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Latent heat load for u.h.f band

To overcome the difficulties of television coverage of some areas of the country, remotely controlled unmanned sites are being employed. These sites need components which have a high order of reliability with a minimum of maintenance. For this purpose a u.h.f high power test/standby load has been designed, which utilizes the latent heat of vapourization of water to dissipate the r.f power with a minimum of associated equipment and no moving parts.

This load therefore has distinct advantages over the conventional water dielectric type in this application, and the performance compares very favourably. The principle on which the design is based and typical performance figures for maximum c.w power are presented.

Introduction

The problems associated with television coverage in remote areas of the country or where the natural terrain causes difficulties in transmission and reception, are mostly being solved by the use of unmanned repeater stations.

Where an increase in the output of existing transmitters is impracticable or uneconomic, these smaller remotely controlled stations, very often on comparatively inaccessible sites, are utilized. Consequently the equipment used at these remotely controlled transmitters must have a high order of reliability with the minimum of maintenance.

Design objective

Test loads for dissipating the unwanted power from the standby transmitter during normal broadcasting times or whilst measurements are being made of the quality of transmission, are usually of the water dielectric type which require some form of pumping and possibly forced air cooling equipment as well to make them operational.

In order to dissipate 20kW of r.f power in this type of load a coolant flow rate of over seven litres/minute would be required to operate at a temperature 40°C above ambient. The relationship between flow, temperature and power is as follows:

$$\text{Flow rate (L/min)} = \frac{\text{Power (kW)} \times 14.4}{\text{Specific heat of liquid (cal/gramme/°C)} \times \text{Temp rise (°C)}}$$

The load would need a heat exchanger to cool the liquid or a large reservoir or radiator with a surface area greater than $30m^3$ to dissipate the power by convection and radiation.

The concept of a load utilizing the latent heat of water vapourization as a means of dissipating power is therefore very attractive as such a load would not need the attendant pumping and/or forced air cooling equipment.

Marconi design

Basically the load consists of a radiating $3\frac{1}{8}$in E.I.A. feeder immersed in a lossy medium which is allowed to boil and the steam vented to the atmosphere. To minimize the cost of the load a commercially available water cylinder, having a nominal capacity of 227.5 litres (50 gallons), has been modified to suit this application.

The fact that in remote areas there may well be no main-water services on site is of no consequence as the latent-heat load only requires a suitable capacity header tank to maintain the fluid level during operation. Although the device is capable of operating equally satisfactorily using tapwater as the lossy medium, the fluid level being maintained through a simple ball valve, it would however need regular draining and descaling owing to the mineral elements contained in the local water supply which would slowly increase in concentration. Therefore, to optimize performance and to give a

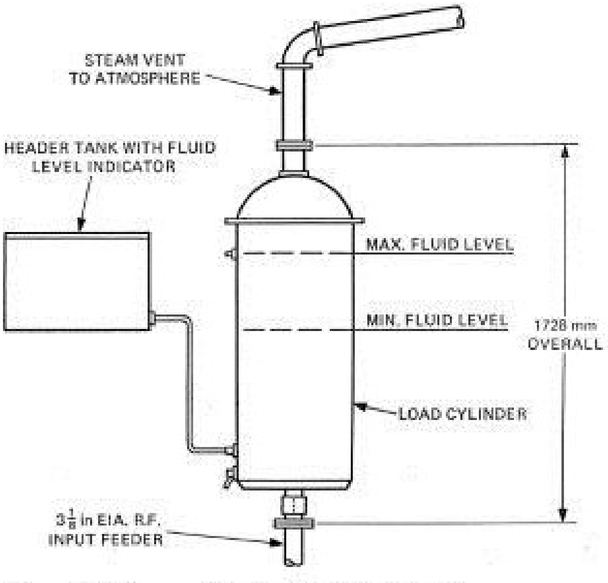

Figure 1. Diagram showing latent heat load

repeatable conductivity to the fluid, distilled or demineralized water is recommended with an initial additive of an inorganic salt to give a conductivity similar to tapwater, ≏700 micromho/cm. As this additive does not steam distil in operation the device only needs topping up subsequently with distilled or demineralized water.

A header tank having a capacity of 182 litres (40 gallons) gives a satisfactory period of continuous operation at an input power level of 20kW without the need for refilling.

The power radiated in the form of heat from the surface of the device is given by:

$P = E_t (T^4 - T_o^4)$

where P = radiated power in watts/metre^2

E_t = total thermal emissivity of the surface

σ = Stefan-Boltsmann constant = 5.67×10^{-8} watt-metres^{-2} × degrees Kelvin^{-4}

T = temperature of radiating surface in degrees Kelvin

T_o = temperature of surroundings in degrees Kelvin (ambient)

The total thermal emissivity varies with the degree of roughness of the surface finish of the material and is increased by painting the surface matt black. However, unless a very strictly controlled thickness of paint is applied, the greater emissivity of the colour will be lost since the paint is a poor thermal conductor. For this reason the thermal emissivity figure for untreated raw finish copper, i.e 0.07 at 300K, is used in the following power handling calculation:

$$P = 0.07 \times 5.67 \times 10^{-8} \times (371.15^4 - 293.15^4)$$
$$= 47.2 \text{ watts/metre}^2$$

Since the Marconi design has a total surface area of 2.52m^2, $P = 119$ Watts. A shield may be fitted to the load to protect any temperature sensitive components in close proximity to this radiated heat.

From cooling curves, determined by experiment, the device dissipates a total of 1.96kW by natural convection, conduction and radiation, the cooling rate being 0.124°C/min at 98°C which leaves 18.04kW to be dissipated by the latent heat of water vapourisation for an input power of 20kW.

The latent heat of water = 2256.67 joules/g and 18.04kW = 18.04×10^3 joules/s so, water consumption in g/s by vapourization will be:

$$\frac{18.04 \times 10^3}{2.25667 \times 10^3} = 8.0 \text{g/s or } 28.8 \text{L/h}$$

Note: For water, g/s is approximately equal to cm^3/s.

The operating capacity of the load cylinder from maximum to minimum fluid levels is 71.6 litres which, with the 182 litres in the 'header' tank, gives a total of 253.6 litres, sufficient for 8.8 hours continuous operation at 20kW input power before the 'header' tank needs refilling. This time is increased if the transmitter is used for several shorter periods as the time taken to reach the boiling point of the fluid has not been allowed for in the above calculation.

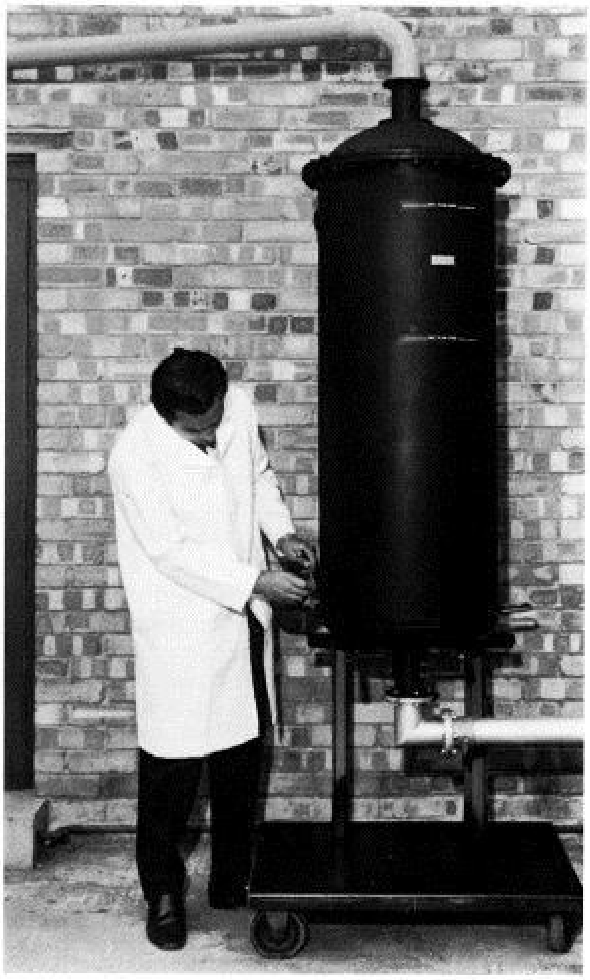

Figure 2. U.H.F latent heat load

Electrical performance

The impedance of the device is matched to that of the 3⅛in EIA input feeder for any desired 8MHz wide operating channel between 470 and 960MHz with a v.s.w.r of less than 1.04:1 (typically 1.02:1). Inherent in the design of this type of load is a slight 'jitter' in the reflected power when the fluid is boiling, due to reflections from air bubbles nucleating in close proximity to the radiating coaxial feeder and rising to the surface of the fluid. This causes approximately 1° phase variation, and at a nominal v.s.w.r of 1.02, produces a variation from 1.015 to 1.025. Such a variation does not normally affect the test measurements needed on site but if, as for some waveform measurements such as differential phase, etc, the characteristic is troublesome, time is available prior to boiling for such tests to be made. (As the output power is approximately only 60 per cent of full power when transmitting test waveforms the time available would be some two hours).

The c.w power handling capacity of the load is limited only by the rating of the 3⅛in EIA standard rigid coaxial feeder, i.e 22kW at 500MHz falling to 15kW at 1000MHz at normal operating ambient temperatures of 10 to 30°C. Designs to suit larger feeder sizes to give a higher power handling capability should be possible, but it is important to note that the figures quoted in this article are for near maximum input power levels and therefore the heating times are at a minimum and water loss figures at a maximum.

Operation

The header tank should be fitted with a non-executive low-level alarm or can be connected to an interlock on the transmitter, but the load will not be damaged by operation below the minimum fluid level though the transmitter will 'see' a worsening v.s.w.r and would eventually trip due to the impedance mismatch.

Should lagging of the load cylinder be required to reduce external heat dissipation, a 25 per cent efficient covering would reduce the maximum continuous operating period, before making up the fluid level in the header tank, to 8.55 hours at 20kW input power. The air flow of 1300 ft^3/min for each transmitter when operational would be sufficient to keep the ambient temperature to within 2 or 3°C of normal without any lagging of the load cylinder. At switch-off the ambient temperature would rise gradually but during the half hour required to warm up the transmitter would quickly return to normal.

To increase the operational time between refillings of the header tank when operating on continuous maximum input power, it would be possible to pass the steam through a section of finned pipe mounted on an external wall of the transmitter building partially to condense the exhausted steam by natural convection and feed the condensate back to the header tank. However, to incorporate a 100 per cent efficient condenser would once again bring in the necessity for a forced cooling system which would destroy one of the major advantages of the load.

The Marconi load Type F1277-02 shown in figures 1 and 2 weighs approximately 55kg when empty and for ease of installation is designed to be shipped as a complete unit (excluding the header tank). It is used primarily with Marconi transmitters B7319 and B7320. The B7320 is the main transmitter having two Klystrons giving separate sound and vision outputs of 7½kW vision and 2½kW sound. The B7319 is the lower power single Klystron standby transmitter with a combined sound and vision output of 2½–3kW.

Conclusion

This new Marconi load demonstrates that, utilizing the latent heat of vapourization of water, r.f power can be successfully dissipated with distinct advantages over the more conventional water cooled loads. In particular these new loads are an obvious choice for transmitter installations at remote, unmanned stations, where maintenance services are only provided at infrequent intervals.

Acknowledgement

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