I have succeeded in preventing offsetting in drawn tungsten filaments without using the Battersea crucible process by mixing with the tungsten powder certain refractory materials such as the oxids of thorium, zirconium, yttrium, erbium, didymium, or ytterbium. I have used with especial success thorium nitrate, which gives thoria when decomposed. A small amount of the above mentioned oxids, or of compounds or solutions which upon heating or other treatment will yield these oxids, may be mixed with the tungstic oxid before reduction or with the metal powder after reduction, or may even be introduced after the metal has been made into a stick, either by soaking the stick in a solution of a suitable substance or by heating the stick in the presence of a suitable material in the vaporous condition. When thorium nitrate is used, for example, I employ an amount which is equivalent to 2% or less of thoria referred to tungsten. The essential point seems to be that the material should be introduced before the tungsten is sintered. Such additions, particularly in the case of a filamentary body, may actually produce a certain amount of ductility and flexibility in the sintered filament without mechanical working. Usually, however, instead of directly adding these substances, I prefer to employ the treatment above described of simply firing the tungstic oxid in a Hessian or Battersea crucible, for this treatment is simple, successful and reliable.

While I have referred to a considerable extent to the manufacture of ductile tungsten in which so-called additions are introduced at some stage of the process in order that the resulting product may be especially valuable when used for filaments of incandescent lamps, and in connection with other uses where the metal is to be exposed for long periods of time to high temperatures, nevertheless operative and useful incandescent-lamp filaments may be made by carrying out my process as herein described, omitting the additions whether produced by direct introduction of additional material, as above described, or by the Battersea-crucible process; and where it is sought to obtain ductile tungsten for uses in which it is not likely to be exposed to high temperatures, the introduction of such additional substances may be entirely unnecessary. I do not however wish it to be understood that metal prepared with the additions can only be used in incandescent lamps and for similar purposes, as such metal can, as far as my present knowledge extends, be used for any purpose to which the ductile tungsten prepared without the use of the additions is applicable.

In connection with the swaging operation it should be noted that I have departed radically from the ordinary swaging process, in which the dies are long and the metal is held a considerable time in the machine or passed very slowly through it, so that a number of blows are struck at the same place on the metal, and a smooth surface is produced. I find it highly desirable, particularly in the earlier stages of the swaging process, to use a die with a very short working face such as I have shown in the drawings, and to pass the metal through the machine at high speed and so that it is still highly heated when it emerges from the dies. Indeed, it is best not to allow two successive blows to be struck at too closely overlapping places, because each impact of the die abstracts a certain amount of heat from the material and unless this precaution be observed there is great danger that a blow will be struck upon metal which is too cold to endure it without cracking. Preferably, then, the metal emerges from the swaging machine, not smooth, but showing every distinct blow of the hammer, and therefore with an irregular wavy surface.

The swaging operation, though the most successful at the moment, is not the only operation by which my invention can be practised. For example, I have succeeded, without any swaging operation whatever and using only wire-drawing dies, in producing perfectly ductile tungsten. In this case I have begun the operation with sintered conductors of relatively small size. For example, I have used ordinary sintered series tungsten incandescent lamp filaments of the diameter of 25 mils. Where the original body is so small in diameter it is relatively easy to expel injurious impurities in the sintering process, and the devices above described to facilitate this end, which are of importance in the case of the larger bodies which are required for economical large-scale production of lamp filaments, or for the preparation of larger articles, such as X-ray tube targets, projectiles, contacts, etc., become relatively unimportant where the original sintered body is of sufficiently small diameter. I point these filaments by the process of the Whitney Patent, No. 1,008,762, above referred to, and carefully insert the point into a die which is heated to 600 to 650° C. The pointed end is then seized with hot pliers (otherwise it would break) and the filament is then with great care and with a regular steady pull drawn through the die, the diameter of which should be not less than ½ a mil. (.0005 inch less than the maximum diameter of the filament at any point. The filament is then in a similar way drawn through a die having a diameter of ½ a mil. (.0005 inch) less than that of the first die, and so on down to 13 mils. Below this size the dies should vary in steps of one-quarter of a mil. until a size of say four mils. is