N80 24781

# COST ESTIMATING BRAYTON AND STIRLING ENGINES

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## Abstract

Brayton and Stirling engines were analyzed for cost and selling price for production quantities ranging from 1000 to 400,000 units per year. Parts and components were subjected to indepth scrutiny to determine optimum manufacturing processes coupled with make or buy decisions on materials and small parts. Tooling and capital equipment costs were estimated for each detail and/or assembly. For low annual production volumes, the Brayton engine appears to have a lower cost and selling price than the Stirling engine. As annual production quantities increase, the Stirling becomes a lower cost engine than the Brayton. Both engines could benefit -- cost wise -- if changes were made in materials, design and manufacturing process as annual production quantities increase.

## Objective/Purpose

The principal objective of this study by JPL was to determine production costs and selling prices for both Brayton and Stirling engines to be used in solar energy applications for annual production volumes of 1,000, 25,000, 100,000, and 400,000. The purpose of the study was to use the generated numbers to compare the relative cost and selling price of different engines when they are used in solar power conversion units.

## Introduction

The engines evaluated in this study were the following:

Brayton Engine - As designed by AiResearch Manufacturing Company of California. The engine was updated to 20 KW from a basic subatmospheric design of 10 KW.

Stirling Engine - As designed by United Stirling (USS) of Malmo, Sweden. The engine was a P-40 design modified for solar energy application and was rated at 30 KW.

This study estimated the cost of direct labor and material which results in a cost number. A figure of $10.00/hr. was applied for direct labor. Estimates were made of the tooling, capital equipment and factory area required to assist in determining the selling price of the engines.

The engines evaluated by JPL were existing designs. No attempt was made to modify the design with an eye to reducing the cost.

Each of the companies involved - both AiResearch and United Stirling have indicated that modifications could be made to their engine designs to reduce the estimated costs.

## Methodology

Each engine part, component, assembly (major and minor), and its final assembly was examined and evaluated as to the cost of its material and method of manufacture based on the particular annual production volume under review. When estimating the costs of engines produced at the rate of 1000/year, it was assumed that most of the items would be purchased from small shops and assembled in an in-house facility.

When the production run increases to 25,000/year, it was assumed that a make or buy decision would be made to obtain the lowest cost based on a tradeoff of capital investment versus labor cost. Again, the assembly would be performed in-house. It should be noted that a production of 25,000 engines per year requires an engine every four (4) minutes with an eight (8) hour working day.

As the production increases to 100,000 units/year, it was assumed that most items would be made in-house with the necessary investment in tooling and capital equipment. Assembly would be in-house and would require an engine every minute based on an eight hour working day. With production at 400,000 units per year, multiple and duplicate facilities would be required and they would have to operate two eight (8) hour working shifts per day.

The evaluation was performed by examining either detailed drawings or actual parts and in some cases both drawings and parts were available for examination. The study evaluated the costs of direct labor and direct material only. Costs were determined for annual production volumes of 1000, 25,000, 100,000 and 400,000.

For low production volumes of 1000 and 25,000 units/year the engine manufacturing costs are considered to be labor intensive, whereas the manufacture of engines at higher production volumes would be capital intensive which can result in lower unit costs for materials and labor.

Estimates were also made for the probable cost of both the tooling, the capital equipment and the factory area that would be required for each of the production volumes under consideration.

Selling prices were determined by using a modified "Interim Price Estimation Guidelines" (IPEG) which was developed by JPL for use in the LSA program. The modified IPEG provides for indirect labor and material, factory area, amortization of tooling and capital equipment, financing, taxes, inflation, profit, etc.

## Restrictions

In order for JPL to obtain detailed information (drawings, specifications, etc.), from which cost estimates of engines could be made, manufacturers of Brayton and Stirling engines were contacted and requested to supply the

required information. The manufacturers agreed to supply the necessary information provided JPL would execute an Agreement of Confidentiality and/or a Secrecy Agreement that would preserve the proprietary rights of the companies involved.

The result of these agreements means that JPL cannot publish detailed cost information on parts, components or assemblies. The only information that can be published are the final estimates of cost numbers for a complete engine.

Representatives from both United Stirling (USS) and AiResearch Manufacturing Company of California have reviewed and concurred with the JPL approach to the manufacturing process selected for each component, etc. Additionally, these representatives reviewed the costing analysis and the cost numbers generated by JPL for material, direct labor, tooling and capital equipment.

## Results

The cost estimate for the engines in an annual production of 100,000 is shown in Table 1. A chart showing the cost reductions obtained wih increases in annual production volumes is illustrated in Figure 1. A chart showing the selling price of the engines at various annual production quantities is illustrated in Figure 2.

ACKNOWLFDGEMENT

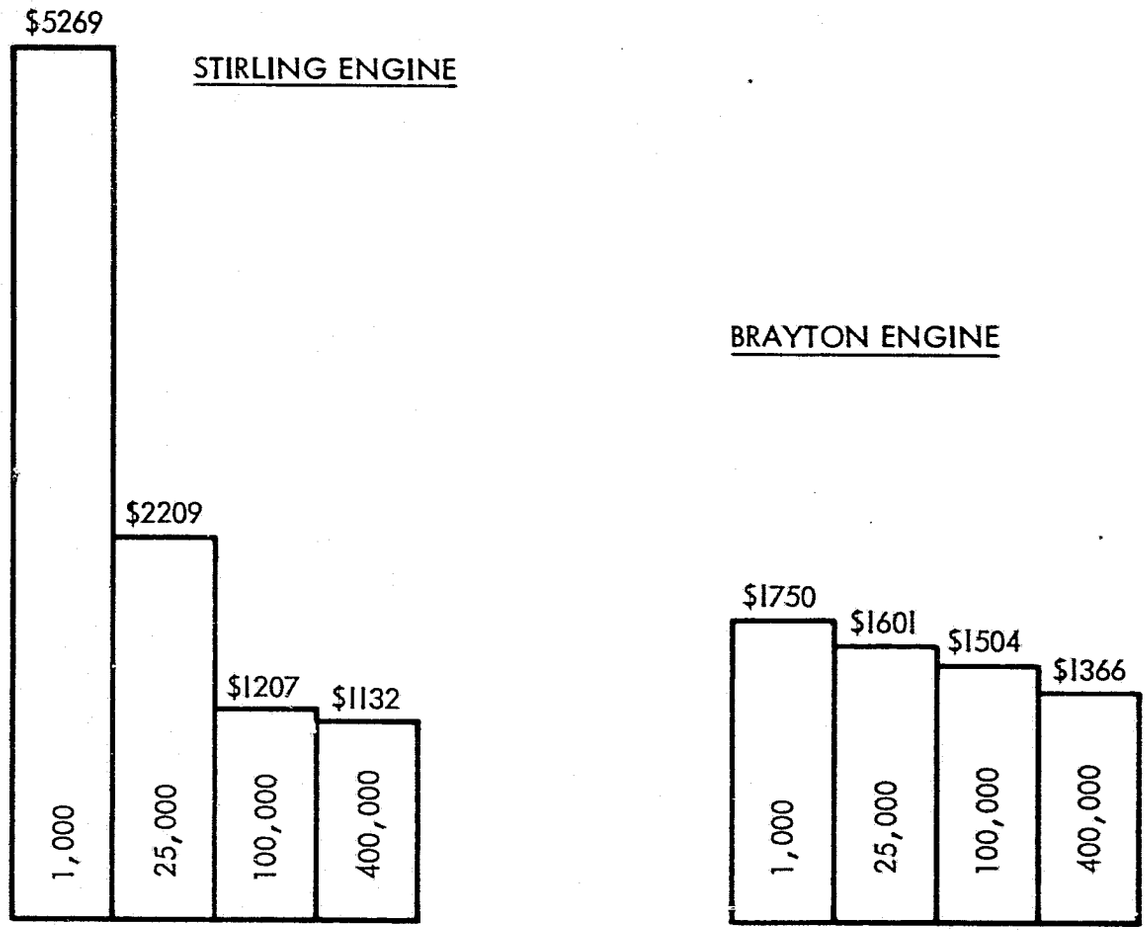
The research described in this paper was carried out at the Jet Propulsion Laboratory/California Institute of Technology and was sponsored by the United States Department of Energy through an agreement with the National Aeronautics and Space Administration.

ENGINE COST ESTIMATE

100,000 UNITS/YEAR

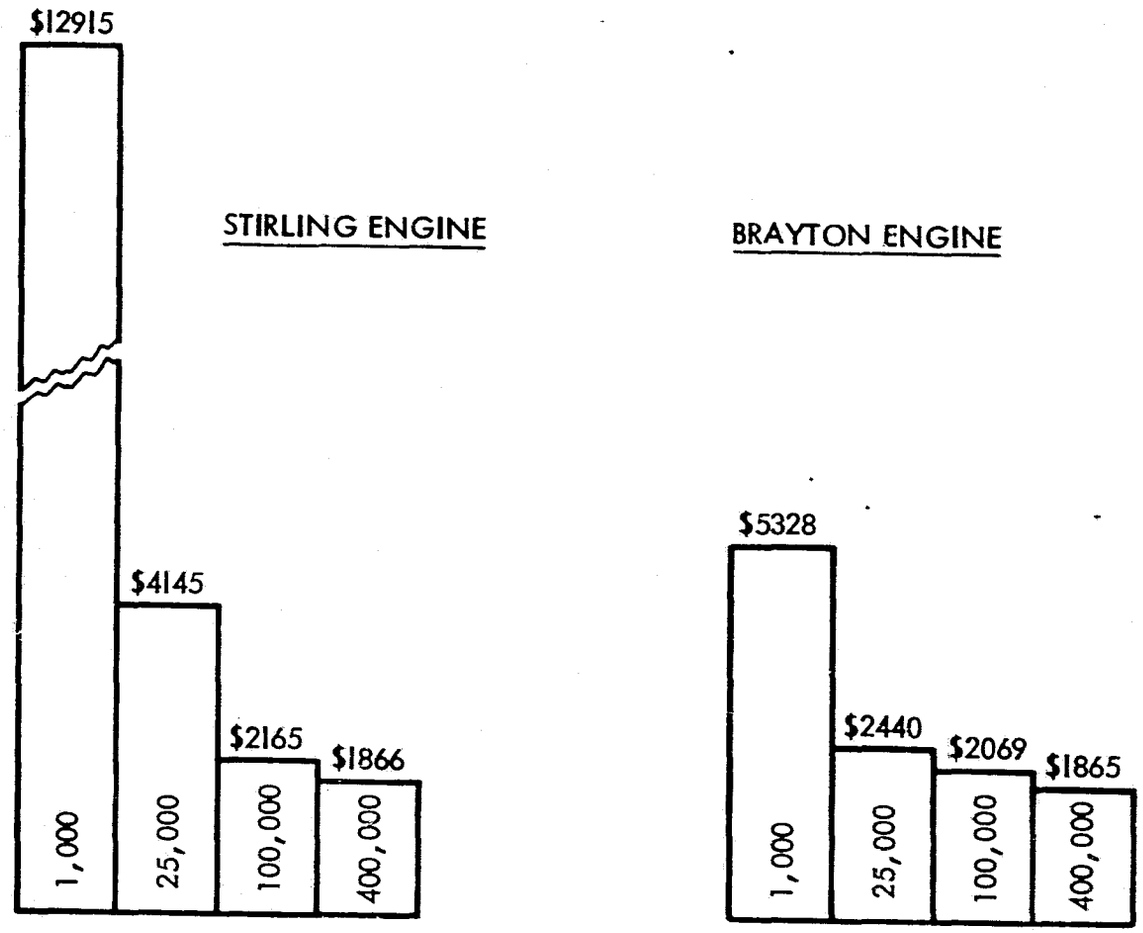
| | BRAYTON | STIRLING |
|---|---|---|
| RAW MATERIAL AND/OR PURCHASED PARTS | $1,317.78 | $1,055.77 |
| LABOR HOURS | 12.53 | 12.12 |
| LABOR COST @ $10.00/HOUR | $125.30 | $121.20 |
| MISCELLANEOUS | -- | $30.00 |
| TOTAL ENGINE COST (LABOR & MATERIAL | $1,504.08 | $1,206.97 |
| CAPITAL EQUIPMENT | $20,775,575 | $70,565,000 |
| TOOLING | $9,081,800 | $22,229,000 |
| TOTAL CAPITAL EQUIPMENT & TOOLING | $29,857,375 | $92,794,000 |

TABLE 1




ENGINE COST VS ANNUAL VOLUME

FIGURE 1




ENGINE PRICE VS ANNUAL VOLUME

FIGURE 2