DEVELOPMENT OF SALT CYCLE PROCESS INSTRUMENTATION

By

C. E. Huck and O. H. Koski

Process Control Development Operation
Chemical Development
Chemical Research and Development
HANFORD LABORATORIES

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HANFORD ATOMIC PRODUCTS OPERATION
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DEVELOPMENT OF SALT CYCLE PROCESS INSTRUMENTATIONSUMMARY

Instrumentation for analysis and control of key Salt Cycle Process variables is being developed as part of Chemical Development's engineering scale studies of the process. The current program includes instrumentation for continuously determining liquid level, density, and uranium concentration of the melt, and for integrating ampere-hours during the electrodeposition step. In addition, systems have been devised for controlling the cathode-to-reference electrode voltage both for the primary electrolysis and for a micro-electrode device used to obtain data on pre-electrolysis condition of the melt. Development work is also underway on a versatile control circuit for regulating melt temperature of multiple pots using a single motor generator.

This report describes these instrumentation systems and their application to the Salt Cycle Process.

DISCUSSIONMolten Salt Density and Liquid Level Measuring System

The density of the molten salt in the electrolysis pot can be used to approximate the amount of dissolved uranium in the melt. Although density and liquid level can be obtained with differential pressure cells and purge tubes, possible plugging and radioactive containment problems with the use of purge gas prompted the development of devices which would circumvent these problems.

The density measurement system developed is based on determining the weight of a submerged quartz plummet whose volume and weight in air are known.

The plummet is weighed by a strain gage load cell in conjunction with a Brown strain gage recorder. The recorder is equipped with a span and zero calibration to facilitate the changes of plummets to be used with the load cell without need for the calibrating of the recorder for each plummet used. The accuracy of the system appears to be within 1% for a density range from 15 to 3 gms/cc. A diagram of the system is shown in Figure 1.

The liquid level in the salt cycle electrolysis bath is obtained with the following system: A quartz float supports a Hastalloy D rod which positions a coated iron core in a rotameter transmitter. The position of the core is read out with a Dynalog recorder. The system is shown in Figure 2. The range of the instrument is 10-1/4 inches with an accuracy greater than 1%.

Uranium Photometer

A filter photometer is currently under development for accurately determining uranium concentration in the melt.

The photometer contains a light source from which light is directed down a quartz tube to a cell at the end of the probe. The light passes thru a 2mm thickness of solution and is reflected by quartz prisms such that its direction is changed 180 degrees and directed up the quartz tube, focused, and split into two beams. The intensity of the light on a narrow wave length band, about 800 mu, is measured from one beam; the intensity of the light at about 1100 mu is measured from the other beam. The intensity of the light at 800 mu gives a measure of the initial intensity before absorption and at 1100 mu the intensity will be a measure of the uranium concentration.

The light intensities are determined by current outputs of photo tubes using an instrument termed a differential photometer. This device measures the current from two sources; applies an adjustable scaling factor, subtracts dark current values, and provides a voltage analog of the current values as an output. An output which is an analog of differential between the scaled current values is also available and the concentration may be computed from this value. It is also possible to use the two outputs in external circuitry to yield values which are proportional to the concentration.

Figure 3 shows the photometer system in schematic form.

Electrolysis Voltage Control and Ampere-Hour Integration

The electrolysis voltage control unit originally provided for the salt cycle experiments was comprised of a 3-phase servo-driven variable auto transformer with step-down transformer and rectifiers. Feedback was direct from anode and cathode to a voltage comparison bridge with a current sensitive relay as an unbalance detector. This relay in turn actuated other relays which controlled the servo-motor direction.

It was desired to control the cathode-to-reference electrode potential with this control unit. This problem was solved by reading the potential with a high impedance voltmeter whose output was fed to a recorder with a proportioning resistor and set point. By using the reference voltage available in the unit as a bridge voltage across a bridge comprised of the proportioning resistor and half of the voltage comparison bridge, and using the relay detector again as an error sensing device the unit was closed loop controlled. The speed of the forward loop (voltage output was approximately 1 volt/sec) was excessive for proper stability due to the time constants associated primarily with the recorder balancing. System stability was achieved by slowing down the forward loop with a gear reduction unit between the servo-motor and variable auto transformer.

A schematic diagram of the subject system is to be found in Figure 4.

A useful measurement in the control of the Salt Cycle Process is the integrated ampere-hour product for each batch electrolysis.

The system developed for the Pyrochemical Test Facility consists of a shunt which produces a voltage analog of the electrolysis current, a millivolt-to-current converter and an integrator utilizing a current signal input.

As the electrolysis current varies from 0-500 amps, the integrator output of 0 to 500 counts per hour indicates the total integrated ampere-hour product.

A schematic diagram of the system is presented in Figure 5.

Measurement of Bath "Wetness"

A test is made of the electrolysis bath "wetness" which is believed to be indicative of the quality of the uranium dioxide deposit which will be formed. To accomplish this measurement, a microelectrode array consisting of an anode, cathode, and reference electrode are immersed in the salt bath. The anode-to-cathode current at controlled cathode-to-reference electrode potential is plotted versus time. This plot is inferential of the quality of the deposit.

This instrumentation system is composed of three electrodes, a 0 to 5 DC power supply with voltage output from 0.1 to 10 volts, a high impedance input voltage measuring device, an isolation and inverting amplifier and a voltage controller.

A Keithley micro-microammeter with an input resistor was used as the high impedance input reference-to-cathode voltage measuring device. An Electronic Control Systems magnetic operational amplifier was used as an isolation inverting amplifier, and a Philbrick P65 operational amplifier with input and feedback circuitry functioned as the output voltage controller. Feedback signals from the Keithley-Electronic Control Systems magnetic amplifier measuring system were fed into the voltage controller.

Figure 6 presents a schematic of the circuitry used. Optional control by feedback from the anode and cathode is available.

Control of voltage showed a maximum error of 0.015 volts in the range from 0.050 to 10 volts.

Induction Heater Work Station Control System

An existing 30 kw, 9,600 CPS electro-mechanical induction heating generator, attached to a 15 kw capacity work station in 321A Building is not being used to full capacity. Development of a second, independently-controlled work station for the 30 kw generator was initiated during the latter part of 1961. The proposed work station

control system will make use of silicon controlled rectifiers (SCR's) to control the temperature of the new work station while the existing system controls the generator DC field current to control the temperature of the existing work station. Some interaction between the two control systems might reasonably be expected during start-up and steady-state operation but due to the relatively steady nature of the heating rates for fused salt loads, this is not expected to be an insurmountable problem. The advantages of multiple work stations on a single induction heating generator are manifold, in that convenience and ease of operation are greatly increased and large cost savings would result over buying individual generators for each work station.

The SCR pulse control circuit was developed and successfully operated in February of this year but when connected to the 0.3 to 5 ma output of the available Brown Electro Volt Controller, the timed spacing between SCR firing pulses fluctuated at a rapid rate. The fluctuations in pulse spacing were determined to be caused by relatively large 5 and 60 CPS ripple voltages in the output of the controller which were amplified by the input transistor amplifier of the solid state controller to cause the indicated fluctuation in pulse timing. The 5 and 60 CPS ripple components could not be successfully filtered out using conventional low pass filters because a large circuit time constant resulted especially for the 5CPS component, which increased the controller response time excessively.

As shown in the diagram, Figure 7, the solid state controller varies the firing angle of the power-controlling SCR's by generating a firing pulse at the correct time after the start of each half cycle of the 9600 CPS sine wave. Illustration 2a indicates the work station current wave shape for a 100% power output from the SCR's and 2b shows the current wave shape for 50% power output. SCR operation in the subject circuit is identical to that of thyratrons when phase shift control of their firing angle is used. Thyratrons are not suitable for use at frequencies as high as 9600 CPS because of their slow deionization time of up to 75 microseconds which limits them to the power line frequencies. SCR's typically turn off in 15 to 25 microseconds making them suitable for use at about 10 kc where a half wave period equals 50 microseconds. In addition, thyratrons have a forward conduction voltage drop of 8 volts compared with about 1 volt for SCR's which indicates that the SCR's are better from an internal power dissipation standpoint and also for transmitting as high a voltage as possible to the AC load.

Obviously, the wave shape shown as 2b in Figure 7 is not a sine wave but because of the parallel capacitor bank indicated in C₂, which resonates with the work coil inductance, the resulting current in the work coil should be a pure sine wave for any amount of controller output current. The major remaining objective is therefore to determine whether resonance in the work coil can be maintained for any value of current input to the secondary work station.

FIGURE 1

Salt Bath Density Measuring System

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FIGURE 2

Liquid Level Measuring System

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FIGURE 3

Salt Bath Probe Photometer

(D) Relay Unbalance Detector

(R) Resistors in Voltage Comparison Bridge

FIGURE 4

Schematic of Electrolysis Voltage Control System

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FIGURE 5

Salt Cycle Ampere Hour Integrator

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FIGURE 6

Schematic of Micro Electrode Voltage Supply and Control

TIC = Temperature Indicating Controller
TRC = Temperature Recording Controller

FIGURE 7

Schematic Diagram of the Solid State Secondary Work Station Controller for use With the Fused Salt Induction Heating Generator