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MEASUREMENT AND ANALYSIS ON BEARING CHARACTERISTICS OF GAS BEARING CIRCULATOR (B_1)

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Japan Atomic Energy Research Institute

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The bearing loads were measured and analyzed for the gas-bearing type circulator of the Helium loop HENDEL. From results of the study, it was found that the static load acting to bearing pads in the journal bearing does not remain constant as expected and is not isogonal due to the external forces from momentum changes and pressure gradient of the working gas and from electro-magnetic force in the driving motor.

As to the dynamic load in the bearing, it was found to depend on the static load and was also found that the absolute value of its vector is not constant in a rotation of the shaft.

It was predicted and reasoned that the divergent shaft vibration is caused by the vibrational dynamic load in absolute value and relatively low stiffness of the spring-pivot. To improve weak points of the gas-bearing circulator, some new design criteria are offered and the substantial methods are also indicated to realize those criteria.

Keywords: Gas Circulator, Gas Bearing, Tilting Pad, Pivot, Vibration, Whirling, Dynamic Load, Static Load, Instability, Gas Cooled Reactor, Helium Loop

ガスベアリング循環機のベアリング特性に関する測定および解析

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ヘリウムループ“HENDEL”に使用中のガスベアリング型循環機のベアリング荷重に関する測定および解析を行った。これらの試験結果からジャーナルベアリングのパッドに作用する静荷重は予想されていたような一定値に留まらないうえ，作動気体の運動量および圧力勾配と駆動用電動機における電磁力による外力に起因して，非等方的であることが明らかになった。

ベアリングに作用する動荷重についてはその値が静荷重に依存し，そのベクトルの絶対値は一回転中に変動することも判った。

循環機シャフトの発散的振動は上記の動荷重の振動とスプリングピヴォットの比較的低い剛性に起因することが実験結果および解析結果から推論され，予知された。

ガスベアリング式循環機に関するこれらの弱点を解決するため，二三の設計概念とこれらを具体化する方法についても言及した。

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CONTENTS

目　　次

LIST OF FIGURES AND TABLES

1. OUTLINE

The static and dynamic loads were measured and analyzed for gas bearing circulator(B_1) which made by Alsthom Atlantique Co., FRANCE, regarding to rotating speed, gas pressure, differential pressure, driving current, etc.

The results showed that the static and dynamic load are not the value decided only from revolution speed as expected, but are governed by another parameters too. It was also found that static and dynamic load correlates each other, that is, when static load is large on the radial bearing pad, dynamic load also increases to very high value on the pad.

It has been presumed that the static load of radial bearing rises up monotonically until revolution speed increases to a certain value, thereafter, it keeps nearly constant value by the action of spring pivots. The result showed, however, to be not always so and three cases are found.
Those are:

(a) The static load rises up to much higher value than the pre-loaded value of the spring pivot.

(b) The static load decreases from a certain value with increasing of circulator speed.

(c) As presumed formerly, the static load rises up until revolution speed reaches to a certain value, thereafter it keeps nearly constant value regardless of increasing speed.

The constant value of static load mentioned above has been presumed as same as pre-loaded value of the spring pivot. And this constant static load had been expected to be changable by adjusting pre-loading of the spring pivots.

Neverthless of above presumption, the result showed clearly that static and dynamic loads are affected by not only revolution speed but also gas pressure, differential pressure and other factors. It was also found the load acting to an each pad is not same for three pads in both upper or lower radial bearing. that is, static load is not isogonal(isometric) in both upper and lower radial bearings.

The case (c) described above seems to be limited only in the case when the circulator is operated in very low power such case as the test without impeller or the case as in free air with impeller.

Thus it seems that the design and balancing techniques should be discussed more for this type circulators.

To investigate the governing factors of bearing loads, the series of tests were carried out in air and Helium gas with the condition for revolution speed of 3000 to 8000 rpm, gas pressure of 10 to 30 bar, differential pressure of 0.0225 to 1.43 bar and temperature of 20 to 300 deg respectively.

The measured values of static and dynamic load are correlated with selected variables using multi-variables least-square method. The correlating variables are selectable any kinds and numbers from revolution speed, gas pressure, differential pressure, driving current and another six measured parameters.

From the result of analysis, it was found that when revolution speed and gas pressure are selected as the variables, the calculated values of static and dynamic loads are scattered relatively much against the measured values of them for both upper and lower bearings as shown in Figs 13 to 16. If four parameters; revolution speed, gas pressure, differential pressure and driving current are dealt as the variables in the correlation, they are so correlative as to static and dynamic loads for both upper and lower bearings as shown in Figs 17 to 20.

2. MEASUREMENT

The bearing loads were measured substituting a instrumented pivot for the fixed type pivot in both upper and lower journal bearings. Signals from the pivots were led to direct-current and alternating-current amplifiers to measure static load and dynamic load respectively. The amplified signals were connected to Honneywell model-101 18-channels magnetic data-recorder and to NEC-Sanei type 7V14 scanning digitizer.

The circulator speed was measured by Hewlett Packard 5316A counter counting pulses from the speed sensor, and was converted into analogue signal using Yokogawa-Hokushin model 3161 frequncy to voltage converter.

All of the digital signals were led to Hewlett Packard 9836C computer for calculation, drawing and storing. The analogue signals of loads and revolution speed are connectable to Yokogawa-Hokushin type 3023 X-Y recorders and Hewlett Packard 5423A dynamic signal analyzer.

The dynamic signal analyzer transforms the vibrational sinals of loads and shaft displacement into frequency-domain and time-domain data in digital manner. The frequency-domain and time-domain data from the analyzer were also led to the computer to draw frequency spectram maps and Lissajous' figures of the vibrational signals.

The computer connected with the all digital measuring devices through IEEE standard General Purpose Interface Bus in the testing. The vibrational signals were also connected to two Techtronics model 464 storage oscilloscopes to monitor and prevent the abnormal vibrations.

The following parameters were also measured analyzing how the loads were affected from them.

(1) revolution speed

(2) driving current of the motor

(3) pressure of workig gas

(4) differential pressure across the circulator

(5) gas temperature in inlet nozzle

(6) gas temperature in outlet nozzle

(7) flow rate of gas

(8) temperature of the motor-stator's winding

(9) temperature of a pad in the upper journal bearing

(10) temperature of a pad in the lower journal bearing

All signals described above are also stored and connected as same manner as load signals, thus it is able to process any data in any manner manually or automatically.

The test was conducted for the regenarative type gas circulator(B_1) in connection with the Helium test-loop "HENDEL"[1] using measuring set up described above under the conditions as follows:

(a) Speed Range ; 3000 to 8300rpm, roughly, same to below

(b) Inlet Gas Temperature; room temperature, 200, 300deg

(c) Gas Pressure ; 10, 20, 30, 40kg/cm^{2}G

(d) Differential Pressure; 0.2, 0.4, 0.6, 0.4, 1.2, 1.4kg/cm^2

(values at nearly 8000 rpm, equivalent to flow control valve openings as same pressure drop as above)

Another parameters mentioned above in (1) to (10) vary naturally from changing above conditions (a) to (d).

The test was also carried out in air as same manner as in Helium loop without blower casing for both case with impeller and without impeller. In the test in air and Helium, the vibrational movement of shaft was detected using additional two distance-sensors positioned on upper side of the upper bearing in 90deg direction. The absolute value and frequency component of shaft vibration were measured from the signals of these sensors. The trace of shaft movement was drawn with Lissajous' method from these signals as shown in Fig.24.

Prior to all tests, the clearance between journal and bearing pads and centering of the shaft were measured and adjusted again and again using dial-guages with extreme carefulness.

The measured static and dynamic load were plotted with revolution speed in analogue and digital manner, however, the absolute value of the static load may not be accurate because it is very difficult to know how much load acts to the sensor-pivot when circulator is stopped and also difficult to prevent drifting of signals from the direct-current amplifiers completely. In other words, the dynamic load and relative value of the static load are acuurate enough and reliable because the sensor-pivots themselves are calibrated very accurately.

The conditions of spring-pivots were adjusted and confirmed as follows:

(a) Pre-Loading	;	39 kgf	(upper bearing)
	;	40 kgf	(lower bearing)
(b) Spring Constant	;	46.3 kgf/mm	(upper bearing)
	;	54.4 kgf/mm	(lower bearing)
(c) Movable Range	;	0.34 mm	(upper bearing)
	;	0.35 mm	(lower bearing)
(d) Diametral Clearance	;	0.02 mm	(upper bearing)
	;	0.02 mm	(lower bearing)

Among the all tests, the acceleration detectors were additionally attached to outside of the outer casing at the level of upper and lower bearings. And the signals from the detectors were also recorded in the magnetic tape and were connectable to the dynamic signal analyzer and the oscilloscope.

3. ANALYTICAL METHOD

If the measurable function Y is governed by m variables X_1, X_2, ... and X_m, we can express the relations of measured functions and variables as following manner for n measurements.

$$\left.\begin{array}{l} Y_1 = f_1(X_1, X_2, \ldots, X_m) \\ Y_2 = f_2(X_1, X_2, \ldots, X_m) \\ \cdots\cdots\cdots\cdots\cdots \\ \cdots\cdots\cdots\cdots\cdots \\ Y_n = f_n(X_1, X_2, \ldots, X_m) \end{array}\right\} \quad (3.1)$$

where, m ; number of variables

n ; number of measurements

We have errors in measured values generally, then the equations of measurement to yield are ;

$$\left.\begin{array}{l} Y_1 - f_1(X_{01}, X_{02}, \ldots, X_{0m}) = v_1 \\ Y_2 - f_2(X_{01}, X_{02}, \ldots, X_{0m}) = v_2 \\ \cdots\cdots\cdots\cdots\cdots\cdots\cdots \\ \cdots\cdots\cdots\cdots\cdots\cdots\cdots \\ Y_n - f_n(X_{01}, X_{02}, \ldots, X_{0m}) = v_n \end{array}\right\} \quad (3.2)$$

where, $X_{01}, X_{02}, \ldots, X_{0m}$; most reliable value of variables

$v_1, v_2, \ldots, v_n$; residual errors

Solving X_{01}, X_{02} ... and X_{0m} with multi-variables least square method[2] from equations (3.2), we have;

$$\left.\begin{array}{l} \dfrac{\partial S}{\partial X_{01}} = 0 \\ \dfrac{\partial S}{\partial X_{02}} = 0 \\ \cdots\cdots \\ \cdots\cdots \\ \dfrac{\partial S}{\partial X_{0m}} = 0 \end{array}\right\} \quad (3.3)$$

where, $S = \sum_{i=1}^{n} v_i^2$

Supposing linear systems for eq.(3.2), we obtain;

$$
\left.\begin{array}{l}
Y_1 - (A_{11}X_{01} + A_{12}X_{02} + \dots + A_{1m}X_{0m}) = v_1 \\
Y_2 - (A_{21}X_{01} + A_{22}X_{02} + \dots + A_{2m}X_{0m}) = v_2 \\
\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \\
\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \\
Y_n - (A_{n1}X_{01} + A_{n2}X_{02} + \dots + A_{nm}X_{0m}) = v_n
\end{array}\right\} \quad (3.4)
$$

where, A_{11}, ... ,A_{nm} ; matrix of coefficiets

From equations (3.3) and (3.4), the linear simultaneous equation to solve the most reliable values are given as follows:

$$
\left.\begin{array}{l}
S_{11}X_{01} + S_{12}X_{02} + \dots + S_{1m}X_{0m} = R_1 \\
S_{21}X_{01} + S_{22}X_{02} + \dots + S_{2m}X_{0m} = R_2 \\
\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \\
\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \\
S_{m1}X_{01} + S_{m2}X_{02} + \dots + S_{mm}X_{0m} = R_m
\end{array}\right\} \quad (3.5)
$$

where, $S_{jk} = \sum_{i=1}^{m} (A_{ji}A_{ki})$

$R_k = \sum_{i=1}^{m} (A_{ki}Y_i) \qquad j, k = 1, 2, \dots\dots, m$

In the case n in eq.(3.1), (3.2) and m in (3.1) to (3.5) are expressed m >> n, the most reliable variables are soluble. That means if the function Y is the measured value of static or dynamic load in upper or lower bearing, and matrix of coefficients in eq.(3.4) are measured variables(or parameters), formulation of the load is possible most reliably for any number of the parameters.

If number of the variables or kinds of them are satisfiable in the analysis, the calculated values from the formula will be well correlated with measured values of the load for any experimental conditions.

In the practical analysis for the circulator, 260 experimental points are calculated directly from data file of the computer disk, that means n equal to 260 in eq.(3.4).

The case of non-linear system are also analyzed for the experimental data using similar method to the linear case, however, it was found the results of it has no meaningful differences.

4. RESULTS OF TEST AND ANALYSIS

4.1 TEST RESULTS

The measured values of load and test conditions are summarized in Table 4.1 for analogue plotting of dynamic and static loads with the figures' number. The results in air test shown in Fig.1a and 2a correspond to the data just after and nearly six hours after begining of the test respectively. A slight difference is found between them, it may be caused by the bearing clearance change at stopped condition from the temperature change.

Through the Figs.3a to 7a for room temperature Helium, the increase of pressure apparently causes a great much changes of the static load with revolution speed. On the other hand, temperature and differential pressure of the gas give a less influence on the loads as shown in Figs.8a to 11a.

The absolute value of the static load is not satisfiable through Figs.1a to 11a as described previously, however, the relative changes of static load are measurable in satisfiable accuracy. Therefore absolute value of the loads themselves are measurable in a certain accuracy and are presumable from the pre-loading values of the spring-pivots. Because the static load steeply rise up to the value as same as pre-loading value with the revolution speed and thenafter it keeps, or increases, or decreases its value. Consequently the absolute value of static loads are decidable from the pre-loading values.

As shown in Table 4.1, the maximum variation of the static load through the test occures in the condition for Fig.7a that is room temperature and 40kg/cm^2 of Helium. It indicates that if the revolution speed changes from 3500 to 7500rpm in this condition, the static load increases from 51 to 122kgf in upper bearing and decreases from 36 to 19kgf in lower bearing. In other words, the load variations in the condition are +71kgf and -17kgf in upper and lower bearing respectively.

The fact mentioned above means that at the revolution speed of 7500rpm, the static load in upper bearing is 71kgf at least and probably equal to the sum of pre-loading value(39kgf) in upper bearing and 71kgf ($\cong$110kgf), and in lower bearing, it is probably and nearly equal to the difference of pre-loading value(40kgf) in it and 17kgf ($\cong$23kgf).

The dynamic load, of course, is a value produced from the complex vibration phenomena in the rotor-bearing system. Thus the dynamic load is affected by the condition of balancing, stiffness of the rotor, pivot-spring and gas film in the bearings etc.. The dynamic loads were directly plotted with the revolution speed in Figs.1b to 11b corresponding to the conditions of Figs.1a to 11a.

For the upper bearing, a small peak, the first order critical speed appears around 6900 rpm. According to the increase of gas pressure or bearing stiffness, it disappears under a skirt of the second order vibration and the dynamic load itself rises up. The absolute value of dynamic load in lower bearing is comparatively small, however, it also increases with pressure of the gas from the same reason for upper bearing.

The dynamic load in both upper and lower bearings are plotted in Fig.12 with the static load for the conditions of Figs.3 to 11. It shows obviously that the dynamic loads grow up with the increase of bearing stiffness which is simply caused by gas pressure and also by increasing of static load with gas pressure. Consequently, the more gas density causes the more dynamic load directly and indirectly. Therefore, the load condition in atmospheric air remarkably differs from the condition in high pressure and high temperature gases consequently.

Fig.24 shows an example of Lissajous' figure of the shaft motion detected by distance sensors on upper bearing position, "D" shape in the figure expresses the containing of second order harmonics and a touch of whirling is felt from the double traces of the figure.

4.2 RESULTS OF ANALYSIS

The most reliable values of correlated linear function, $X_{0_1}, X_{0_2}, \ldots, X_{0_m}$ in eq.(3.5) are shown in Table 4.2 for the cases of two variables and four variables are taken into account. The normalized values of revolution speed and gas pressure are two variables for the former case, the normalized values of differential pressure and electric current are additional variables for the latter case. In the analysis, both of the static load and the dynamic load are correlated as the function for upper and lower bearings.

Another combinations of the variables have been tried in the analysis, however, it can not find out more suitable one at the time. The correlative plots of measured values vs. calculated values of the loads are shown through Figs.13 to 16 for the case of two variables, and Figs. 17 to 20 show in same manner for the case of four variables.

Correlativeness in case of the two variables is particularly bad for the static load of lower bearing and in case of the four variables are applied, it indicates better correlativeness for any kind of the load. From these results, we may presume that the four variables, - revolution speed, pressure, differential pressure and electric current - affect the loads more or less in bearings of this circulator.

The frequency spectral maps of shaft movement are shown in Figs.20 and 21 for the test in Helium of 260deg, 30kg/cm^{2}G with diametral bearing clearance of 0.02mm at stopped condition.

Basic components and higher order harmonics of the shaft vibration are clearly displayed and the components with nearly half frequency of revolution speed appear above the speed of around 9000 rpm. This indicates the whirling phenomenon occures in those revolution speed, however, the whirling is a complicated phenomenon and the relation to the load condition is uncertain. Those are the facts for the time being that the initiation of the whirling is not always at same speed and it seems that the operating condition of the circulator gives much influences on it. Supposing from the data and the theories on the bearing, the whirling must be caused by the relatively low stiffness and the low damping factor of the bearing systems compared to those of the liquid-lubricated bearings.

Fig.23 shows a similar spectral map analyzed from the acceleration signal on outer casing of the circulator. It is easier detecting the acceleration on outercasing than detection of shaft vibration, thus detection and analysis of the acceleration make it possible to investigate the operating conditions and secure the circulator without special attachment of the shaft movement sensor.

5. DISCUSSION ON RESULTS

From the results of test, it will be able to presume as following items:

(1) As presumed previously when the circulator rotor is operated without the force perpendicular to its axis, the hydro-dynamic forces on pads increase with the revolution speed monotonically and isogonally until the spring-pivot initiates deformation. And the force overcome the pre-loading value, the static load will be kept in nearly constant value because clearances between the journal shaft and pads increase with the force.

(2) When the circulator is running in connection with the high pressure gas loop, An additional force act to the impeller from pressure gradient around the impeller and momentum changes of gas at inlet and outlet of the circulator. This force changes with gas pressure or density, differential pressure, revolution speed and

other factors.

(3) The clearance of circulator motor's rotor and stator can not be made exactly uniform around its circumference in general, and it changes with displacement of the spring-pivot, therefore, the force perpendicular to rotor axis or tumbling moment is generated by electro-magnetic force between rotor and stator. And the electric current, which produces the electro-magnetic force, affected by speed, gas pressure, differential pressure and other factors.

(4) From the causes mentioned in (2) and (3), additional tumbling moment or external force acts on the rotor when the circulator is running in practical use. And it increases with the input power of the circulator.

(5) Only one load sensor is equiped in both upper and lower radial bearings in the same direction respectively. Therefore, if component of the force vector compresses the load sensor, measured value of static load must increase with revolution speed monotonically.

(6) On the contrary, if vector component of the force is reversal, measured static load will remain nearly constant until the spring pivot initiates deformation. After the beginning of deformation, measured value will decrease gradually because the clearance increases between the load sensing pad and shaft. In other word, the shaft displaces toward spring-pivot side compressing the

spring and away from sensor-pivot.

(7) Three pivots in a bearing are arranged rotationwise with 120 deg spaces in the order from fixed type, sensor-type and to spring-type.

(8) When large static load is applied to a pad, rigidness of gas film adjacent to the pad must increase because of pressure increasing in the clearance. Thus a large dynamic load will be observed for the same balancing conditions at the pad where large static load is applied.

(9) The electric current is affected by circulator speed, gas pressure, differential pressure etc., however, it is found that the measured static and dynamic load are correlatable only in the case that current itself is dealt as one of the variables.

This means the current itself affects with static load and dynamic load finally. Consequently, it should be understood that magnetic force in the ciculator is one of important factors as same as the force from gas to the impeller for condition of the loads.

6. CONCLUSION AND RECOMMENDATIONS ON DESIGN CRITERIA

The spring-pivots in both upper and lower journal bearing must be intended to keep the static load in constant and high value. And it causes high stiffness and high load capacity in the bearings. The constant and high stiffness of the gas film make it possible to operate the circulator in stable conditions for whole range of the operating speed.

From the reason above, the effectiveness of spring-pivots is most important and the special feature of this type circulator. Therefore if the effectiveness of the spring-pivot is out of expectance, the circulator will not be operated in stable conditions.

As described in the preceding chapter, the force act to the circulator impeller from the momentum change of working gas and pressure gradient across the impeller, the electro-magnetic force also acts to the motor-rotor horizontally or in tumbling manner. These force or moment causes unequal forces to the each pads in both upper and lower journal bearings, consequently it makes too much and too small displacements of spring-pivots in the two journal bearings respectively.

As to the dynamic load in the journal bearing, we must know that the dynamic load which is measured for only one pad in the each bearing will not same for three pads in the bearing except the case of very low power operation. If the static load is so large and non-isogonal by the force or moment described above and the vector component of it directs to the spring-pivot, the journal shaft will supported under the relatively low stiffness condition because stiffness of the spring-pivot is much lower than it of the gas film. Thus the journal shaft will be kept in the fluffy condition and unequality of the dynamic load also becomes so large as proportional to the value of static load as understanding from Fig.12.

The unequality of the dynamic load causes the force vector component which rotates and changes absolute value in the rotor.

According to this force vector, the motion of the rotor also makes additional force vector component of gyro-effect which is proportional to the velocity of motion and rotating speed and is perpendicular to the motion.

Resulting from these force components and fluffy suporting, the rotor falls into the unstable condition and tends to vibrate divergently.

Generally speaking, non-steady and non-linear system of the dynamic load in the above case makes it possible to generate the instability of the rotor.

As understanding from above descriptions, the basic problems are non-uniformity of static load which caused from external forces and low stiffness of the spring-pivot. Therefore we must realize following improvements basically to prevent the instability of the rotor:

(1) Cancelling or decreasing of external force to the rotor.

(2) Increasing the stiffness of spring-pivots.

(3) Increasing the damping factor of spring-pivots.

Substantiating the basic criteria mentioned above, we may offer the following methods respectively:

(1) Decreasing or cancelling the external force due to the momentum changes and pressure gradient of gas, it will be very effective to equip two stage impeller and casing which have the inlet or the outlet nozzles in inverse direction each another. And it will be also effective that we set the rotor in the position where it is not always the geometrical center of the motor stator but the position where the magnetic forces are

balanced all directionally.

(2) It is rather difficult to increase stiffness of the spring-pivot simplly because if spring constant of the springs are increased, it makes impossible to keep the static load in the nearly constant value. Therefore we should design the most suitable spring based on the consideration of static load-keeping and stiffness for the vibration.

(3) It will be most effective way to increase damping factor of the spring-pivot and the present author has designed the special pivot for this purpose.

As described above, it should be re-discussed with effectiveness of the spring-pivot and also with meanings of the balancing techniques in the condition of free air or no impeller. We must be careful that the practical operating loads differ from the balancing condition which is traditionally carried out in free air.

The pressure gradient around the impeller is comparativelly large for the regenerative type impller, thus we must be more careful of that the tumbling moment of this type become larger than another type circulators.

It must have close relations with above descriptions that the twice troubles had occured in the circulator(B_1) which has a single stage regenerative type impeller. Therefore we should make more investigations on the troubles to ensure and verify reliability and capability of the circulator not only for the Helium-loop but also for a nuclear reactor use. This circulator tends to occure the "whirling" even at present in the operating condition around 9000 rpm. (see Figs 21, 22)

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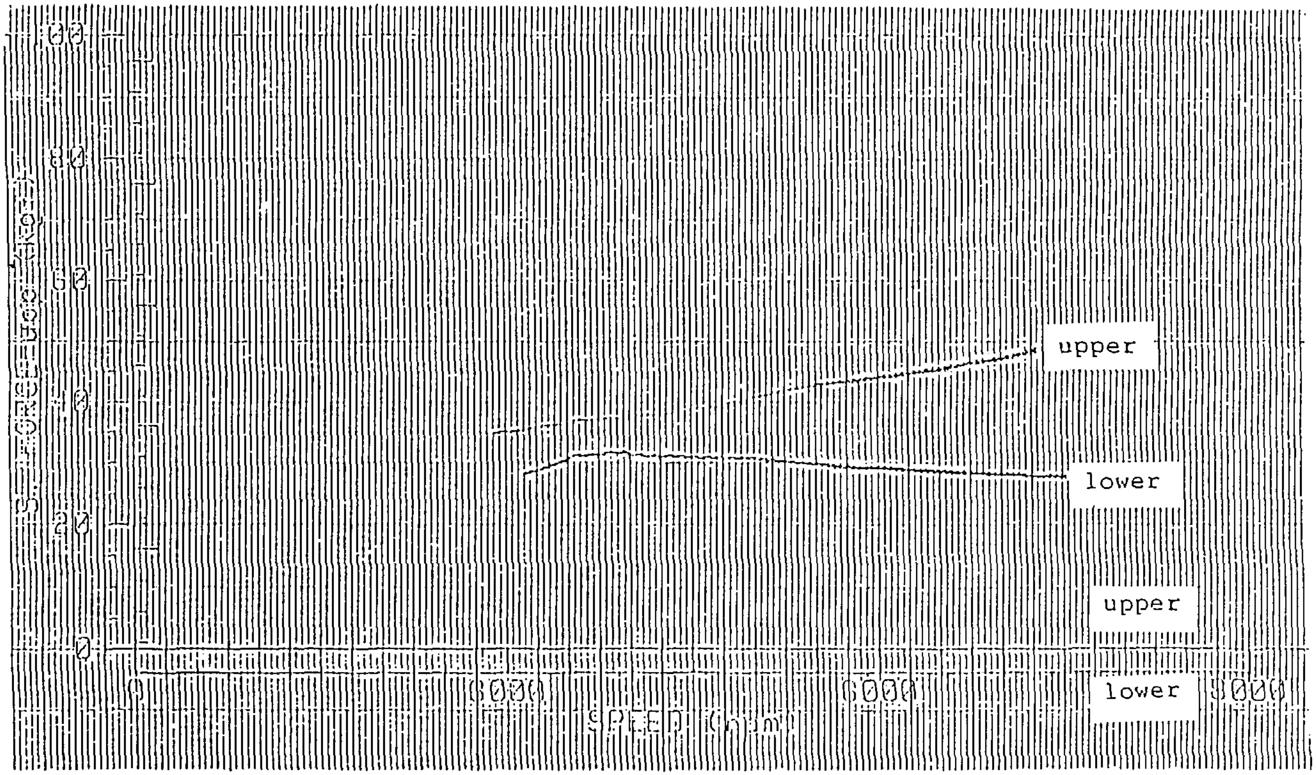


Fig.1a Static Load in Air just after Begining of Test

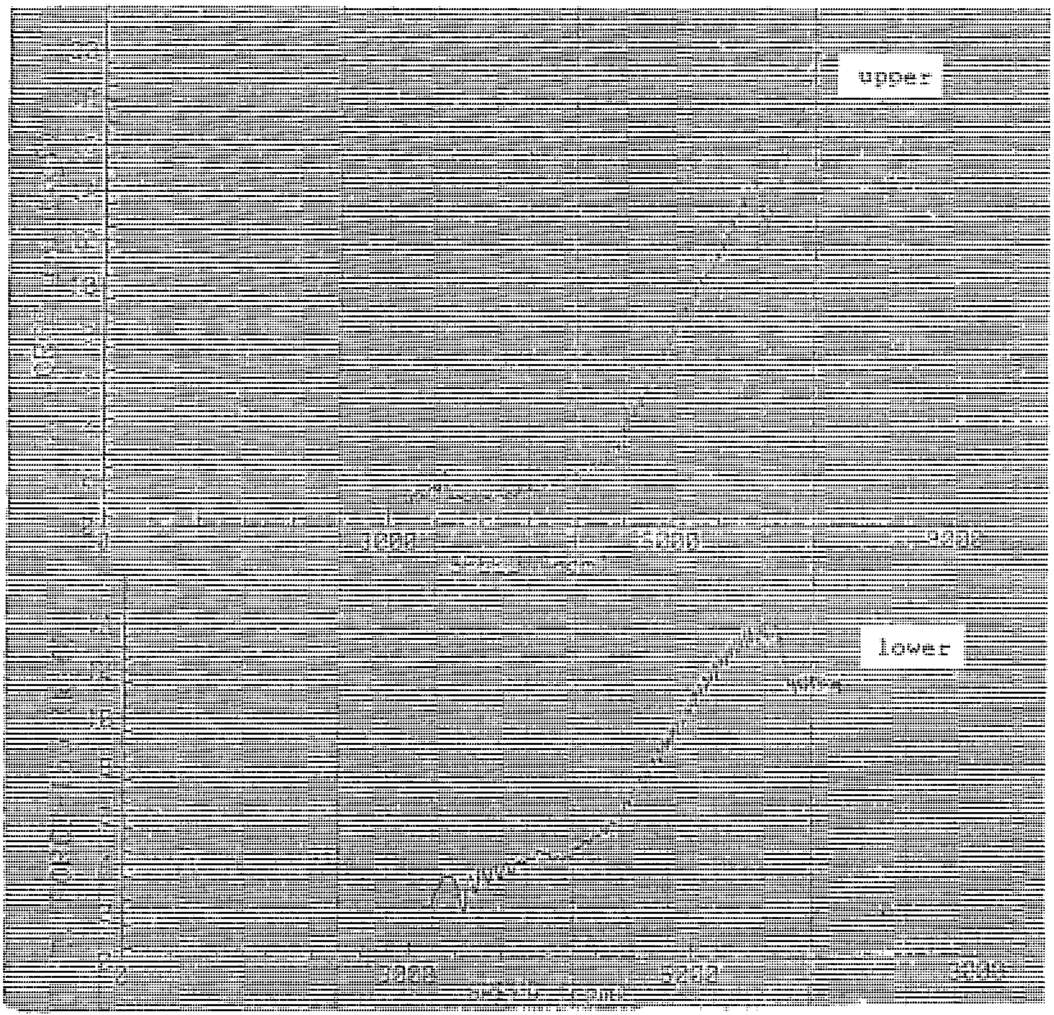


Fig.1b Dynamic Load in Air just after Begining of Test

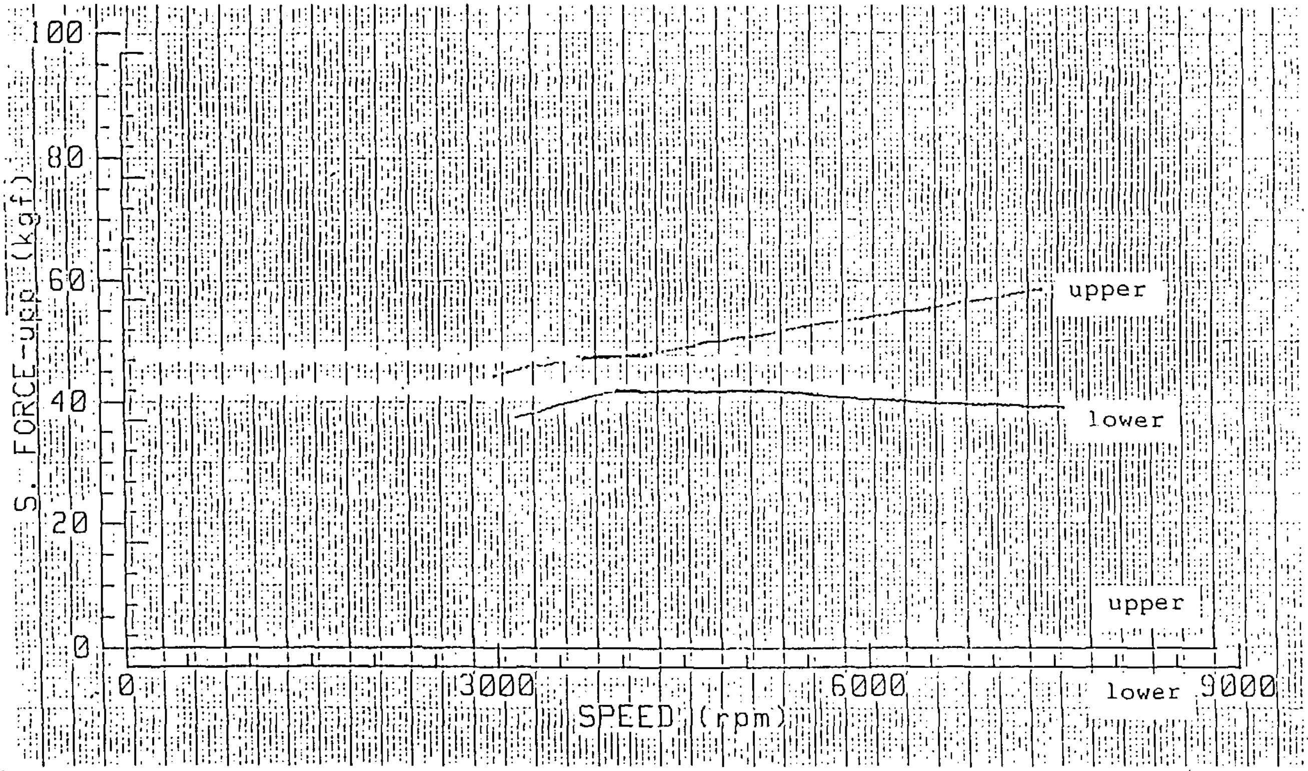


Fig.2a Static Load in Air after 6 Hours of Begining Test

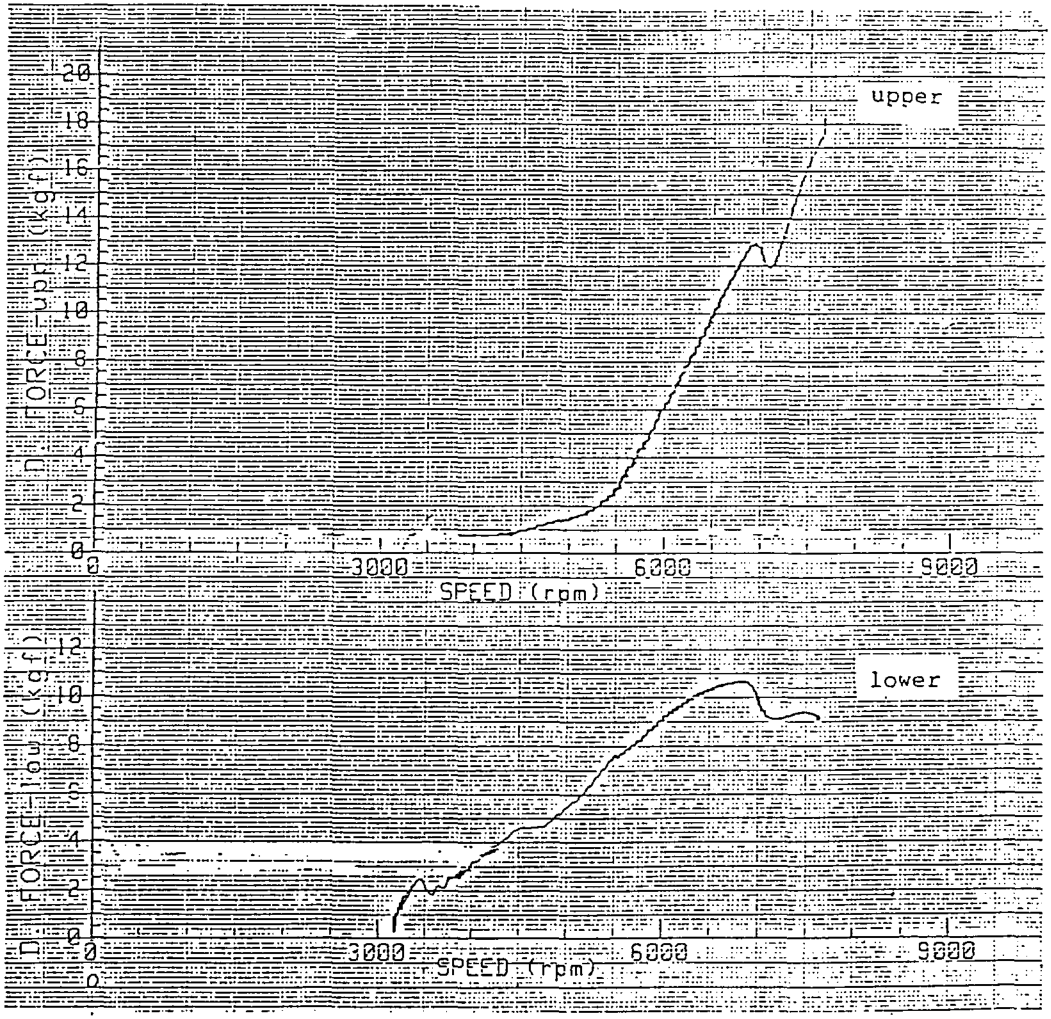


Fig.2b Dynamic Load in Air after 6 Hours of Begining Test

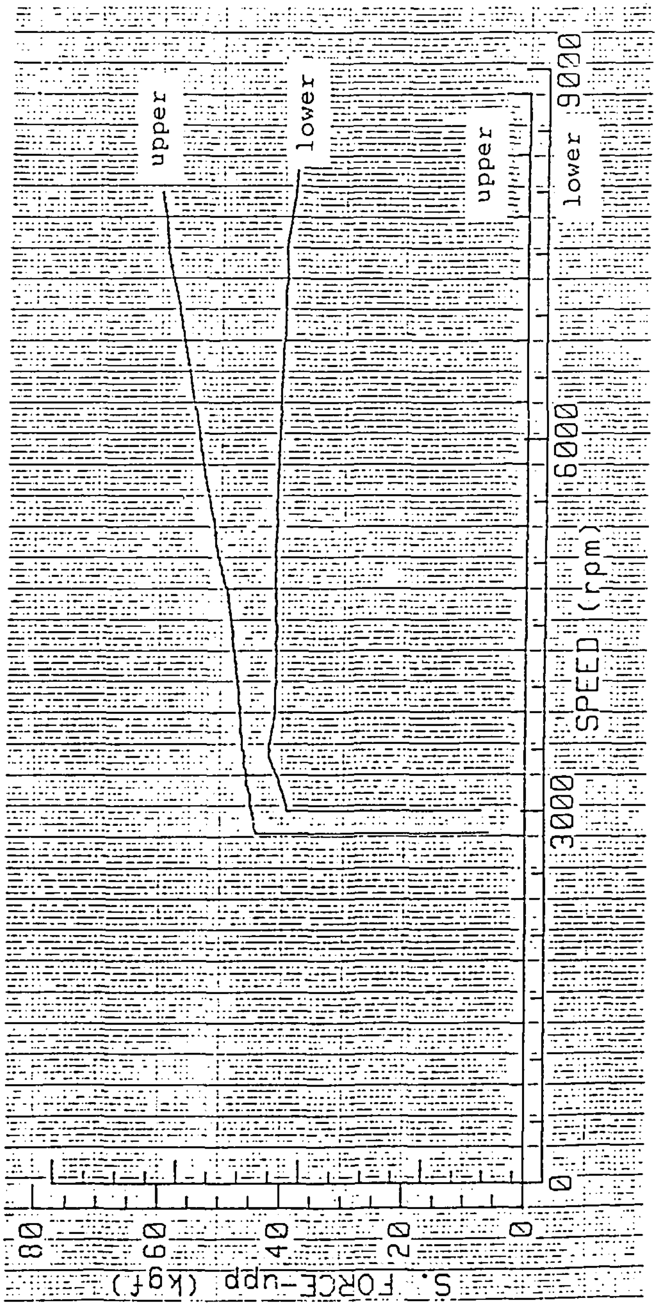


Fig.3a Static Load in Helium of 27deg, 5.4kg/cm² G
(Δp=0.26kg/cm² at 7500rpm)

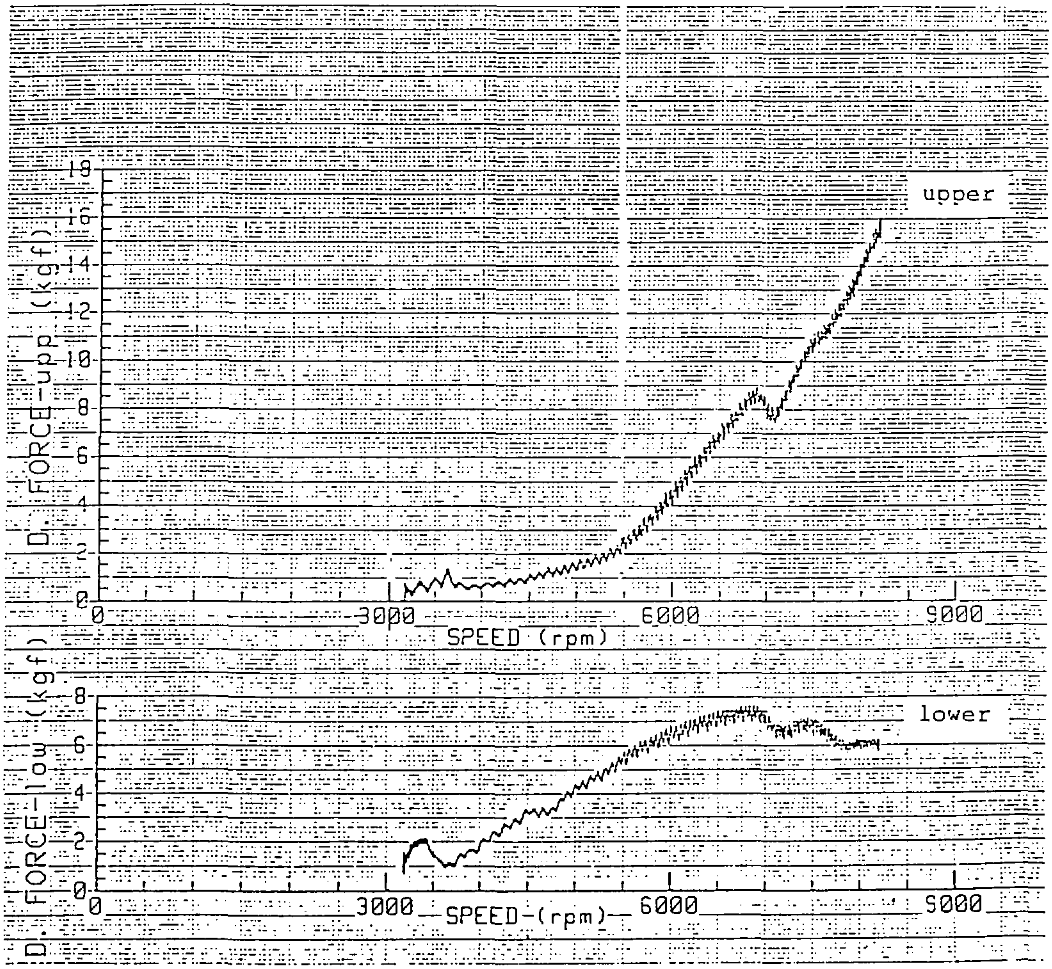


Fig.3b Dynamic Load in Helium of 27deg, 5.4kg/cm^{2}G
(Δp=0.26kg/cm^2 at 7500rpm)

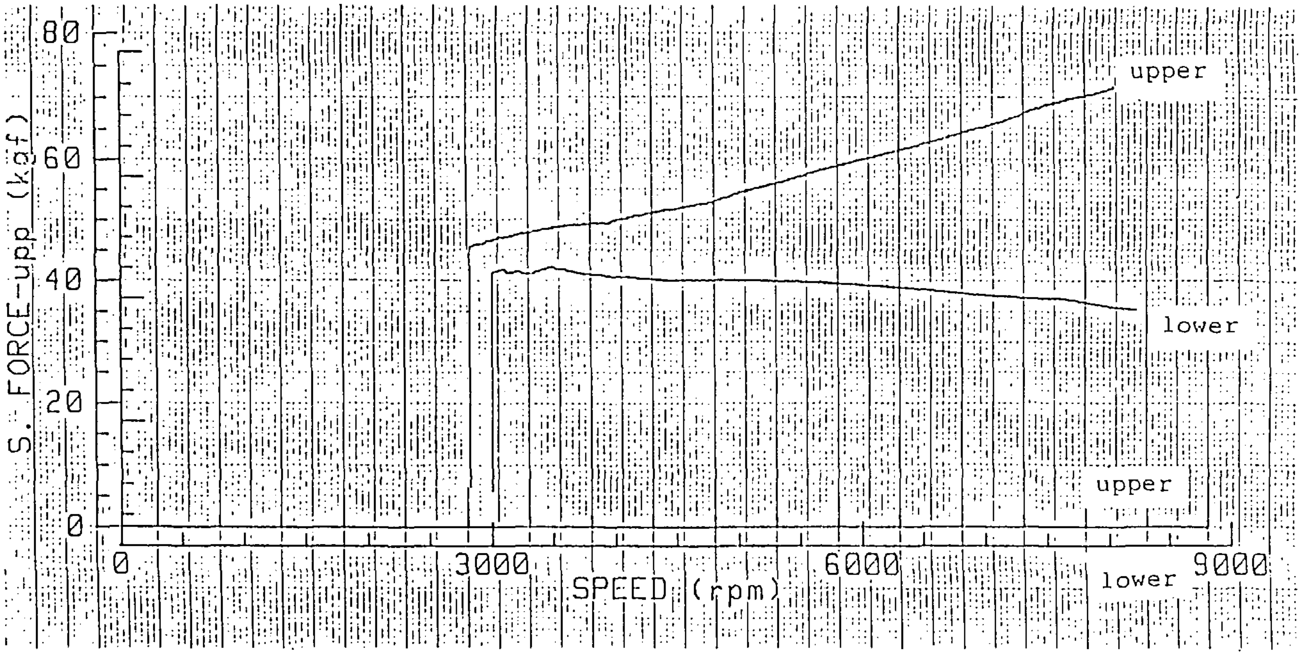


Fig.4a Static Load in Helium of 27deg, 10kg/cm^{2}G
(Δp=0.43kg/cm^2 at 7500rpm)

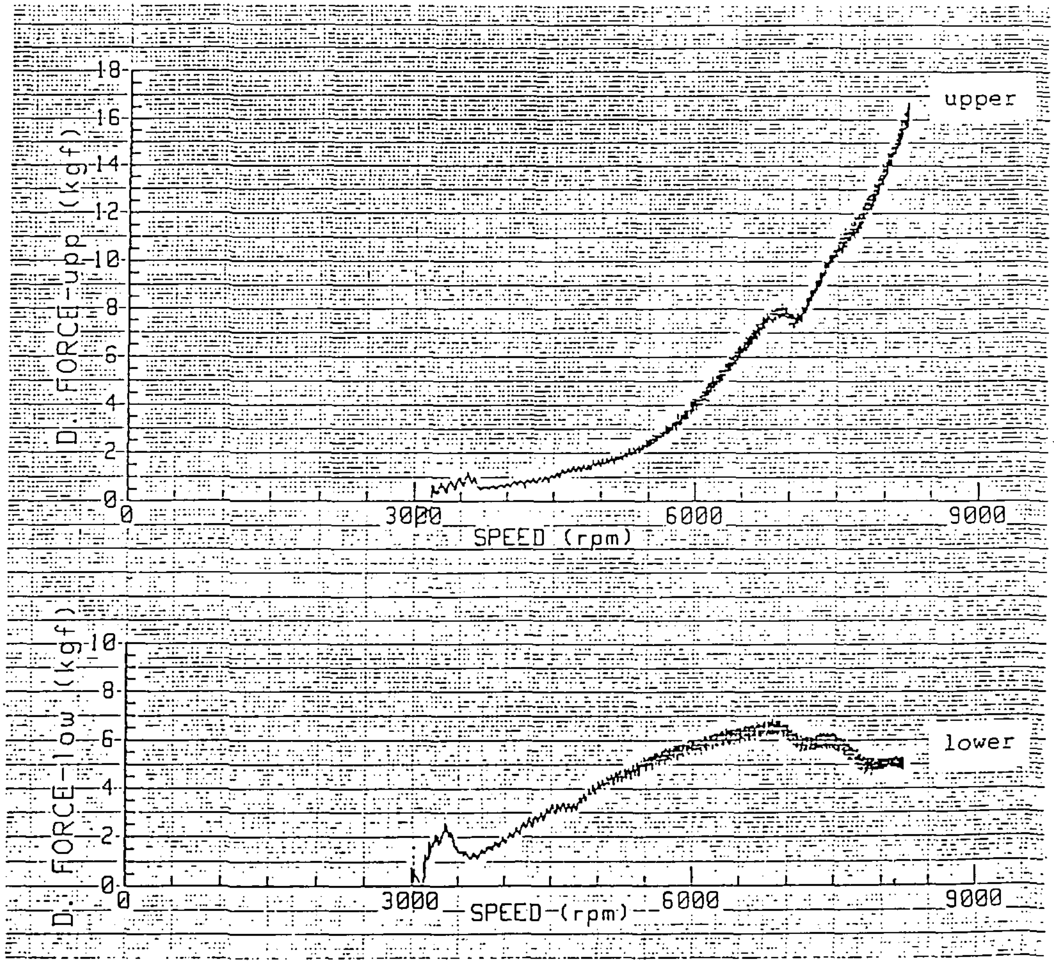


Fig.4b Dynamic Load in Helium of 27deg, 10kg/cm²G
(Δp=0.43kg/cm² at 7500rpm)

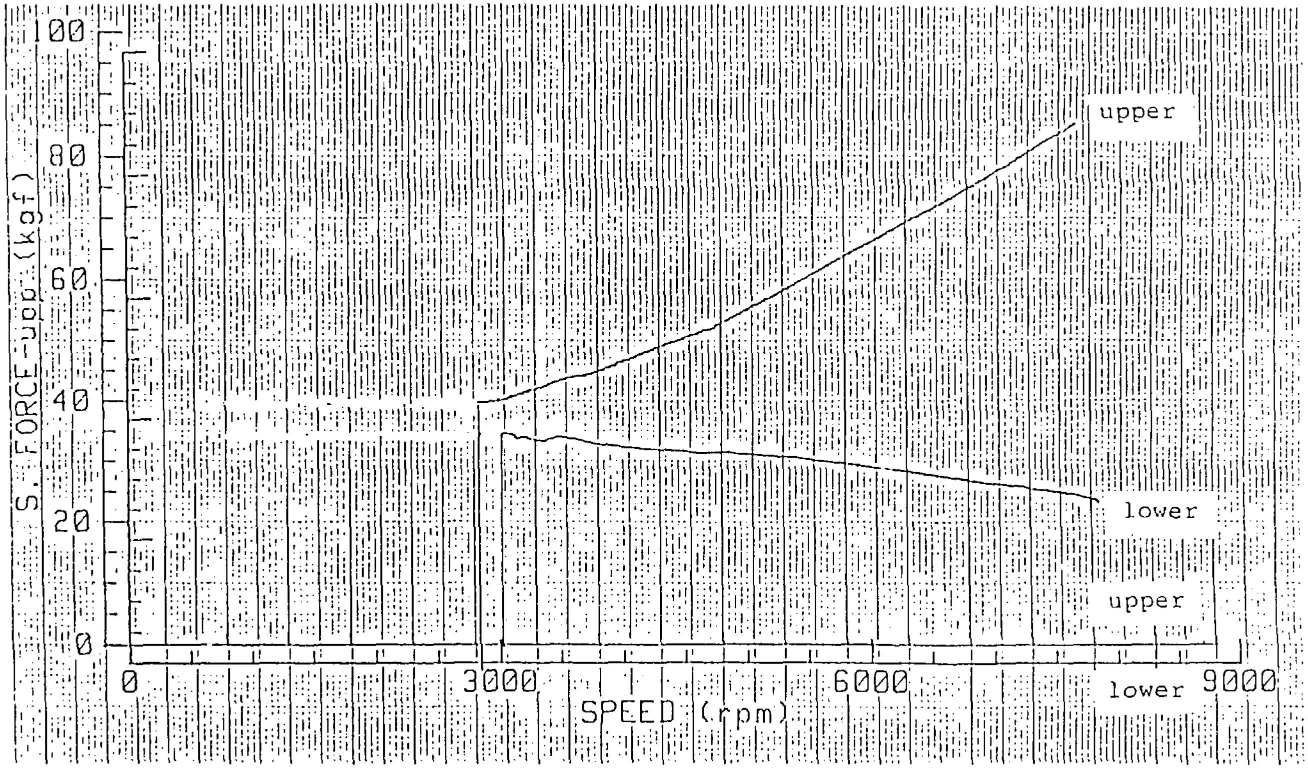


Fig.5a Static Load in Helium of 27deg, 20kg/cm^{2}G
(Δp=0.69kg/cm^2 at 7500rpm)

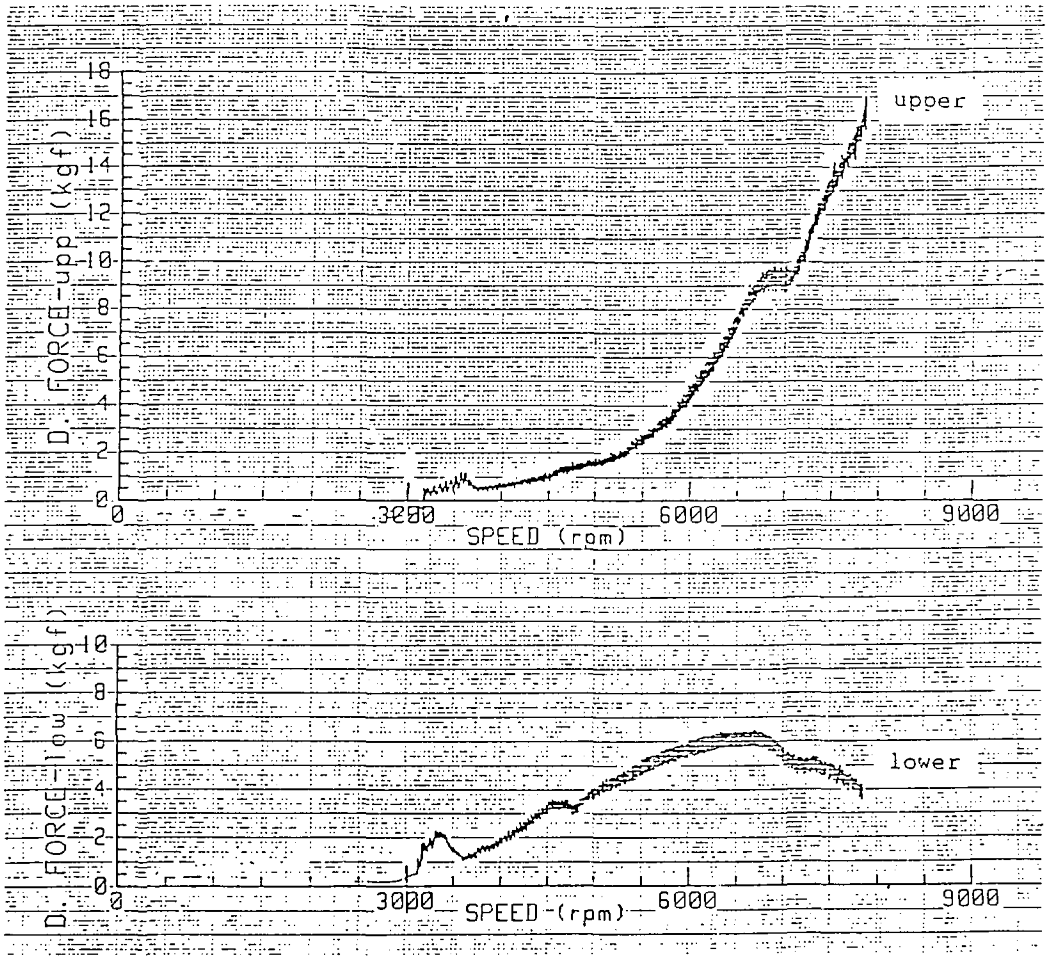


Fig.5b Dynamic Load in Helium of 27deg, 20kg/cm²G
(Δp=0.69kg/cm² at 7500rpm)

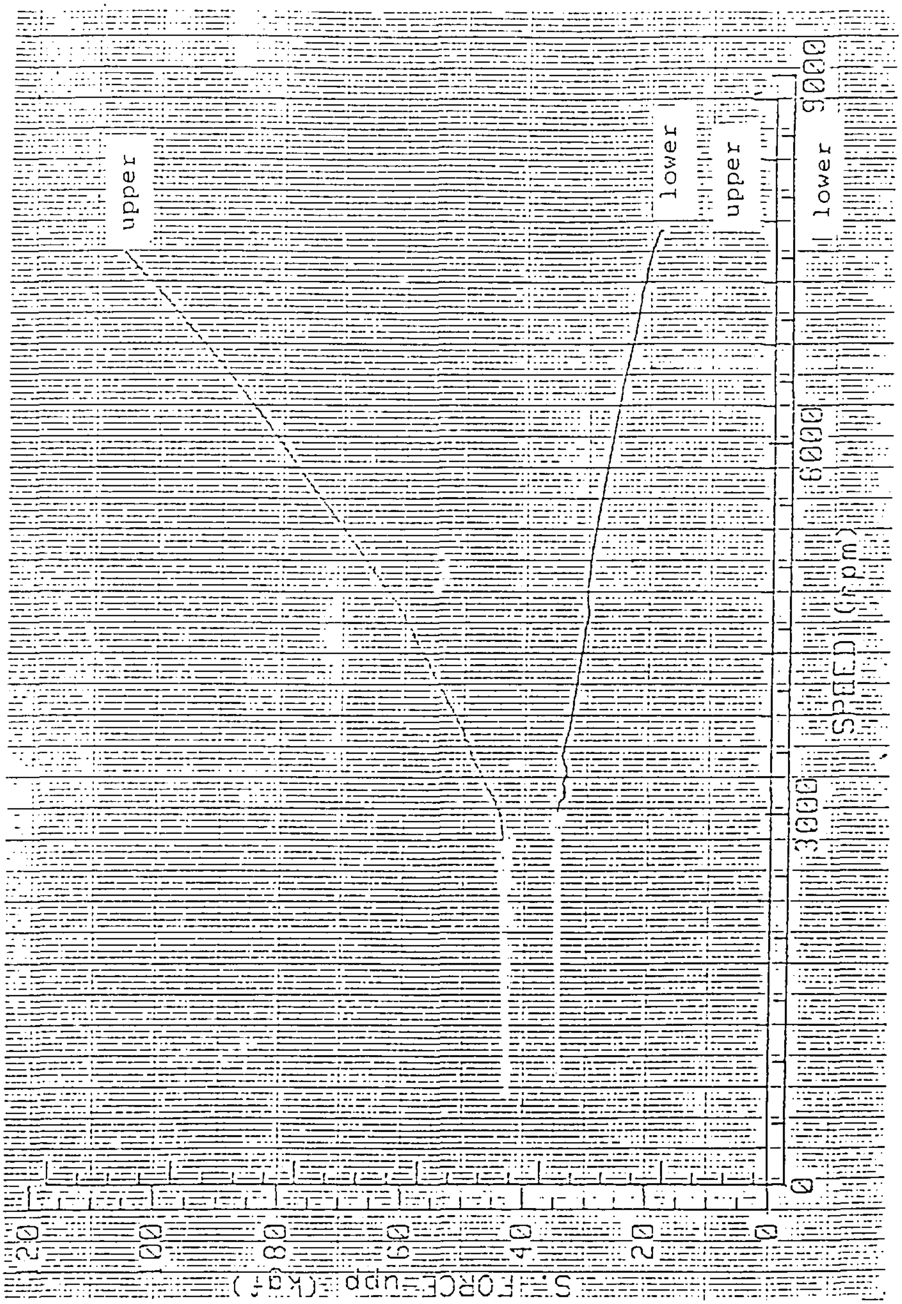


Fig.6a Static Load in Helium of 27deg, 30kg/cm²G
(Δp=0.94kg/cm² at 7500rpm)

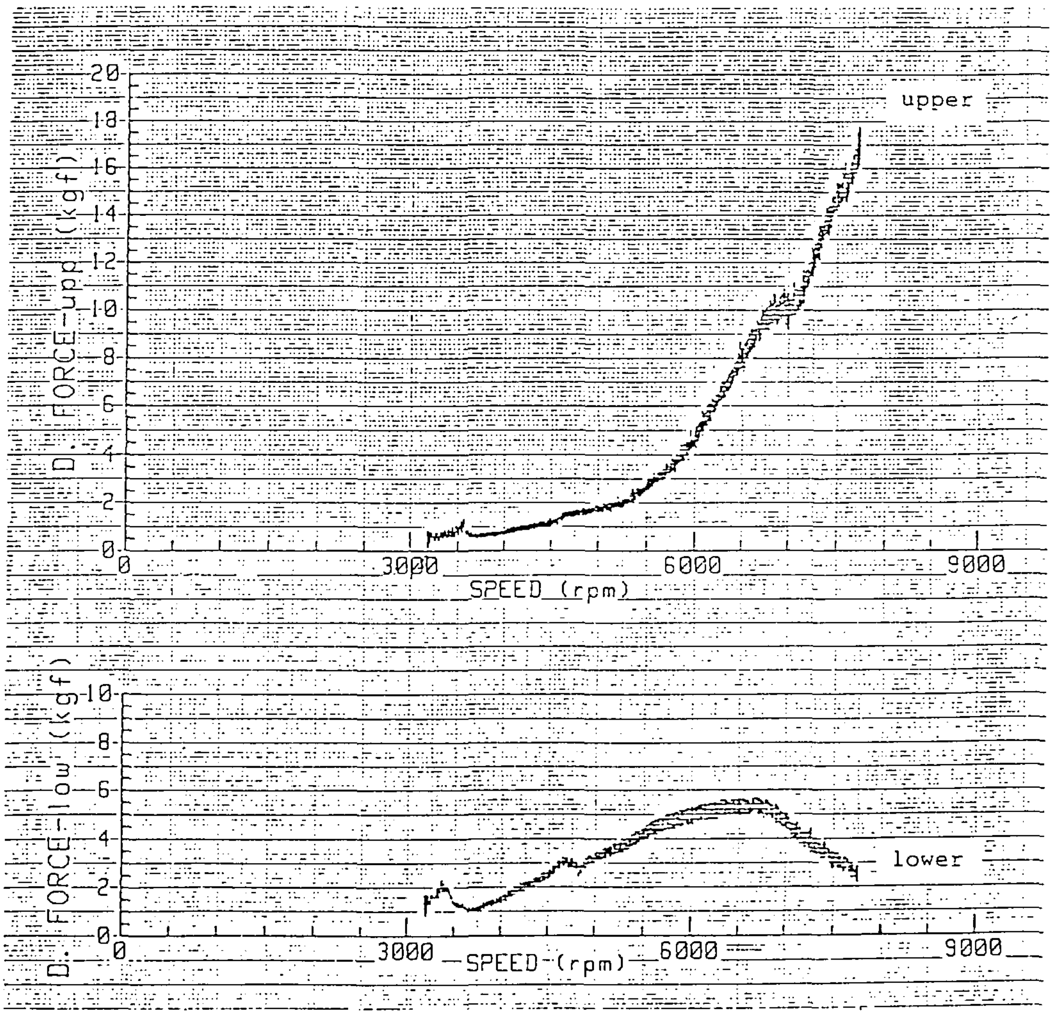


Fig.6b Dynamic Load in Helium of 27deg, 30kg/cm²G
(Δp=0.94kg/cm² at 7500rpm)

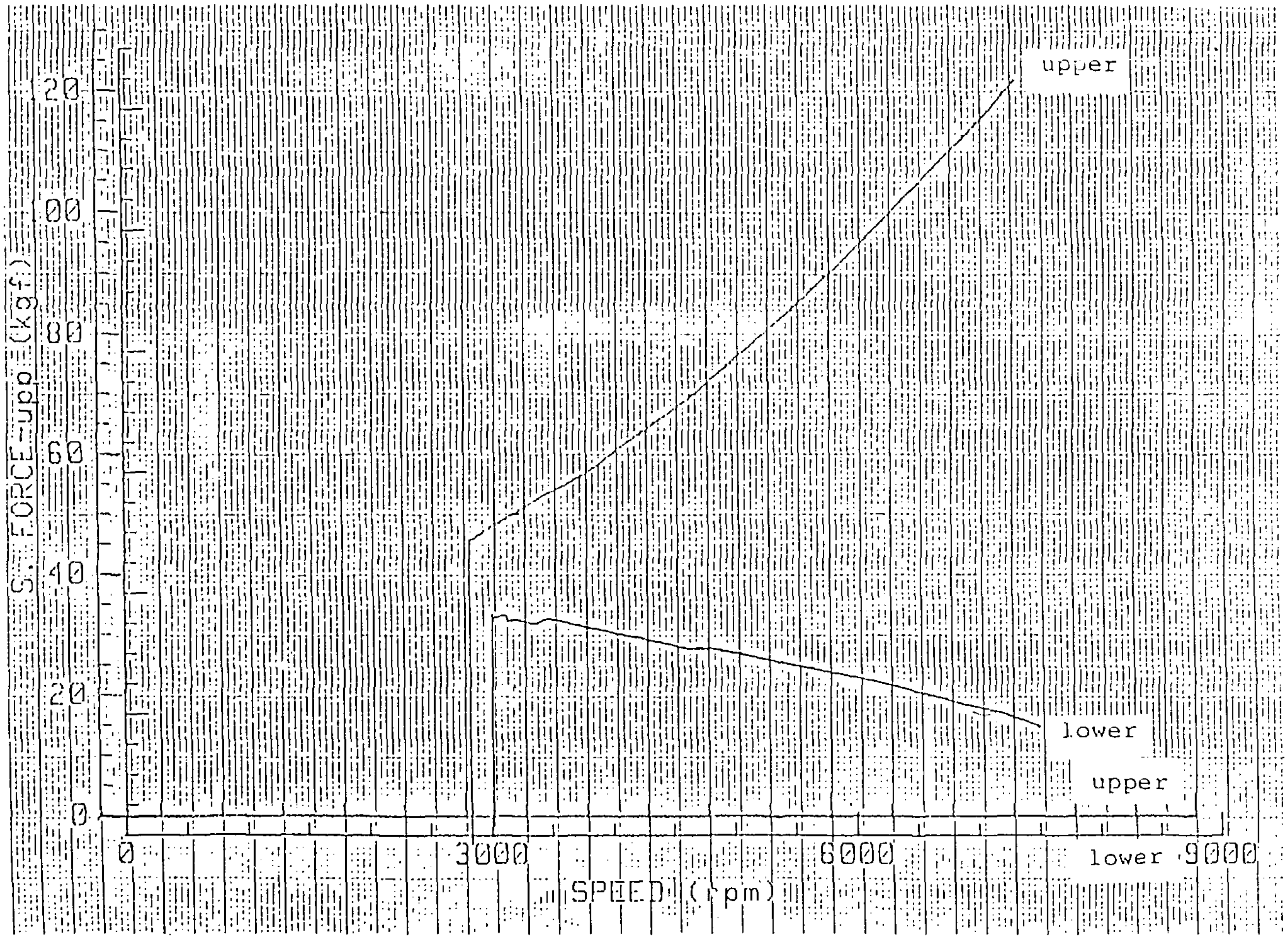


Fig.7a Static Load in Helium of 27deg, 40kg/cm^{2}G
(Δp=1.18kg/cm^2 at 7500rpm)

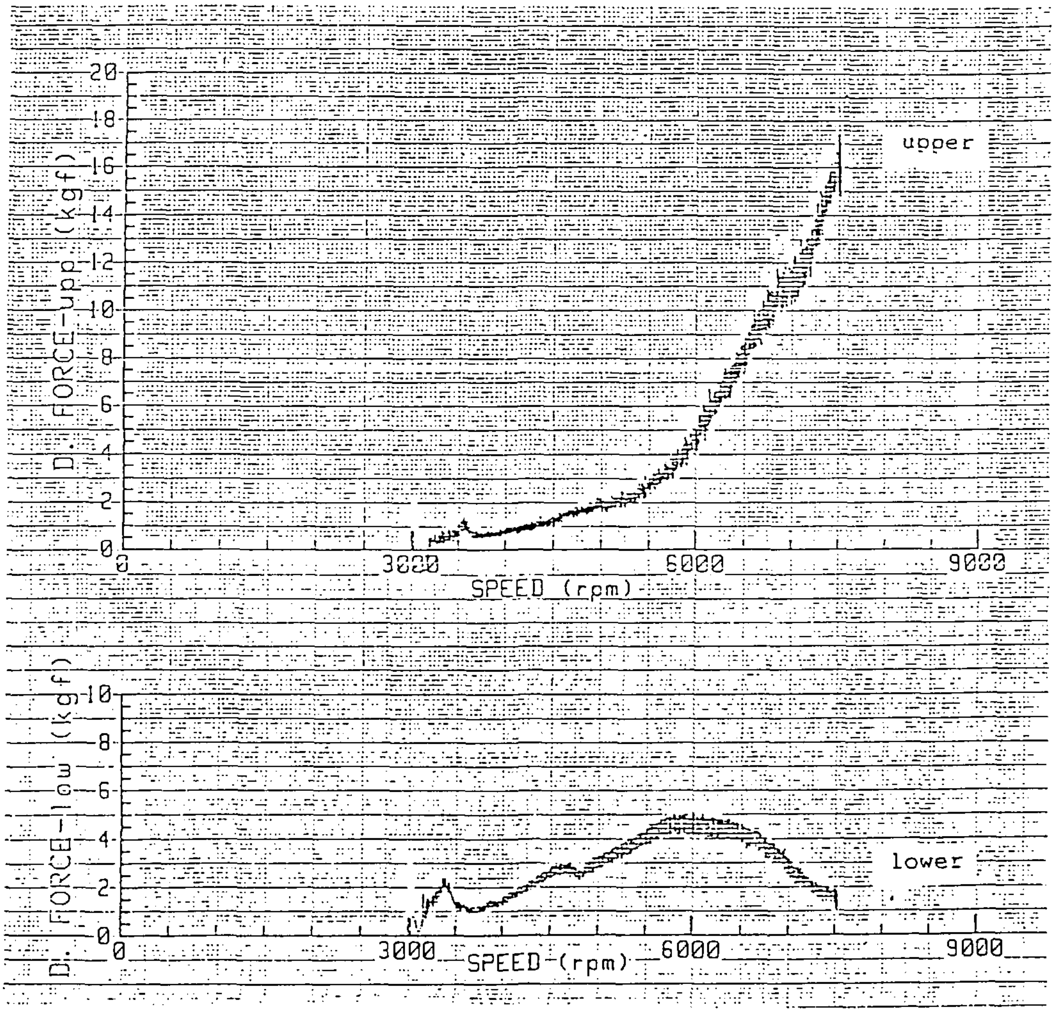


Fig.7b Dynamic Load in Helium of 27deg, 40kg/cm²G
(Δp=1.18kg/cm² at 7500rpm)

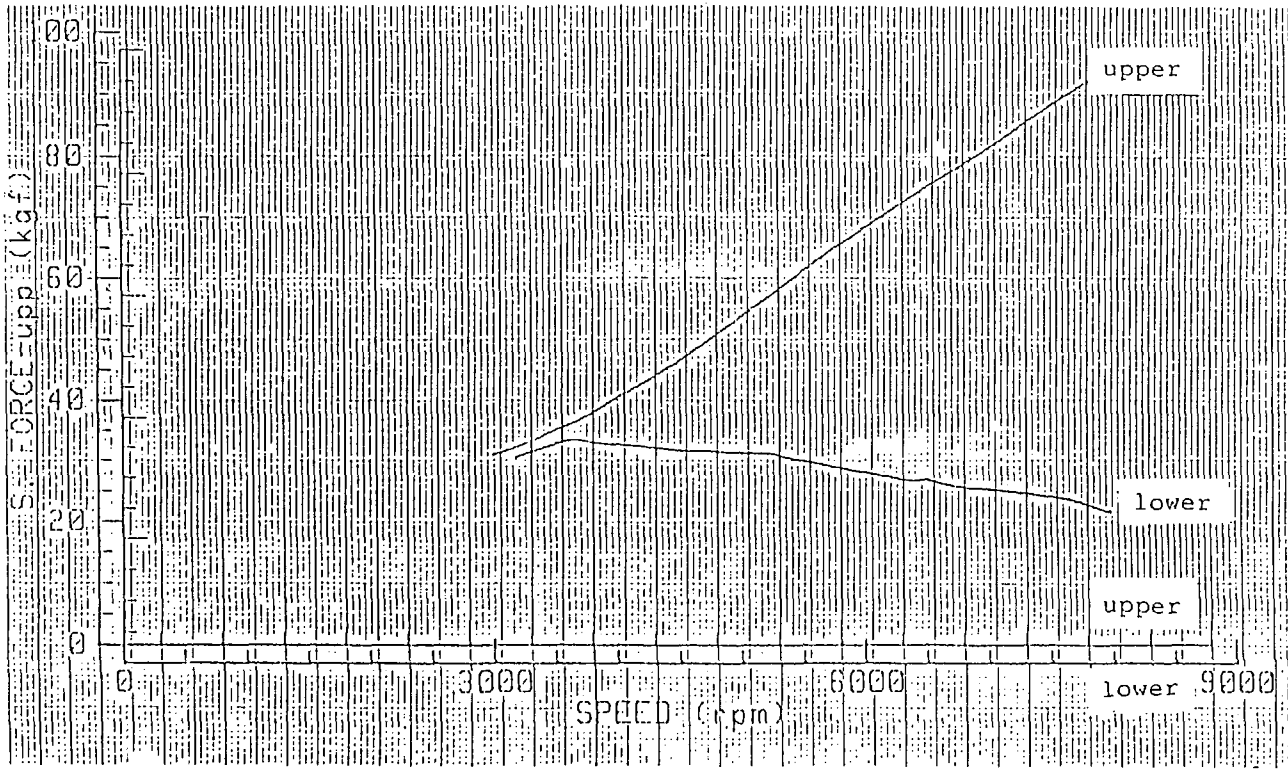


Fig.8a Static Load in Helium of 300deg, 40kg/cm²G
(Δp=0.78kg/cm² at 7500rpm)

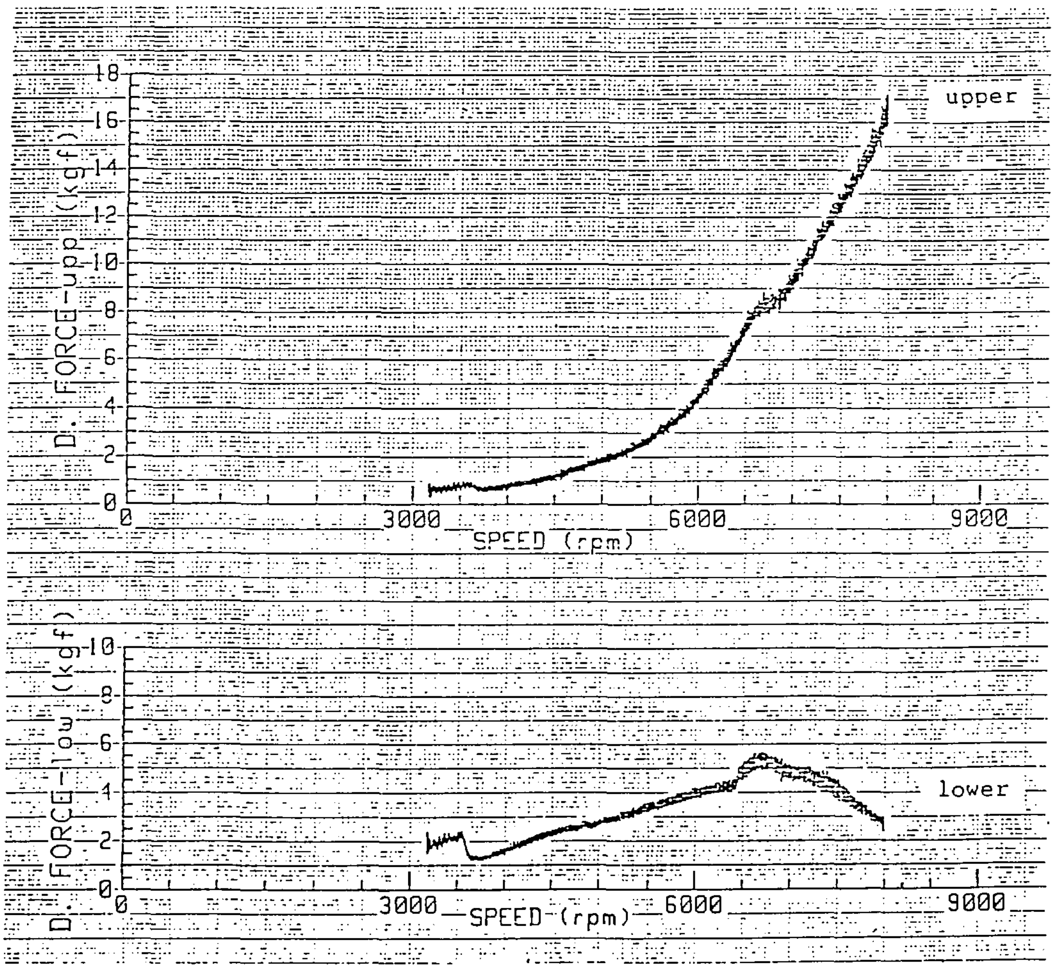


Fig.8b Dynamic Load in Helium of 300deg, 40kg/cm²G
(Δp=0.78kg/cm² at 7500rpm)

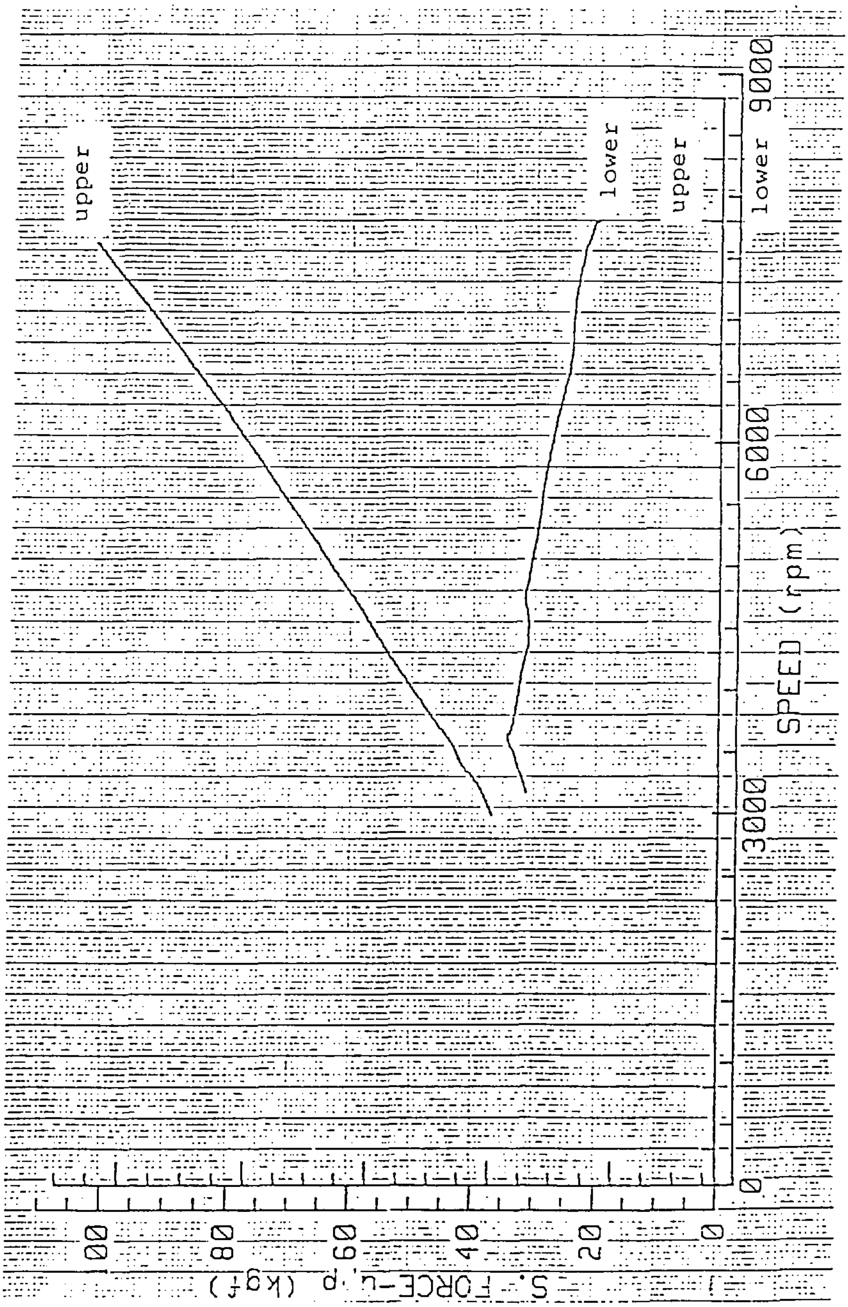


Fig.9a Static Load in Helium of 178deg, 40kg/cm^{2}G
(Δp=0.83kg/cm^2 at 7500rpm)

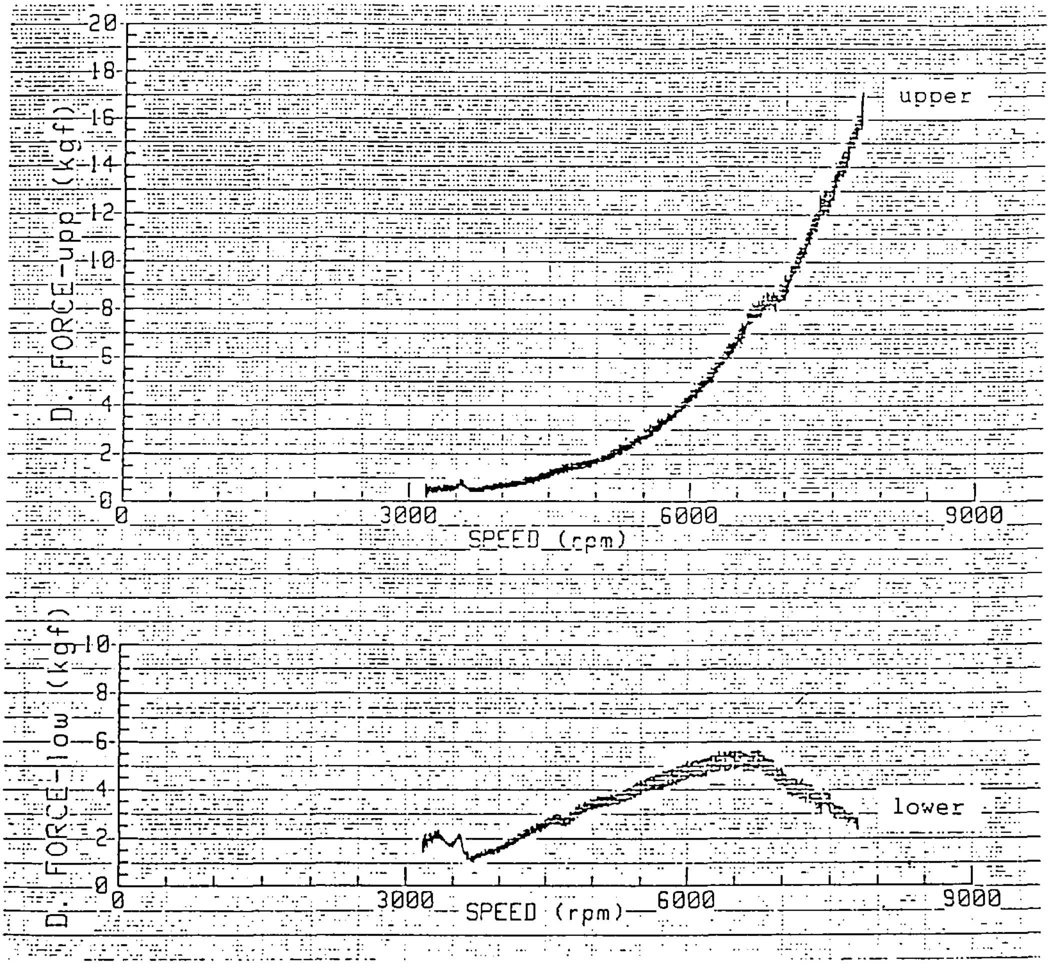


Fig.9b Dynamic Load in Helium of 178deg, $40kg/cm^2G$
($\Delta p=0.83kg/cm^2$ at 7500rpm)

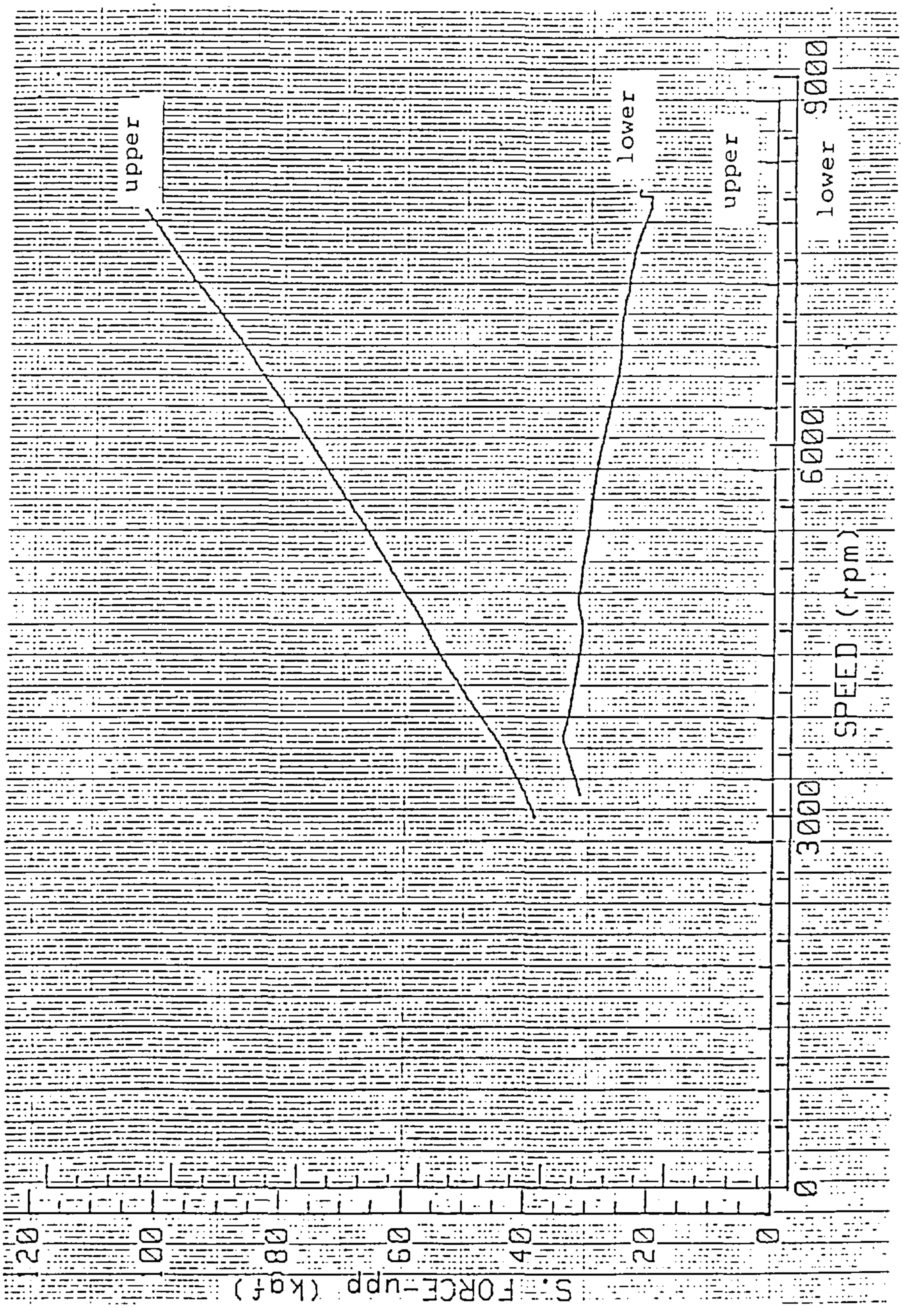


Fig.10a Static Load in Helium of 178deg, 40kg/cm^{2}G
(Δp=1.13kg/cm^2 at 7500rpm)

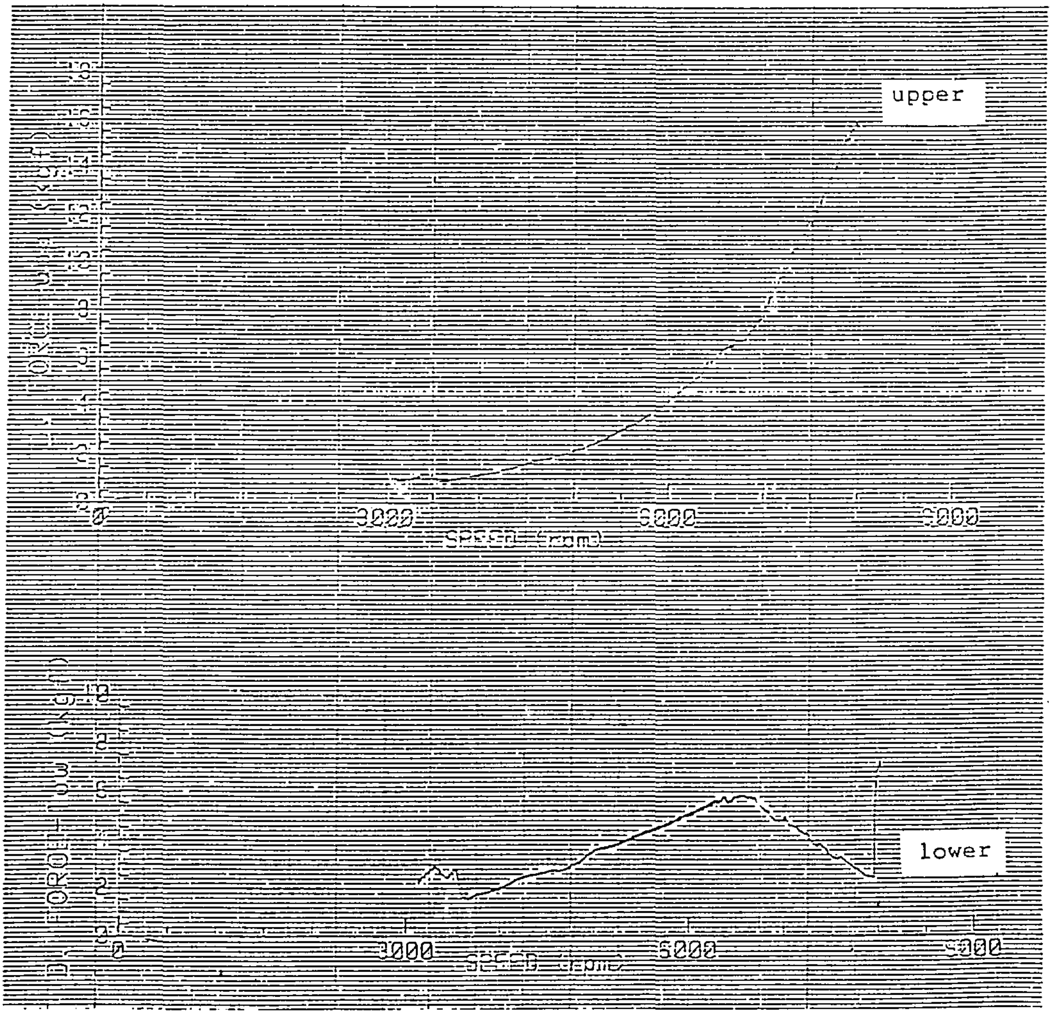


Fig.10b Dynamic Load in Helium of 178deg, 40kg/cm^{2}G
(Δp=1.13kg/cm^2 at 7500rpm)

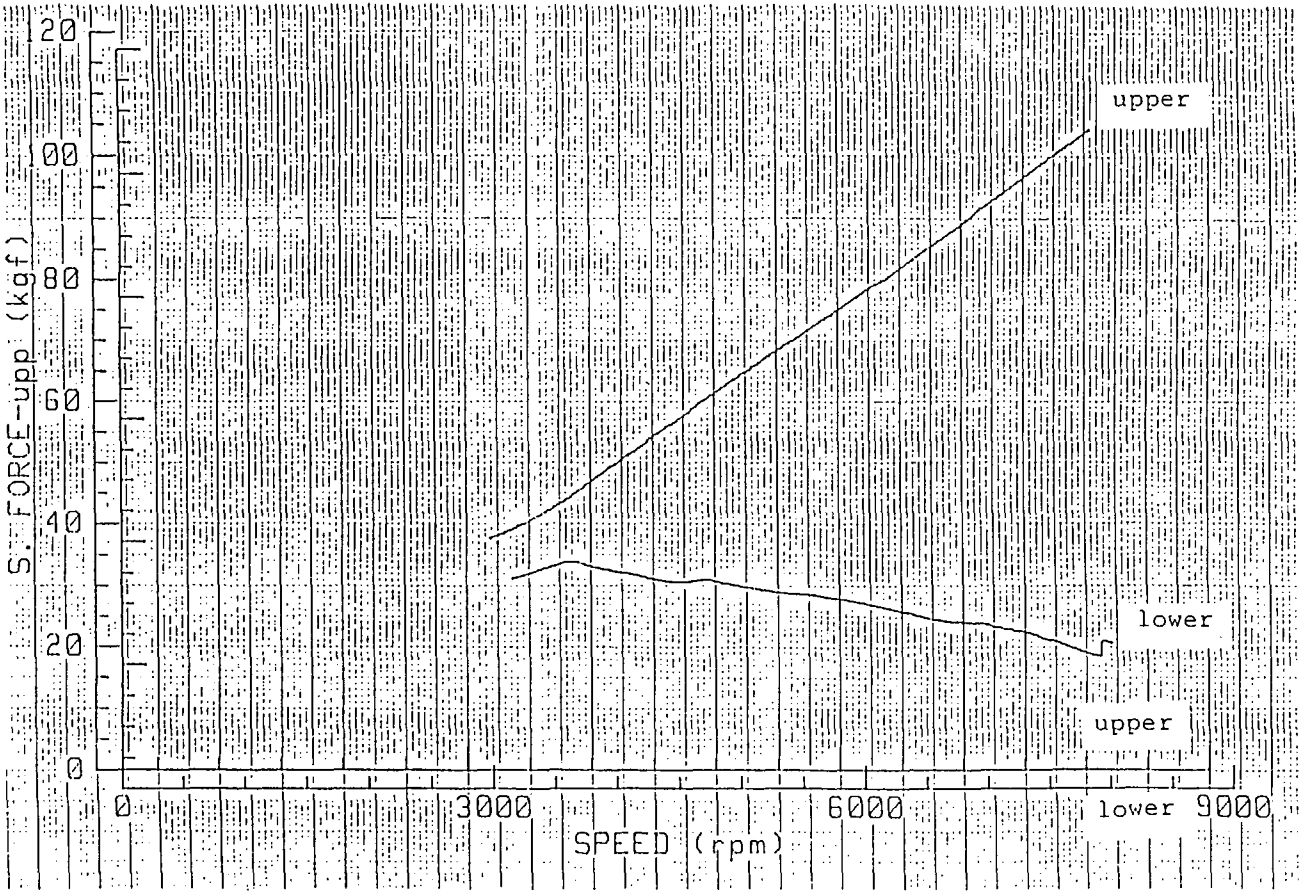


Fig.11a Static Load in Helium of 178deg, 40kg/cm^{2}G
(Δp=1.28kg/cm^2 at 7500rpm)

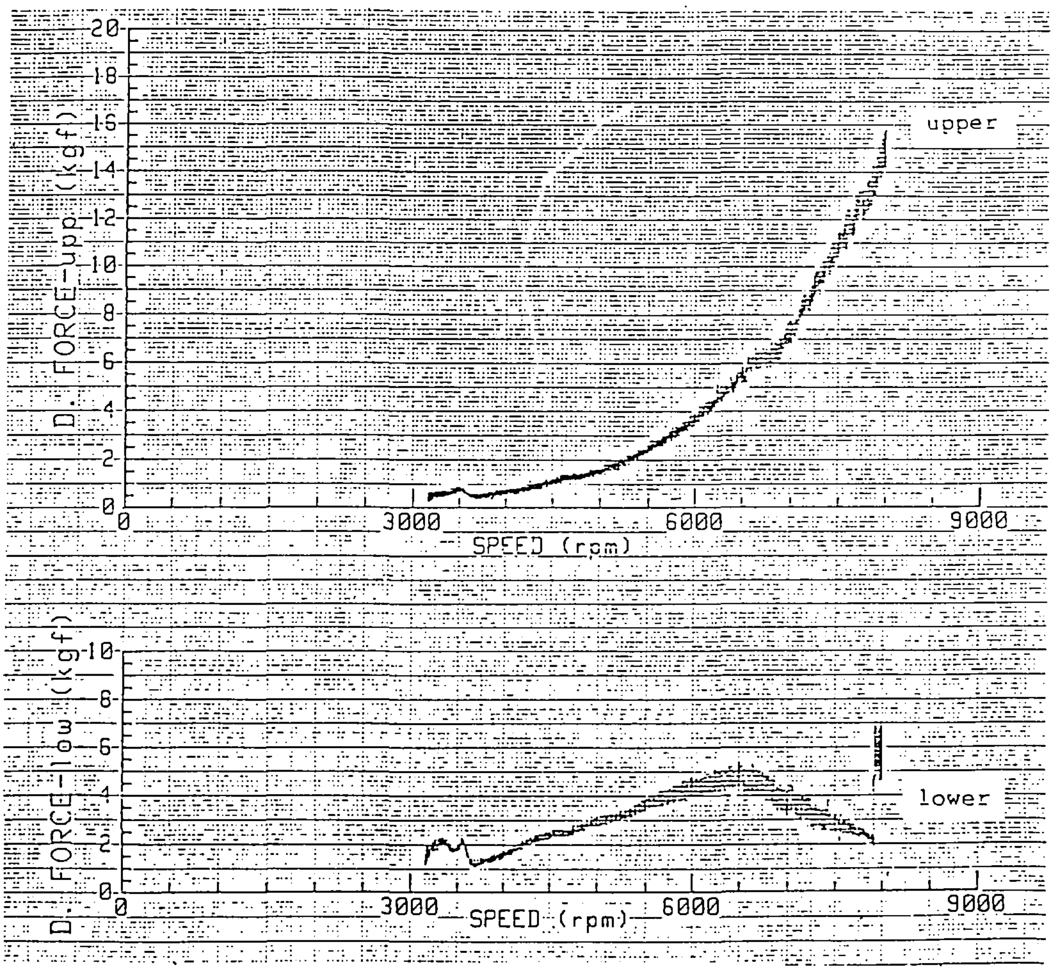


Fig.11b Dynamic Load in Helium of 178deg, 40kg/cm²G
(Δp=1.28kg/cm² at 7500rpm)

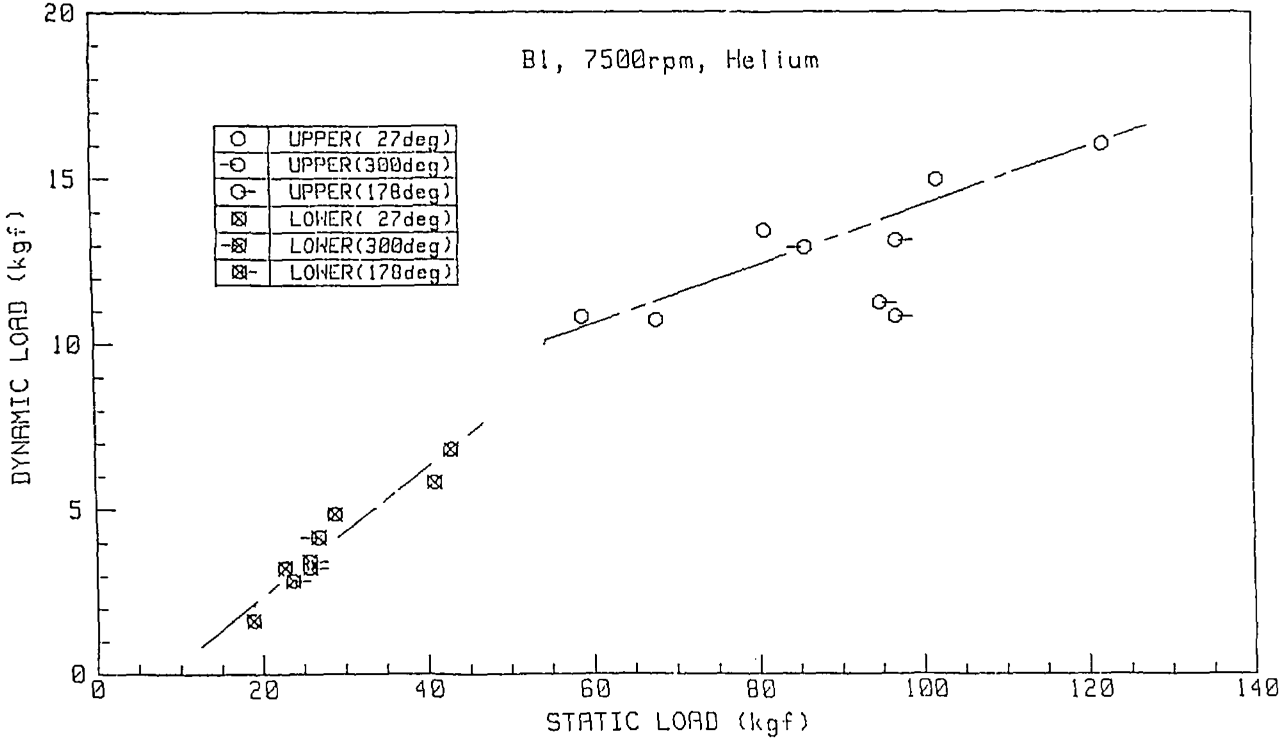


Fig.12 Correlation of Static Load vs. Dynamic Load for Upper and Lower Bearing

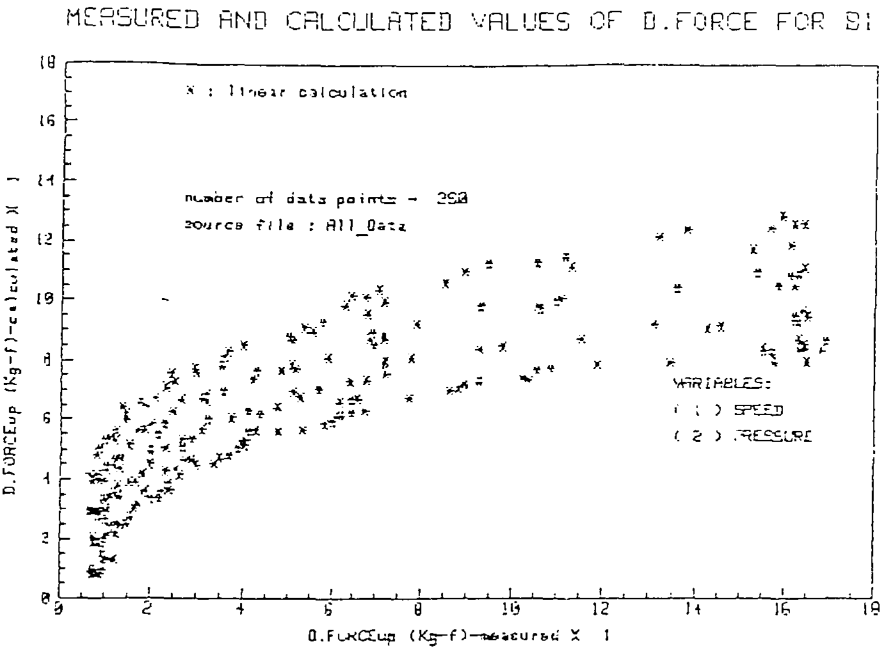


Fig.13 Correlation of Measured Values vs. Calculated Values for Dynamic Load in Upper Bearing in Case of 2 Parameters

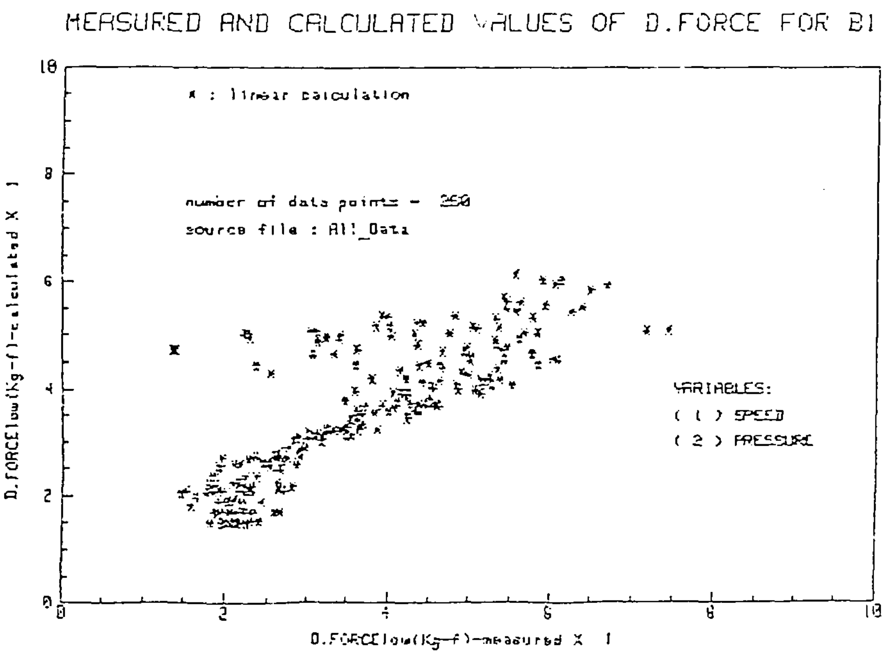


Fig.14 Correlation of Measured Values vs. Calculated Values for Dynamic Load in Lower Bearing in Case of 2 Parameters

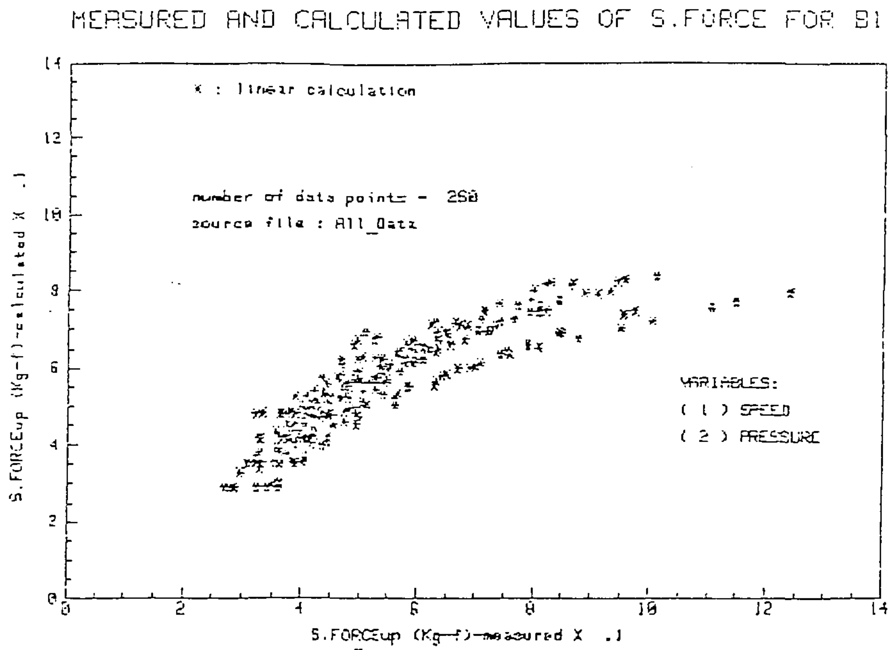


Fig.15 Correlation of Measured Values vs. Calculated Values for Static Load in Upper Bearing in Case of 2 Parameters

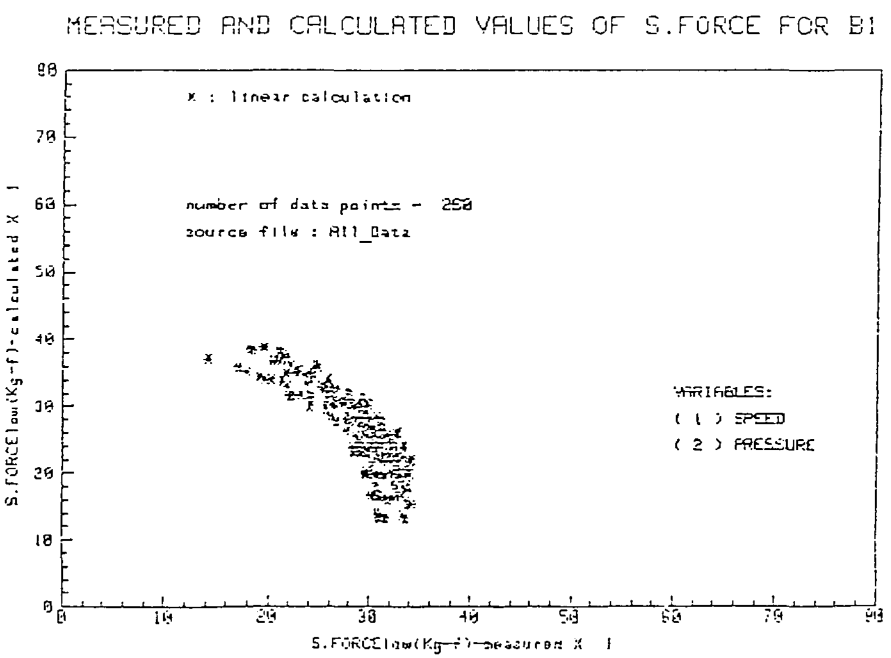


Fig.16 Correlation of Measured Values vs. Calculated Values for Static Load in Lower Bearing in Case of 2 Parameters

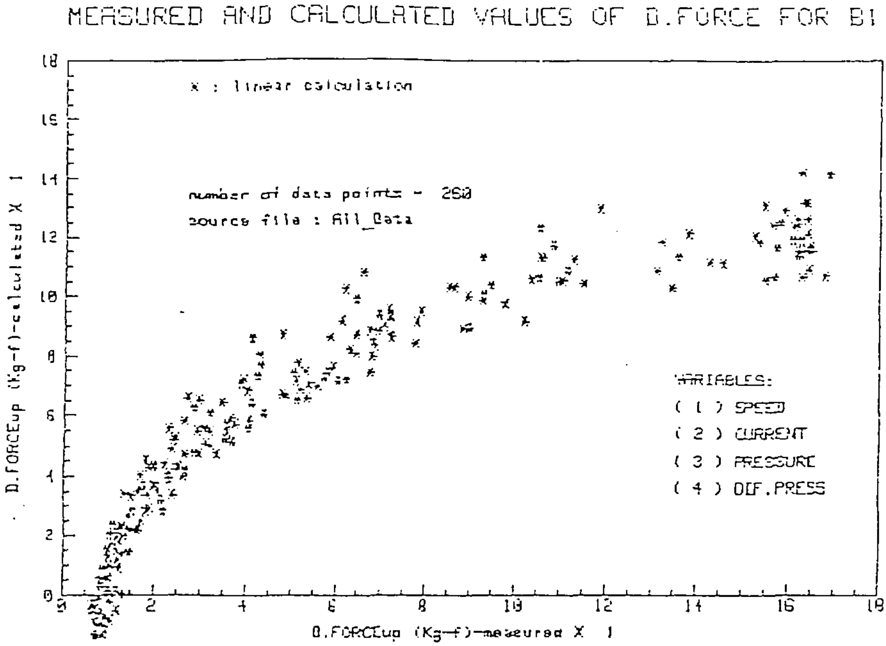


Fig.17 Correlation of Measured Values vs. Calculated Values for Dynamic Load in Upper Bearing in Case of 4 Parameters

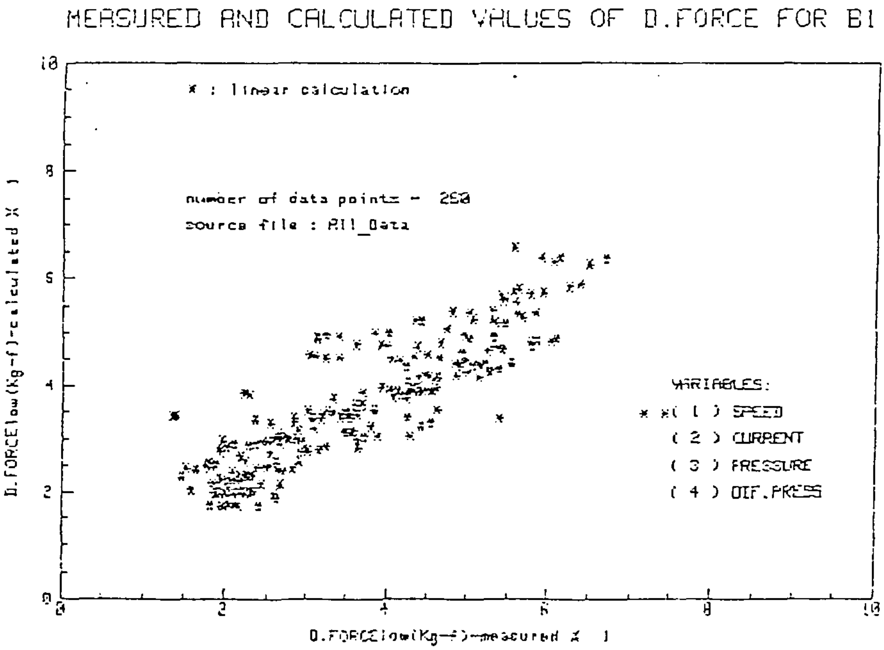


Fig.18 Correlation of Measured Values vs. Calculated Values for Dynamic Load in Lower Bearing in Case of 4 Parameters

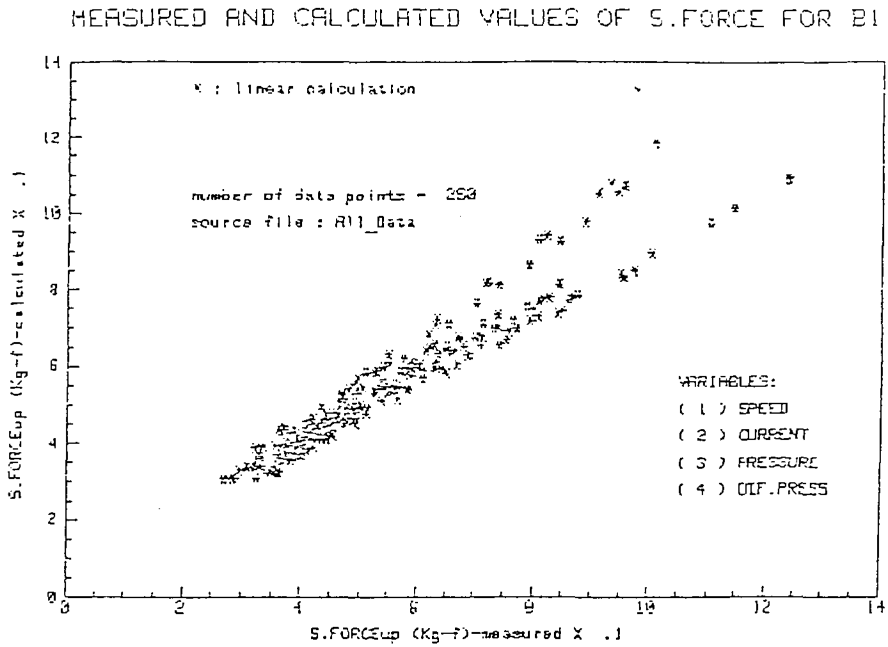


Fig.19 Correlation of Measured Values vs. Calculated Values for Static Load in Upper Bearing in Case of 4 Parameters

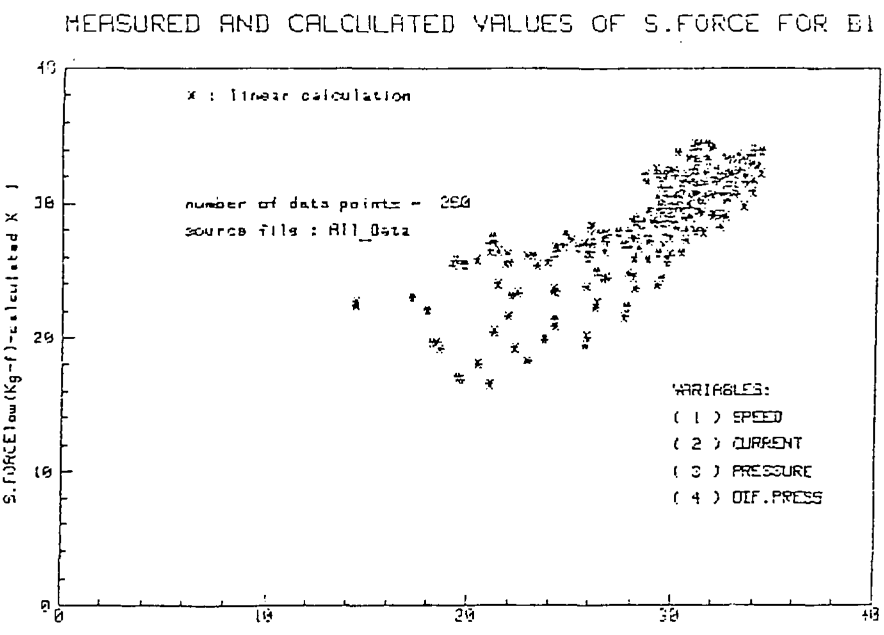


Fig.20 Correlation of Measured Values vs. Calculated Values for Static Load in Lower Bearing in Case of 4 Parameters

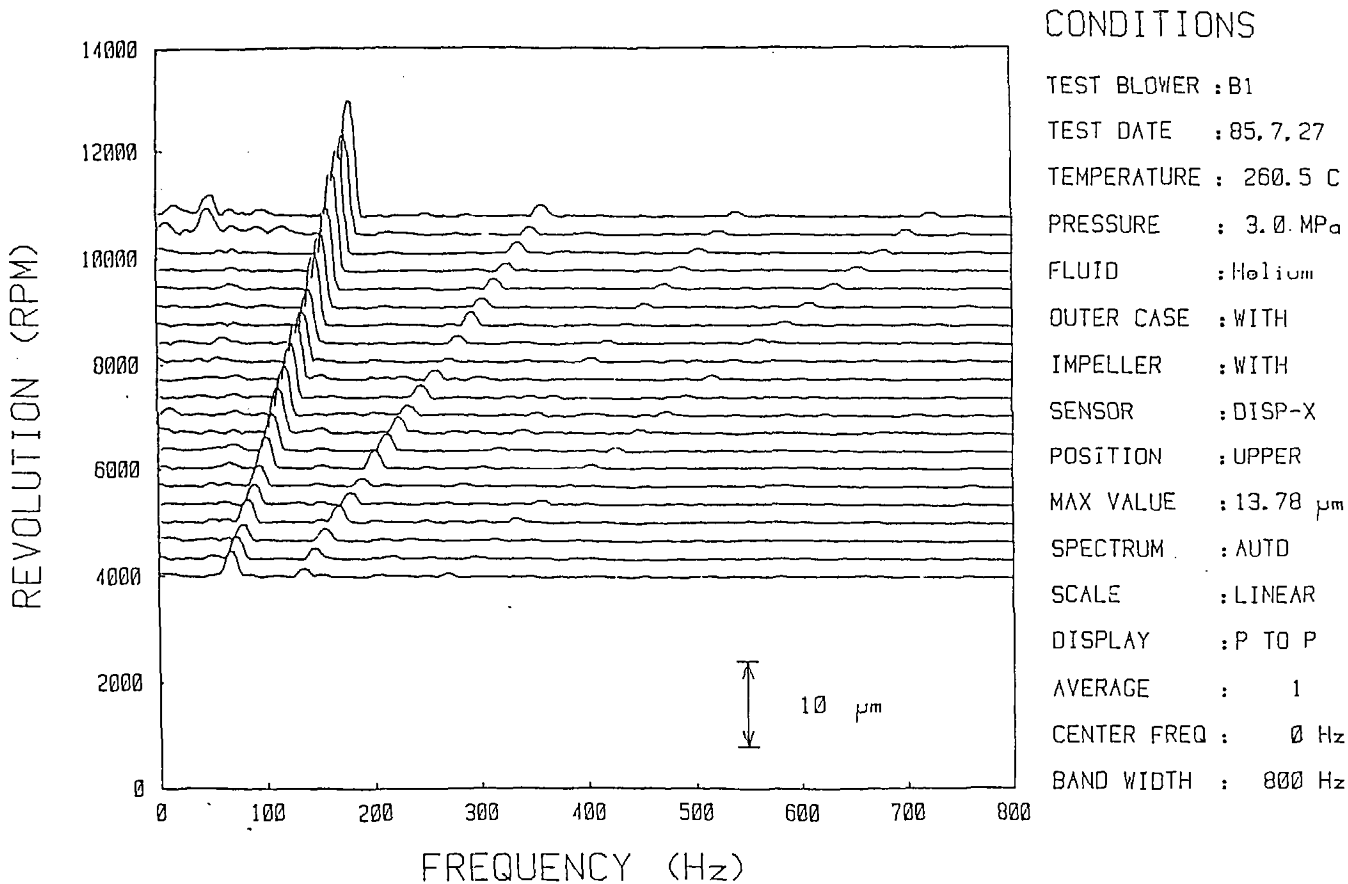


Fig.21 Spectral Map of Shaft Displacement at Upper Bearing in Helium Test for Diametral Bearing Gap C_b=0.02mm

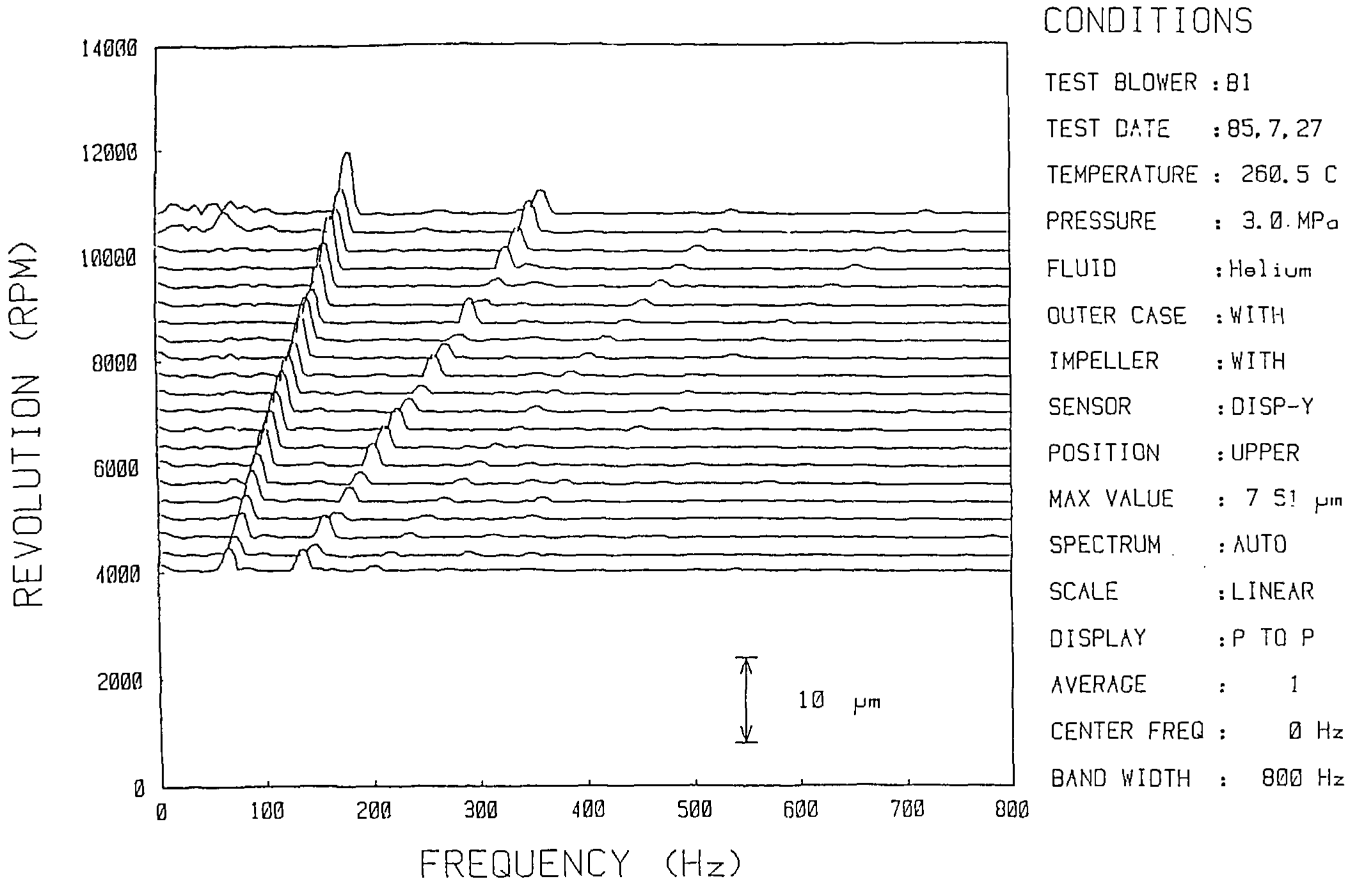
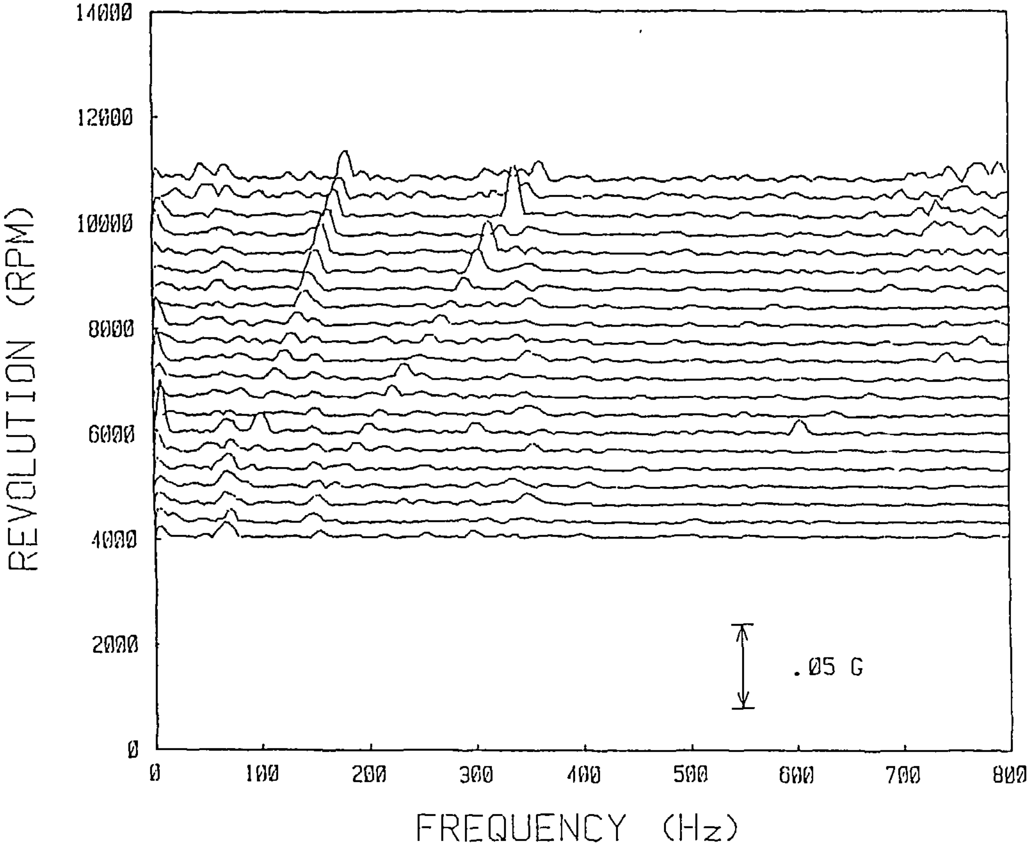


Fig.22 Spectral Map of Shaft Displacement at Upper Bearing in Helium Test for Diametral Bearing Gap C_b=0.02mm



CONDITIONS

TEST BLOWER : B1
TEST DATE : 85, 7, 27
TEMPERATURE : 260.5 C
PRESSURE : 3.0 MPa
FLUID : Helium
OUTER CASE : WITH
IMPELLER : WITH
SENSOR : ACCEL
POSITION : UPPER
MAX VALUE : .03 G
SPECTRUM : AUTO
SCALE : LINEAR
DISPLAY : PEAK
AVERAGE : 1
CENTER FREQ : 0 Hz
BAND WIDTH : 800 Hz

Fig.23 Spectral Map of Casing Acceleration at Upper Bearing Level in Helium Test for Diametral Bearing Gap C_b=0.02mm

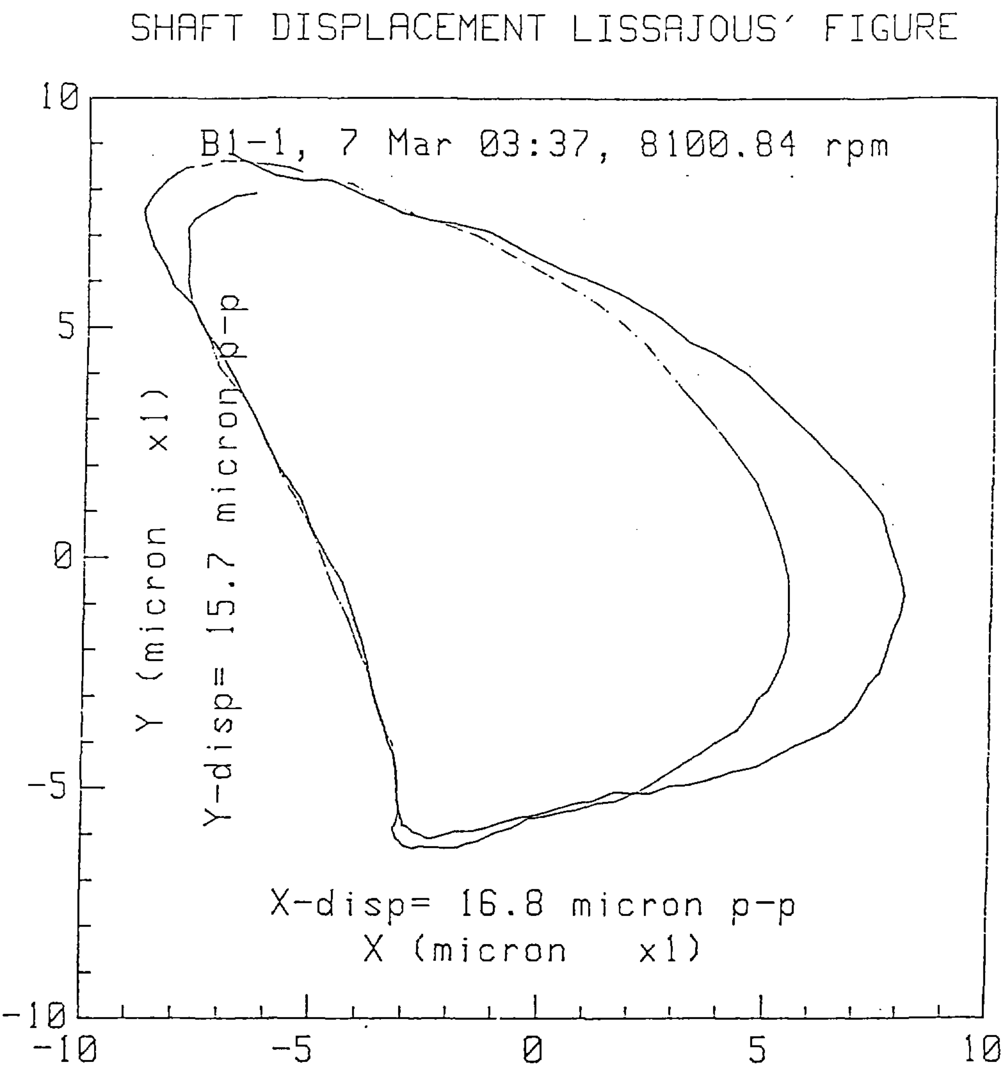


Fig.24 Lissajous' Figure of Shaft Displacement at Upper Bearing Level in Helium of 199deg, 40kg/cm²G (C_b=0.02mm)

Table 4.1 Test Conditions for Static and Dynamic Loads at Specified Speed

Fig. No.	Gas	Temp. (deg)	Pressure (kg/cm²G)	Dif.Press. (kg/cm²)	STATIC LOAD (kgf)				D.LOAD(kgf)	
					UPPER		LOWER		UP.	LOW.
					7500 rpm	3500 rpm	7500 rpm	3500 rpm	7500 rpm	7500 rpm
1a,b	air	R.T.	-	-	60	47	44	47	18.5	11.0
2a,b	air	R.T.	-	-	58	46	43	43	13.6	9.1
3a,b	He	27	5.4	0.256	59	47	43	46	10.8	6.8
4a,b	He	27	10.0	0.429	68	48	41	46	10.7	5.8
5a,b	He	27	20.0	0.694	81	43	29	33	13.4	4.8
6a,b	He	27	30.0	0.955	102	47	23	37	14.9	3.2
7a,b	He	27	40.0	1.18	122	51	19	36	16.0	1.6
8a,b	He	300	40.0	0.779	86	33	27	35	12.9	4.1
9a,b	He	178	40.0	0.831	97	40	26	37	13.1	3.4
10a,b	He	178	40.0	1.13	95	41	26	36	11.2	3.2
11a,b	He	178	40.0	1.28	97	40	24	36	10.8	2.8

Table 4.2 Correlated Linear Coefficients for Bearing Loads

FUNCTION (LOAD) (kgf)	COEFFICIENTS FOR NORMALIZED VARIABLES			
	speed(rpm) / 12000	current(A) / 300	pressure *) (MPa) / 4.0	dif. press (MPa) / 0.2
dynamic (upper)	26.70	-19.82	-1.221	15.24
dynamic (lower)	9.938	-0.4380	-0.3411	-3.672
static (upper)	39.57	45.85	7.594	73.79
static (lower)	0.08433	91.81	-1.547	-62.10

*) guage pressure

APPENDIX

SOURCE DATA OF TEST ON B_1 CIRCULATOR

DATE OF TEST: NOVEMBER 20-22, 1985

Symbols in List

SPEED : Revolution Speed (rpm)

CURRE : Electric Current (A)

Tg-in : Inlet Helium Temperature (deg-C)

PRESS : Helium Pressure (kg/cm^2G)

DIF.P : Differential Pressure (kg/cm^2)

D.FORu : Dynamic Load of Upper Bearing (kgf)

D.FORl : Dynamic Load of Lower Bearing (kgf)

S.FORu : Static Load of Upper Bearing (kgf)

S.FORl : Static Load of Lower Bearing (kgf)

FLOW : Flow Rate of Helium (kg/s)

Tgout : Outlet Helium Temperature (deg-C)

Tmot : Temperature of Motor Winding (deg-C)

Tj.lo : Temperature of Lower Journal Bearing Pad (deg-C)

Tj.up : Temperature of Upper Journal Bearing Pad (deg-C)

No	SPEED (rpm)	CURRE (A)	Tg-in (deg)	PRESS (atg)	DIF.P (ata)	D.FORu (kgf)	D.FORl (kgf)	S.FORu (kgf)	S.FORl (kgf)
1	3157.0	116.0	13.9	9.8	.06	.87	1.94	34.27	33.63
2	3272.5	116.0	13.5	9.8	.06	.68	2.32	35.10	33.43
3	3993.5	118.1	13.9	9.8	.10	1.02	2.28	38.79	33.77
4	4700.5	118.8	13.9	9.8	.14	1.39	3.43	41.75	33.92
5	5418.0	121.1	13.9	9.8	.19	2.46	4.44	45.64	33.82
6	6030.5	122.2	14.2	9.7	.24	4.06	5.39	48.92	33.41
7	6681.5	125.1	13.7	9.7	.29	6.82	5.79	52.78	32.54
8	7350.0	127.4	13.9	9.6	.35	8.52	5.35	57.09	31.44
9	8043.0	132.0	14.2	9.6	.42	15.27	5.46	61.50	28.80
10	8127.0	131.5	13.6	9.6	.43	16.12	5.42	62.07	28.29
11	7665.0	127.7	13.8	9.6	.38	11.29	4.81	59.46	29.47
12	6937.0	125.5	14.2	9.6	.32	7.18	5.32	54.35	30.82
13	6219.5	121.7	13.6	9.7	.25	5.07	4.91	50.52	31.95
14	5505.5	120.4	13.6	9.7	.20	2.97	4.26	47.39	32.57
15	4777.5	118.0	13.5	9.7	.15	1.79	3.51	44.54	32.62
16	4042.5	117.9	13.9	9.8	.10	1.13	2.37	40.25	32.08
17	3262.0	114.8	14.0	9.9	.06	.86	2.28	36.38	31.02
18	3146.5	116.5	13.8	9.9	.06	.74	1.97	36.17	31.59
19	3150.0	117.8	15.1	19.7	.11	.67	2.03	38.78	32.18
20	3391.5	118.7	15.7	19.7	.13	.98	2.23	40.60	33.56
21	4102.0	122.0	15.4	19.6	.20	1.06	2.18	44.65	32.69
22	4840.5	125.4	15.7	19.6	.28	1.73	2.91	49.93	31.85
23	5505.5	130.7	15.7	19.6	.37	2.69	3.63	56.22	31.06
24	6139.0	133.3	15.2	19.5	.46	4.34	4.53	63.25	29.67
25	6804.0	140.2	15.4	19.5	.56	7.18	5.01	70.80	27.77
26	7458.5	148.4	15.7	19.5	.67	10.56	4.33	79.05	25.78
27	7899.5	155.2	15.7	19.4	.76	16.20	3.93	84.43	22.38
28	7896.0	155.0	15.7	19.4	.76	15.83	3.99	84.53	22.05
29	7409.5	147.6	16.0	19.5	.68	10.62	4.04	79.01	24.15
30	6692.0	138.7	15.7	19.5	.56	6.96	4.64	70.06	26.78
31	5967.5	131.3	15.7	19.6	.44	4.26	4.07	62.97	28.75
32	5243.0	126.5	15.9	19.6	.34	2.50	3.54	56.16	29.81
33	4536.0	122.6	15.8	19.7	.25	1.55	2.94	49.53	30.47
34	3794.0	119.5	16.3	19.7	.17	1.04	1.85	43.65	30.80
35	3157.0	117.3	16.3	19.7	.11	.81	1.92	38.99	30.62
36	3157.0	117.8	15.9	19.7	.12	.71	2.06	38.88	30.95
37	3153.5	118.2	17.7	29.8	.11	.86	1.88	41.09	31.49
38	3150.0	118.3	17.2	29.9	.11	.84	1.91	41.09	31.49
39	3636.5	119.8	17.7	29.9	.16	1.02	1.49	45.50	33.04
40	4350.5	124.8	17.8	29.9	.23	1.31	2.54	51.21	31.16
41	5075.0	128.3	17.7	29.7	.32	2.03	3.10	58.54	30.13
42	5736.5	134.7	17.8	29.6	.41	3.26	3.84	66.94	28.73
43	6356.0	141.3	17.7	29.5	.51	5.16	4.57	75.44	26.64
44	7007.0	151.8	17.7	29.5	.61	7.21	4.49	84.87	24.20
45	7700.0	163.4	18.3	29.4	.75	14.57	3.41	95.57	20.38
46	7805.0	165.0	18.6	29.4	.77	16.28	3.11	97.38	19.18
47	7812.0	164.9	19.4	29.4	.76	16.22	3.04	97.29	19.30
48	7668.5	162.0	19.7	29.4	.74	14.26	3.24	95.43	19.74
49	6947.5	148.8	20.1	29.5	.62	7.19	4.39	84.24	23.28
50	6237.0	139.4	20.7	29.5	.49	5.32	4.16	74.19	25.80

No	SPEED (rpm)	CURRE (A)	Tg-in (deg)	PRESS (atg)	DIF.P (ata)	D.FORu (kgf)	D.FORl (kgf)	S.FORu (kgf)	S.FORl (kgf)
51	5523.0	131.6	20.7	29.6	.38	3.13	3.64	65.04	27.92
52	4798.5	126.2	20.8	29.7	.29	2.01	2.78	56.67	29.19
53	4084.5	121.8	20.7	29.8	.20	1.14	2.24	49.44	29.89
54	3276.0	117.9	20.8	29.8	.13	.77	2.22	42.24	29.79
55	3146.5	118.2	20.9	29.9	.12	.87	1.96	41.16	30.62
56	3150.0	117.9	20.8	29.9	.12	.89	1.93	41.19	30.90
57	3153.5	120.8	19.1	39.8	.20	.73	1.96	44.90	31.16
58	3164.0	120.5	19.4	39.8	.20	.86	1.83	44.81	31.12
59	3874.5	127.2	19.2	39.8	.31	1.01	1.89	54.16	30.57
60	4592.0	133.7	18.9	39.8	.44	1.70	2.49	64.35	28.06
61	5309.5	144.3	19.4	39.7	.59	2.36	3.02	75.78	26.59
62	5929.0	157.5	19.4	39.7	.75	3.97	3.64	87.65	24.17
63	6552.0	175.8	19.7	39.6	.91	6.46	3.60	100.39	21.40
64	7227.5	192.1	20.0	39.5	1.11	10.36	2.36	114.65	17.18
65	7619.5	203.7	20.7	39.3	1.24	16.47	1.39	124.22	14.37
66	7619.5	203.2	20.7	39.4	1.23	16.50	1.38	124.01	14.38
67	7623.0	203.4	21.6	39.4	1.23	15.74	1.41	123.94	14.37
68	7024.5	183.7	22.1	39.5	1.05	8.64	2.55	110.53	17.95
69	6317.5	161.0	22.3	39.6	.85	5.85	3.48	95.13	21.91
70	5586.0	148.4	22.4	39.7	.66	3.51	3.24	80.88	24.30
71	4879.0	137.3	22.6	39.7	.50	2.26	2.62	69.02	26.27
72	4165.0	128.7	23.2	39.8	.36	1.34	2.20	58.30	27.82
73	3384.5	122.2	22.8	39.8	.24	1.03	2.07	48.04	28.39
74	3150.0	120.3	23.2	39.9	.20	.82	2.00	45.29	29.24
75	3157.0	117.8	196.0	39.9	.08	.75	2.26	37.84	28.59
76	3220.0	119.1	196.1	39.9	.08	.75	2.30	38.16	29.15
77	3941.0	120.4	195.8	39.9	.13	1.05	1.79	44.00	30.36
78	4641.0	122.9	196.2	39.9	.19	1.73	2.88	49.26	29.47
79	5358.5	127.2	195.8	39.8	.26	2.58	3.50	56.43	28.70
80	5978.0	132.0	196.5	39.8	.32	4.09	4.24	63.26	28.00
81	6608.0	138.8	196.2	39.8	.41	6.76	4.86	70.95	26.04
82	7297.5	145.1	196.4	39.7	.49	10.22	4.49	79.48	24.72
83	7882.0	152.7	196.2	39.6	.59	16.81	3.14	86.72	20.98
84	7875.0	152.8	196.1	39.6	.59	16.31	3.13	86.67	21.22
85	7812.0	149.5	196.2	39.6	.58	15.71	3.14	86.22	21.42
86	7098.0	140.1	196.5	39.7	.47	8.84	4.15	77.18	24.35
87	6377.0	131.6	196.1	39.8	.38	6.04	4.25	68.60	26.10
88	5652.5	128.6	196.1	39.8	.30	3.71	3.68	60.96	28.06
89	4928.0	122.6	195.8	39.9	.22	2.43	2.89	53.96	29.69
90	4210.5	120.1	195.8	39.9	.16	1.47	2.20	47.51	30.32
91	3440.5	116.8	195.1	39.9	.10	1.22	2.67	40.01	29.37
92	3157.0	117.3	194.9	39.9	.08	.92	2.12	36.91	30.06
93	3146.5	119.3	193.1	40.0	.17	.93	2.05	39.25	30.83
94	3150.0	119.1	193.7	40.0	.17	.87	2.11	39.30	30.83
95	3465.0	120.8	193.3	40.0	.21	1.12	2.59	41.96	32.35
96	4182.5	125.0	193.4	40.0	.31	1.26	2.09	47.52	30.58
97	4914.0	132.1	194.0	39.9	.43	1.92	2.92	54.12	29.69
98	5575.5	139.2	194.8	39.9	.56	2.91	3.88	62.05	28.12
99	6195.0	148.3	194.9	39.9	.70	4.31	4.55	70.30	26.22
100	6856.5	161.5	195.5	39.9	.86	6.45	4.63	79.30	24.20

No	SPEED (rpm)	CURRE (A)	Tg-in (deg)	PRESS (atg)	DIF.P (ata)	D.FORu (kgf)	D.FORl (kgf)	S.FORu (kgf)	S.FORl (kgf)
101	7525.0	177.0	195.8	39.9	1.04	10.86	3.34	88.79	21.22
102	8029.0	189.9	195.8	39.9	1.19	16.42	2.22	95.64	18.22
103	8036.0	189.8	196.0	39.9	1.19	16.34	2.26	95.50	18.44
104	7948.5	186.3	196.0	39.9	1.17	15.50	2.29	94.40	18.61
105	7241.5	166.3	196.5	39.9	.97	9.27	3.61	84.36	22.26
106	6520.5	152.4	196.5	39.9	.79	6.12	4.25	74.21	24.22
107	5803.0	141.6	196.3	39.9	.62	3.91	3.57	65.54	26.29
108	5075.0	132.6	195.8	39.9	.47	2.42	2.99	57.68	27.99
109	4361.0	125.8	195.9	39.9	.35	1.56	2.38	50.27	29.25
110	3598.0	120.9	195.7	39.9	.23	.97	1.60	42.28	29.03
111	3146.5	119.2	196.1	40.0	.17	.89	2.14	36.88	29.45
112	3153.5	118.8	195.5	40.0	.17	.87	2.07	36.83	29.99
113	3157.0	119.8	192.8	39.9	.20	.85	1.99	38.95	30.82
114	3440.5	121.4	192.8	39.9	.24	1.01	2.62	41.58	32.28
115	4158.0	127.7	193.0	39.9	.36	1.14	2.19	48.20	30.37
116	4879.0	136.0	193.4	39.9	.51	1.85	2.91	55.09	29.44
117	5551.0	144.9	193.7	39.9	.66	2.77	3.64	63.56	27.72
118	6181.0	153.6	193.7	40.0	.82	4.15	4.28	72.03	25.80
119	6818.0	171.1	194.1	40.0	1.00	6.20	4.42	80.86	23.68
120	7493.5	186.3	194.5	40.0	1.21	10.54	3.07	91.11	20.48
121	8120.0	205.5	194.9	39.9	1.43	16.90	7.17	100.89	19.49
122	8123.5	205.0	195.1	39.9	1.43	16.30	7.43	100.86	19.65
123	7609.0	187.0	195.5	39.9	1.26	11.88	5.40	93.24	21.05
124	6888.0	169.1	195.5	39.9	1.03	6.60	3.81	82.22	22.89
125	6174.0	152.5	195.6	39.9	.83	4.82	3.72	72.46	25.73
126	5456.5	140.9	195.5	39.9	.65	3.01	3.16	63.25	27.60
127	4735.5	132.0	195.6	40.0	.48	2.02	2.54	55.03	29.23
128	4018.0	125.0	195.5	40.0	.34	1.14	1.86	47.05	29.82
129	3213.0	119.8	195.5	40.0	.21	.75	2.41	37.20	28.44
130	3150.0	119.8	195.0	39.9	.20	.87	2.16	36.33	29.68
131	3153.5	117.7	196.2	29.8	.09	.77	2.31	37.79	32.57
132	3164.0	117.2	196.3	29.9	.09	.95	2.14	37.86	32.59
133	3895.5	119.3	196.7	30.0	.14	1.04	1.81	42.19	32.93
134	4606.0	122.2	197.1	30.0	.20	1.85	2.62	46.56	31.24
135	5323.5	125.0	197.0	29.9	.27	2.70	3.53	52.86	30.65
136	5950.0	128.7	196.7	29.8	.34	4.14	4.28	59.06	29.62
137	6583.5	133.6	196.3	29.7	.42	6.43	5.26	65.71	27.55
138	7252.0	140.1	195.6	29.7	.51	9.28	4.94	73.31	25.84
139	7938.0	148.4	195.6	29.7	.61	16.22	4.02	81.09	21.76
140	7931.0	148.7	196.0	29.7	.61	16.51	3.85	81.15	21.96
141	7472.5	142.6	196.3	29.7	.54	11.52	4.36	76.56	23.83
142	6762.0	135.2	196.0	29.8	.45	7.21	4.91	68.13	25.98
143	6037.5	129.4	196.0	29.8	.36	4.81	4.13	61.01	28.11
144	5320.0	124.9	195.8	29.8	.28	2.91	3.46	54.93	29.52
145	4588.5	120.8	196.2	29.8	.20	1.83	2.59	48.16	30.48
146	3888.5	119.0	195.6	29.9	.14	1.08	1.89	43.21	31.00
147	3157.0	117.3	195.9	29.9	.09	.77	2.34	36.86	30.56
148	3164.0	117.5	195.5	29.9	.09	.89	2.23	36.51	31.05
149	3157.0	116.3	196.7	19.9	.06	.96	2.22	33.33	31.12
150	3545.5	117.3	196.8	19.9	.08	1.22	2.83	36.28	33.53

No	SPEED (rpm)	CURRE (A)	Tg-in (deg)	PRESS (atg)	DIF.P (ata)	D.FORu (kgf)	D.FORl (kgf)	S.FORu (kgf)	S.FORl (kgf)
151	4270.0	119.2	197.1	19.9	.12	1.25	2.76	39.78	32.89
152	4991.0	121.3	197.3	19.8	.16	2.05	3.49	43.31	32.58
153	5649.0	122.0	197.1	19.8	.21	3.23	4.61	47.80	32.49
154	6293.0	124.4	196.7	19.8	.26	5.13	5.22	52.73	31.36
155	6947.5	127.6	196.4	19.7	.32	6.93	5.78	57.98	29.91
156	7612.5	132.1	196.1	19.7	.38	10.96	5.08	63.71	27.82
157	8141.0	135.2	196.1	19.7	.44	16.28	5.44	67.20	25.65
158	8137.5	135.4	196.1	19.7	.44	16.10	5.60	67.21	25.60
159	7864.5	132.2	196.3	19.7	.42	13.59	5.31	65.23	25.94
160	7150.5	128.0	196.3	19.7	.35	7.90	4.96	59.51	28.63
161	6429.5	123.7	196.3	19.7	.28	5.92	4.99	54.24	29.92
162	5708.5	121.3	195.9	19.7	.22	3.61	4.37	50.66	31.11
163	4980.5	118.8	196.3	19.8	.17	2.32	3.34	47.44	31.54
164	4259.5	118.3	195.9	19.8	.12	1.36	2.66	42.10	31.95
165	3475.5	116.3	196.3	19.9	.08	1.33	2.66	37.71	30.92
166	3157.0	116.5	196.3	19.8	.06	.74	2.44	35.54	31.65
167	3157.0	116.3	196.1	9.8	.03	.90	2.26	28.85	31.21
168	3164.0	115.9	195.8	9.9	.03	.90	2.18	28.85	31.16
169	3815.0	116.6	196.5	9.9	.05	.90	1.93	33.02	34.30
170	4543.0	117.3	196.6	9.9	.07	1.46	3.09	35.77	33.90
171	5257.0	117.5	196.7	9.9	.10	2.53	4.31	38.23	34.10
172	5897.5	118.6	197.5	9.8	.12	3.71	5.54	40.94	34.25
173	6527.5	119.5	197.5	9.8	.15	5.81	6.03	43.82	33.48
174	7192.5	121.5	197.1	9.8	.18	7.04	5.84	46.82	32.89
175	7889.0	122.0	196.4	9.7	.22	11.16	6.39	50.60	30.85
176	8589.0	123.8	196.1	9.7	.26	16.19	6.14	53.08	29.79
177	8592.5	124.4	195.5	9.7	.27	16.42	5.91	53.08	29.44
178	8494.5	123.8	195.8	9.7	.26	15.66	6.06	52.59	29.24
179	7763.0	120.7	196.0	9.8	.22	10.54	5.57	49.81	30.16
180	7045.5	119.3	196.5	9.8	.18	6.76	5.31	46.77	31.90
181	6321.0	119.3	196.5	9.9	.15	5.59	5.35	44.25	32.62
182	5596.5	117.3	196.7	9.9	.11	3.56	4.51	42.24	33.03
183	4886.0	117.2	196.3	9.9	.09	2.12	3.70	40.26	33.12
184	4172.0	115.7	196.1	9.8	.06	1.26	2.66	38.30	32.84
185	3356.5	115.5	195.5	9.9	.04	1.07	2.64	35.74	30.92
186	3153.5	115.8	195.3	9.8	.03	.88	2.29	32.49	31.81
187	3160.5	115.6	276.8	9.9	.02	.81	2.26	27.16	31.00
188	3692.5	115.5	275.6	9.9	.03	.84	1.94	29.72	33.90
189	4399.5	116.5	275.9	9.9	.06	1.47	2.85	33.11	33.16
190	5120.5	117.2	276.2	9.9	.08	2.36	3.70	35.70	33.78
191	5782.0	118.1	276.6	9.8	.10	3.61	5.07	38.33	34.05
192	6412.0	118.8	277.7	9.8	.13	5.41	5.86	41.04	33.51
193	7080.5	119.4	278.3	9.8	.15	6.44	5.62	43.65	32.67
194	7766.5	120.9	279.5	9.8	.19	9.46	6.26	47.00	31.24
195	8470.0	122.8	280.6	9.8	.22	13.81	6.69	49.76	29.97
196	8771.0	123.1	282.0	9.8	.24	15.93	5.57	51.14	29.37
197	8316.0	121.1	282.8	9.8	.21	13.22	6.49	49.12	29.32
198	7591.5	120.2	283.5	9.8	.18	8.95	5.78	46.91	31.10
199	6867.0	118.6	283.8	9.8	.14	6.32	5.47	44.41	32.00
200	6160.0	117.5	284.3	9.8	.12	5.14	5.25	42.44	32.69

No	SPEED (rpm)	CURRE (A)	Tg-in (deg)	PRESS (atg)	DIF.P (ata)	D.FORu (kgf)	D.FORl (kgf)	S.FORu (kgf)	S.FORl (kgf)
201	5432.0	116.3	283.8	9.8	.09	3.01	4.59	40.62	33.04
202	4700.5	117.2	283.3	9.9	.06	1.92	3.02	38.83	32.47
203	3972.5	116.8	282.5	9.9	.04	1.23	1.97	36.47	31.89
204	3174.5	115.0	281.9	9.9	.02	.90	2.24	28.61	31.07
205	3153.5	116.0	280.4	9.9	.02	.77	2.32	28.01	31.65
206	3157.0	116.5	273.2	19.8	.05	.89	2.08	31.07	30.73
207	3160.5	116.1	272.7	19.8	.05	.92	2.04	30.95	31.00
208	3433.5	116.6	272.4	19.8	.06	1.11	2.71	32.55	32.60
209	4126.5	117.7	272.7	19.8	.09	1.23	2.11	37.65	33.22
210	4861.5	119.1	273.3	19.8	.13	1.88	3.21	41.02	32.75
211	5540.5	120.4	274.6	19.8	.17	3.15	4.31	45.13	32.33
212	6167.0	122.4	276.2	19.8	.22	4.89	5.17	49.31	31.39
213	6828.5	125.5	278.2	19.7	.27	6.86	6.04	53.65	29.92
214	7500.5	127.9	279.9	19.7	.32	9.31	5.68	58.18	28.98
215	8193.5	131.9	281.8	19.7	.38	15.36	5.94	62.42	26.42
216	8295.0	131.9	283.2	19.7	.39	16.42	5.63	63.16	25.93
217	7644.0	127.2	283.8	19.7	.34	11.07	5.03	59.09	27.28
218	6926.5	124.1	284.3	19.7	.28	7.17	5.02	54.10	29.03
219	6202.0	120.9	284.3	19.7	.22	5.21	4.84	50.12	30.32
220	5488.0	119.6	283.6	19.8	.17	3.23	4.02	47.15	31.10
221	4763.5	117.6	283.0	19.8	.13	2.18	2.85	44.31	31.46
222	4042.5	116.7	282.3	19.8	.09	1.34	2.03	39.67	31.54
223	3209.5	118.0	280.9	19.9	.05	1.07	2.14	32.48	30.21
224	3150.0	116.1	279.8	19.8	.05	.97	2.09	31.61	30.77
225	3157.0	116.8	285.3	29.9	.07	.94	2.06	33.23	29.79
226	3713.5	119.1	285.3	29.9	.11	.87	1.82	37.52	32.25
227	4431.0	120.1	286.4	29.9	.15	1.55	2.51	42.88	30.37
228	5148.5	122.4	287.8	29.8	.21	2.34	3.56	47.79	30.70
229	5789.0	125.8	289.2	29.8	.27	3.78	4.38	53.36	29.77
230	6419.0	130.9	290.7	29.8	.34	5.72	5.28	59.04	28.16
231	7087.5	133.7	292.1	29.8	.41	7.79	5.43	64.75	26.68
232	7773.5	140.8	293.1	29.7	.50	13.11	4.75	71.45	24.17
233	8043.0	142.8	293.5	29.7	.53	16.39	4.42	73.97	22.80
234	8043.0	142.5	294.1	29.7	.53	16.39	4.35	74.01	23.09
235	7322.0	135.5	293.6	29.7	.44	9.79	4.67	67.43	25.33
236	6608.0	129.4	292.0	29.7	.36	6.79	5.14	60.49	26.56
237	5873.0	125.0	291.3	29.8	.29	4.42	4.07	55.29	28.41
238	5166.0	122.1	290.2	29.8	.22	2.72	3.21	51.40	29.39
239	4431.0	119.1	289.1	29.9	.16	1.69	2.45	44.74	29.62
240	3703.0	116.9	288.3	29.9	.10	.86	1.54	38.97	30.41
241	3150.0	116.6	286.9	29.9	.07	.97	2.06	33.08	29.68
242	3150.0	116.6	286.2	29.9	.07	.86	2.14	32.77	30.01
243	3157.0	117.2	287.2	39.9	.08	.76	2.03	33.33	29.29
244	3804.5	119.5	287.2	39.9	.12	.93	1.66	38.95	31.07
245	4518.5	122.4	287.5	39.9	.18	1.66	2.67	46.18	29.29
246	5239.5	126.9	288.9	39.9	.25	2.66	3.19	52.78	28.80
247	5859.0	130.7	290.0	39.8	.32	4.07	4.24	59.37	28.16
248	6506.5	136.3	290.6	39.8	.39	6.22	5.14	66.52	25.95
249	7168.0	141.9	291.1	39.7	.47	8.96	4.66	74.05	25.01
250	7864.5	152.0	291.8	39.7	.57	15.51	3.40	81.81	21.10

No	SPEED (rpm)	CURRE (A)	Tg-in (deg)	PRESS (atg)	DIF.P (ata)	D.FORu (kgf)	D.FORl (kgf)	S.FORu (kgf)	S.FORl (kgf)
251	7927.5	150.0	291.8	39.6	.58	16.46	3.24	82.80	21.00
252	7626.5	145.5	291.5	39.7	.54	13.46	3.63	80.00	21.84
253	6895.0	137.5	291.0	39.7	.44	7.74	4.22	71.37	24.60
254	6195.0	131.2	290.3	39.8	.35	5.36	3.94	63.53	26.74
255	5470.5	125.4	289.8	39.8	.28	3.38	3.26	56.81	28.26
256	4742.5	122.5	289.0	39.8	.20	2.21	2.71	50.02	29.93
257	4007.5	119.5	288.4	39.9	.14	1.26	1.82	42.33	30.16
258	3216.5	117.0	287.7	39.9	.09	.98	2.18	33.53	28.65
259	3150.0	117.3	286.7	39.9	.08	.81	2.06	32.33	29.42
260	3157.0	117.4	285.8	39.9	.08	.75	2.11	32.30	29.64

No	FLOW (kg/s)	Tgout (deg)	Tmot (deg)	Tj.lo (deg)	Tj.up (deg)	D.FORu (kgf)	D.FORl (kgf)	S.FORu (kgf)	S.FORl (kgf)
1	.095	16.1	21.9	19.4	17.4	.87	1.94	34.27	33.63
2	.098	15.7	21.8	17.5	18.5	.68	2.32	35.10	33.43
3	.122	16.0	19.0	17.9	15.4	1.02	2.28	38.79	33.77
4	.144	16.8	21.8	19.4	14.7	1.39	3.43	41.75	33.92
5	.168	17.9	21.1	17.9	18.0	2.46	4.44	45.64	33.82
6	.186	19.4	21.5	19.4	18.3	4.06	5.39	48.92	33.41
7	.207	20.3	18.9	19.2	21.3	6.82	5.79	52.78	32.54
8	.229	22.2	19.0	20.7	16.0	8.52	5.35	57.09	31.44
9	.251	24.4	20.3	21.0	15.6	15.27	5.46	61.50	28.80
10	.255	25.6	25.0	20.9	16.2	16.12	5.42	62.07	28.29
11	.240	26.9	25.8	22.1	17.3	11.29	4.81	59.46	29.47
12	.218	26.1	20.6	22.5	16.9	7.18	5.32	54.35	30.82
13	.194	25.0	23.8	21.6	21.6	5.07	4.91	50.52	31.95
14	.171	23.1	23.8	20.5	22.0	2.97	4.26	47.39	32.57
15	.150	22.2	25.8	20.3	24.1	1.79	3.51	44.54	32.62
16	.128	20.7	20.7	20.3	23.3	1.13	2.37	40.25	32.08
17	.100	19.9	23.5	21.6	19.3	.86	2.28	36.38	31.02
18	.096	19.3	24.0	21.0	20.6	.74	1.97	36.17	31.59
19	.182	17.7	20.6	19.5	18.6	.67	2.03	38.78	32.18
20	.195	17.9	21.1	19.0	18.4	.98	2.23	40.60	33.56
21	.240	18.3	19.7	19.4	20.3	1.06	2.18	44.65	32.69
22	.286	19.0	19.0	20.1	14.1	1.73	2.91	49.93	31.85
23	.329	20.5	20.1	19.4	21.0	2.69	3.63	56.22	31.06
24	.369	21.7	20.7	19.6	19.4	4.34	4.53	63.25	29.67
25	.409	23.3	19.7	19.7	16.6	7.18	5.01	70.80	27.77
26	.451	25.2	23.7	21.1	23.8	10.56	4.33	79.05	25.78
27	.480	27.0	20.1	20.5	17.3	16.20	3.93	84.43	22.38
28	.479	28.5	26.6	22.6	26.0	15.83	3.99	84.53	22.05
29	.451	28.8	19.4	21.5	16.8	10.62	4.04	79.01	24.15
30	.406	27.3	22.2	22.2	21.8	6.96	4.64	70.06	26.78
31	.359	25.8	24.1	22.6	21.5	4.26	4.07	62.97	28.75
32	.314	24.7	24.0	22.9	24.4	2.50	3.54	56.16	29.81
33	.269	23.1	25.7	21.6	16.2	1.55	2.94	49.53	30.47
34	.224	22.1	22.9	21.8	20.3	1.04	1.85	43.65	30.80
35	.181	20.7	24.0	22.1	20.6	.81	1.92	38.99	30.62
36	.181	20.0	23.9	21.3	19.6	.71	2.06	38.88	30.95
37	.111	18.9	20.9	18.9	18.1	.86	1.88	41.09	31.49
38	.110	18.7	20.6	19.1	18.7	.84	1.91	41.09	31.49
39	.132	18.9	19.6	18.5	21.8	1.02	1.49	45.50	33.04
40	.161	19.7	17.8	19.7	14.5	1.31	2.54	51.21	31.16
41	.192	20.3	20.9	18.8	15.8	2.03	3.10	58.54	30.13
42	.220	21.0	21.4	20.0	19.7	3.26	3.84	66.94	28.73
43	.247	22.0	20.3	19.9	20.3	5.16	4.57	75.44	26.64
44	.277	23.5	24.6	18.4	24.1	7.21	4.49	84.87	24.20
45	.303	24.8	27.3	22.2	15.5	14.57	3.41	95.57	20.38
46	.309	26.2	19.0	20.8	18.1	16.28	3.11	97.38	19.18
47	.309	27.3	19.4	21.1	18.9	16.22	3.04	97.29	19.30
48	.303	27.7	21.8	21.8	25.0	14.26	3.24	95.43	19.74
49	.272	27.3	20.8	24.4	18.5	7.19	4.39	84.24	23.28
50	.242	26.8	25.0	23.9	21.5	5.32	4.16	74.19	25.80

No	FLOW (kg/s)	Tgout (deg)	Tmot (deg)	Tj.lo (deg)	Tj.up (deg)	D.FORu (kgf)	D.FORl (kgf)	S.FORu (kgf)	S.FORl (kgf)
51	.212	25.8	25.4	22.4	23.7	3.13	3.64	65.04	27.92
52	.182	25.2	27.7	24.1	24.2	2.01	2.78	56.67	29.19
53	.150	24.3	25.4	23.9	19.4	1.14	2.24	49.44	29.89
54	.113	23.7	24.4	23.3	22.3	.77	2.22	42.24	29.79
55	.106	22.8	25.0	22.8	20.9	.87	1.96	41.16	30.62
56	.105	22.9	24.1	22.9	21.8	.89	1.93	41.19	30.90
57	.162	21.2	21.2	19.5	18.8	.73	1.96	44.90	31.16
58	.162	21.1	20.5	19.7	19.9	.86	1.83	44.81	31.12
59	.208	20.9	23.9	20.7	22.2	1.01	1.89	54.16	30.57
60	.254	22.1	24.3	18.5	14.8	1.70	2.49	64.35	28.06
61	.297	23.3	19.0	19.7	20.8	2.36	3.02	75.78	26.59
62	.336	24.8	21.5	20.5	20.8	3.97	3.64	87.65	24.17
63	.373	26.1	18.9	18.9	23.6	6.46	3.60	100.39	21.40
64	.412	28.0	28.0	20.4	19.3	10.36	2.36	114.65	17.18
65	.436	30.2	29.1	23.6	15.7	16.47	1.39	124.22	14.37
66	.435	31.7	30.2	24.7	17.0	16.50	1.38	124.01	14.38
67	.436	31.9	30.1	25.3	16.8	15.74	1.41	123.94	14.37
68	.401	32.4	20.4	25.8	26.1	8.64	2.55	110.53	17.95
69	.359	31.1	26.3	24.1	22.3	5.85	3.48	95.13	21.91
70	.317	29.8	24.3	24.3	23.2	3.51	3.24	80.88	24.30
71	.270	28.9	25.3	25.3	25.6	2.26	2.62	69.02	26.27
72	.229	27.9	28.7	23.9	18.5	1.34	2.20	58.30	27.82
73	.179	26.4	23.9	24.3	21.0	1.03	2.07	48.04	28.39
74	.160	26.1	25.5	23.6	21.8	.82	2.00	45.29	29.24
75	.143	196.4	27.8	26.7	25.7	.75	2.26	37.84	28.59
76	.146	195.4	27.6	26.1	26.2	.75	2.30	38.16	29.15
77	.191	195.8	24.7	25.0	22.0	1.05	1.79	44.00	30.36
78	.231	196.9	25.5	26.5	26.0	1.73	2.88	49.26	29.47
79	.272	197.3	27.6	25.8	26.4	2.58	3.50	56.43	28.70
80	.310	198.7	27.3	26.9	26.4	4.09	4.24	63.26	28.00
81	.346	199.5	30.2	27.3	24.6	6.76	4.86	70.95	26.04
82	.383	200.5	25.7	28.6	24.4	10.22	4.49	79.48	24.72
83	.417	201.7	31.7	29.5	33.0	16.81	3.14	86.72	20.98
84	.419	202.0	27.9	30.5	29.9	16.31	3.13	86.67	21.22
85	.414	202.4	31.3	29.9	25.3	15.71	3.14	86.22	21.42
86	.376	201.7	34.6	30.2	26.4	8.84	4.15	77.18	24.35
87	.333	200.8	31.9	30.8	30.9	6.04	4.25	68.60	26.10
88	.293	199.7	30.1	30.5	30.9	3.71	3.68	60.96	28.06
89	.252	198.7	31.7	30.2	27.0	2.43	2.89	53.96	29.69
90	.210	197.6	29.1	31.3	32.8	1.47	2.20	47.51	30.32
91	.165	196.9	30.6	30.9	28.1	1.22	2.67	40.01	29.37
92	.143	195.7	31.5	30.8	29.0	.92	2.12	36.91	30.06
93	.087	193.4	29.7	26.0	25.6	.93	2.05	39.25	30.83
94	.088	193.7	27.3	25.8	24.8	.87	2.11	39.30	30.83
95	.102	193.7	27.3	26.6	27.7	1.12	2.59	41.96	32.35
96	.136	194.2	23.5	26.0	29.7	1.26	2.09	47.52	30.58
97	.167	196.3	26.2	25.5	24.1	1.92	2.92	54.12	29.69
98	.196	198.1	28.1	26.2	27.6	2.91	3.88	62.05	28.12
99	.219	200.4	27.8	27.4	26.3	4.31	4.55	70.30	26.22
100	.246	203.6	25.2	28.1	24.7	6.45	4.63	79.30	24.20

No	FLOW (kg/s)	Tgout (deg)	Tmot (deg)	Tj.lo (deg)	Tj.up (deg)	D.FORu (kgf)	D.FORl (kgf)	S.FORu (kgf)	S.FORl (kgf)
101	.272	206.8	35.7	30.2	33.5	10.86	3.34	88.79	21.22
102	.294	210.2	33.9	29.1	35.4	16.42	2.22	95.64	18.22
103	.292	212.2	32.9	33.3	27.0	16.34	2.26	95.50	18.44
104	.291	212.9	34.4	31.4	35.8	15.50	2.29	94.40	18.61
105	.262	212.3	30.9	35.3	33.1	9.27	3.61	84.36	22.26
106	.233	210.5	39.0	35.4	35.4	6.12	4.25	74.21	24.22
107	.204	207.3	36.1	35.1	34.3	3.91	3.57	65.54	26.29
108	.174	204.9	34.2	34.9	37.1	2.42	2.99	57.68	27.99
109	.144	202.6	36.1	34.0	35.1	1.56	2.38	50.27	29.25
110	.109	200.8	38.6	34.9	30.2	.97	1.60	42.28	29.03
111	.085	199.0	35.6	34.6	32.7	.89	2.14	36.88	29.45
112	.086	198.1	35.7	33.6	31.4	.87	2.07	36.83	29.99
113	.022	193.6	30.2	28.4	27.9	.85	1.99	38.95	30.82
114	.042	193.2	29.1	28.4	26.4	1.01	2.62	41.58	32.28
115	.076	194.5	32.9	29.3	25.5	1.14	2.19	48.20	30.37
116	.103	196.0	26.3	28.9	24.7	1.85	2.91	55.09	29.44
117	.125	198.9	31.4	28.2	29.1	2.77	3.64	63.56	27.72
118	.143	202.2	30.7	29.6	29.1	4.15	4.28	72.03	25.80
119	.163	205.9	27.0	30.0	28.3	6.20	4.42	80.86	23.68
120	.181	211.1	38.4	33.3	37.1	10.54	3.07	91.11	20.48
121	.202	216.9	36.6	30.7	33.8	16.90	7.17	100.89	19.49
122	.200	220.9	32.8	33.5	38.8	16.30	7.43	100.86	19.65
123	.186	222.3	39.0	35.4	31.8	11.88	5.40	93.24	21.05
124	.165	220.5	36.4	36.8	34.6	6.60	3.81	82.22	22.89
125	.144	217.3	38.8	37.3	38.1	4.82	3.72	72.46	25.73
126	.116	213.5	39.8	38.6	34.3	3.01	3.16	63.25	27.60
127	.099	210.3	37.3	38.8	33.3	2.02	2.54	55.03	29.23
128	.073	206.9	39.8	37.2	38.0	1.14	1.86	47.05	29.82
129	.022	204.0	39.8	37.2	35.4	.75	2.41	37.20	28.44
130	.015	201.7	38.6	36.7	34.9	.87	2.16	36.33	29.68
131	.247	195.5	26.6	25.2	25.1	.77	2.31	37.79	32.57
132	.248	195.6	27.4	25.5	24.7	.95	2.14	37.86	32.59
133	.309	196.0	25.9	24.5	23.6	1.04	1.81	42.19	32.93
134	.371	197.4	30.0	24.5	21.8	1.85	2.62	46.56	31.24
135	.431	198.9	26.3	25.9	27.6	2.70	3.53	52.86	30.65
136	.482	199.6	27.0	25.9	26.1	4.14	4.28	59.06	29.62
137	.538	200.8	25.9	25.5	29.9	6.43	5.26	65.71	27.55
138	.598	201.5	28.5	25.9	30.2	9.28	4.94	73.31	25.84
139	.657	203.3	27.8	27.0	27.3	16.22	4.02	81.09	21.76
140	.657	204.4	31.8	28.2	31.6	16.51	3.85	81.15	21.96
141	.617	204.4	35.1	30.4	33.8	11.52	4.36	76.56	23.83
142	.555	203.7	34.0	30.7	30.5	7.21	4.91	68.13	25.98
143	.493	202.2	31.8	30.7	29.8	4.81	4.13	61.01	28.11
144	.431	201.0	33.1	30.6	30.2	2.91	3.46	54.93	29.52
145	.369	199.5	34.6	29.5	26.5	1.83	2.59	48.16	30.48
146	.308	198.5	29.3	29.3	26.7	1.08	1.89	43.21	31.00
147	.244	197.4	31.7	29.9	27.0	.77	2.34	36.86	30.56
148	.244	196.3	31.4	29.6	28.1	.89	2.23	36.51	31.05
149	.166	195.3	27.1	25.0	24.7	.96	2.22	33.33	31.12
150	.186	194.9	26.4	25.0	26.1	1.22	2.83	36.28	33.53

No	FLOW (kg/s)	Tgout (deg)	Tmot (deg)	Tj.lo (deg)	Tj.up (deg)	D.FORu (kgf)	D.FORl (kgf)	S.FORu (kgf)	S.FORl (kgf)
151	.227	195.7	29.0	26.0	28.7	1.25	2.76	39.78	32.89
152	.269	197.0	25.5	25.5	27.0	2.05	3.49	43.31	32.58
153	.309	198.2	28.6	25.3	23.5	3.23	4.61	47.80	32.49
154	.346	199.6	27.7	25.5	26.7	5.13	5.22	52.73	31.36
155	.383	200.8	27.9	26.7	26.0	6.93	5.78	57.98	29.91
156	.420	201.9	31.5	27.9	26.0	10.96	5.08	63.71	27.82
157	.453	203.8	29.7	26.7	29.0	16.28	5.44	67.20	25.65
158	.452	204.6	32.7	27.6	26.2	16.10	5.60	67.21	25.60
159	.436	205.5	33.2	29.9	32.8	13.59	5.31	65.23	25.94
160	.396	204.7	34.0	28.1	25.5	7.90	4.96	59.51	28.63
161	.354	203.2	32.1	30.3	29.6	5.92	4.99	54.24	29.92
162	.312	202.1	32.1	29.9	28.8	3.61	4.37	50.66	31.11
163	.270	200.3	30.7	29.2	24.8	2.32	3.34	47.44	31.54
164	.229	199.2	31.0	31.0	32.1	1.36	2.66	42.10	31.95
165	.184	198.1	31.0	30.3	30.7	1.33	2.66	37.71	30.92
166	.164	197.0	31.7	29.2	28.1	.74	2.44	35.54	31.65
167	.089	192.4	28.2	25.3	24.8	.90	2.26	28.85	31.21
168	.088	192.0	27.9	25.0	24.7	.90	2.18	28.85	31.16
169	.105	192.0	27.6	23.9	24.7	.90	1.93	33.02	34.30
170	.127	192.9	31.0	24.1	20.8	1.46	3.09	35.77	33.90
171	.146	193.7	30.3	25.8	25.5	2.53	4.31	38.23	34.10
172	.165	195.7	29.0	25.3	25.3	3.71	5.54	40.94	34.25
173	.185	197.5	27.9	25.7	23.5	5.81	6.09	43.82	33.48
174	.204	199.0	27.1	26.7	27.1	7.04	5.84	46.82	32.89
175	.225	200.8	29.7	27.5	30.5	11.16	6.39	50.60	30.85
176	.245	202.3	27.9	27.5	26.4	16.19	6.14	53.08	29.79
177	.246	203.2	29.6	27.0	25.7	16.42	5.91	53.08	29.44
178	.242	204.6	29.0	28.7	26.1	15.66	6.06	52.59	29.24
179	.223	204.4	31.8	29.6	24.2	10.54	5.57	49.81	30.16
180	.201	203.8	34.2	28.7	28.0	6.76	5.31	46.77	31.90
181	.180	202.7	30.9	29.0	27.3	5.59	5.35	44.25	32.62
182	.158	201.4	30.7	28.5	30.4	3.56	4.51	42.24	33.03
183	.137	199.9	35.4	29.2	32.2	2.12	3.70	40.26	33.12
184	.116	199.0	29.7	29.0	31.2	1.26	2.66	38.30	32.84
185	.093	197.7	31.7	29.2	25.2	1.07	2.64	35.74	30.92
186	.085	196.7	33.0	28.6	25.7	.88	2.29	32.49	31.81
187	.073	271.8	31.7	28.4	27.3	.81	2.26	27.16	31.00
188	.086	270.6	31.8	27.4	28.2	.84	1.94	29.72	33.90
189	.104	271.2	34.4	28.2	28.9	1.47	2.85	33.11	33.16
190	.124	271.6	31.8	27.0	25.3	2.36	3.70	35.70	33.78
191	.140	272.7	32.9	27.4	26.3	3.61	5.07	38.33	34.05
192	.156	274.5	31.6	28.3	26.4	5.41	5.86	41.04	33.51
193	.174	275.9	28.5	29.3	26.7	6.44	5.62	43.65	32.67
194	.191	278.4	34.4	30.0	24.6	9.46	6.26	47.00	31.24
195	.208	281.0	31.2	29.8	27.7	13.81	6.69	49.76	29.97
196	.217	283.8	31.5	29.3	30.2	15.93	5.57	51.14	29.37
197	.206	285.9	34.5	29.7	30.7	13.22	6.49	49.12	29.32
198	.187	286.5	31.7	30.9	34.6	8.95	5.78	46.91	31.10
199	.168	286.0	32.7	31.9	30.4	6.32	5.47	44.41	32.00
200	.150	285.1	34.0	31.4	30.2	5.14	5.25	42.44	32.69

No	FLOW (kg/s)	Tgout (deg)	Tmot (deg)	Tj.lo (deg)	Tj.up (deg)	D.FORu (kgf)	D.FORl (kgf)	S.FORu (kgf)	S.FORl (kgf)
201	.133	283.8	32.3	30.9	28.2	3.01	4.59	40.62	33.04
202	.114	283.0	33.6	30.7	33.1	1.92	3.02	38.83	32.47
203	.096	281.5	32.8	30.7	26.7	1.23	1.97	36.47	31.89
204	.075	279.7	34.7	31.0	30.1	.90	2.24	28.61	31.07
205	.074	277.9	34.7	31.0	28.6	.77	2.32	28.01	31.65
206	.142	269.2	30.6	28.4	27.2	.89	2.08	31.07	30.73
207	.143	268.8	30.8	27.9	26.8	.92	2.04	30.95	31.00
208	.154	268.2	30.5	27.6	28.3	1.11	2.71	32.55	32.60
209	.189	268.8	29.8	28.3	27.9	1.23	2.11	37.65	33.22
210	.225	270.1	32.9	28.2	28.9	1.88	3.21	41.02	32.75
211	.259	271.4	28.3	28.3	25.7	3.15	4.31	45.13	32.33
212	.291	274.4	29.3	27.4	27.9	4.89	5.17	49.31	31.39
213	.322	277.5	27.3	29.1	28.4	6.86	6.04	53.65	29.92
214	.355	279.9	29.4	30.2	31.3	9.31	5.68	58.18	28.98
215	.388	283.9	32.8	29.5	27.3	15.36	5.94	62.42	26.42
216	.396	287.5	33.9	30.6	32.1	16.42	5.63	63.16	25.93
217	.367	288.4	29.0	30.5	33.6	11.07	5.03	59.09	27.28
218	.328	288.6	30.3	32.5	27.6	7.17	5.02	54.10	29.03
219	.294	288.0	32.8	32.5	31.2	5.21	4.84	50.12	30.32
220	.258	286.5	35.1	32.5	31.6	3.23	4.02	47.15	31.10
221	.222	284.7	36.9	31.1	31.5	2.18	2.85	44.31	31.46
222	.187	283.4	36.6	32.2	27.6	1.34	2.03	39.67	31.54
223	.146	281.7	33.4	31.5	29.9	1.07	2.14	32.48	30.21
224	.141	279.8	34.5	31.1	29.9	.97	2.09	31.61	30.77
225	.209	281.4	30.2	27.6	26.3	.94	2.06	33.23	29.79
226	.248	281.7	30.5	28.3	24.9	.87	1.82	37.52	32.25
227	.301	282.8	31.6	26.8	31.7	1.55	2.51	42.88	30.37
228	.354	285.3	29.8	27.9	28.0	2.34	3.56	47.79	30.70
229	.401	287.8	29.0	28.3	29.1	3.78	4.38	53.36	29.77
230	.446	290.3	29.0	29.4	28.0	5.72	5.28	59.04	28.16
231	.496	293.1	34.2	29.0	26.9	7.79	5.43	64.75	26.68
232	.543	296.4	31.9	30.2	26.4	13.11	4.75	71.45	24.17
233	.565	299.2	35.3	30.9	33.8	16.39	4.42	73.97	22.80
234	.564	300.8	33.7	33.7	28.5	16.39	4.35	74.01	23.09
235	.512	300.4	30.7	34.3	30.7	9.79	4.67	67.43	25.33
236	.461	298.8	36.3	33.7	31.1	6.79	5.14	60.49	26.56
237	.410	296.7	34.5	33.7	33.0	4.42	4.07	55.29	28.41
238	.357	294.5	37.0	34.9	30.3	2.72	3.21	51.40	29.39
239	.304	292.0	35.6	33.7	29.9	1.69	2.45	44.74	29.62
240	.251	290.1	35.4	33.2	34.7	.86	1.54	38.97	30.41
241	.208	288.3	35.1	33.2	31.7	.97	2.06	33.08	29.68
242	.208	286.5	34.3	32.5	30.7	.86	2.14	32.77	30.01
243	.205	285.7	31.0	28.7	27.5	.76	2.03	33.33	29.29
244	.252	285.7	31.0	29.1	27.1	.93	1.66	38.95	31.07
245	.306	286.8	33.1	28.0	26.3	1.66	2.67	46.18	29.29
246	.362	288.6	29.5	28.7	32.5	2.66	3.19	52.78	28.80
247	.410	290.0	29.5	29.5	28.9	4.07	4.24	59.37	28.16
248	.460	292.4	29.0	30.1	29.1	6.22	5.14	66.52	25.95
249	.510	294.3	33.9	30.6	28.7	8.96	4.66	74.05	25.01
250	.560	296.5	29.5	32.0	33.1	15.51	3.40	81.81	21.10

No	FLOW (kg/s)	Tgout (deg)	Tmot (deg)	Tj.lo (deg)	Tj.up (deg)	D.FORu (kgf)	D.FORl (kgf)	S.FORu (kgf)	S.FORl (kgf)
251	.566	297.8	30.5	33.4	29.9	16.46	3.24	82.80	21.00
252	.543	298.0	38.8	35.1	28.9	13.46	3.63	80.00	21.84
253	.488	297.1	32.3	35.3	30.5	7.74	4.22	71.37	24.60
254	.436	295.3	34.9	35.7	34.6	5.36	3.94	63.53	26.74
255	.382	293.7	35.9	34.4	36.5	3.38	3.26	56.81	28.26
256	.328	291.5	36.9	35.4	29.2	2.21	2.71	50.02	29.93
257	.272	290.6	34.1	34.9	31.5	1.26	1.82	42.33	30.16
258	.213	288.8	35.2	34.9	31.1	.98	2.18	33.53	28.65
259	.205	287.3	34.9	33.7	32.2	.81	2.06	32.33	29.42
260	.209	286.2	35.4	33.6	31.7	.75	2.11	32.30	29.64