LINAC COMPONENTS, PROVISIONAL SPECIFICATIONS

No. 3 TIMING EQUIPMENT.

The method of inflection into the A.G. P.S. is such that effective injection is limited to the period between the moment at which the inflector electrode voltage is removed, and a moment 6.7 µsec earlier. We shall call this the inflection period.

For normal operation we shall usually wish to inject during the whole of the inflection period, so the ion-source pulse would conveniently be a little longer (at both ends) than the inflection period, mainly to allow for any relative time error or jitter between them: about 10 or 11 µsec ion source pulse, which gives about 2 µsec margin at each end, would be reasonable. If it turns out that this 4 µsecs of uselessly beam is undesirable, then the ion source pulse will have to be made the same length or a little shorter than the inflection period, and the time error between them kept down to a fraction of a microsecond. For some types of injection studies it will be useful to reduce the injection period to various values between 1/2 and 6 µsecs, and to place this shorter period at various times within the inflection period; this will be done by varying the length (and starting time) of the ion source pulse if this is easily arranged, otherwise some form of beam-chopper will be necessary.

To place the injected beam in the centre of the phase-stable region in the synchrotron, within ± 10 o/o of its height, the operations above must occur at the correct moment of the synchrotron programme within ± 5 µsec*, so the relative timing of ion source, inflector, beam chopper if any, between one another has to be more precise than their "absolute" timing as a whole from the synchrotron. It is therefore proposed to derive a pulse from the synchrotron R.F. frequency by

*We are assuming \( \dot{\theta} = 12 \text{ Kg/sec} \) and operation on the 20th harmonic.
an $F_1$ type device (see CERN-PS/HGH 7 and CERN-PS/HGH 5) about 20 $\mu$secs before the ideal instant of injection, and to have a variable delay unit of 5 to 30 $\mu$sec range, 0.2 $\mu$sec precision, between the $F_1$ device and each of the ion source, inflector, and beam chopper if any. The $F_1$ device should have its resonant* frequency adjustable over a range of $\pm 6$ per mil (corresponding to $\pm 70$ $\mu$sec variation in injection timing) to allow full exploration of the phase stable region in the synchrotron. An $F_1$ device at a fixed, lower resonant frequency, followed by a 0-140 $\mu$sec adjustable delay, could be used instead, but this is not so good a solution.

Several components, notably the main pulser and magnet pulser and various gating circuits, require to be triggered at times of the order of 200 $\mu$sec before the inflection period. For this purpose it is proposed to have another $F_1$ device ($F'_1$) which provides a pulse 250 $\mu$sec before the one already required ($F_1$), by virtue of having a 2.1 o/o lower resonant frequency, and then a number of 5-250 $\mu$sec range variable delay units, one for each of these pulses, gates etc. The variation in timing required in $F_1$ for exploration purposes must also occur in $F'_1$, i.e. they must be gang-tuned over $\pm 6$ per mil range of frequency.

$F_1$ units with the sort of precision we require are being developed for the purpose of checking the accuracy of the synchrotron frequency-computer, so it is likely that the linac group can make its requirements of $F_1$ units without doing much development work.

To obtain a system of maximum flexibility the output pulses of the two $F_1$ units, the input pulses required by, and the output pulses given by, the delay units of both kinds, should all be the same. Unless new technical considerations appear, we can standardise on the triangular pulse of CERN-PS/EE 3. All modulators, gates etc. should then be built to respond to

* By resonant frequency we mean the R.F. frequency at the instant when the device produces its output pulse, so the effect of any intrinsic time lag is included.
such pulses, containing where necessary their own preamplifiers or
electronic relays to do so.

The two gauged \( F_1 \) units and the collection of short and long
variable delay units already described cover the basic requirements of
linac timing equipment: their specifications are given in Appendix I.
Various other requirements which arise are dealt with below.

**Simulator.**

To set up or test the linac when the synchrotron is not operating
we need a unit to simulate \( F_1 \) and \( F'_1 \). This can conveniently have a variable
repetition rate.

**Interpulser.**

We shall want the facility to operate the linac at a faster repetition
rate than the synchrotron, for example: linac at 1 pulse per second with every
fifth pulse being injected into the 1 pulse per 5 second synchrotron. Thus a
unit is required that behaves, between synchrotron pulses, like the simulator
already mentioned; and it will probably be convenient to make a single unit
which will do either job. When running the synchrotron at very much reduced
repetition rate, or on a single-shot basis, this unit would be set to run on
from one synchrotron pulse indefinitely until blocked by a signal warning it
of the imminence of the next.

When using this interpulser to run the linac faster than the synchrotron
some components (e.g. the R.F. system) will be required to operate on every
pulse, but some others (e.g. ion source, inflector, perhaps pulsed focusing)
may only be required on the pulses at which the synchrotron is operating. This
is easily arranged by connecting the delay-units for the former to the
interpulser and the delay units for the latter to the \( F_1 \) or \( F'_1 \) unit.
Checking

Most of the checking of this timing equipment will be done by triggering a scope time-base from $F'_1$ or $F''_1$ and putting any or all of the outputs of the delay units onto the Y plates. The scope should have at least a 30 and a 300 μsec sweep time available. The time difference between the $F'_1$ and the $F'_1$ pulse should be checked (to check both the ganging and the synchrotron frequency law in this interval) by having an additional long-delay unit triggered by $F'_1$ and set always at 250 μsecs delay. $F'_1$ should probably be checked by having another similar unit $F''_1$, not tunable and more stable than $F'_1$ and $F''_1$, giving a signal at the centre of the nominal range of $F'_1$, or (probably more usefully) at the centre of the ideal inflection period.

A general check on the delay units, done when the components that they trigger are switched off, can be made more speedy and convenient by operating the simulator at say 10 or 100 pulses per second. If such a facility is provided it must be made safe against false moves by designing all modulators etc in such a way that they neither suffer nor do any harm when triggered at a high rate.

Machine Parameters

All the above, and Appendix I, are based on the assumptions that we use a harmonic number of 20 and a rate-of-rise of 12 Kgauss/sec. An appendix will be issued to deal with the effect of changing these parameters if such a change seems likely.

The effects of small differences in $B$ from a nominal 12 Kgauss/sec are as follows:
1. If the difference between $\dot{B}$ and its nominal figure exceeds about 10 o/o the resonant-frequency difference between $F_1$ and $F_1'$ ought to be altered by retuning the latter.

2. An error or a change in $\dot{B}$, less than 10 o/o, can readily be dealt with by operating the ordinary control knobs (checking against $F_1'$).

3. Changes in $\dot{B}$, even including erratic ones from pulse to pulse, can be ignored if they do not exceed about 1 o/o.

If there is an error in the synchrotron frequency computer the above remarks about $\dot{B}$ can in principle be applied to errors in $\dot{\omega}$. It is very unlikely that such errors can be large enough to matter in the present connexion because the computer must generate the correct $\omega$, at injection and subsequently, within a few parts per mil or better, for other reasons: so we can be reasonably certain that $\dot{\omega}$ will, already in the last few hundred microseconds before injection, have the correct relationship to $\dot{B}$ within 1 o/o.
**APPENDIX I**

**SUMMARY OF DETAILED SPECIFICATIONS.**

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**A. The standard pulse (CERN-PS/EE 3):**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Form</td>
<td>triangular</td>
</tr>
<tr>
<td>Rise-time</td>
<td>0.1 µsec</td>
</tr>
<tr>
<td>Amplitude</td>
<td>50 volts</td>
</tr>
<tr>
<td>Polarity</td>
<td>positive</td>
</tr>
<tr>
<td>Fall</td>
<td>2 µsec exponential</td>
</tr>
<tr>
<td>Jitter</td>
<td>&lt;0.05 µsec</td>
</tr>
<tr>
<td>Impedance</td>
<td>75 ohms</td>
</tr>
</tbody>
</table>

An instrument producing standard pulses should make them within say ±10 o/o of these parameters: an instrument receiving standard pulses should be designed to operate satisfactorily so long as they are within say ±40 o/o.

**B. The F₁ and F₀ unit:**

<table>
<thead>
<tr>
<th>Input:</th>
<th>R.F., from the synchrotron R.F. system, at a few tens of volts on 75 ohm cable, properly terminated.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output:</td>
<td>Of F₁, a standard pulse at the instant when the R.F. frequency passes 2.944 MHz, adjustable (ganged with F₁) over a range of ±18 KHz, stability and precision ±1 KHz (corresponding to ±5 µsec timing error) or better. About 6 outputs required.</td>
</tr>
</tbody>
</table>
Of $F'_1$, a standard pulse at the instant when
the R.F. frequency passes 2.984 MHz, adjustable
(ganged with $F'_1$) over a range of $\pm 18$ KHz, sta-
bility and precision $\pm 1$ KHz or better. About
6 outputs required. 
Stability and accuracy of the ganging to be such
that the 60 KHz difference between $F'_1$ and $F_1$ is
constant within $\pm 1$ KHz or better.

C. The $F''_1$ unit (for checking):

<table>
<thead>
<tr>
<th>Input</th>
<th>As for $F'_1$, $F''_1$.</th>
</tr>
</thead>
</table>
| Output | A standard pulse at the instant when the R.F.
|        | frequency passes through 2.9497 MHz, stability
|        | and accuracy preferably better than $\pm 1$ KHz.
|        | About 2 outputs required. |

D. The short-delay units:

<table>
<thead>
<tr>
<th>Input + Output</th>
<th>Standard pulses. Three equivalent output terminals.</th>
</tr>
</thead>
</table>
| Delay         | Adjustable 5 to 30 µsecs, calibrated in µsecs,
|               | accurate and stable to about $\pm 0.2$ µsec. |
| Repetition rate | Capable of handling zero to say 100 pulses per second. |

Two or three such units, plus spares + replacements, required.
E. The long-delay units:

- **Input + Output:** Standard pulses. Three equivalent output terminals.
- **Delay:** Adjustable 5 to 250 µsecs, calibrated in µsecs, accurate and stable to ± 5 µsecs or better.
- **Repetition rate:** Capable of handling zero to say 100 pulses per second.

Four or five such units, plus spares and replacements, required.

F. Inter-pulser and Simulator unit:

When switched to operation as interpulser:

- **Inputs:** Two input terminals I and I' accepting standard pulses from F_s and F_t respectively.
  One input terminal for blocking signal, preferably to accept any shape positive pulse of 50 V amplitude.
- **Outputs:** About 6 output terminals designated type 0, and about 6 output terminals designated type 0'. A standard pulse coming in terminal I always appears, without significant delay, as an output on all terminals 0, and similarly for I' and 0'.
  Any pulse coming in on I' initiates a free-running process which has a repetition rate adjustable over the range 0.1 to 2 per second, generating standard pulses on 0' terminals each followed 250 (+ 5 or less) µsec later by a standard pulse on 0 terminals. This process to continue, for a period which can be set to any value from 0.5 to 20 seconds or to infinity.
unless and until stopped by a signal appearing on the blocking-signal input terminal.

When switched to operation as simulator:

Inputs: None. There should be no effect on operation or output even if the input terminals remain connected and pulses are fed into them.

Outputs: The same terminals are used as for use as an interpulser, and the free-running process is also just the same as for interpulser use except that a manual control (switch or push-buttons) is used to initiate it and to block it. To have a higher (≈100/sec) repetition rate available may be convenient.

H.G. Hereward.