(d) Exit speed. Equipment has been purchased and assembled which will enable a greater flexibility of drawing speed and draw stress than was previously used. Wire exit speeds will be independently controllable from 30 to 600 fpm. Should relatively high exit speeds be possible, it is anticipated that the heat generated during deformation may allow lower environmental preheat temperatures to be used. The unit will also be able to provide controlled drawing loads ranging from about 0.1 to 150 lbs.

Beryllium wire representing both ingot and powder origin has been purchased. The wire is nominally 0.020-inch diameter and is to be reduced in the annealed condition. On the basis of previous experience obtained in the HYDRAW of this material (see Reference (1)), the wire will be pre-coiled by a warm-wrapping technique (at 600 F) and will be paid out from within the hydrostatic container from a free vertical coil. The coil will be loaded in a unit which will also house the die. This unit will facilitate the handling of the wire and die during loading in the hydrostatic container.

Initially, the HYDRAW experiments will be conducted at temperatures up to 550 F. This requires preheating the container, fluid, and the wire and die unit. However, studies are currently being made of techniques for locally heating the wire around the die orifice. This will allow the container and most of the fluid to be maintained at or near room temperature, which should reduce the problems of sealing and materials handling accordingly.

HYDRAW of Titanium Tubing

Contacts have been made with possible vendors of titanium tubing for use in the process parameter studies. Until the available tube sizes are established, the experimental trials cannot be planned in detail – especially in regard to the design of mandrels and dies. Only three out of nine seamless tube manufacturers have expressed an interest in producing the Ti-6Al-4V alloy tubing in the sizes and quantities required. It is anticipated that a working arrangement can be established with at least one of these companies by which the tube manufacturer can participate in the evaluation of the tubes produced by HYDRAW. The use of the manufacturer's test facilities would minimize wasteful duplication of equipment.

The approximate tube stock sizes which will be initially evaluated by HYDRAW are as follows:

OD, inches	ID, inch	Wall Thickness, inch
1.125	0.981	0.072
0.625	0.527	0.049

The HYDRAW trials will be aimed at determining the processing parameters required to reduce both the bore diameter and the wall thickness of the tubing.

To best utilize the capabilities of the HYDRAW process, very high draw loads will be required to provide draw stresses in the order of 150,000 psi. A special hydraulic draw bench is currently being designed with this capacity. The drawing unit will be designed for use on Phases II and III of the program also.

HYDRAW TOOLING FOR PROTOTYPE PRODUCTION

The preliminary design studies have indicated that the container to be used for the HYDRAW of beryllium wire should be of straight-bore multi-ring construction but the container to be used for the HYDRAW of titanium tubing might be of right-angle or side-bore design. These conclusions are based on the design requirements for each application and on the limited amount of design data available on side-bore container design. The fluid pressure level required for the HYDRAW of beryllium wire, at least 200,000 psi, for a long-fatigue-life side-bore container appears to be too high based on the present-day technology for such designs. A side-bore design would have an advantage in paying out wire tangentially from a large coil of wire stock. However, it is anticipated that paying out wire from a straight-bore container will present no problems.

An advantage of the side-bore design for extrusion of tubing is the ability to use vertical hydraulic presses without large vertical "daylight" between platens and without deep pits beneath them to extrude long lengths of product. It is estimated that a side-bore system can be designed to withstand pressures (P) on the order of 150,000 psi. It appears that this level should be sufficient for HYDRAW of titanium alloy tubing, since it will be possible to apply a draw stress (D) of at least 125,000 psi to the tube product (together with the 150,000 psi fluid pressure). This would make the total P + D = 275,000 psi, which is adequate to effect substantial tube reductions in a single pass. A model study of the right-angle system is to be conducted to determine with a greater degree of certainty the feasibility of containing pressures in the order of 150,000 psi and higher. This study will be conducted in the near future.

Design of a Container for the HYDRAW of Beryllium Wire

The straight-bore, multi-ring container for the HYDRAW of beryllium wire has been designed on the basis of the fatigue-strength criterion established in an earlier program(1). In addition to beryllium wire, the container will have the capability of being used for a wide variety of hydrostatic extrusion applications. It has been designed to withstand pressures of 250,000 psi on a bore of 7-inches diameter by 30 inches long. Thus a coil of wire up to at least 6-inches diameter can be accommodated co-axially in the container. To add to the versatility of the tooling, the container has also been designed to withstand up to 350,000 psi on a 4-inch diameter bore, provided that a liner material having suitable properties is available. This pressure capability would be achieved by press fitting a 4-inch bore liner into the 7-inch bore.

The outer dimensions and number of rings of the container were calculated for the 7-inch bore container using optimum design procedures. This was done using the computer code MULTIR developed in an earlier program(1). A summary of the calculations is shown in Table 1. The following generalized fatigue relations, formulated in an earlier program(1), were used in the design:

$$A_n (\sigma_\theta)_r + B_n(\sigma_\theta)_m = \sigma_n$$

or

$$A_n S_r + B_n S_m = \sigma_n \qquad (1a, b)$$