PROBLEMS OF ELECTRONIC MEASURING METHODS IN TEST FLIGHTS OF GLIDERS

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1. TEST FLIGHT PROBLEMS IN SZD - GENERAL DESCRIPTION

Test flight problems can be divided into two parts. The first part does not need measurements or the installation of data acquisition systems in the glider. This group includes such flights as production test flights of serial gliders and initial flights on prototypes to get to know new characteristics before the main test program.

The second part needs measurements with various apparatus configurations. This group can also be divided into two parts. One so-called factory-state tests, are made in cooperation with the Polish Civil Aircraft Authority, to obtain certification of a new type and to collect information on experience with a prototype. This is important for any necessary modifications and exploration of characteristics. They need numerical results, such as tape records. The second part of this group comprise typical research measurements for construction and technology development.

1.1 Some Factory-state Tests and Requested Measurements

- Stability tests, measured quantities are: elevator deflection, angle and force on control stick versus flight velocity.

- Spin tests, measured quantities are: acceleration, velocity, number of turns, control deflections.

- Flutter tests. This is the very important part of factory test programs. Many parameters are recorded, for example: vibrations, accelerations, control deflections, velocity. This method will be discussed later.

- Pull up from diving - maximal gravity load test, measured quantities are: velocity and acceleration at the center of gravity.

- Aerobatic tests, recorded parameters are: acceleration, altitude, control deflections.

- Defining the speed-polar needed especially for high-performance gliders.

Three methods are used: traditional, comparing flights, and so-called energetic method (being evolved).

1.2 Research Tests

This group forms a big subject. Three examples are presented here: Flutter tests, load spectrum measurements and study of aerodynamic features.

2. FLUTTER TESTS

This program is carried out to check that the glider is free from flutter through the range of velocities and to prove its proper characteristics. The records of measured quantities are appended to the test flight report; this is demanded by the authority. When flutter appears, the purpose of tests is to define the character of the vibrations, to find correlation between signals, phase, amplitude and, of course, flight speed range for this phenomena.

The method of testing is to generate vibrations of the airframe during flight at a given speed and then check the amplitude envelope and frequency. The speed is increased step by step in several flights. The glider is excited in two ways: impulse and oscillatory. The excitation is made by each control surface separately.

The test procedure: The pilot should carefully reach the proper speed, turn on the instrumentation and make a series of excitations. The latter comprises respectively: impulse aileron deflection, impulse rudder deflection, impulse elevator deflection, then in the same order fast oscillatory deflection. All of this, for one flight speed, takes about 30-35 seconds.

Oscillographic recorders are used in that program. Vibration measurements are taken at several points of the airframe, also flight speed, acceleration at the center of gravity and the deflection angle of each control surface. These last parameters are recorded to get information on what kind of excitations have been developed, how fast and severe they were.

Figure 9 shows typical location of vibration sensors, this basic configuration will indicate almost every kind of flutter. Sometimes however, vibrations have to be measured at a large number of points to determine the phenomena exactly. For example, two or three sensors are fixed on the wing surface to indicate the form of the oscillation and its amplitude. Also, a vibration sensor is fixed on the tail just in front of the fin, the indicate vertical flexural oscillations of the fuselage.

Computer simulations of different flutter modes are made as a part of the design calculations for each prototype, and the location of the sensors depends on the results.

The Polish Civil Aircraft Authority demands also resonance tests of the glider before flutter test flights are made. The results are taken into consideration as well.

The frequency of vibration induced usually lies near 6 Hz; it depends on the part of airframe concerned and on the flight speed. Acceleration amplitude, peak to peak, lies usually in the range 2 to 4g. Two oscillograph records are shown in Figure 10 where:

V - velocity
n_{sm} - acceleration at center of gravity
β_l - aileron deflection angle
β_h - elevator deflection angle
β_v - rudder deflection angle
n_{sh} - acceleration of horizontal stabilizer vibrations
n_s - acceleration of wing vibrations
n_v - acceleration of fin vibrations.

These records show what kind of excitation was used, how big it was, also what were the results for speeds up to 120 km/h. For example, oscillatory excitation of the rudder gives oscillatory movement (biggest on the fin) with decreasing amplitude. Conclusion: there is no flutter. All parts of the record have the same synchronized time base.

3. LOADS SPECTRUM MEASUREMENTS

This program was carried out to find out data for fatigue tests. The nature of the method depends on the direct measurement by mean of strain-gauges, determining the stress at the structure station concerned.

The strain gauges were glued on the spar root at a point 2/3 of the spar root length from the end. They were connected to a full bridge system enabling measurements of the wing bending moment to be made. Philips strain-gauges of 120 ohm resistance and 30mm base were used. The SRD recording system was used for measurements. In addition, three parameters were recorded: speed, accelerations and the marker.

The calibration was made on the ground by applying various forces on the wing tip. The linearity was checked over the whole measuring range, as well as hysteresis error by applying different static gravity accelerations in spirals. The test specimen was the club-class glider SZD 51-1 "Junior." The measurements were taken in various operating conditions, namely:

- take-off and landing ground runs on grass airfield,
- as above but on concrete runways,
- as above but on field landing,

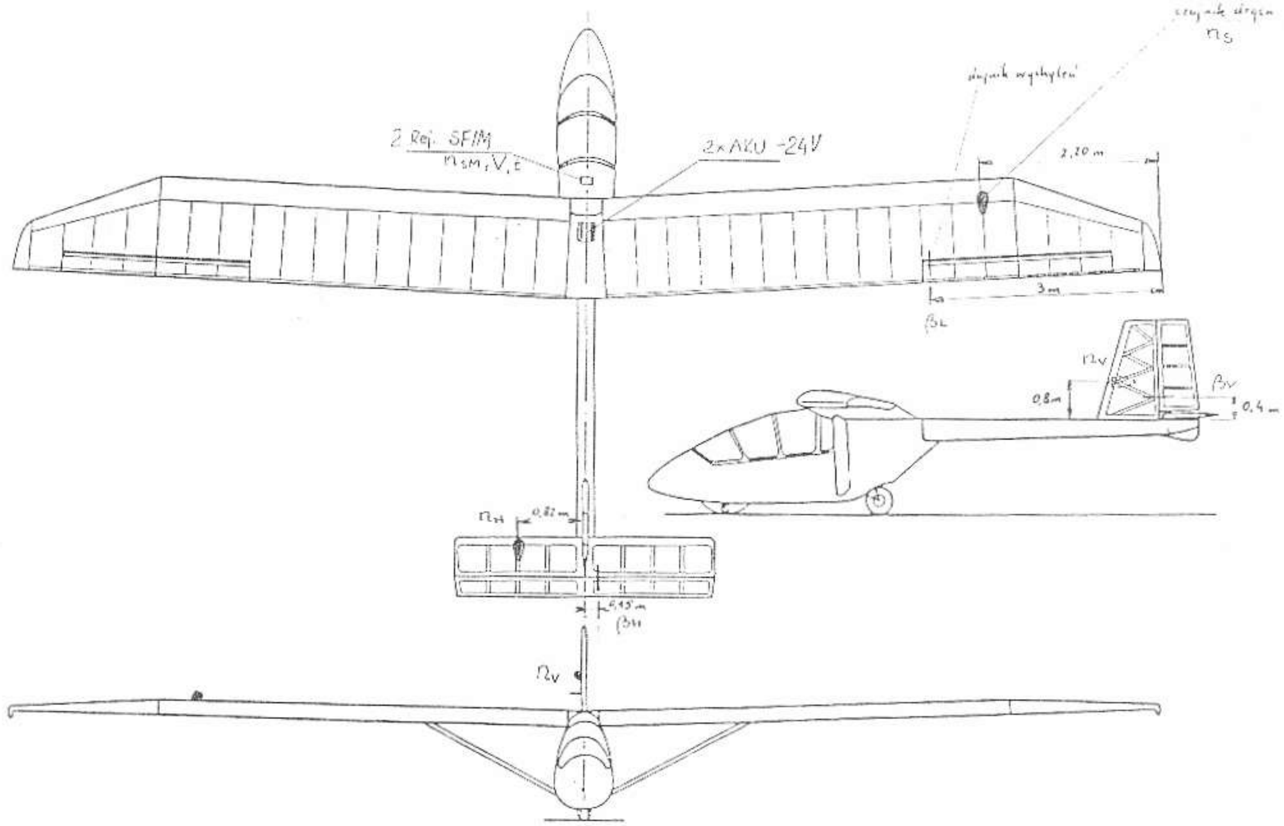


FIGURE 9. Location of vibration sensors, PW-3 "Bakcyl".

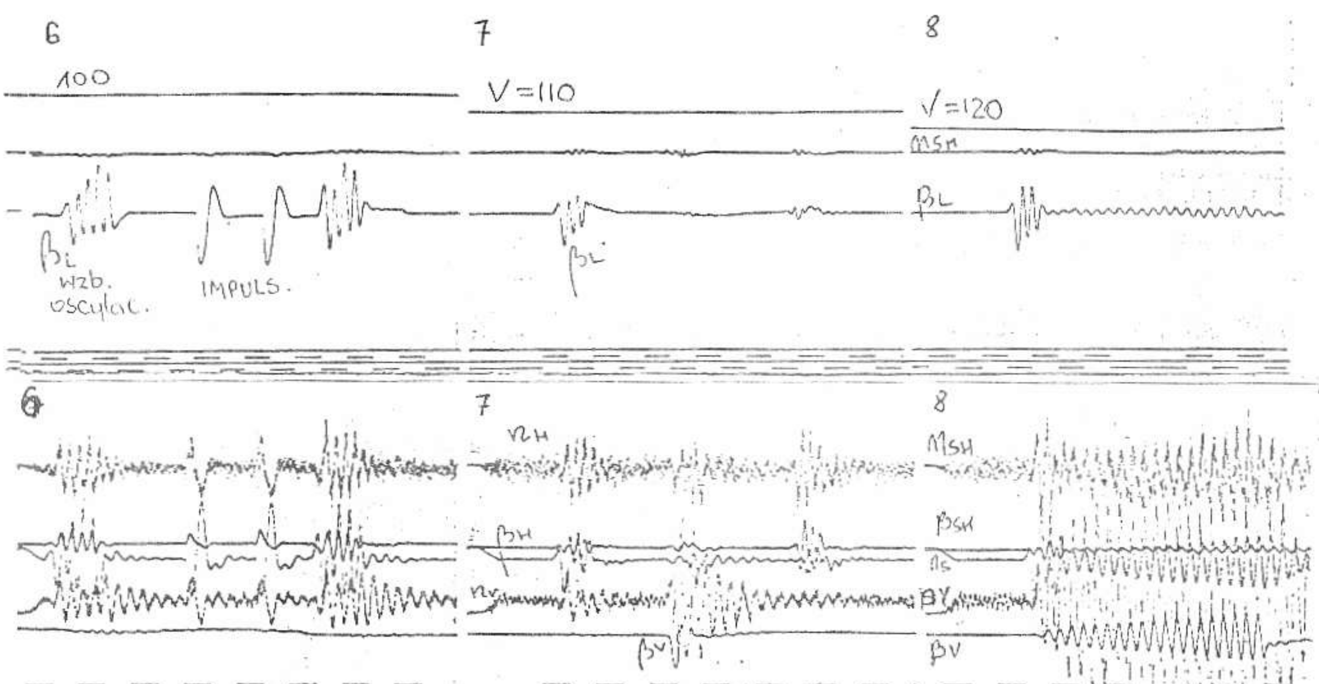


FIGURE 10. Flutter test vibration oscillograms.

- winch launching,
- aerobatic and towed flights, and
- taxiing on the grass airfield.

The Representative recordings for such conditions are shown on Figures 1 through 8. The time scale is 2.3 seconds per large square.

A computer signal analysis was made to prepare a loading block for the ground fatigue tests.

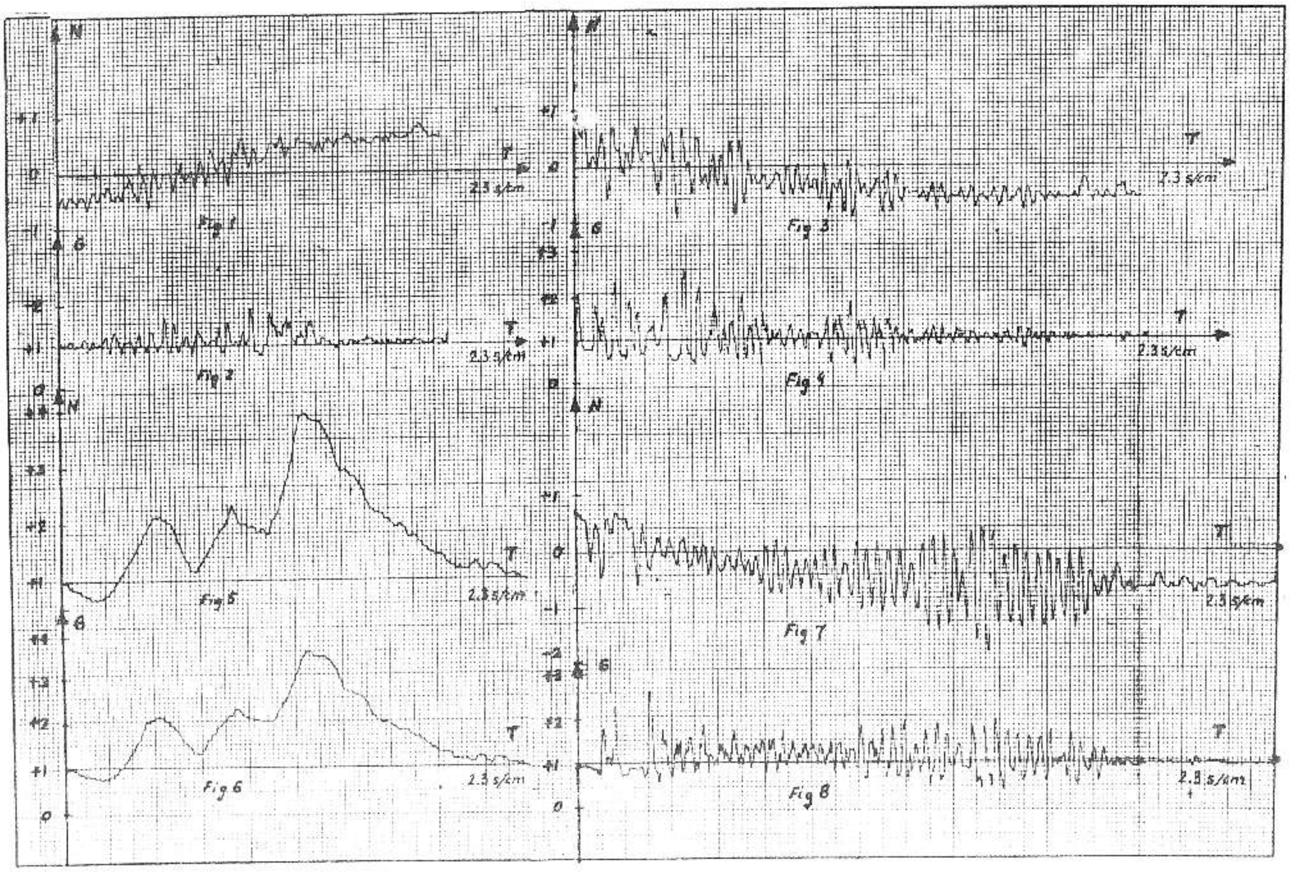
Figure 11 shows the load envelope during winch launching, where the wind speed was about 5 m/s. A fatigue test is being done on the basis of these measurements. This program was carried out last summer and autumn and it will be extended to find the load spectrum for flights in thermals.

4. METHODS OF RESEARCHING THE GLIDER'S AERODYNAMIC FEATURES

4.1 Optimization of Flap Deflection Angles Versus Flight Speed

This subject has been investigated to define optimum operating conditions of an automatic flap control system on the SZD 52-2 "Krokus" glider. The prototype of the device was constructed in the factory. It is under test now. The program was based on the well known wing drag measuring method proposed by Richard H. Johnson.

The main difference is that drag was measured by means of exact small-range differential pressure transducer. It was recorded on magnetic tape. A flap deflection angle was recorded as well as the pressure difference and speed.



FIGURES 1 TO 8. Load spectrum measurements.

Figure 1 - loadings in take-off on grass airfield
Figure 2 - the same take-off but accelerations
Figure 3 - loadings in landing - grass airfield
Figure 4 - the same landing but accelerations
Figure 5 - loadings during two turns of spinning
Figure 6 - the same but accelerations
Figure 7 - loadings in a field landing (meadow in mountains)
Figure 8 - the same but accelerations.

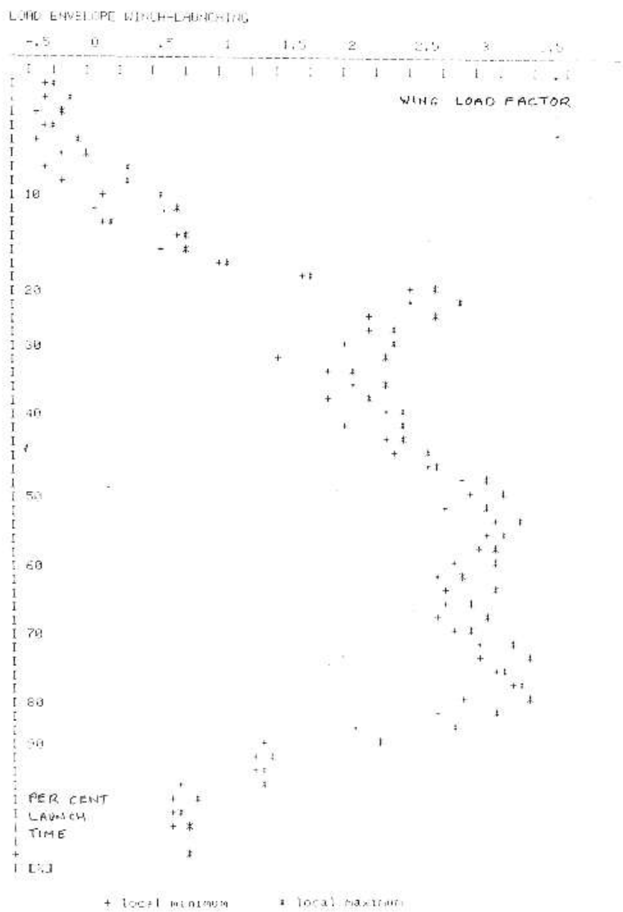


FIGURE 11.

The transducer range was ± 2mbar, permitting measurement of the small differences of the wing drags in various flap settings for low speeds. For flight speeds from 80 to 110 km/h the changes of drag, caused by extreme flap settings, equals about 0.2 mm H_2O for V=80 km/h to 0.3 mm H_2O for 110 km/h. Flap positions from -7.5 degrees to plus 5 degrees. Figure 12 shows the probe construction.

4.2 Deceleration Method for Speed-polar Measurement

There were difficulties in using this method in the past, but it became feasible recently, when electronic measuring-recording systems and computer data analysis were available. The principles are well known. The glider should dive to high speed and then, after regaining level flight, the pilot should keep exactly constant altitude. All kinetic energy turns into work against aerodynamic drag. The speed decrease contains information about the glider drag.

First trials with this method were made in 1987. Having not such advanced apparatus as, for example DFVLR has, we had to find another solution. Pilotage procedure for keeping exactly constant altitude is based on indications of a statoscope. This is built as a combined system of inductive small-range differential-pressure transducer, supplying generator, phase detector and RL8 recorder. The transducer measuring range, ± 2 mbar, and its error, 0.5% F.S.O. provides a resolution of about 0.1 m in a range of ± 20 m relative altitude.

The statoscope measures the static pressure relative to the pressure in the balancing reservoir, which is cut off at the beginning of constant-altitude flight. The velocity is measured by a differential pressure semi-conductor transducer with total error 0.5% F.S.O. The block diagram of the system is shown on Figure 13. The probe characteristic of static pressure versus flight speed is exactly defined for computer calculations. Also, the standard altitude and temperature of the air are measured in each run. The temperature is measured by a digital thermometer with ± 0.1 degrees C resolution. Figure 14 shows typical records of relative altitude and velocity versus time. Keeping the altitude constant is a matter of pilot practice.

The possible errors from vertical air movements can be eliminated in two ways. The first way is to chose a suitable time for the measurements, as for example early morning. The second way is to record the atmospheric pressure gradient using the statoscope, just before the flight.

The data analysis is made in steps. The first step is data preparation, by A/D conversion of the recorded signals and storing them on a floppy disk. Then, plotting can be done as shown in Figure 14. The left hand diagrams show altitude, the right hand ones show speed.

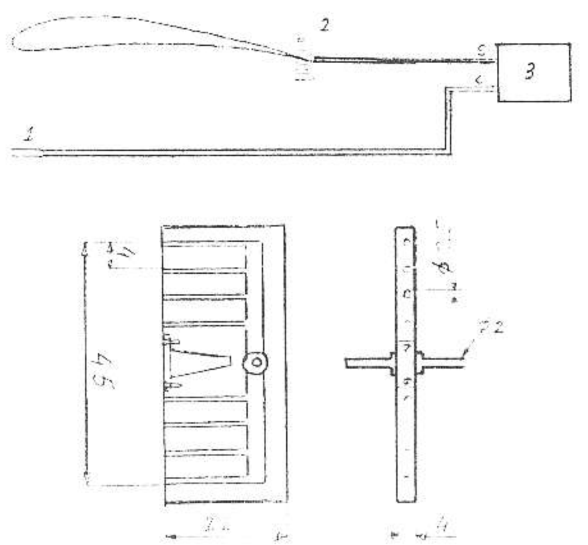


FIGURE 12. Drag probe construction.

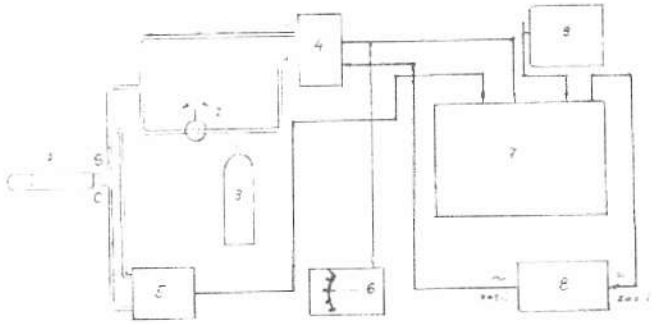


FIGURE 13. Schematic arrangement of measuring-recording system for deceleration method. (1)Probe of static and dynamic pressure. (2)Cut-off valve. (3)Reservoir of 1 l. (4)Differential pressure transducer of statoscope. (5)Differential pressure transducer of air speed indicator. (6)Statoscope indicator. (7)RL 8 recorder. (8)Supplying generator. (9)24v battery.

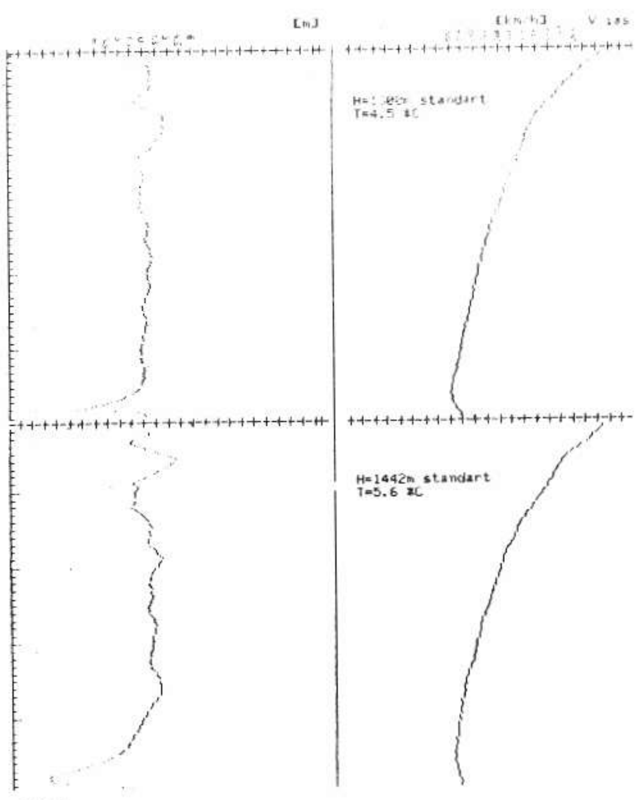


FIGURE 14. Altitude and velocity records.

The final result is the polar curve approximated from few measurements by means of a 3 degree polynominal approximately, Figure 15.

The accuracy of this method now is similar to that of measurements made in only a few high flights of the traditional method. This method is fast but was not accurate until now. Results can be achieved in two not especially high flights. It will be improved by applying a new measuring system.

5. A SHORT DESCRIPTION OF DATA ACQUISITION SYSTEMS

5.1 Oscillograph System

This system is based on three oscillographic recorders, using a combination of various mechano-optic and megneto-optic transducers. It is produced by SFIM Schlumberger firm. Photosensitive paper tapes are used. One recorder is able to register up to 6 parameters and the time base. Two recorders can work synchronously. There are generally two types of cooperating sensors, one potentiometric and one inductive. The first type for accelerations, force, speed, control deflections, etc., and the second inductive vibration sensors and small range differential pressure transducers. In addition, the system can register such values as altitude, inclination angle and temperature. Typical accuracy is from 0.5% to 1% F.S.O.

5.2 SRD Recording System

This contains a 9-track measuring cassette recorder RL8 and the stationary reader CS8. The system is working in FM-mode with synchro-signal recorded on 9-th track, which is also the 1 kHz time base. The RL8 recorder is equipped with a digital monitor for current reading parameters of any selected channel.

All parameters are recorded on one side of ordinary compact-cassette. The stationary reader CS8 has digital display of the selected channel and for real time. The device is equipped with two analog outputs with channel selection and parallel multi-output connector, also time base. There are two kinds of frequency-to-voltage converters, one for dynamic quantities and the second, more exact, for static ones.

The RL8 recorder cooperates with a larger number of SFIM potentiometric and inductive transducers, also with semiconductor pressure transducers and strain gauges.

Some parameters:

RL8

Input voltage range	± 0.25 V to +/- 50 mV
FTC	- 0.01%/°C
Linearity error	0.1%
Power supply	12V, 1.2 A or 0.8 A
Tape feed speed	4.75 cm/s
Housing	220 x 200 x 80 mm
Weight	3 kg with battery

CS8

Output voltage range	0 to 5V
Total error below	1%
Power supply	220V, 50 Hz

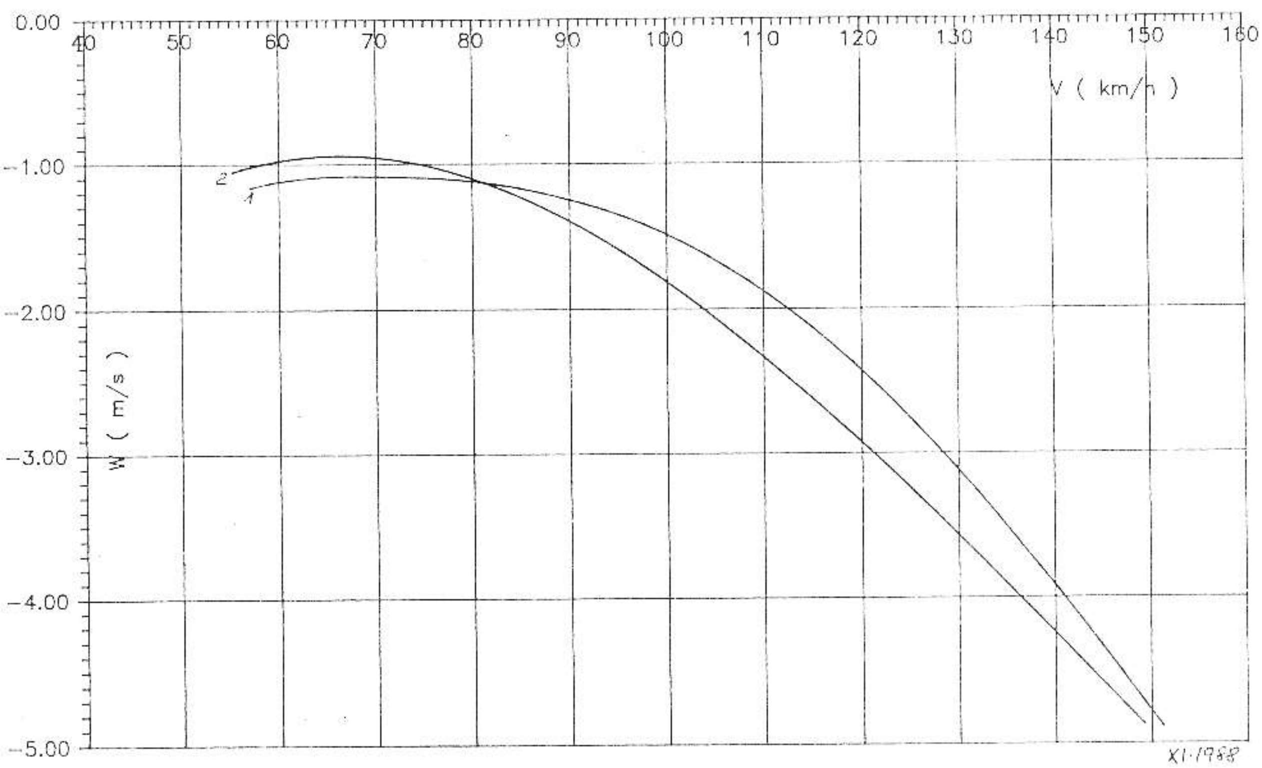


FIGURE 15. Polar curves for PW-3 at 22.86 kg/m2. (1) Classical method. (2) Deceleration method.

5.3 The Modular Measuring Computer System MSK I

This is an 8-bit computer working under CP/M operational system based on a Z 80 microprocessor and is equipped with interfaces:

- 8-bit A/D converters with 16-channel multi plexer
- 4-channel D/A converters
- multi-purpose interface for serial and parallel printers, tape recorder, EPROM programming
- graphics arranger chart 512 x 512 picsels
- floppy disk controller for two floppy disk drives of 5 1/2 inch.

The software environment contains the system and its accessories such as macroassembler, debugger ZSID, etc. Also, Basic 80, Fortran 80, Pascal MT+ compilers and Basic-interpreter are included. There are specialized measurement programs, for such things as load spectrum analysis and general data sampling and small programs, as for example, comparing flight analysis and data transmissions to IBM.

5.4 A New Portable Data Acquisition Unit

A quite modern electronic recorder is being developed for our purpose. This recorder is totally based on microprocessor technique with big RAM, enabling recording of 16 channels of up to 30 minutes duration. The most important feature is the independent programming of data sampling procedure for every input.

It will cause a development of measuring techniques. The device will be applied also for flutter tests, as well as advanced computer data analysis.