STAINLESS STEEL PRODUCTS INC.

2880 N SAN FERNANDO BLVD

BURBANK CALIFORNIA

REPORT NO. 231-

Date February 3, 1965

REVISION N/C

GEORGE C. MARSHALL SPACE FLIGHT CENTER

HUNTSVILLE, ALABAMA

SUMMARY REPORT
(including design analysis)

P.O. No. NAS 8-11583

SSP Part No. 3303324

NASA Specification 60B24450

Contract Period 1-30-64 to 2-3-65

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SUMMARY REPORT - BELLOWS, TUNNEL FUEL TANK

This summary report is being submitted in compliance with the requirements of Contract No. NAS 8-11583 and will summarize the findings made during the performance of this contract.

During the production of this assembly No. 3303324, Procurement Specification No. 60B24450, no significant improvements were found necessary since this was a follow-up contract and most of the problems were resolved during the completion of Contract No. NAS8-5297. However, this contract was received before completion of the original contract and the overlap resulted in specification revisions to both orders simultaneously.

The Purchase Order, dated 1-30-64, required the manufacture of 18 production parts and three Sample Test parts; these quantities being reduced by telegram dated April 22, 1964 and confirmed by letter of July 1964, to 12 productions parts and two Sample Test parts.

The correction of problems encountered during the Qualification Testing on Contract No. NAS 8-5297 required that E.O. 303 be incorporated. This E.O. required the drilling and insertion of helicoils in seal flange No. 3303324-4. A full report of the reasons was contained in the original Summary Report.

During the manufacturing process the only difficulty that arose was the shrinkage of the 3303324-5 flange when it was welded to the bellows assembly causing the 25.125/25.115 dimension to be out of tolerance on final assembly. This discrepancy was submitted on a Deviation Authorization Request form to Marshall Space Flight Center to allow an increase in drawing tolerance of this dimension to 25.125/25.100. The discrepant parts were corrected to this new tolerance and shipped.

The two Sample Tests required by the contract were completed without incident and the test reports were submitted to Marshall Space Flight Center for approval These approvals were given on 1-12-65 and this contract is now considered closed.

DESIGN ANALYSIS

Buckling from external pressure

When a bellows is pressurized externally, it buckles in the same manner as a thin cylinder. Therefore from

$$P_{cr} = \frac{2E}{(1-\nu^2)} \left[\frac{t_{eb}^{\ 3}}{\overline{D}} \right]$$

Where E = Youngs Modulus = 29,000,000

ν = Poisson's Ratio = .34

$$\overline{D} = \left(\frac{O.D.^2 + I.D.^2}{2} \right)^{1/2} = \left(\frac{29.9^2 + 27.45}{2} \right)^{1/2}$$

$\overline{D}$ = 28.62 inches diameter

$$t_{eb}^3 = \frac{2t\ N_p h^3}{Pitch} = \frac{2 \times .025 \times 1 \times 1.225^3}{.666}$$

t_{eb}^3 = .138

$$P_{cr} = \frac{2 \times 29{,}000{,}000 \times .138}{(1-.34^2) \times 28.62}$$

P_{cr} = 386 psig

The critical failure point because of the external loading, will be the end convolution on either end of the bellows due to the carry-back end moment of the neck attachment to the end flanges. This condition will cause a reduction of collapsing pressure of 70% resulting in an actual pressure of 120 psig (determined from previous test data.)

Collapsing characteristic of the bellows necks or end attachment sleeves has been maintained by capping the bellows necks over the end attachment flanges thus allowing the end flanges to support the imposed load.

In this configuration the bellows fatigue characteristics will be as follows:

Motion stress $\sigma M = \frac{41400 \times 10 \times tXST}{N_c h^2}$ (assuming complete elastic characteristics for each of the calculations)

$$\sigma M = \frac{41.4 \times 10^6 \times .025 \times 4}{1.225^2 \times 30} = 91,960 \text{ lbs/sq.in.}$$

From the Cycle Life Curve it is clearly indicated that the required motions are well within the capabilities of this bellows.

Spring Rate $Z_a = \frac{N_p \times Ks\ 33.6 \times 10^6 \times D_1 \times t^3}{N_c h^3}$

$$Z_a = \frac{1 \times 1 \times 33.6 \times 10^6 \times 27.45 \times .025^3}{30 \times 1.225^3}$$

Spring Rate $Z_a = 261$ lbs/in.

Thickness required to prevent deformation of convolution sidewall:

$$t = \sqrt{\frac{P \times h^2}{2 \times 120,000}}$$

$$t = \sqrt{\frac{55 \times 1.255^2}{2 \times 120,000}}$$

$$t = .01855 \text{ inches}$$

The preceding calculations are based upon formulae from Technical Design of Stainless Steel Bellows, Stainless Steel Products, Inc., and show that the bellows design conforms with all the requirements contained in Boeing Specification 60824450. Since a similar unit was qualified for the Marshall Space Flight Center, it can be stated that all preceding calculations have been verified by testing.