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DATA RECORDING IN H.M.S. EXMOUTH

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H.M.S. *Exmouth*, although a fully operational ship of the Fleet, still has an important function to perform in the development of equipments associated with the efficiency of the future Navy.

The implications of new design with particular reference to performance analysis and fault tracing are far reaching. The Type 21 and 42 ships now under construction will benefit from the trial now in progress in H.M.S. *Exmouth* of a continuous monitoring system for the main propulsion machinery.

The system augments the arrangements already fitted, which consist mainly of Bell and Howell transducers, a signal conditioning unit and an ultra-violet recorder. These, while extremely useful, entail the marking of the recording paper and making written notes when changing the condition of the main parameters being recorded.

These parameters are:

CPP oil distribution box
Auxiliary servo motor oil pressure
Shaft-driven CPP oil pump discharge pressure
Motor-driven pump discharge pressure
P3—H.P. compressor delivery pressure
P3P—H.P. compressor delivery pressure modified.
Fuel pump delivery pressure
Servo air pressure MCR console
Air signal to functional generators
Olympus throttle signal
L.P. compressor speed
Olympus power turbine entry temperature
Propeller pitch displacement
Ship's speed
Shaft horsepower
Shaft speed

Historically, the analysis of any particular condition or occurrence could involve the unravelling of at least one roll of recording paper. There is also the disadvantage that unless the paper is processed the tracings are not permanent.

The integration of the Bell and Howell CPR 4010 tape recorder into the existing instrumentation monitoring system covering the engine and transmission has several distinct advantages:

(*a*) The recordings are permanent and the tape can be stored. If so desired the tape can be erased and used again.

(*b*) Combined use of the voice track and reel revolution counter enables a permanent recording of all commands to be made. Any relevant comments during trials can also be recorded.

(*c*) Dynamic analysis of all parameters is more easily made as only the particular section of the recording need be replayed and displayed on the ultra-violet recorder. Because of the wide range of speeds available on the tape machine, the time base can be expanded.

(*d*) The use of frequency-modulated recording techniques enhances the signal to noise ratio which is very advantageous when monitoring low signals.

The new tape recorder and signal conditioning unit have been combined with the previous system in one console in a compact but very flexible manner tailored to the ship's particular requirements.

The system layout (See FIG. 1) is as follows:

(*a*) The top section houses the tape transport (covered by a hinged perspex panel), and all the operating switches.

(*b*) The next two sections contain the 14 channels of record and reproduce amplifiers along with the two switched monitoring units for individual calibration of each channel.

(*c*) This unit provides each transducer in the system with its own excitation supply, calibration facility, and rationalization network.

(*d*) This unit provides amplification of each transducer output signal for matching to the tape and ultra-violet recorders.

(*e*) The bottom unit is a 'patch' panel to which all the various unit inputs and outputs, including the transducer outputs, are connected so allowing easy cross-connection as required. Any 14 of the 16 parameters can be monitored at one time.

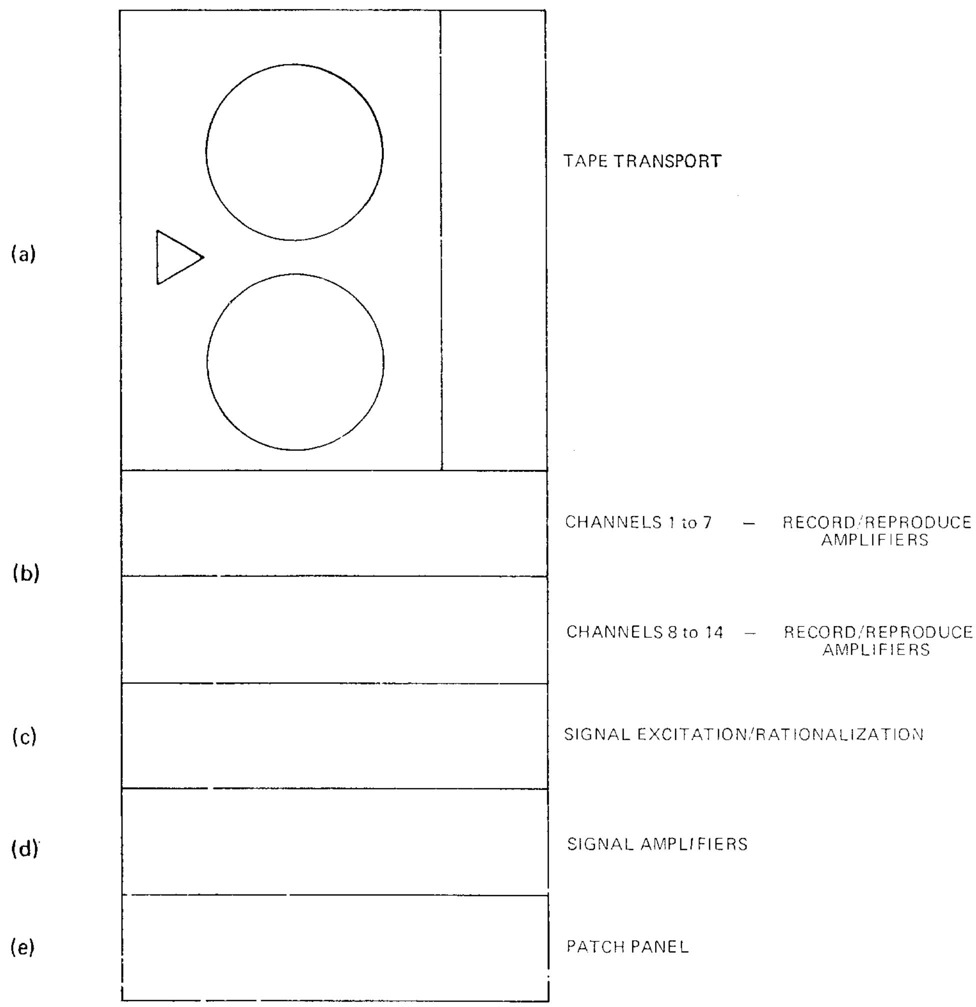

FIG. 1—SCHEMATIC LAYOUT OF MONITORING SYSTEM CONSOLE

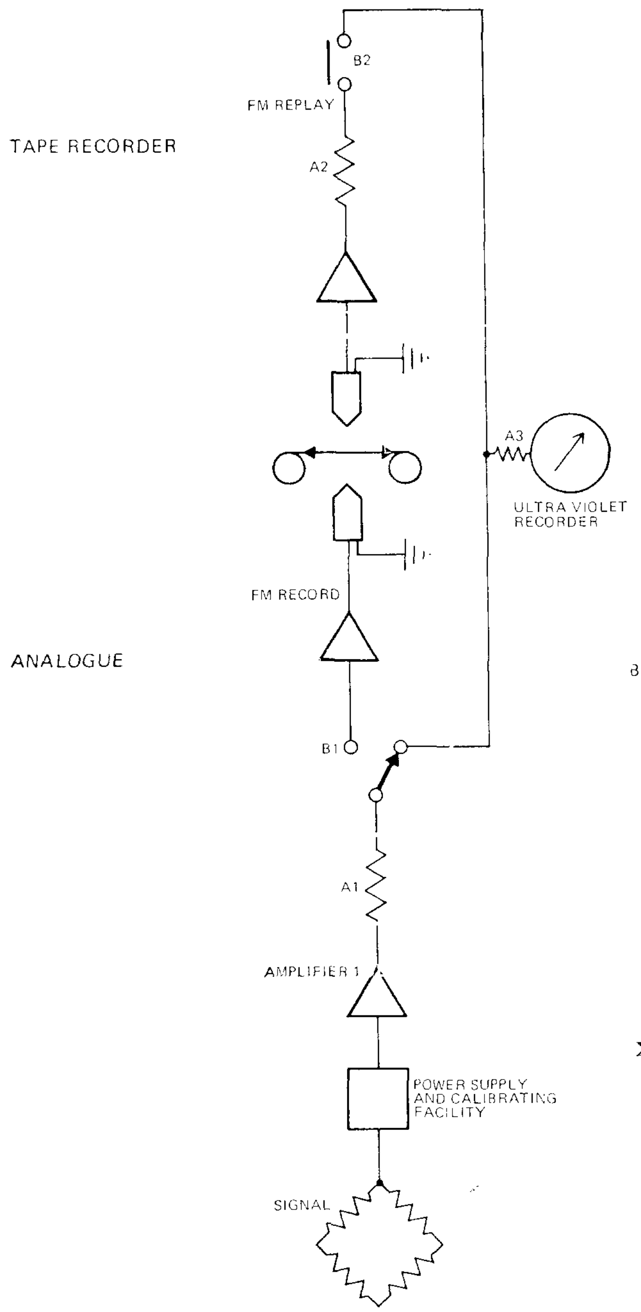

FIG. 2—BLOCK DIAGRAM OF SYSTEM LAYOUT (ONE CHANNEL)

A = Module Conditioning

B = Patch type function selector

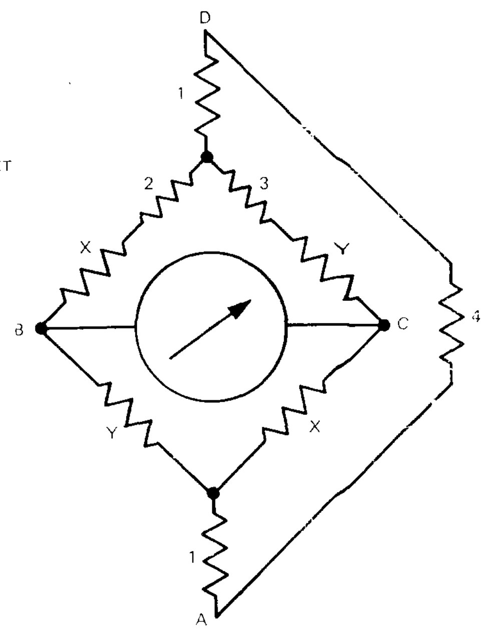

FIG. 3

X and Y = Active arms
1 = Voltage droppers
2 = Bridge balance
3 = Bridge balance and thermal compensation
4 = Impedance matching resistor

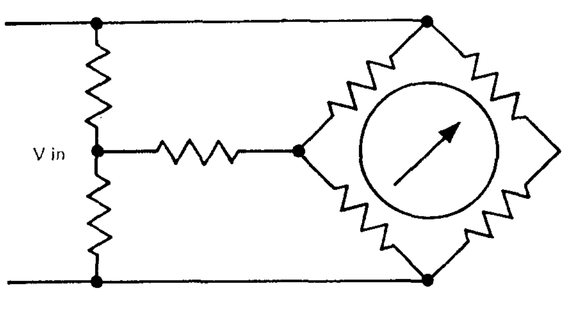

FIG. 4

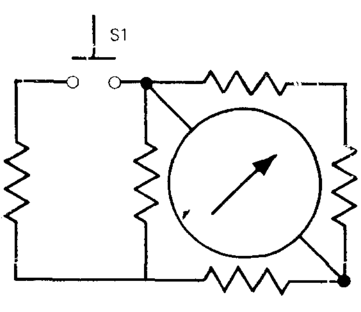

FIG. 5

Without the patch panel a complex system of switching would be required with all its associated inherent pick-up problems. This unit is supplied with a range of co-axial leads which are suitable for cross-connecting.

An easily removable orange perspex panel has been made to cover the front of the housing so that, once the whole unit system has been calibrated, the sub-units can be protected from any accidental switching.

The system is screwed to the main bulkhead and covers a subsidiary junction box which houses all main feed lines to and from the transducers.

Access for servicing is made easy by removable side-panels on the console. The individual amplifiers can be readily accessible by the use of extender cards which are provided.

Consider the functions of each unit in the system (see FIG. 2):

Signal

We need some form of electrical signal, proportional to or relatable to the parameter being measured. Generally, pressure sensing transducers operating on the four active arm Wheatstone Bridge principle are used.

The advantages of these devices are:

(*a*) Rationalized sensitivity, which makes setting up easier.

(*b*) High stability with respect to vibration and temperature, which is essential in a marine environment and when measuring hydraulics.

(*c*) High frequency response, which in this case is of little use as the tape recorder is running at slow speed and will therefore have a narrow band-width.

The disadvantages are:

(*a*) Low voltage output; it is high enough to drive a U.V. recorder galvanometer directly, but not sufficient to drive a magnetic tape recorder.

(*b*) Low output impedance, for the same reasons.

(*c*) Requirement for some form of exciting voltage.

However, some of the parameters cannot be measured in terms of pressure so another form of electrical source has to be adapted, e.g. shaft revolutions. In this case, the output is taken from the shaft revolutions tachometer which is a d.c. source proportional to the rate of revolution. All other signals not dependent on pressure are taken in the same way.

Power Source and Calibration Facility

As already stated, the transducer channels require an exciting voltage to make them function. For those not familiar with the principle, see FIG. 3.

The unit is arranged so that a voltage is applied to points A and D. The resistors are arranged so that the application of pressure will cause resistors X to be put in tension and resistors Y to be put in compression. Initially, the voltage measured between B and C was zero because Xs and Ys were all equal, or made equal by the addition of balance resistors 2 and 3. The tension or compression of the active arms so caused will change their electrical resistance and a voltage output across B and C will be directly proportional to the applied pressure and also directly proportional to the exciting voltage. Obviously the latter is limited by the resistance and hence the power handling capability of X and Y.

Stabilized power supplies with a nominal output of 10 volts d.c. have been used to drive the transducers. To avoid pick-up problems, individual isolated units have been used for each channel.

Incorporated in each unit is a bridge balance facility. Although the units can be manufactured to read virtually zero for zero pressure, parameters like atmospheric pressure and the height of one unit with respect to another will cause variations in zero output or 'Residual Unbalance'. A simple resistive network similar to the one shown in FIG. 4 is used to correct for these errors.

Here, part of the exciting voltage is fed either positively or negatively to the output to 'balance' the unit.

It was also decided that it would be useful to have a convenient calibration signal available to facilitate setting up the transducers without applying pressure.

The manufacturers have calibrated the transducers individually and included in the calibration certificate is the value of a shunt resistor which will give 80 per cent of full-scale output when placed in parallel with one arm of the bridge as shown in FIG. 5.

By closing S1, the bridge is unbalanced by 80 per cent full-scale and the system can be set up statically.

Amplifier 1

As already said, some signals were too weak to be fed directly on to tape; amplifiers were therefore introduced to all signals so that some sort of rationalization of levels and impedances could be achieved.

In the old system (using only an ultra-violet recorder), these signals had all been reduced to a level so that they could drive electromagnetic galvanometers. In the new system, in general, all signals are raised by approximately the same amount to enable them to be put on to tape. The increase in value is in the order of tens of millivolts to volts.

Here again, in order to keep pick-up noise to a minimum, the signal outputs were boosted as high as possible and the amplifier gain kept as low as possible. In this manner, a high voltage has been obtained which can be fed into the tape recorder or the U.V. recorder, or the output of the tape recorder onto the U.V. recorder.

It is desirable to have compatibility between the output of Amplifier 1 and the output of the FM reproduce amplifier, so that when the signal is applied to the galvanometer by either path it will reproduce identically. This has been achieved by conventional resistance impedance matching, using simple series or series/parallel or potential divider networks at A1 and A2. Conventional electromagnetic damping is required for the type of galvanometer used, and this has been incorporated at A3. Basically, this consists of one resistance placed in parallel with the galvanometer so that an alternative current path is provided thus controlling the dynamics of the movement.

The FM Tape Recorder

The device is a fourteen channel record/replay machine with voice track in addition to the data channels. The machine is capable of recording at speeds from $\frac{15}{16}$ inches per second to 60 inches per second; in this application, reproduce speeds of $\frac{15}{16}$ inches per second and 60 inches per second only are available and are the only ones required.

The prime requirement of the system is for long recording time; by using standard one inch by 3600-feet tape, the recording time can be approximately twelve and a half hours' duration. This can be increased up to about sixteen hours by the use of 4600-feet tape. However, if all the information is recorded on tape at its lowest speed, there is no time expansion available on this machine. The U.V. recorder, though, has a top speed of 256 cm. per second, so that one second of tape information cramped onto $\frac{15}{16}$ inches of tape can be placed onto photographic paper with approximately $\times 100$ time expansion.

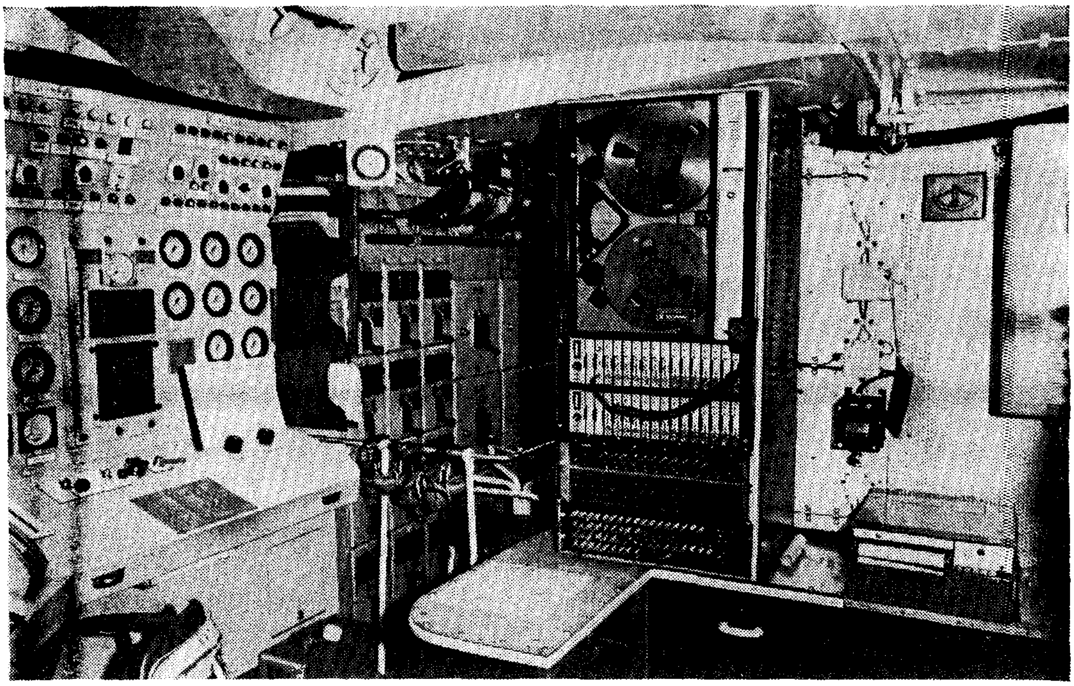

FIG. 6—BELL AND HOWELL DATA RECORDING UNIT

Features worthy of note on the machine are the auto-load facility which eliminates the problems associated with threading the tape when loading.

The transport has no pinch rollers. The old method of holding the tape against the capstans with little rubber rollers has been superseded in a machine of the quality of the CPR 4010. Here, by the application of a sophisticated tape path and tension system, the tape is brought into direct contact with the capstan and heads. This, of course, does not mean that the tape is rasping a groove across the heads during the fast wind/rewind modes because the system is so designed that, in these modes, aerodynamic lifting occurs and the tape no longer remains in contact.

Tape Recorder Installation

Installation of the equipment proved to be relatively easy despite the lack of available space in the machinery control room. Rewiring on site was negligible as the majority of new connections were incorporated into the console during assembly at the manufacturers.

The signal conditioning amplifier from the original ultra-violet system was removed from the bulkhead and incorporated in the recorder cabinet. Wiring in the vicinity was removed by ship's staff to provide space, and additional supplies were provided.

All inputs and power supplies were then led to a small junction box for coupling to the recorder amplifier console, the recording oscillograph now being supplied from the recorder.

The bulkhead was stiffened to accomodate the increased weight of the recorder which is mounted on four resilient mountings. Total installation time amounted to about 50 man-hours.

Setting to work of the equipment was hampered by an overheating problem within the recorder which was overcome by improving the air flow within the cabinet. Several transducer faults became apparent during initial runs; these have been or are in the process of being rectified.

Erasure of tapes is proving difficult as the recorder does not have tape erasure facilities covering the voice annotation refinement. It is hoped that this problem will be eliminated by bulk erasure of tapes using a device at present being obtained.

Conclusion

While in no way replacing the human element in the marine engineering branch, automatic data-logging will, in these days of reduced complements and yet still higher ship availability, be a valuable asset to the navy of the future.

The monitoring equipment recently installed in H.M.S. *Exmouth* will be particularly useful as the present gas generator reaches its Declared Overhaul Life, and it promises to be vital in performance analysis and fault finding.

Comment by Ship Department

This article on Data Recording relates to the system officially designated 'Dynamic Data Recording (D.D.R.)', which is under consideration for new construction ships. Such a system enables the user to obtain behaviour records of chosen parameters against time. By comparison against 'ideal' records obtained when setting systems to work, deviations can be detected providing assistance for diagnosis. This is common practice in servo control.

It goes without saying that a visual record is needed by the engineer, but these suffer from the disadvantage that they require excessive storage space and consume large quantities of expensive paper. In a propulsion machinery system, several parameters need simultaneous recording to achieve a broad picture of behaviour; for this reason, a need arises at times for some more convenient recording method. Magnetic tape recorders provide an attractive alternative and the unit in H.M.S. *Exmouth* is being fitted to explore whether the inclusion of such equipment is justified: cost is a significant factor to be weighed against usage.

Efforts are being made to find an inexpensive continuous loop tape recorder so that, at any given moment, a record exists of the immediately preceeding period. If this can be provided at reasonable cost and the benefit is significant, then such a DDR system would be a viable proposition for the Fleet.

Approved arrangements for the Type 21 frigate and the Type 42 destroyer will include permanent facilities for extraction of data from the control system and from the propulsion machinery; display, however, is limited to an ultra-violet recorder except during special trials when other recorders may be introduced.