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GIO ANALYZER (AUTO-ANALYZER FOR GASES IN OIL)

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I. INTRODUCTION

The Buchholz relay has long been used for the detection of gases evolved inside transformers in order to keep accidents to a minimum. Even recently, there have been several reports of devices for the direct analysis of the composition of the gas in this relay or in a conservator. However, with the only Buchholz relay, the initial abnormalities could not be detected sufficiently or could not be detected at all. In order to solve this problem and detect the abnormalities rapidly, Fuji Electric developed for the first time in the world a technique for the early detection and diagnosis of faults in oil-immersed transformers by analyzing the gases dissolved in the insulating oil. At present, this technique is being used widely both domestically and abroad, and is playing an important role in the prevention of transformer faults. Recently, this technique has proved to be valuable not only in the transformer field, but also in the cable field.

Previously when this technique was applied, the gases in the oil were extracted from the transformer oil at the site and then the extracted gases were analyzed by gas chromatography. All steps in this method were manual and the disadvantages of complexity and time consuming operations could not be overcome. Fuji Electric, however, has now overcome these disadvantages and has made the technique easier to apply. This has been accomplished by the development of an auto-analyzer for gases in oil in which all of the operations such as extraction of the gases from the collected oil samples and analysis of the extracted gases are completely automatic. This report will introduce an outline and the features of this equipment. If this equipment is used, the work of analyzing the extracted gases in the laboratory will become much more efficient, and there will be a considerable savings in labor. If required, this equipment can be connected directly with the transformer and can be used directly at the site to monitor the dissolved gases in the transformer oil.

II. EQUIPMENT CONSTRUCTION

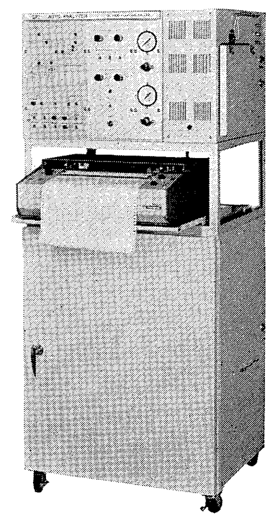


Fig. 1 GIO auto-analyzer

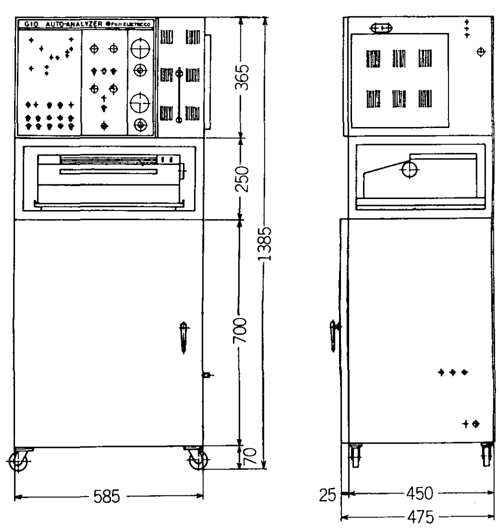


Fig. 2 Dimensions of equipment

This equipment consists of a sampler section, an analyzer section and recorder. *Fig. 1* shows an outerview and *Fig. 2* shows the external dimensions.

1. Sampler Section

The sampler section introduces the oil samples,

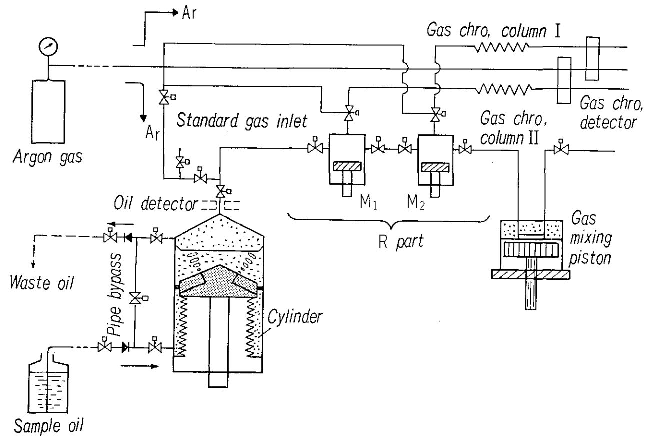


Fig. 3 Schematic diagram of equipment

extracts the gases from the oil, collects the extracted gases and injects them into the gas chromatograph. A schematic diagram is shown in *Fig. 3* and the cylinder used for introducing the oil sample and extraction of the gases from the oil is shown in *Fig. 4*. The piston in the cylinder is constructed of a stainless steel bellows in such a way that there is no possibility of oil or extracted gas leaking to the exterior. The bottom of the bellows is attached to the cylinder base. The piston head contains small holes, the space between the bellows and the inner wall of the cylinder (V part in *Fig. 4*) and the space at the top are connected.

When oil samples are taken, the drain cock of the oil sample container or the transformer drain cook are connected to the oil inlet port on the bottom of the cylinder, and the valve on the side part of the cylinder and the bypass pipe valve are opened and the cylinder head valve is closed. As the piston moves up and down, the oil is circulated as shown by the arrow in *Fig. 3*. In this way, the oil remaining in the cylinder after the previous sampling is either disposed of or returned to the transformer, and the new oil sample can be taken in the cylinder. Then, when the piston reaches the upper limit it stops and all the valves are closed (at this time, a constant amount of 100 m*l* of oil is in V part in *Fig. 3*). Then the piston descends and there is a pressure reduction in the upper space (the Torricelli vacuum principle). The oil sample in the V part is rapidly sucked into the pressure-reduced upper part via the small holes in the piston head so that the gas dissolved in the oil can be effectively extracted.

Then the gases extracted from the oil are pushed out through the cylinder head valve by the piston and enters the measuring valve system (part R in *Fig. 3*). The gases which have entered the measuring valves M_1 and M_2 in part R are injected into the path of the carrier gas for the gas chromatograph by piston and are analyzed. The speed of the cylinder piston is automatically switched among three speeds, most suitable at the time of oil sampling, gas extraction and transport of the extracted gases respectively.

2. Analyzer Section

The analyzer section employs the gas chromatograph system. At present, it is considered that H_2, CO_2, CO, CH_4, C_2H_2, O_2 and N_2 must be analyzed for the diagnosis of transformer faults. Therefore, the analyzer has been designed to analyze these gases efficiently. A special unit was developed from which unnecessary functions were excluded. In normal analyses of the above gases, the analysis is divided into two parts using two columns, one containing Molecular Sieves 5 A and the other Porapak N, for example. This special analyzer has been designed so that these two analysis are performed simultaneously and the time required has thus been reduced to about half of the previous time. Calibration of the gas chromatograph (preparation of the calibration curves) is performed in the normal way by using the standard gas inlet port shown in *Fig. 3*. *Table 1* shows the main specifications of the equipment.

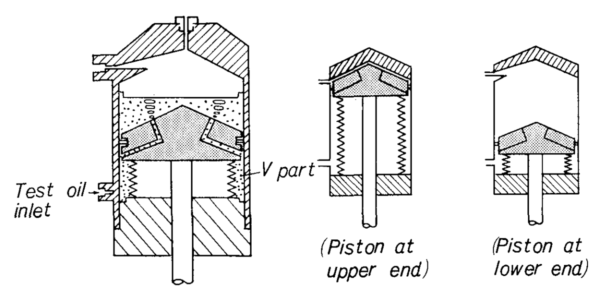


Fig. 4 Cylinder

III. OPERATION OF THE EQUIPMENT

This equipment has various numbers of operating steps. However, since all the operations are performed in sequence once the automatic start switch has been pushed, the analysis chart can be obtained in about one hour once the switch is pushed without any manual operation after the samples have been placed in the equipment. In addition to automatic operation, each operation step can be switched over to manual if required. *Table 2* shows the operation sequence. The main steps are as follows.

1. Oil Sampling

The cylinder oil inlet port are connected to the oil sample container or the transformer drain cock, and the return pipe in the oil drain port is connected to the disposal container or the transformer. The sample oil is brought into the cylinder by the movement of the bellows piston. The piston moves 10 strokes and stops when the piston head is in contact with the top of the cylinder. At this time, about 100 m*l* of the new sample oil is sampled in the space between the cylinder inner wall and the

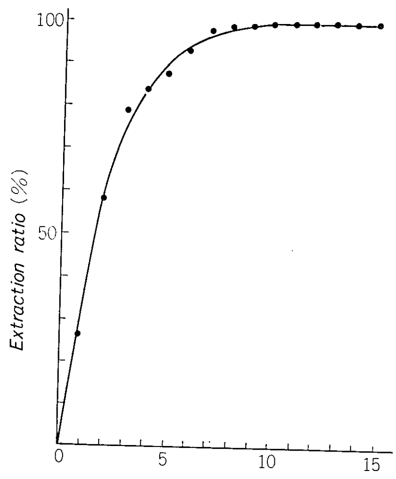


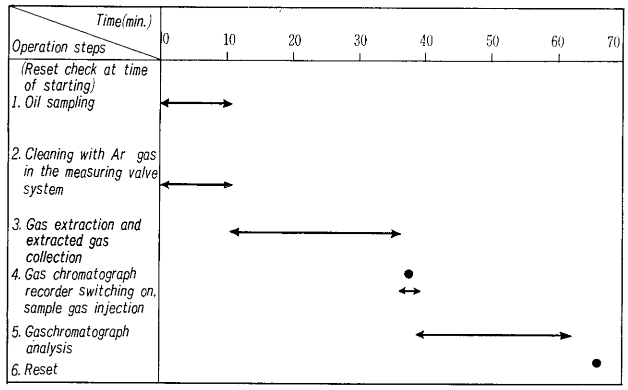
Fig. 5 **Curve of relative volume of evolved gas in oil against degassing process**

bellows. The amount of oil sample collected is determined in accordance with the equipment.

2. Cleaning with Argon Gas in the Measuring Valve System

Since argon gas is used as the carrier gas for analysis in this equipment, this gas is brought into the measuring valve system at a rate of 100 m*l*/min. in parallel with the oil sampling step, and performs

Table 2 **Sequence specifications of equipment**



cleaning in the system. This cleaning completely removes any gases from previous samples which might remain.

3. Extraction of Gases in the Oil and Collection of Extracted Gases

The gases in the oil are extracted in the cylinder by the mechanism described in section II. 1. and are collected in the space of the upper part of the cylinder. The piston which has descended rises again and when it reaches the required position (about 20 mm from the top), the head valve opens and the

Table 1 **Specifications of equipment**

I	Sampler section	
	Piston movable length	60 mm
	Velocity of bellows' action	3 stage, automatic Oil sampling Upwards motion when gas extracting Downward motion when gas extracting
	No. of stokes of bellows' action	1) At oil sampling 10 strokes 2) At gas extracting 12 strokes
	Total capacity in measuring valve system	13.5 m*l*
	Measuring valve vol.	2.5 m*l*
II	Analyzer section	(Gas chromatograph system)
	Carrier gas	Argon (Ar, reserved by user)
	Column	1) Porapack N (H_2, CH_4, C_2H_4, CO_2, C_2H_2 use) 2) Molecular sieve 5 A (H_2, CH_4, O_2, N_2, CO use)
	Detector	T C D
	Type of analysis	Two columns are used simultaneously
	Detector sensitivity	100 ppm (for 2 m*l* of sample)
III	Recorder	
	Measuring range	1 mV rating or 10 mV rating
	Sensitivity	0.15% of full scale
	Accuracy	±0.5% of full scale
	Response	1 second full scale
	Effective recorder length	250 mm
	No. of recorder pen	Two pens
	Recorder paper speed	Standard 5, 10, 20 mm/min
IV	Others	
	Dimensions	585×475×1,385 mm
	Weight	ca. 160 kg
	Power source	100V, 50/60 Hz, 1 kVA

extracted gases enter the measuring valve system. When the piston reaches the top of the cylinder, the head valve is closed but the extracted gases have already been collected completely in a uniform state in the measuring valve system by that time.

In order to avoid mixing of the oil in the measuring valve system, an oil detector using a phototransistor is provided in the cylinder head. At the time of gas extraction, the piston makes 12 strokes (no. of extractions: 12) but the gas is completely extracted from the oil by this process and the entire amount is collected in the measuring valve system. *Fig. 5* shows a curve of the ratio the gas already extracted at each extraction to the total amount of dissolved gas using oil saturated air as the sample. From this curve, it is evident that the oil is completely degassed by 12 extractions. Since the gas mixing piston (refer to *Fig. 3*) descends before the gas extraction, the pressure in the measuring valve system becomes negative and the extracted gases are easily introduced from the cylinder into the system. At the time the extraction is completed, the gas mixing piston returns to its original position and the pressure in the system becomes positive.

4. Sample Gas Injection and Analysis

When the extracted gases have been collected in the measuring valve system, the gas chromatograph recorder is switched on, the two measuring valves operate in succession and the sample gases are injected into the Porapack N column and the Molecular sieve 5 A column used in this special gas chromatograph. The gas analysis then begins and the recorder writes out the gas chromatogram in succession.

The analysis is completed in about 20 minutes after the injection of the gas and the equipment is reset to complete the operating sequence. The recorder uses two pens and two types of gas chromatograms can be recorded on the same sheet of paper in this special gas chromatograph. Therefore, a major feature is that two different analysis can be performed side by side simultaneously. Since the capacities of the measuring valve system and the measuring valves themselves are determined in accordance with the equipment, the ratio the amount of sample gases into the gas chromatograph to the total volume of extracted gases is calculated beforehand. Therefore, if the amounts of each gas component can be known from the analysis results, it is also possible to find out the amounts of the components in the extracted gases or the total amount of gases in the oil.

IV. FEATURE OF THE EQUIPMENT

This equipment has the following features:

1) Handling is facilitated since the sampler and analyzer sections are both in one cabinet to form a single unit.
2) Operation is very simple since all operations are automated. However, if necessary, the equipment can be switched over to manual operation and all steps can be performed easily by switches on the operating panel.
3) Since a special construction is used for the bellows piston in the sampler cylinder, there is absolutely no need to worry about gas or oil leak.
4) Since there are no glass parts or vacuum pumps used, reliability is high and maintenance is easy.

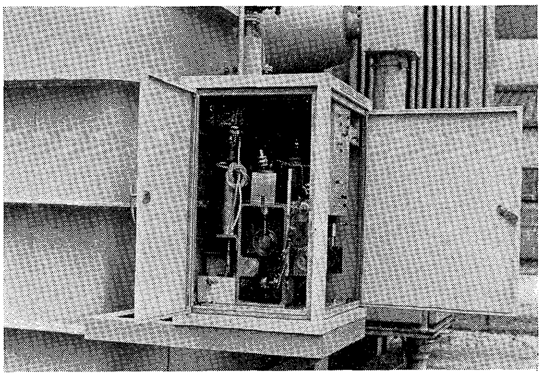


Fig. 6 Field test of equipment

Fig. 6 shows a field test being conducted with this equipment attached to the main transformer in the Fuji Electric work shop. This test has been continuing for about one year and the overall functions and life have been confirmed. *Table 3* shows test results using the analyzer.

The technique of diagnosing transformer faults by analysis of gases in the transformer oil has been gradually gaining in significance and importance in recent years and is being widely applied as one aspect of transformer maintenance and management as well as the after-service of transformer manufacturers.

Table 3 **Results measured by GIO auto-analyzer**

Iteme / Gas composition	Measuring results of GIO analyzer		Measuring results of conventional system by Torricelli's vacuum
	Sampler A	Sampler B	
Dissolved gas contents m*l*/oil-100 m*l*	7.38	7.40	7.30
N_2 %*	93.5	93.6	92.2
O_2 %	5.52	5.48	6.99
H_2 %	0.03	0.03	0.03
CH_4 %	Tr.	Tr.	Tr.
CO %	0.11	0.10	Tr.
CO_2 %	0.75	0.80	0.67
C_2H_6 %	0.03	0.02	0.03
C_2H_4 %	Tr.	Tr.	Tr.

* Indicate % volume for dissolved gas content