10cm diameter, to construct a magnetic levitation system, to construct rotation coils and to construct a disk braking system. Investigation of the detailed theory of such effects, in our view, should properly follow a repeatable demonstration of the Podkletnov observations beyond reasonable doubt.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

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