

TABLE OF CONTENTS
(Continued)

| | <u>Page</u> |
|--|-------------|
| Controlled-Relief Die | 89 |
| Double-Reduction Die - Extrusion Ratio 4:1. | 89 |
| The Potential of Die Design | 93 |
| SECTION II | |
| XIV. SUMMARY OF SECTION II | 97 |
| XV. HYDROSTATIC EXTRUSION OF TUBING | 98 |
| Tooling | 98 |
| Effect of Floating-Mandrel Arrangement | 98 |
| 7075-O Aluminum Tubing | 102 |
| Extrusion Ratio | 102 |
| Lubrication | 102 |
| Effect of Stem Speed | 104 |
| Extrusion Ratio | 104 |
| Lubrication | 104 |
| Effect of Mandrel Taper | 106 |
| Re-Extrusion of As-Extruded Tubing | 106 |
| Ti-6Al-4V Titanium Alloy Tubing | 106 |
| Extrusion Ratio | 107 |
| Effect of Mandrel Taper | 107 |
| Lubrication | 107 |
| Stem Speed | 109 |
| Re-Extrusion of As-Extruded Tube | 109 |
| XVI. HYDROSTATIC EXTRUSION OF SHAPES | 110 |
| Die Design for the Extrusion of Shapes | 110 |
| Die Design for the Extrusion of Shapes From Round Billets | 110 |
| Die Design for Re-extrusion of T-Sections | 110 |
| Experimental Procedure | 113 |
| Cold Hydrostatic Extrusion and Re-extrusion of 7075-0 Aluminum Shapes | 113 |
| Extrusion Pressure Requirements | 113 |
| Die Design | 115 |
| Stem Speed and Billet Surface Finish | 115 |
| Billet Lubrication | 115 |
| Extrusion of Re-entrant Channel Section | 115 |
| Re-extrusion of 7075-0 Al T-Sections | 115 |
| AISI 4340 Steel T-Sections | 116 |
| Re-extrusion of Ti-6Al-4V Alloy T-Sections | 118 |
| Re-extrusion of Cb-752 Columbium Alloy T-Section | 118 |

TABLE OF CONTENTS
(Continued)

| | <u>Page</u> |
|--|-------------|
| XVII. THE HYDRAW OF WIRE AND SHAPES | 120 |
| The HYDRAW Process | 120 |
| HYDRAW Tooling | 120 |
| Draw Control and Draw Load Measurement | 120 |
| Wire Coil Configurations | 122 |
| Experimental HYDRAW Procedure | 122 |
| Preparation of the Point on Wire and Shape | 122 |
| Operational Sequence | 124 |
| HYDRAW of Ti-6Al-4V Titanium Alloy Wire | 124 |
| HYDRAW of Beryllium Wire | 126 |
| The Starting Wire | 128 |
| Experimental Developments | 128 |
| HYDRAW of Beryllium Wire of Ingot Origin | 130 |
| HYDRAW of Beryllium Wire of Powder Metallurgy Origin | 131 |
| Tensile Data on Beryllium Wire | 131 |
| HYDRAW of TZM Molybdenum Alloy Wire | 132 |
| HYDRAW of 7075-0 Aluminum T-Sections | 132 |
| XVIII. TANDEM EXTRUSION | 134 |
| XIX. ECONOMIC ANALYSIS OF THE HYDROSTATIC EXTRUSION OF SOLID ROUNDS AND TUBING | 137 |
| Conversion Costs to Produce Rounds by Hydrostatic Extrusion and by Conventional Hot Extrusion | 139 |
| Hydrostatic Extrusion of Rounds | 139 |
| Conventional Hot Extrusion | 141 |
| Comparison of Hydrostatic Extrusion and Hot Extrusion Conversion Costs | 141 |
| Conversion Costs to Produce Ti-6Al-4V Titanium Alloy Tubing by Hydrostatic Extrusion | 142 |
| XX. REFERENCES | 147 |