THE DEVELOPMENT OF A HAEMOGLOBINMETER AND FIELD MICROSCOPE FOR PRIMARY HEALTH CARE USE IN DEVELOPING COUNTRIES

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Introduction

There is a pressing need for appropriately designed diagnostic instruments for rural health clinics in developing countries. This paper describes some work carried out in conjunction with Primary Diagnostics Ltd. to develop a haemoglobinmeter (the Anaemascan™) and a field microscope. Both designs are tailored to their severe working environment and to as low a price as possible given their specification. For both devices the work develops ideas originally formulated by Primary Diagnostics Ltd. The paper describes the design approach and the measures taken to ensure the effectiveness of the instruments.

The Anaemascan™

The Anaemascan (figure 1) uses light colourimetry of blood samples treated according to the alkaline haematin D-575 method. In this method 30µl of neat blood is added to a plastic cuvette containing 3ml of a mixture of 0.1M sodium hydroxide and Triton X100. Almost all of the haemoglobin compounds in the neat blood sample are converted to a stable pigment, alkaline haematin that absorbs light maximally at a wavelength of 575nm. The absorbance of light at this wavelength is directly proportional to the amount of haemoglobin present in the original neat blood sample.

The instrument uses a robust super-bright green/yellow light emitting diode (LED) as a light source with a peak emission wavelength of 590nm. A LED has the advantage of low power consumption, virtually no heat generation, very long life and physical robustness which is important in a field instrument. The output from the LED is further modified by an optical interference filter which has a central wavelength of 580nm and a halfbandwidth of 10nm. The interference filter is one of the most expensive and fragile items in the instrument and we have been investigating an alternative system using a very narrow bandwidth LED with a peak emission wavelength of 574nm in conjunction with an infrared filter. A photodiode in the light path beyond the interference filter is used in a feedback loop to maintain a constant light output from the LED. Absorbance of light by the cuvette containing the treated blood sample is measured by means of a light intensity to frequency converter device. The output of this...
device is fed directly into a microcontroller. In this way appropriate measuring resolutions can be obtained by integrating the output over a fixed period of time (currently 6s). The Anaemascan can be calibrated with just two standards. One is a 'blank' which is a cuvette containing just sodium hydroxide and Triton X-100 which sets the zero haemoglobin point. The other standard is a cuvette of bovine chlorhaemin, a stable reagent in powder form, which can be diluted appropriately to mimic a sample of known haemoglobin content.

The instrument is completely controlled by a low power microcontroller which converts the light absorbance in the test cell directly to a blood haemoglobin reading in g/dl using the stored calibration values in error checked onboard memory. The results are displayed on a dot matrix liquid crystal display (LCD) driven by the microcontroller. The LCD contrast is fully adjustable from the front panel to compensate for temperature changes. The microcontroller also controls power to the various sections of the electronics as well as placing the instrument into very low power standby after five minutes to conserve battery power. This avoids the problem of having to remember to switch the instrument off. The power supply is designed to enable the instrument to be run from mains voltages between 100 and 240V, 12V sources such as car batteries and solar panels or the on-board NiCd rechargeable batteries. When an external power source is present the internal batteries are charged. When any external power source fails, the internal batteries will continue to power the instrument without interruption.

The sample chamber uses a novel design to hold the sample cuvette orthogonal to the light path. It incorporates a sealed glass tube so that the whole sample chamber can be flushed out to clean any contamination.

The Microscope

The microscope has also been designed to keep the manufacturing cost as low as possible and to take into account its operating environment. The prototype device is shown in Figure 2. Focussing is carried out simply through the rotation of the light tube, with a spring-loaded thread to remove backlash. Micromanipulation is effected through a joystick which moves the slide carrier in orthogonal directions through a 4:1 mechanical reduction. The light tube itself attaches to the body of the microscope using a bayonet fitting which enables changing of the objective. Three objectives are housed in the instrument providing magnifications up to 1000x (needed to detect malarial parasite damage). All the structure above the slide carrier can be hinged backwards to enable cleaning, and in addition the whole instrument hinges into its robust and sealed carrying enclosure. The enclosure has a camera tripod mounting for use in difficult field situations. The light source is a 3000mcd white LED running from a power supply very similar to that used for the Anaemascan. The power supply has its own internal AA size NiCd cells which are charged via a switching power supply from either a mains source (100 - 240V) or 12V source such as a solar
cell. A very cheap and power efficient microcontroller monitors battery charging and controls the microscope sample illumination. The brightness level of the light source is adjustable via sealed pushbuttons through ten levels via pulse width modulation of the white LED. The light source is automatically switched off after about 15 minutes to ensure that the batteries do not become exhausted. A single press of the illumination control buttons restores the light source to it's previously set level.

**Evaluations**

Both instruments have been evaluated at hospitals in the UK to check their basic functioning and, in the case of the Anaemascan, to compare its performance against standard laboratory instruments. Figure 3 summarises the results of the Anaemascan tests and as can be seen it compares very favourably. The microscope has had an initial field evaluation in Indonesia leading to some minor modifications, and a batch of four is about to be tested in various developing countries. The Anaemascan has been evaluated in Kenya and is currently undergoing evaluations in Uganda and Tanzania. A further batch of three instruments is also about to be tested.

**Conclusions**

The two instruments described have both been designed specifically for use in developing countries and although the field evaluations may well highlight features that need developing further it is hoped that their introduction can help improve healthcare provision in developing countries.