FINAL ENGINEERING REPORT
ON CONSTRUCTION OF
BEACON VIDEO DEFRUITING EQUIPMENT
TYPE 2.3NS10

FEDERAL AVIATION AGENCY
Contract FAA/BRD-76

REPORT NO. 4614-1
April 1959

Airborne Instruments Laboratory
A DIVISION OF CUTLER-HAMMER, INC
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by

P. G. Holcombe

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ABSTRACT

In a dense air traffic environment many non-synchronous beacon replies are generated. These replies or "fruit" clutter the PPI display and thereby mask true or synchronous beacon replies. Beacon Video Defruiting Equipment 2.3NS10 was designed to eliminate the fruit or unwanted replies without deterioration of the synchronous replies. This report describes the defruiting equipment and the associated design problems encountered.

A. INTRODUCTION

When several beacon ground stations are located within the same general area, each interrogator receives, in addition to the synchronous replies to its own interrogation, many asynchronous replies (called "fruit") resulting from interrogations of the airborne transponders by other ground stations. These asynchronous replies interfere with normal decoding functions and cause annoying clutter on the displays, making normal tracking difficult for the controller.

Beacon Video Defruiting Equipment Type 2.3NS10 performs the function of a video coincidence detector or synchronous reply filter that permits only those replies that are synchronous with the beacon trigger to pass through the unit to the remoting equipment and displays. Asynchronous replies or fruit are rejected--hence the name defruiting equipment.

In system operation, the beacon interrogator transmits a series of paired pulses at the radar PRF or a submultiple thereof. These interrogations trigger replies from airborne transponders. Normally, each reply from a transponder consists of a train of two to eight pulses with a nominal pulse duration of 0.45 μsec. The first and last pulses of the reply train are spaced 20.3 ± 0.1 μsec apart. Intermediate pulses may occupy any assigned intermediate pulse position, the spacing between adjacent pulse positions being 2.90 ± 0.05 μsec or multiples thereof. The defruiting equipment can operate with the spacing between adjacent pulses set at 1.45 ± 0.1 μsec or less. Some special transponder replies may consist of 1.0-μsec pulses spaced at 16 μsec. The r-f pulses are received at the interrogator, demodulated, and passed as video pulses to the defruiting equipment, to one or more video interconnection equipments via the beacon video remoting equipment (where the display trigger is derived), and to a plan position indicator (PPI). In most cases, transponder replies and radar targets are displayed on the same indicator; therefore, the radar and the beacon system must be synchronized, so that the radar and beacon targets for the same aircraft will be displayed at the same range and azimuth.

Beacon Video Defruiting Equipment Type 2.3NS10 is a part of the Type III Air Traffic Control Radar Beacon System and can be applied to the common military and civil systems. The equipment is connected between a beacon interrogator similar to Beacon Interrogator Type 2.3NS1 and a decoder-mixer similar to Video Interconnection Equipment Type 2.3NS4a via a remoting equipment similar to Beacon Video Remoting Equipment Type 2.3NS7 when long (300 to 10,000 foot) cable lengths are involved. This final report fulfils Items 1 (7) and 2 (7) of the contract.

B. THEORY OF OPERATION

Beacon Video Defruiting Equipment Type 2.3NS10 (Figures 1 and 2) consists of the following units.

1. Video Tracking Unit 2.3NS10/TD-2
2. Video Delay Unit 2.3NS10/TD-1
3. Video Signal Comparator Unit 2.3NS10/CM-1
4. Power Supply 2.3NS10/PP-1

By using the dynamic storage properties of a quartz delay line to compare the replies from successive interrogations, the Beacon Video Defruiting Equipment rejects asynchronous replies or fruit resulting from interrogations by other equipments. The replies are delayed for one interrogator period and compared in a coincidence mixer with those replies received during a second interrogator period. All replies that do not change their position in time by more than a specified amount from one interrogator period to the next are accepted.

Some asynchronous replies may coincide and be accepted on a statistical probability basis together with the synchronous interrogation replies. To reduce the number of these random coincidences in the coincidence mixer, a double comparison can be made by operating the equipment in the double-defruiting mode of operation. In this configuration, the output of the first coincidence mixer is delayed for an additional repetition period and compared with the video that occurs during the next interrogator period in a second coincidence mixer. Thus, replies on three successive sweeps must coincide in time to ensure an output.

To ensure coincidence for successive synchronous interrogation replies, the time delay of the defruiting equipment must be maintained equal to the interrogator period to an extreme accuracy. The environmental specifications for the defruiting equipment are -10 to +60 C. For a quartz temperature coefficient of 70 parts per million per degree centigrade, a 2778-μsec delay line would have a delay variation of about 0.2 μsec per degree centigrade; thus, there would be a 14-μsec difference in the delay periods of the radar and defruiting equipment. When operating in the interlace mode of operation, the two delay lines of the defruiting equipment are in series, and the maximum delay difference could then be as high as 28 μsec.

If the delay lines of both the radar and the defruiting equipment are enclosed in temperature-controlled ovens, the delay difference is greatly reduced.

The delay lines of the radar and defruiting equipment supplied under this contract were temperature-controlled to ±1 C. In this case, the maximum cumulative difference was ±0.6 μsec, consisting of ±0.2 μsec for the radar delay line and ±0.2 μsec for each of the delay lines of the defruiting equipment.

The delay period of the delay lines was factory-set within ±0.2 μsec of the nominal period at a temperature between 68 to 76 C. This delay-period error, added to the error due to the ±1 C thermostat control, results in an overall delay difference of ±1.2 μsec. Theoretically, the delay-line thermostats can be trimmed in the field to improve the matching, but practically it was found laborious and time-consuming to achieve accuracy much better than 0.1 μsec or 0.2 μsec.

To adjust the delay period of the defruiting equipment for the variations in the nominal setting and temperature control, a ± 2.5 μsec tracking delay line was inserted in the delay loop of the defruiting equipment. The ± 2.5 μsec tracking delay allowed a safety factor of slightly more than 100 percent. To allow for misadjustments of the delay-line thermostats, an indication of the relative amount and direction of the tracking error is necessary. A calibrated dial was included to indicate the amount of tracking delay.

The video tracking unit of the defruiting equipment consists of the ± 2.5 μsec tracking delay line and a servo loop for controlling the position of the tracking delay line.

A track pulse is generated from the system trigger, passed through the delay lines and compared with the track pulse of the next time period. The track pulse and delayed track pulse are compared in coincidence circuits, and an error signal is obtained that is dependent on the polarity and amount of the time difference between the track pulse and delayed track pulse. The error signal is integrated to obtain a d-c voltage whose polarity and amplitude depend on the position of the track pulse relative to the delayed track pulse. The d-c output energizes a differential relay that connects power to the tracking motor in the appropriate direction to reduce the error signal. The tracking unit matches the radar delay period with the defruiting equipment delay period to an accuracy of about ± 0.25 μsec.

The trigger for the interrogator is obtained from the associated radar system. The trigger period is determined by a temperature-controlled quartz delay line located in the moving-target-indicator (MTI) portion of the radar. The defruiting equipment is designed for use with an AN/FPS-8 radar or an ASR-3 radar.

These radar systems operate at periods as shown in Table I, column 3. The normal delay-line, the acceptance-gate delay-line, and the nominal tracking delay-line periods of the defruiting equipment are shown in Table I, columns 4, 5, and 6, respectively. The interlace delay-line period (Table I, column 7) is nominally the same as the radar period.

Since the interrogator period is determined by the radar delay-line period, the video tracking delay line effectively matches the quartz delay lines of the defruiting equipment to that of the radar.

Provision has been made for interrogator operation on two interrogation modes (called interlace operation) by using a second quartz delay line in the defruiting equipment.

For interlace operation, each mode (pulse code) is interrogated on alternate periods--that is, one mode is interrogated on the even-numbered normal periods, and the other mode is interrogated on the odd-numbered normal periods. The storage period of the defruiting equipment when in the interlace mode is therefore twice the storage period for the normal mode of operation. In interlace operation, the second quartz line (and its amplifier) is switched in series with the delay loop. The signal levels are adjusted by an automatic gain control (AGC) system to maintain the same signal levels when switching from normal to interlace modes of operation.

The defruiting equipment has two methods of trigger operation. When the ASSOCIATED/INDEPENDENT switch (located in the Video Comparator Unit) is in the ASSOCIATED position, the defruiting equipment tracks the radar trigger. When the ASSOCIATED/INDEPENDENT switch is in the INDEPENDENT position, an internal trigger is generated. The independent method of trigger operation can be used to trigger the interrogator when the radar trigger is not available. In this case the beacon system trigger is generated by the defruiting equipment.

TABLE I

DELAY PERIODS OF RADAR AND DEFRUITING EQUIPMENT

Note All values are given in µsec.

	1 Radar Delay Line		2 Additional Radar Delay		3 Radar and Beacon Interrogator		4 Normal Delay Line		5 Acceptance-Gate Delay Line		6 Nominal Tracking Delay Line		7 Interlace Delay Line
AN/FPS-8 Radar	2778	+	2.5	=	2780.5	=	2775.5	+	2.5	+	2.5	=	2780 5
	2768	+	2.5	=	2770.5	=	2765.5	+	2 5	+	2.5	=	2770.5
	2758	+	2.5	=	2760.5	=	2755.5	+	2.5	+	2.5	=	2760 5
	2788	+	2.5	=	2790.5	=	2785.5	+	2.5	+	2.5	=	2790.5
ASR-3 Radar	(833	+	0)	=	3332*	=	3327.0	+	2.5	+	2.5	=	3332.0
	(810	+	0)	=	3240*	=	3235.0	+	2.5	+	2.5	=	3240.0
	(855	+	0)	=	3420*	=	3415 0	+	2.5	+	2.5	=	3420.0

* 4:1 count-down for Beacon Interrogator; divide by 4 for radar.

This is necessary to obtain the trigger stability required for defruiting operation. During the independent method of trigger operation, the interrogator PRF is no longer determined by the quartz delay line of the radar; rather, it is dependent upon the quartz delay lines of the defruiting equipment.

The test mode of operation of the defruiting equipment affords a convenient means for checking operation when video replies are not present or when there is some doubt about the presence of video replies. In test operation, a video test signal, derived from the trigger (associated or independent), is substituted for the video signal of the beacon interrogator. By using the test video signal in conjunction with the independent (internal) trigger, the defruiting equipment can be checked (except for the tracking feature) without any external connections.

The DEFRUITING and INTERLACE controls can be operated remotely, up to a distance of 1 mile, by switching the LOCAL/REMOTE switch from the LOCAL to the REMOTE position. The remote operator can then select standby, single-defruiting, or double-defruiting modes of operation by switching the DEFRUITING switch to the STANDBY, SINGLE, or DOUBLE position. Interlace or normal modes of operation can be chosen by switching the remote interlace switch to the INTERLACE or NORMAL position.

The trigger operation (independent or associated) and the test function cannot be controlled remotely. The trigger and video inputs to the defruiting equipment are connected directly to the output jacks when the DEFRUITING switch is in the STANDBY position.

Figures 3, 4, and 5 are block diagrams of the Video Signal Comparator Unit, the Video Delay Unit, and the Video Tracking Unit. The video signals enter the system at J4007 or J4008, as shown in Figure 3. After the noise is removed in the threshold circuit, the video is applied to the control grid of the first coincidence tube and simultaneously to the input of a mixer-amplifier. The output of the mixer-amplifier is applied to a cathode follower. The cathode-follower output signal drives a 20-Mc carrier modulator located in the video delay unit.

The modulated carrier is passed through the delay line (or lines if in the interlace mode of operation), and, detected after amplification. The detected signal is amplified and passed through a 0 to ± 2.5 µsec tracking delay line After further amplification, the signal is passed through a 0 to 2.5-µsec acceptance-gate delay line. The video is again amplified and then applied to a variable pulse-stretching network. The video output of the pulse stretcher is amplified and clipped to shape the stretched video signals.

The shaped video output is applied to the suppressor grid of the first coincidence tube as delayed video. If coincidence occurs--that is, a signal occurs in two successive periods--an output is obtained. The coincidence output is amplified and applied to a cathode follower. For single defruiting, this cathode-follower output is connected to output jacks J4005 and J4006 of the Video Signal Comparator Unit and is the system video output.

When the DEFRUITING switch is in the DOUBLE position, the output of the first coincidence tube is added to the incoming (undelayed) video in the mixer-amplifier, instead of being connected to the output amplifier. The video signal that passes around the delay loop is therefore of greater amplitude for double defruiting. The single-defruiting delay circuits are not changed, but an alternative path is provided by a separation circuit preceding the pulse stretchers. The separation circuit permits signals of double amplitude to pass through the alternative double-defruiting path. All signals can pass through the single-defruiting path. The double-defruiting signals are passed through a pulse stretcher, amplified, shaped, and applied to the suppressor grid of the second coincidence tube. The incoming (undelayed) video is applied to both coincidence tubes so that, for a signal that occurs in three successive periods, an output is present from the second coincidence tube. When double defruiting, the output of the second coincidence tube is applied to the amplifier, cathode follower, and video output jacks J4005 and J4006 (system video output).

In the interlace mode of operation, a second delay line and amplifier are inserted in series with the delay loop. The amplifiers are controlled by a carrier AGC, so that the overall amplifier output is the same whether one delay line and amplifier or two delay lines and amplifiers are in the delay loop. Thus, the adjustment of the double-defruiting separation circuit is preserved when switching from the normal to the interlace mode of operation. The output level of both amplifiers is controlled by a common AGC reference level adjustment.

To enable the defruiting equipment delay time to match the radar delay time to within ± 0.25 μsec, a ± 2.5 μsec tracking delay line is inserted in the delay loop. This variable delay line is motor-driven by a servo unit. The error signal of the servo unit is obtained by negatively modulating the carrier signal with a 2-μsec track pulse. The track pulse is passed through the delay loop and separated from the positively modulated video signals after passing through the acceptance-gate delay line. The tracking unit consists of a coincidence comparison circuit where the delayed and undelayed track pulses are compared, an integrator that converts the time difference of the two signals to a d-c voltage, and a relay that applies power to the servomotor.

C. MEASUREMENT PROCEDURES

1 SPECIAL TEST EQUIPMENT

The following special test equipment was required for the design and design testing phase of the contract

- a Stable Trigger Source--jitter less than 0.05 μsec per delay period
- b Three Pulse Generators--Hewlett-Packard Type 212A or equivalent
- c. R-F Signal Generator--5 to 30 Mc.

The ability of the defruiting equipment to defruit or separate synchronous and nonsynchronous replies is based on stable radar or beacon system triggers, therefore, this condition must be simulated to facilitate the testing of the various components as well as the overall defruiting equipment

The three pulse generators were used to simulate video and trigger signals and to generate multiple fruit sources The Type 212A pulse generators included the necessary features of amplitude, width, and position or time delay controls, plus free-running as well as triggered operation. The r-f signal generator was used to check the amplitude response and gain of the carrier amplifiers.

Two stable trigger units were constructed One unit was used to obtain a trigger for the AN/FPS-8 units (PRF = 360 pps) and the other was used to obtain a trigger for the ASR-3 units (PRF = 1200 pps) Figures 6 and 7 are block diagrams of the AN/FPS-8 and ASR-3 test units. The test units each consisted of a blocking oscillator, carrier source, modulator, line driver, delay line, carrier amplifier, detector, and video amplifier. The signal generated by the initially free-running blocking oscillator modulated the carrier. The modulated carrier was applied to the delay-line input via the line driver. The delayed carrier output from the delay line was amplified, detected, and applied to the blocking oscillator, thereby completing the delay loop. The blocking oscillator was thus triggered at a period consisting of the delay-line period plus the additional delay in the blocking-oscillator circuit. The ASR-3 test unit included an additional 4:1 count-down blocking oscillator to convert the 1200-pps signals to 300 pps.

2 OPERATIONAL TEST FEATURES

Operational maintenance is accomplished by using either the internal trigger or the radar trigger. A test video signal is incorporated in the defruiting equipment for test purposes.

3. EXTERNAL TEST EQUIPMENT

The external test equipment required is:

a. Oscilloscope--Tektronix Type 545 or equivalent.
b. Vacuum-Tube Voltohmmeter.
c Pulse Counter--Berkeley Type 5510, or equivalent

The oscilloscope is necessary for 20-Mc carrier envelope measurements, 12-Mc video measurements, and low-frequency power-supply measurements (minimum vertical sensitivity of 50 mv per cm). Use of the continuously variable delay feature of the oscilloscope is helpful in observing delayed signals

The pulse counter is necessary for many design tests, and operationally it is needed occasionally to check the long-term drift of the oven temperatures of the delay lines, since in cases of drift, it is impossible to determine which delay-line oven is drifting

D. DESIGN PROBLEMS

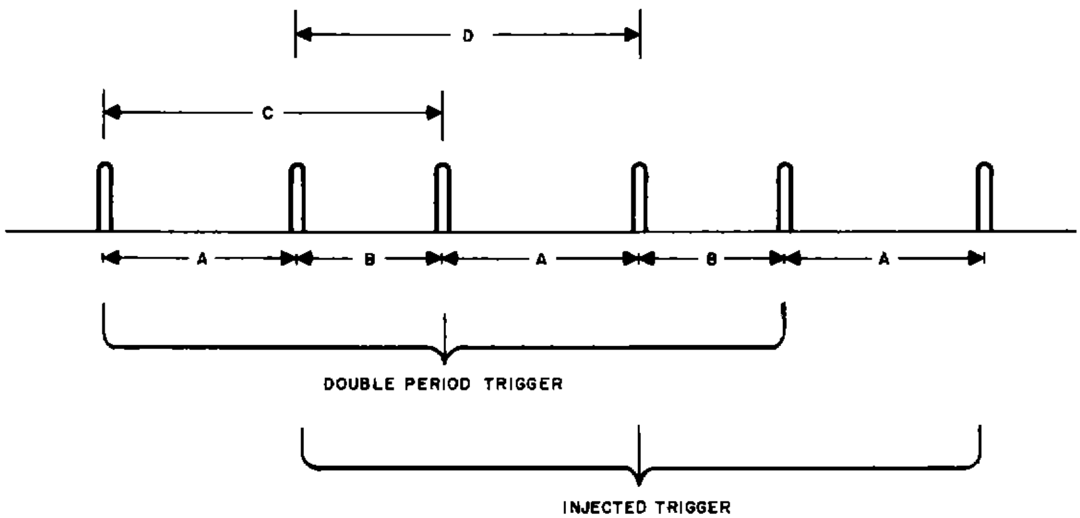
Wherever possible, conventional circuits were used in the design of the defruiting equipment. The design problems were primarily concerned with maintaining circuit simplicity to facilitate packaging while rigidly maintaining the electrical design specifications. Because of the wide-bandwidth requirements, shunt peaking was used extensively in the video circuits, and stagger tuning was used in the carrier amplifiers. A rise and fall time of less than 0.17 μsec each was preserved through the threshold circuits, quartz delay lines and associated circuits, tracking delay line, and acceptance-gate delay line. This feature was incorporated to prevent amplitude variation with pulse width before the separation circuit. It was decided for circuit simplicity to separate the single-and double-defruiting signals by an amplitude means. The amplitude of the double-defruiting signals (second-time-around delay loop) was set to be about 10 db above that of the single-defruiting signals at the carrier modulator. Because of the nonlinearities in the circuits, particularly the separation circuit, the double-defruiting signals are reduced from 10 db to 6 db above the single-defruiting signals at the separation circuit. The separation of the double-defruiting signals from the single-defruiting signals is done by a back-biased diode. The 6-db separation was found sufficient for all environmental and line-voltage conditions including the interlace mode of operation. Reliable video separation was achieved by making many of the amplifiers degenerative and by carefully designing the tracking and acceptance-gate delay lines so that the change in amplitude (with change in delay) was kept to a minimum.

The acceptance-gate delay line is a modification of the original contract. This delay line was included as an added feature so that the incoming (undelayed) video signals could be centered with the delayed video signals (acceptance gates). Since variable pulse stretching was included, some means was necessary to center the undelayed video signals with the acceptance gate for various acceptance-gate widths. Hence the 2 5-µsec manually variable acceptance-gate delay line was inserted in the delay loop. The trigger delay through the acceptance-gate delay line was fixed at 2.5 µsec, and the video delay was made variable (0 to 2.5 µsec) Therefore, the acceptance-gate delay line permits a variable advancement of the position of the acceptance gate to one-half the maximum acceptance-gate width.

Another modification to the contract was the substitution of a nonlinear input-output characteristic for the originally specified proportional characteristic. This was mutually agreed upon as an improvement in system performance. The modification was accomplished by increasing the video input amplification and inserting a limiter after the noise threshold circuit. Figure 8 compares the proportional and limiting input-output characteristics. For low-level input signals, a high system insertion loss is present for the proportional method. The threshold adjustment permits positioning of the input-output curve at any point along the abscissa.

The method of double defruiting used is a deviation from the original specifications. The method used is simpler, it results in less degradation of video signals, and it produces the same output. The method described in the specifications calls for a second coincidence consisting of the second-time-around double-defruiting signals and the output signals of the first coincidence tube. In the modified method, the undelayed video is substituted for the output of the first coincidence tube and applied as the input signal to the second coincidence tube The same signals are required for triple coincidence in both cases. A substantial improvement in pulse response is made possible by not requiring the undelayed video to pass through two coincidence stages; furthermore, a lower video insertion loss is obtained by eliminating the cascading effect of coincidence stages.

One of the problems encountered was that of producing a "normal" period trigger output when operating with the independent (internal) trigger and interlace mode of operation. This requirement of the specification called for a count-up circuit with an accuracy to 0.1 μsec. Since no method of accomplishing this was known, a compromise system was devised whereby a trigger was injected into the approximate middle of the double-period trigger by a detector, amplifier, and blocking oscillator connected to the output of the normal delay-line amplifier. The injected trigger occurs at the PRF of the double period The independent trigger output is shown below.



The periods of C and D are the same Period A is not equal to period B and could be several microseconds more or less This is within system specifications, because the stability of the normal and injected triggers is greater than 0.05 μsec System performance is not affected by period A not matching period B, since range is always measured from the trigger However, period C must equal period D, and both periods must be stable.

One of the major problems was designing a variable pulse stretcher consisting of passive elements. The investigation of pulse-stretcher designs centered around variations of a design conceived by James F. Craib of AIL.* This design incorporated L-C network sections, which were driven by signal pulses applied to each section through diodes. The major drawback of this design was that reflections interfered with later signals. The circuit was modified to include terminations at both ends of the line network. The modified version was found free from interaction of pulses. The output amplitude of the pulse stretcher is constant for constant-amplitude input signals, and the amplitude is not affected by merging pulses. To ensure that the slight ringing that occurred after an output was suppressed below the baseline, the impedances of the line-network terminations were lowered about 10 percent with respect to the characteristic impedance of the line network.

One of the problems in the design of acceptable video delay lines was maintaining a constant-amplitude output In conjunction with delay-line manufacturers, several techniques were investigated to obtain constant-amplitude

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* J F. Craib, "Improved Pulse Stretcher," Electronics, vol 24, June 1951

delay lines Amplitude equalization was found best for the acceptance-gate delay line. However, since the tracking delay line incorporated shorting contacts (required by the tracker), amplitude equalization could not be used. With amplitude equalization, a sawtooth variation of output amplitude is obtained as the output tap passes from a shorting position to a nonshorting position The final design of the tracking delay line was a simple high-quality lumped-section delay line with as low a basic insertion loss as possible (5 percent).

The quartz delay lines for the defruiting equipment were designed in the following manner. The nominal delay was chosen for each delay line and the quartz cut to obtain this nominal delay within 0.2 μsec at a temperature in the range of 68 to 76 C. The quartz was then encapsulated in a hermetically sealed copper case surrounded by insulation. The insulated package was surrounded by a heater element, covered with more insulation, and enclosed in a case that is 16.75 inches in diameter and 2 inches thick. Performance of the quartz delay lines was initially very poor because of the lack of insulation between the quartz and the heater element. A subsequent redistribution of the insulation on all delay lines corrected this fault

Several failures of the delay-line thermostats necessitated repackaging all the delay lines. The internally mounted thermostats were replaced with removable plug-in units. The delay-line case was modified with an internally mounted metal tube that was sealed to the case with the exterior end open. The thermostat was inserted into the tube. In making the change it was considered that, if an electronic control thermostat is to be incorporated at a later date, the mounting tube could house a sensing element and overload thermostat. After further investigation it was decided that the bimetallic thermostat does not offer as great a reliability as an electronic control. Therefore, it is recommended that future incorporation of electronic thermostats in the existing units be contemplated.

Special care was needed to minimize transients. The tracking motor windings were resistively damped to prevent tracking transients.

A d-c level shift of the video signals was observed when the defruiting switch was switched from the SINGLE or DOUBLE defruit to the STANDBY position. To reduce the base-line transients, the video output was changed from a d-c to an a-c coupled circuit.

Transients were also found in switching from the normal to the interlace modes of operation. The first stage of the interlace AGC amplifier was disabled during normal operation to unbalance the interlace AGC loop and to obtain a large bias for the interlace amplifier. The time constant of the AGC amplifiers was made long enough to permit a slow buildup of the AGC voltage during switching. The long time constant prevented the interlace amplifier from passing switching transients. However, the length of the time constant was not made so prohibitively long as to cause appreciable dead-time in switching from the normal to the interlace mode of operation.

E. SYSTEM PERFORMANCE

The defruiting equipment was tested at several field installations Figures 9, 10, and 11 show the PPI displays for standby (no defruiting), single defruiting, and double defruiting. The displays clearly indicate the marked reduction in fruit observed in single defruiting over standby (no defruiting). In the field tests the air traffic density was not great enough to cause fruit to be displayed on the single-defruiting display. Since the fruit has been entirely eliminated by single defruiting, there is no improvement shown in the double-defruiting display. Denser traffic conditions of the future could, however, produce sufficient fruit to require the use of double defruiting.

The defruiting equipment was also tested in the laboratory to obtain fruit counts when using two or three random pulse (fruit) generators The measured results showed close agreement with the results obtained using the following equations.

For single-defruiting operation·

$$N = 6n^2(w_1 + w_2 - 2d)$$

For double-defruiting operation

$$N = 6n^3(w_1 + w_2 - 2d)(w_1 + w_3 - 2d)$$

where

w_1 = width of pulses in the undelayed channel in seconds (0.45×10^{-6}) for single-defruiting and double-defruiting operation.

w_2 = width of pulses in the once-delayed channel at the first coincidence detector for single-defruiting operation.

w_3 = width of pulses in the twice-delayed channel at the second coincidence detector for double-defruiting operation.

d = overlap in microseconds of delayed and undelayed pulses required to produce a full-amplitude output (taken as 0 18 μsec for measurements).

n = a very close approximation of the mean PRF of the three generators.

When the single-defruiting and double-defruiting pulse stretchers are adjusted for the same acceptance-gate width, $w_2 = w_3$ and the equation for double defruiting can be reduced to

$$N = 6n^3(w_1 + w_2 - 2d)^2$$

Table II lists expected fruit counts and actual fruit counts measured at the output of the defruiting equipment Deviations from the expected fruit counts are considered mostly due to deviations in the gate widths from the nominal (2 5 μsec) value.

Only one component failed during the field tests of several units. This failure occurred in the radar delay line associated with the unit being tested at the Newark, New Jersey, installation. Repair of this unit indicated a misadjustment of the thermostat control. The delay line had been damaged because of overheating, but tests of the thermostat indicated that it functioned properly when reset to the correct temperature The particular thermostat was removed from its case and examined thoroughly, and the thermostat contacts were found to be in excellent condition. This failure has shown the need for re-emphasizing the necessity of using a pulse counter when making thermostat adjustments.

TABLE II

CALCULATED AND MEASURED FRUIT COUNTS USING BEACON VIDEO DEFRUITING EQUIPMENT TYPE 2.3NS10

SINGLE DEFRUITING		DOUBLE DEFRUITING	
$N = 6n^2(w_1 + w_2 - 2d)$		$N = 6n^3(w_1 + w_2 - 2d)^2$	
Calculated	Average Measured	Calculated	Average Measured
0.631	0.679	0.189×10^{-3}	0
89.25	87.06	0.554	0.720
338.13	342.6	4.415	5.105

where:

w_1 = width of pulse in undelayed channel = 0.45 μsec

w_2 = width of pulses in once-delayed channel and twice-delayed channel ($W_2 = W_3$) = 2.5 μsec

d = overlap (in μsec) of delayed and undelayed pulses required to produce full-amplitude output = 0.18 μsec

F. CONCLUSIONS AND RECOMMENDATIONS

All the features of the defruiting equipment including the threshold, coincidence, double-defruiting, automatic interlacing, and pulse-stretching circuits, have proved very dependable. Field tests have shown that a wider range of tracking would be desirable in some types of installations. The defruiting equipments described in this report were designed to match specified radar system periods. To accomplish this, the radar delay lines were procured as part of the defruiting-equipment contract.

For specific installations where it is impossible or difficult to replace the radar delay lines, a greater range of tracking or delay matching is necessary in the defruiting equipment. Because of the difficulty in obtaining delay-line components with the required response, the tracking range of the present units cannot be increased without a relaxation of the specification for the minimum acceptance gate. A greater tracking range can be obtained if the minimum acceptance gate is increased from 0.5 μsec to 1 μsec, or preferably 1 5 μsec. This increase in the minimum acceptance-gate width would make possible a prestretching of the delayed video. The wider delayed video pulses would make it possible to use longer video tracking delay lines without a reduction in the pulse amplitude because of the response characteristics of the video-tracking delay line Deterioration of the pulse amplitude as a result of tracking would prevent adequate separation of the double-defruiting signals.

Since an instantaneous transition from the normal to the interlace modes of operation is desired, the interlace delay-line period must always equal the radar period regardless of the tracking range. Failure to match the radar and interlace delay-line periods will result in operation of the video-tracking delay line when mode switching. In the defruiting equipment delivered under this contract, this matching was accomplished by precise trimming of the delay-line thermostats after field installation of the equipment As pointed out previously, provision was made for adapting the delay lines to electronic thermostat control. This change is recommended for improved reliability and long-term stability of matching without periodic adjustments.

For systems with unmatched delay periods, where the tracking equipment is designed to complete the matching, the radar delay lines and the defruiting-equipment interlace delay lines must be kept matched independent of the tracking position. This could be accomplished by switching in any one of four preset lumped video delays, depending on the mode of beacon operation and the radar channel used:

1. Delay for normal mode of beacon operation with radar channel A,
2. Delay for normal mode of beacon operation with radar channel B,
3. Delay for interlace mode of beacon operation with radar channel A,
4. Delay for interlace mode of beacon operation with radar channel B.

Each delay would be adjustable and preset to the desired position. Periodic readjustment of the preset delays could be made, if needed. The maximum preset delay would be limited by the characteristics of the delay line.

A delay line of 20 μsec with a rise and fall time of 0.2 μsec is considered feasible. The preset taps (for the lumped video delays) would be spaced along this delay line. The delay of the tracking delay line would remain ± 2 5 μsec or could possibly be increased to ± 5 μsec. In the latter case, the ± 5 μsec should be divided into ± 2.5 μsec in the normal delay loop and an additional ± 2.5 μsec in the interlace delay loop The two delay lines would be ganged to operate from the same track motor. This would be done on the assumption that a severe change in temperature would more likely exist between the radar and defruiting equipment than between the normal and interlace delay lines of the defruiting equipment Details of how any proposed system of increased tracking range should be accomplished depends considerably on whether the radar and beacon delay lines are matched and whether temperature-control ovens are used.

For radar-beacon systems where all delay lines are temperature-controlled, a small tracking range of ± 2.5 μsec or less is required with the four preset delays inserted for matching, if necessary.

For radar-beacon systems where none of the delay lines are temperature-controlled, a combination of the four preset delays plus a ganged ± 2.5 μsec tracker (± 5 μsec total) is recommended. Considering a delay-line quartz temperature coefficient of 80 parts per million per degree C and a delay-line period of 2778 μsec, the change in delay period with temperature would be 0.22 μsec per degree C. For a ± 2.5 μsec tracking delay line, this would allow coverage over a ± 11 C (± 20 F) temperature differential between the radar and beacon delay lines. This could be retrimmed from time to time by manual adjustments. Since a rapid transition from the normal to the interlace modes of operation is required, it is considered more important to gang the tracker than to increase the normal tracking range.

The situation whereby either the radar or defruiting-equipment delay lines but not both are oven temperature-controlled is not recommended. In this case, the temperature differential could be as high as 86 C (from a nontemperaturecontrolled delay line of -10 C to a temperature-controlled delay line of +76 C). This differential of 86 C at a delay change of 0.22 μsec per C would result in a requirement for a 19-μsec delay correction. It is therefore recommended that either all delay lines be temperature-controlled or none of the delay lines be temperature-controlled. In the latter case, as close a proximity in the same room as possible is recommended.

The defruiting equipment was not designed for use with three-for-one interlacing (three consecutive pulses of mode 3 and one of mode 1 or mode 2). However, if only mode 3 is desired, the defruiting system will provide a defruited output as a 50-percent reduction in the number of video signals for single defruiting and a 75-percent reduction in the number of video signals for double defruiting. Modifications necessary to make Beacon Video Defruiting Equipment Type 2 3NS10 compatible with other than one-for-one interlacing are extensive and in most cases questionable because of the increased complexity. The inability of the defruiting equipment to provide defruiting for the many possible interlacing schemes, including three to one, emphasizes the need for a more compatible defruiting equipment. The problems of delay periods matching with resultant pulse tracking are eliminated by the storage-tube defruiter. Further work on the storage-tube defruiter to improve its performance is contemplated

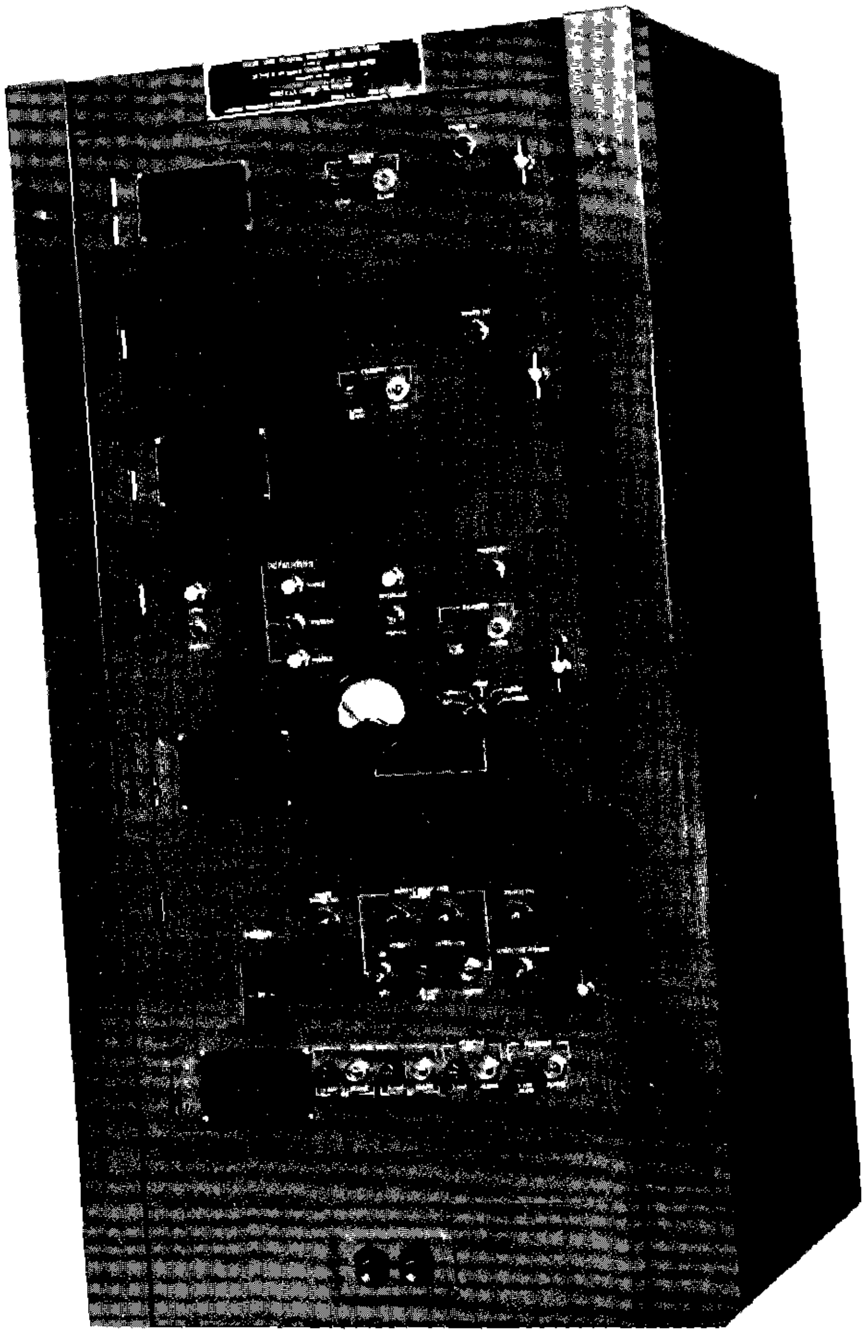

FIGURE 1 BEACON VIDEO DEFRUITING EQUIPMENT, FRONT VIEW

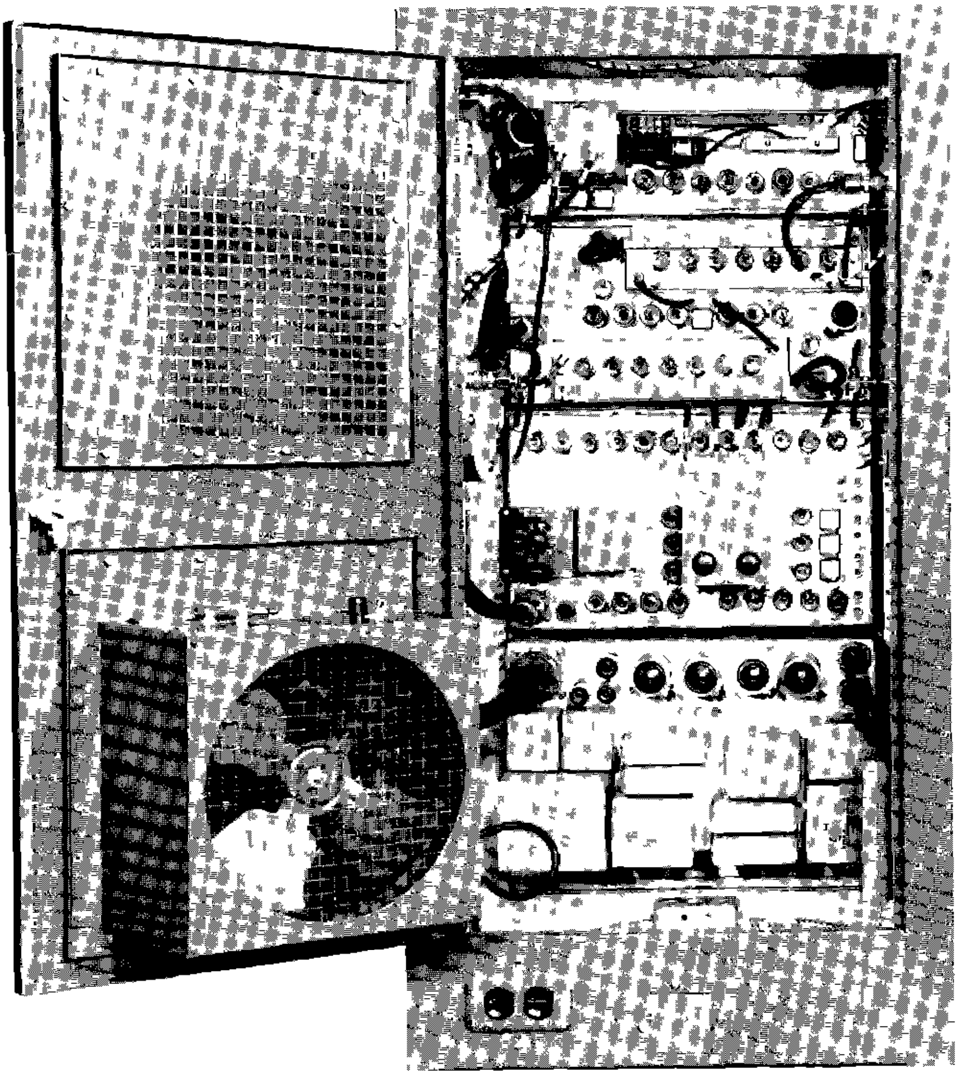

FIGURE 2 BEACON VIDEO DEFRUITING EQUIPMENT, REAR VIEW

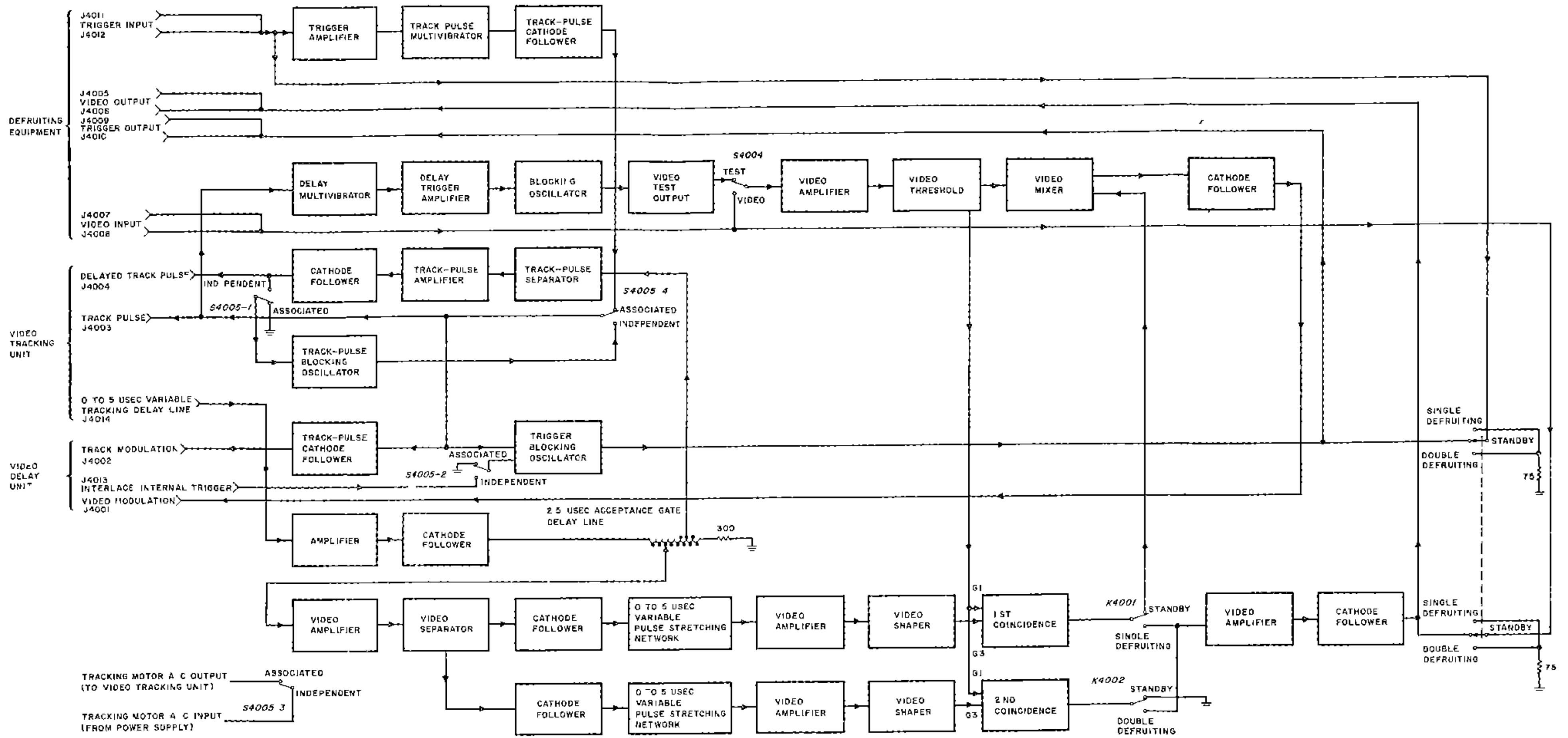

FIGURE 3 BLOCK DIAGRAM OF VIDEO SIGNAL COMPARATOR UNIT

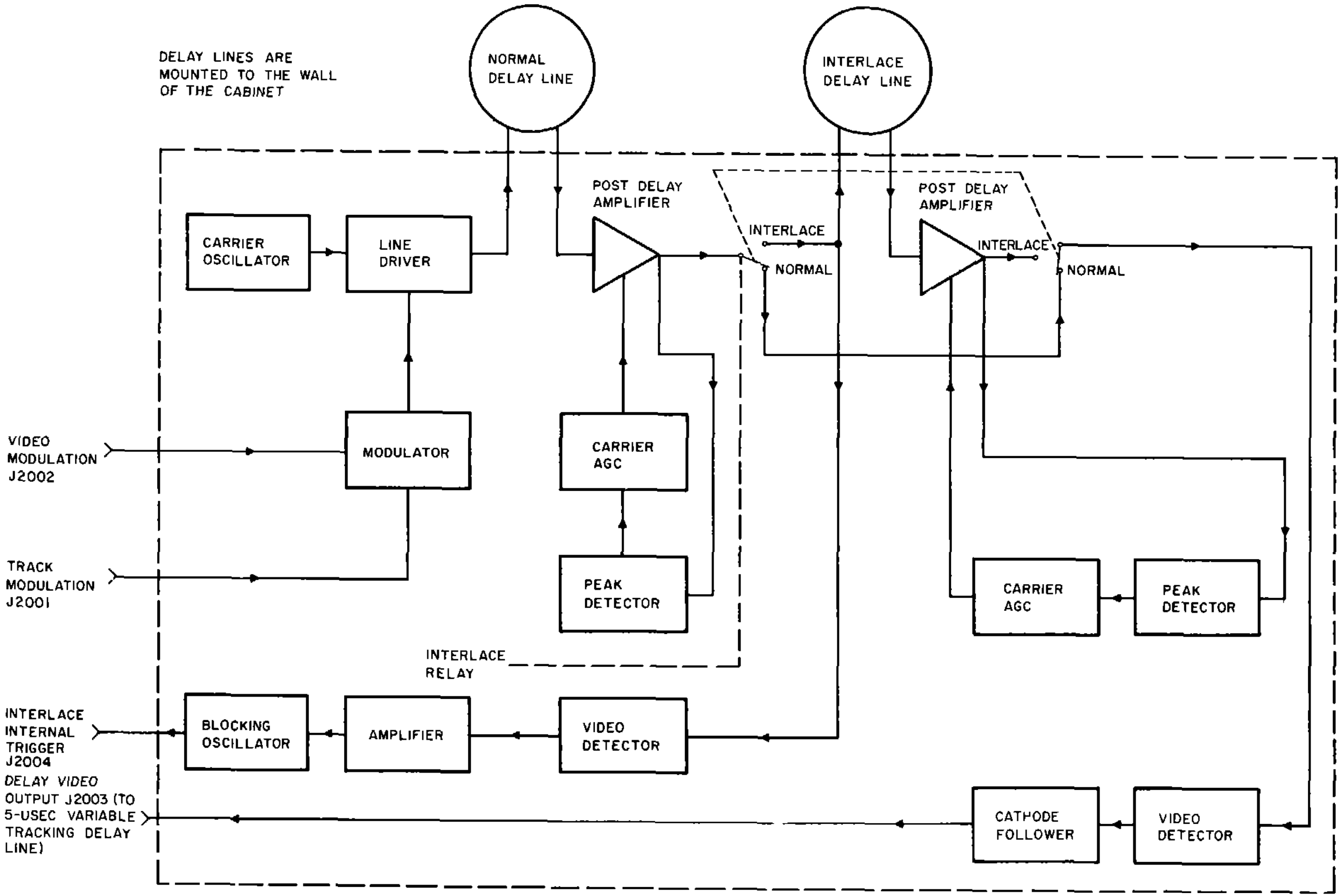

FIGURE 4 BLOCK DIAGRAM OF VIDEO DELAY UNIT

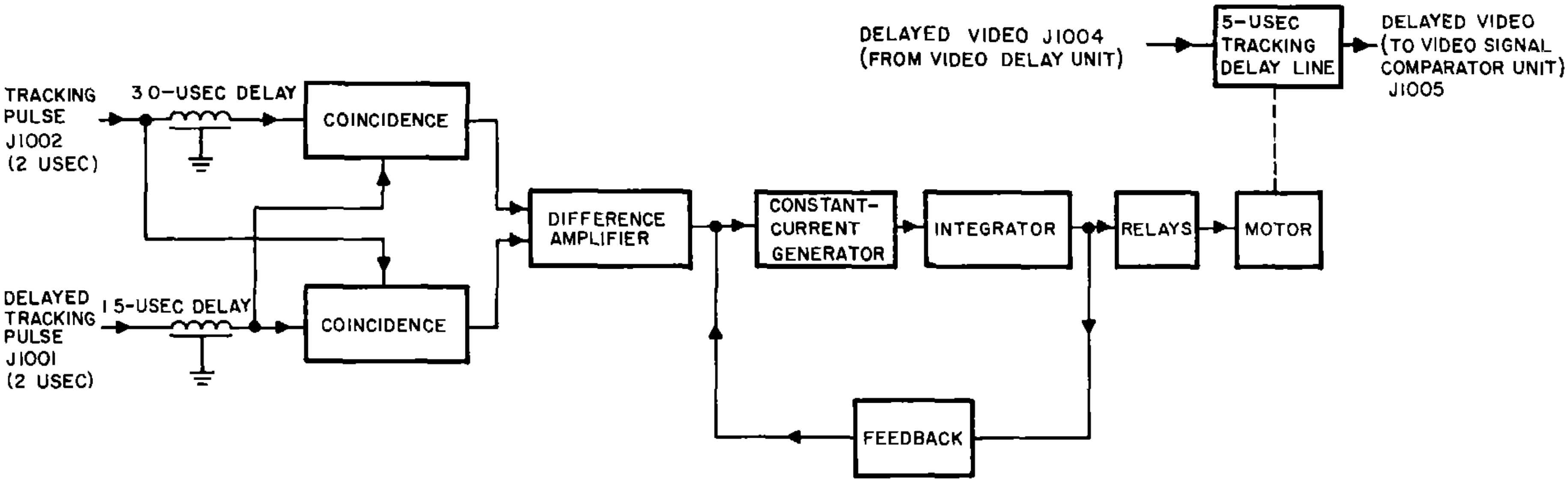

FIGURE 5 BLOCK DIAGRAM OF VIDEO TRACKING UNIT

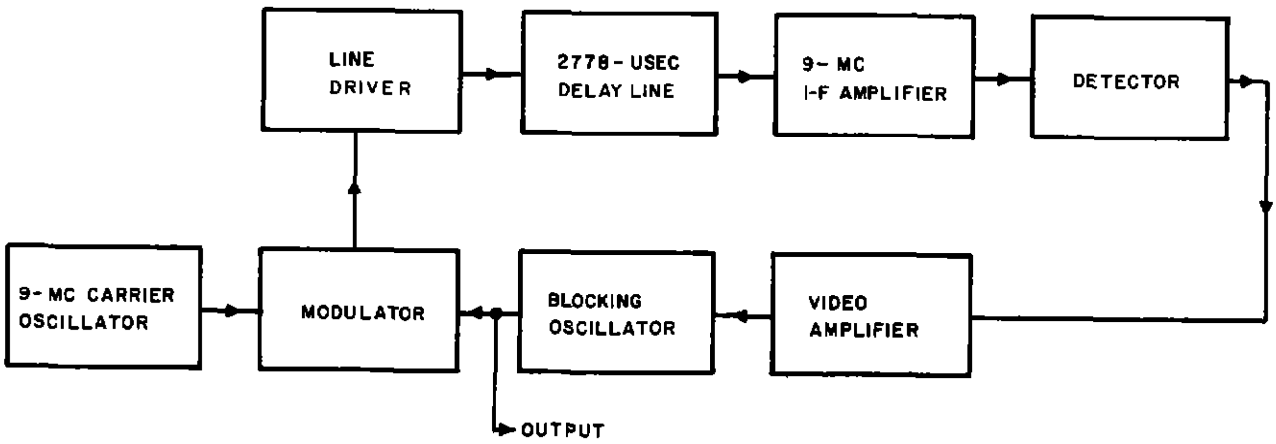

FIGURE 6 BLOCK DIAGRAM OF AN/FPS-8 TEST TRIGGER GENERATOR

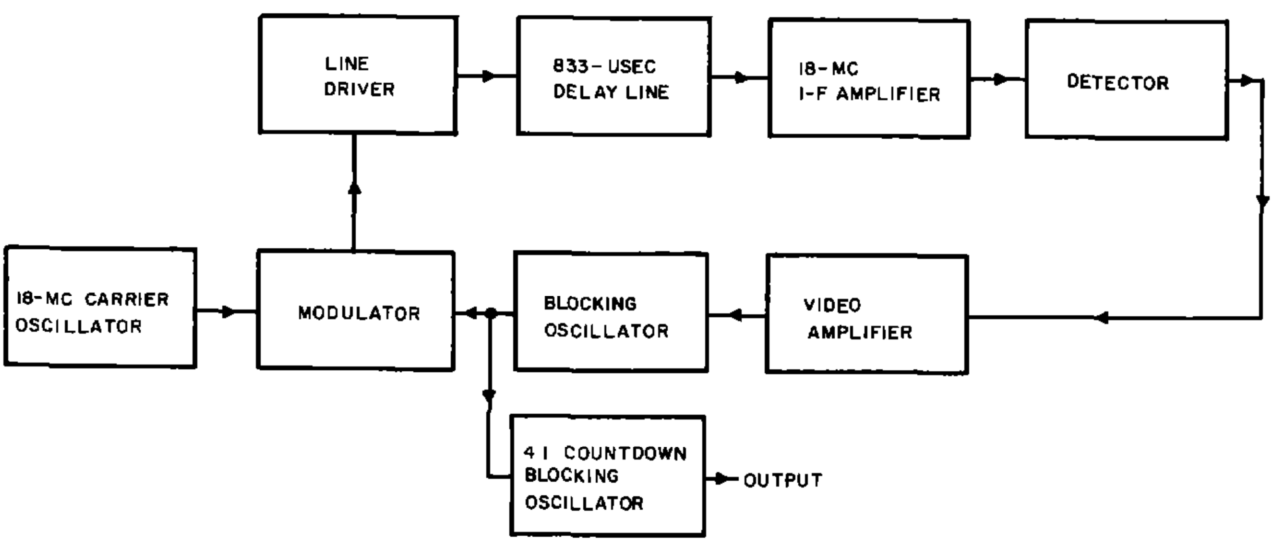

FIGURE 7 BLOCK DIAGRAM OF ASR-3 TEST TRIGGER GENERATOR

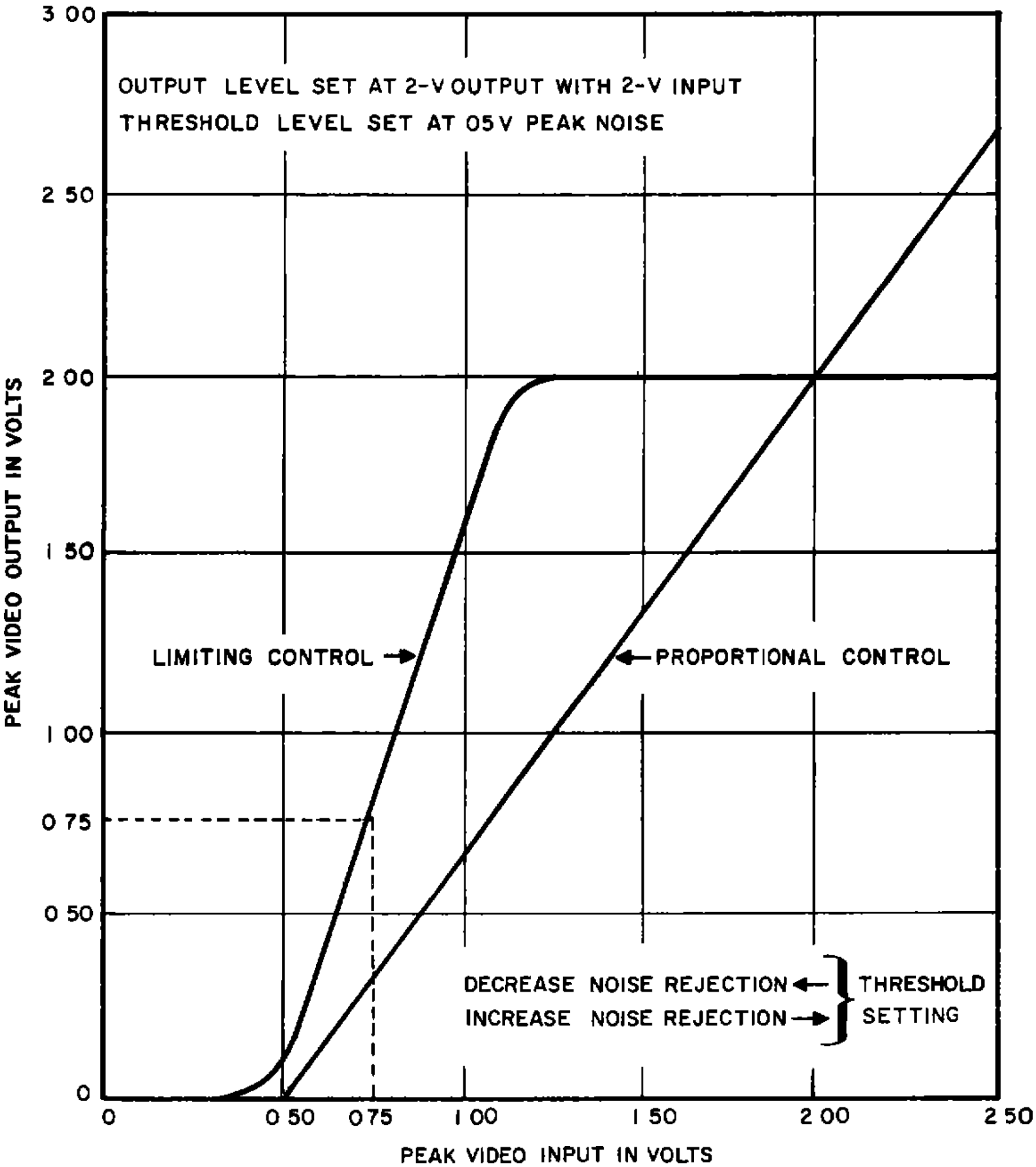

FIGURE 8 VIDEO INPUT-OUTPUT CHARACTERISTICS OF BEACON VIDEO DEFRUITING EQUIPMENT

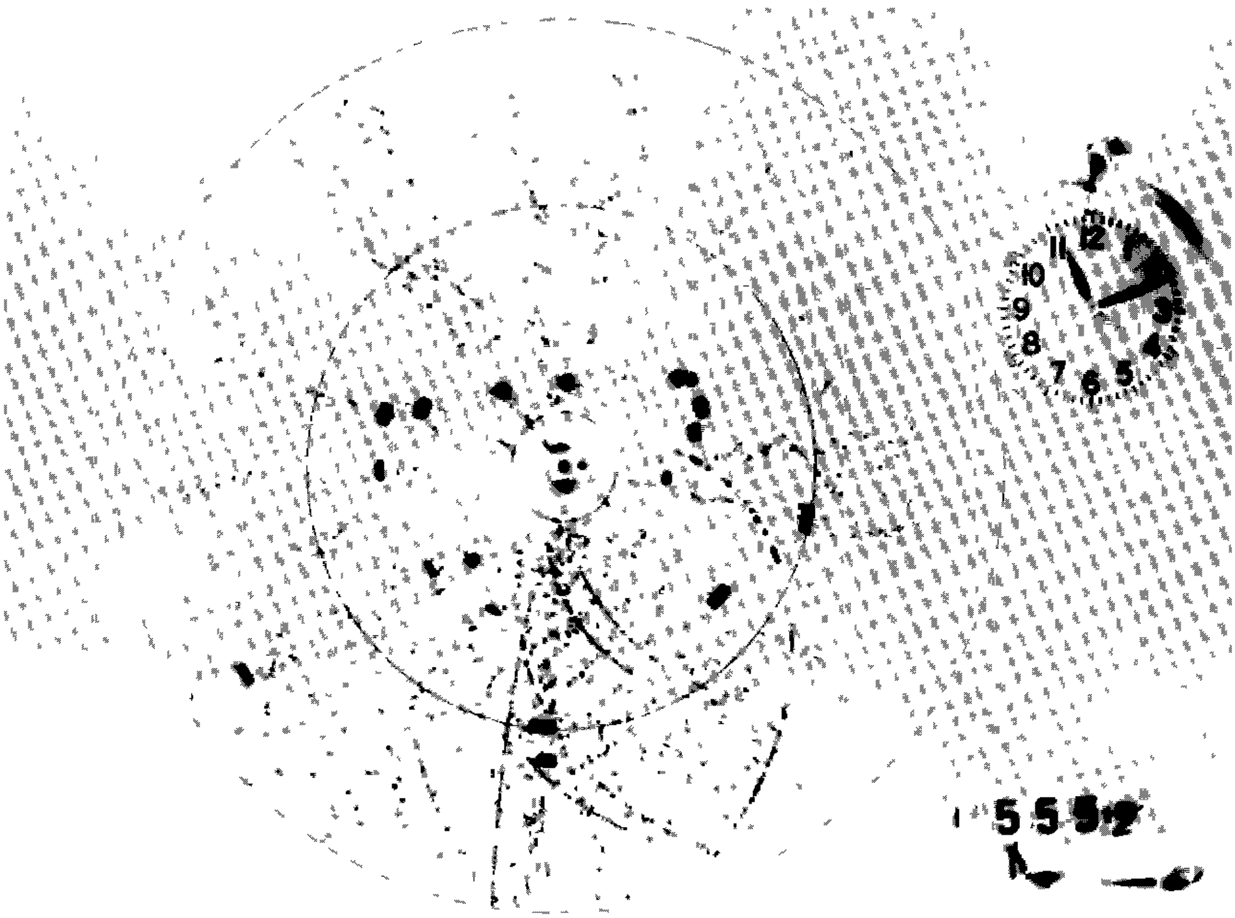

FIGURE 9 PPI DISPLAY FOR STANDBY (NO DEFRUITING) OPERATION

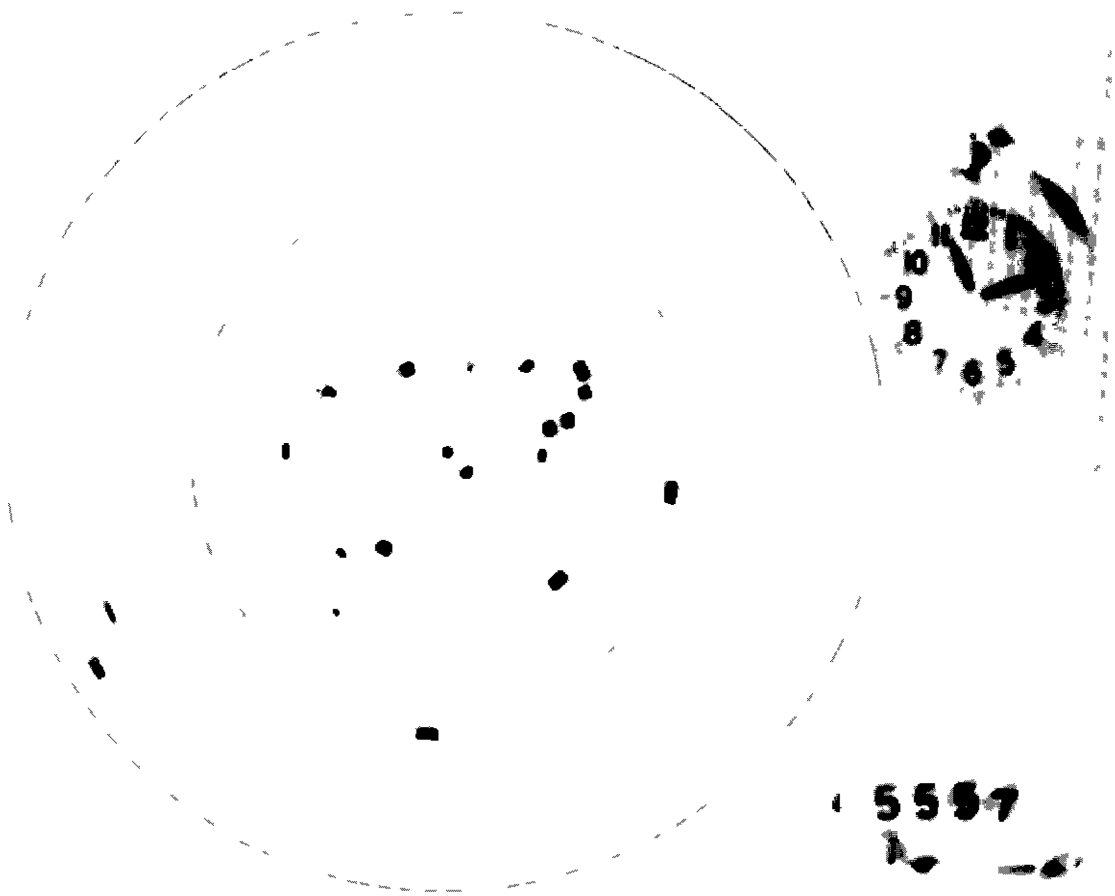

FIGURE 10 PPI DISPLAY FOR SINGLE-DEFRUITING OPERATION

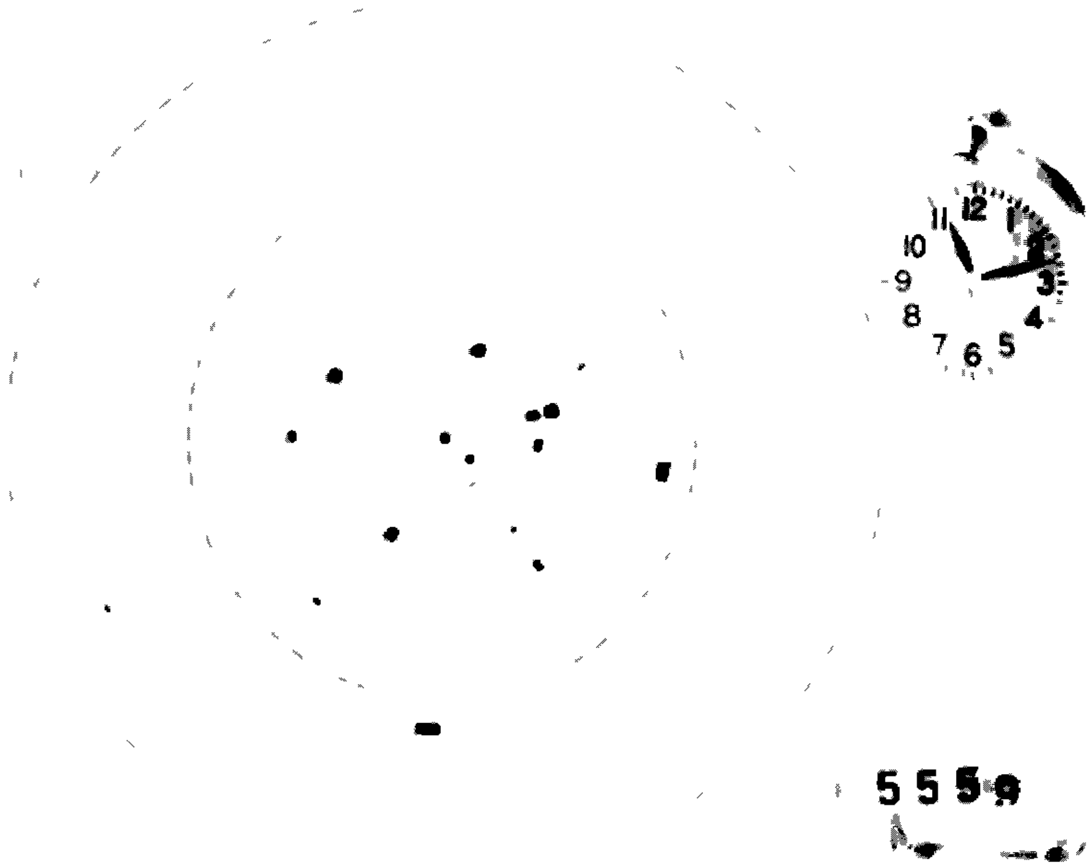

FIGURE 11   PPI DISPLAY FOR DOUBLE-DEFRUITING OPERATION