A RECUPERATIVE GAS FIRED FORGE FURNACE*

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by

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INTRODUCTION

The convenience, portability, and cleanliness of a gas fired forge appeared to make it an ideal heating source for a forge shop located within a large prototype fabrication facility. All gas fired appliances, however, must be derated approximately 4-5% for each 1,000 feet of altitude. Since the elevation of Albuquerque is slightly more than 5,000 feet, a gas fired forge furnace would suffer approximately a 20% reduction in heat output. When a small commercial forge was placed in service it could not overcome the heat loss through its loose fitting door and poorly insulated furnace box to maintain forge welding temperatures. In addition to the heat loss problem, an oxidizing atmosphere developed in the furnace which badly scaled the work.

To overcome the heat deficit and oxidizing atmosphere problems and to reduce fuel consumption, a small gas forge furnace has been developed which incorporates recuperative heating; as the combustion air is drawn into the furnace it is preheated by passing it through a simple heat exchanger which is heated by the exhaust gases from the furnace. This recuperative heating principle is the

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same used by blast and open hearth furnaces but they typically employ complex heat exchangers, and extensive blowers and valving to direct the flow of the intake and exhaust gases. In the furnace described in this article a chimney is provided at the rear of the furnace and the air intake ducts pass through the chimney before reaching the venturi where the fuel gas is injected. Thermocuples were placed in the air intake ducts and the temperature of the recuperated air was 1000 F. Based on data in the Mechanical Engineers Handbook (Industrial Heating Furnaces) fuel savings are directly related to the temperature of the preheated air. The theoretical saving in fuel with 800 F. combustion air is about 19%. The furnace is very quiet, since no blowers are used and the venturi is located in the center of a long tube. To control the furnace atmosphere and to help reduce heat loss, a close fitting swing away door has been incorporated, and the entire furnace is insulated with lightweight high performance ceramic insulation. The resulting furnace easily achieves forge welding temperatures, has a oxygen depleted atmosphere and has proven to be very effective and capable for small machine and hand forging operations.

DEVELOPMENT HISTORY

The basic furnace box (12" X 12" X 6" as shown in photos) was fabricated from 1 inch thick Carborundum 2600 ceramic insulation, with a 16 gage sheet metal jacket. A 12" X 15" X 6" furnace box as suggested on drawing #1, would be more versatile and would allow longer stock to be heated in the furnace. Originally, the front door was hinged across the bottom but this design caused a number of problems. First, when the door was opened an excessive amount of ambient oxygen would enter the furnace. Second, it was possible to come in contact with the hot insulation on the open door . Finally, during forge welding operations the forge welding flux would drip on the open door and the resultant chemical reaction caused rapid degradation of the insulation. A swing away door hinged at the

bottom right corner of the furnace has been a significant improvement. (See Photos # 2 & 3). The boric acid flux also attacked the ceramic bottom. A 1/2" thick bottom liner made of A. P. Green R 7007 Refractory was added, and the forge welding flux is no longer a problem.

The 1"X7" exhaust chimney exiting from the top rear of the furnace allows adequate space for the stainless steel combustion air pre-heaters and can also be adapted for use as a heating zone for long bar stock which often needs to be heated in the middle of the bar. (See Photo # 4 and detail on drawing #1). Fueled by propane at 12 to 15 psi. the furnace reaches the desired temperature range (2300 - 2600 F) in six to eight minutes. Initally two equally sized orifices were used. However, since the gas is fed from one end of the injector tube, the burner furthest from the gas valve was starved. By trial and error it was found that a .028" dia. (#70 drill) upstream and a .031" dia. (#68 drill) downstream orifice equalized the preformance of the burners. The installation of a spark generating igniter has simplified the lighting of the furnace and made this operation much safer. (Not shown in photos).

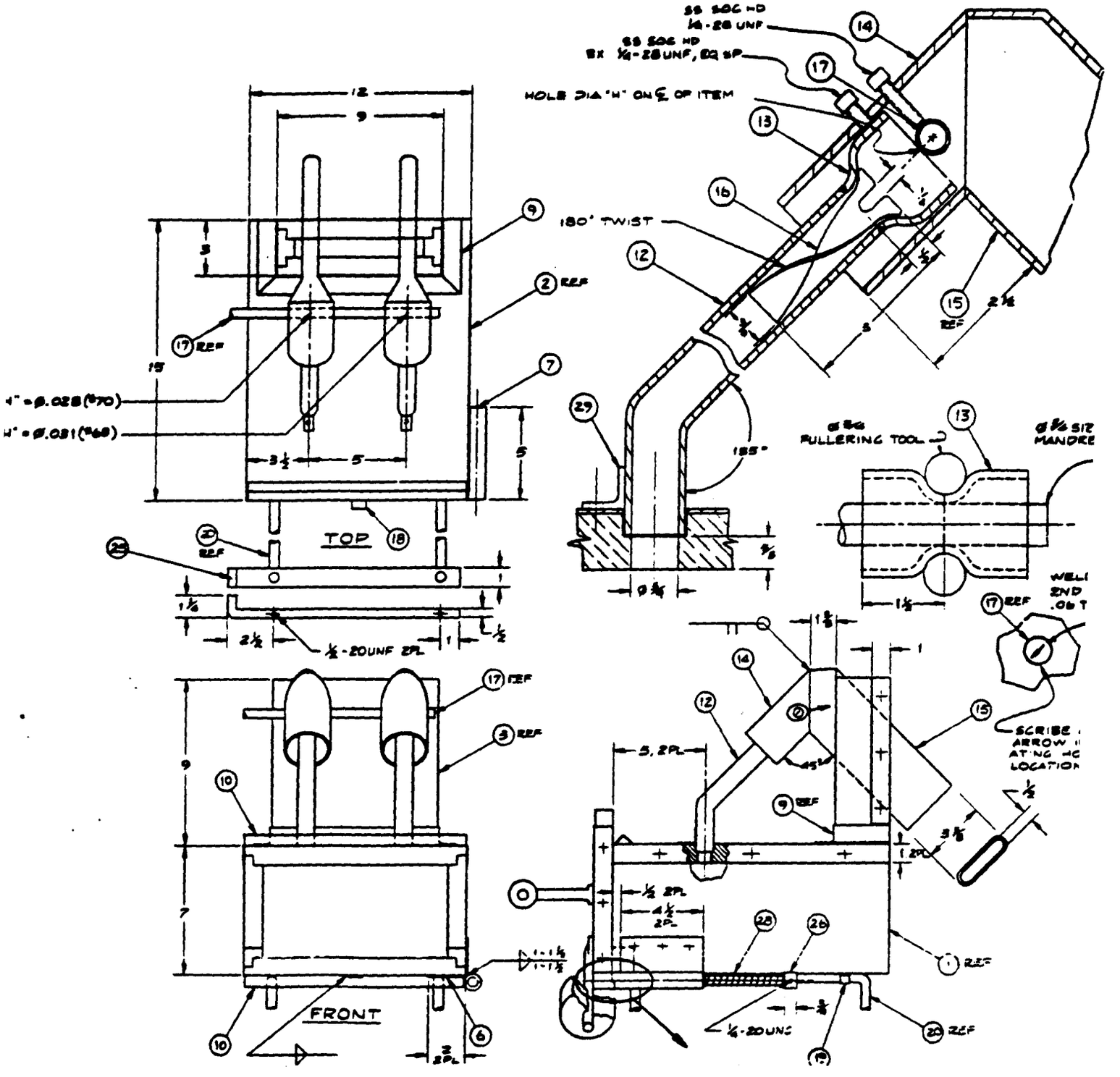
TESTING AND PERFORMANCE

The third generation of this forge furnace has been in use for over a year in the Forging Shop at Sandia National Laboratories with excellent results and minimal maintainence. The furnace was relined with new 2600 insulation board after one year of hard use. Forging temperatures and welding heats above 2300 F are easily achieved. Five gallons of propane will operate the furnace at these temperatures for approximately 7 hours. In contrast, the commercial forge would operate for approximately 3 hours and the prototype furnace (without the recuperators) would operate for 4 1/2 hours at the same temperature levels and on the same quantity of propane. For our in-shop operation the furnace is fueled by 12 - 15 psi. natural gas which is not usually available outside an industrial setting. When used out of the shop the furnace is easily

converted to propane by changing the gas injector tube. (Item # 17 on Drawing # 1 and seen in Photos # 1, 4, 5).
Sandia's Environmental Health Department has tested the furnace for carbon monoxide output. As the furnace was fired up, 2 parts per million were detected and after operational temperatures were reached, no measurable carbon monoxide was recorded.
During normal operation scaling or oxidation of steel parts being heated to forging temperatures is minimal. When parts are placed inside the furnace with the door closed, there is no distinguishable scale until the part is removed and exposed to the atmospheric oxygen. In one situation a 2"X2"X4" block of 1018 steel was inadvertently left in the closed furnace for an extended period of time. The block melted down without decarburization until the door was opened. The absence of carbon monoxide (measured) together with the lack of oxidation (observed), suggests a neutral atmosphere and an air / fuel mixture extremely close to a stoichiometric mixture.

SUMMARY

It is not clear what effect, if any, the recuperators have on the atmosphere inside the furnace but actual fuel savings have been demonstrated. This gas fired forge furnace which uses the recuperative heating design and has been constructed with high quality insulation and a tight fitting swing away door would make an excellent addition to many forging operations. It is lightweight, and therefore easily portable, highly responsive, quiet, and quickly achieves forge welding temperatures, while maintaining an oxygen depleted atmosphere. A forge similar to the one described in this article can be fabricated by anyone with basic mechanical / forging skills. The materials are readily available from a number of distributors and can be purchased for approximately $175. The described design could easily be adapted to a larger forge furnace.


SS SOC HD
1/4-28 UNF
SS SOC HD
8X 1/4-28UNF, EQ SP
HOLE DIA "H" ON ℄ OF ITEM
180° TWIST
TOP
FRONT
1/2-20UNF 2PL
FULLERING TOOL
185°
SCRIBE
ARROW
AT NG HC
LOCATION

DRAWING 1

Photo 1

Photo 2

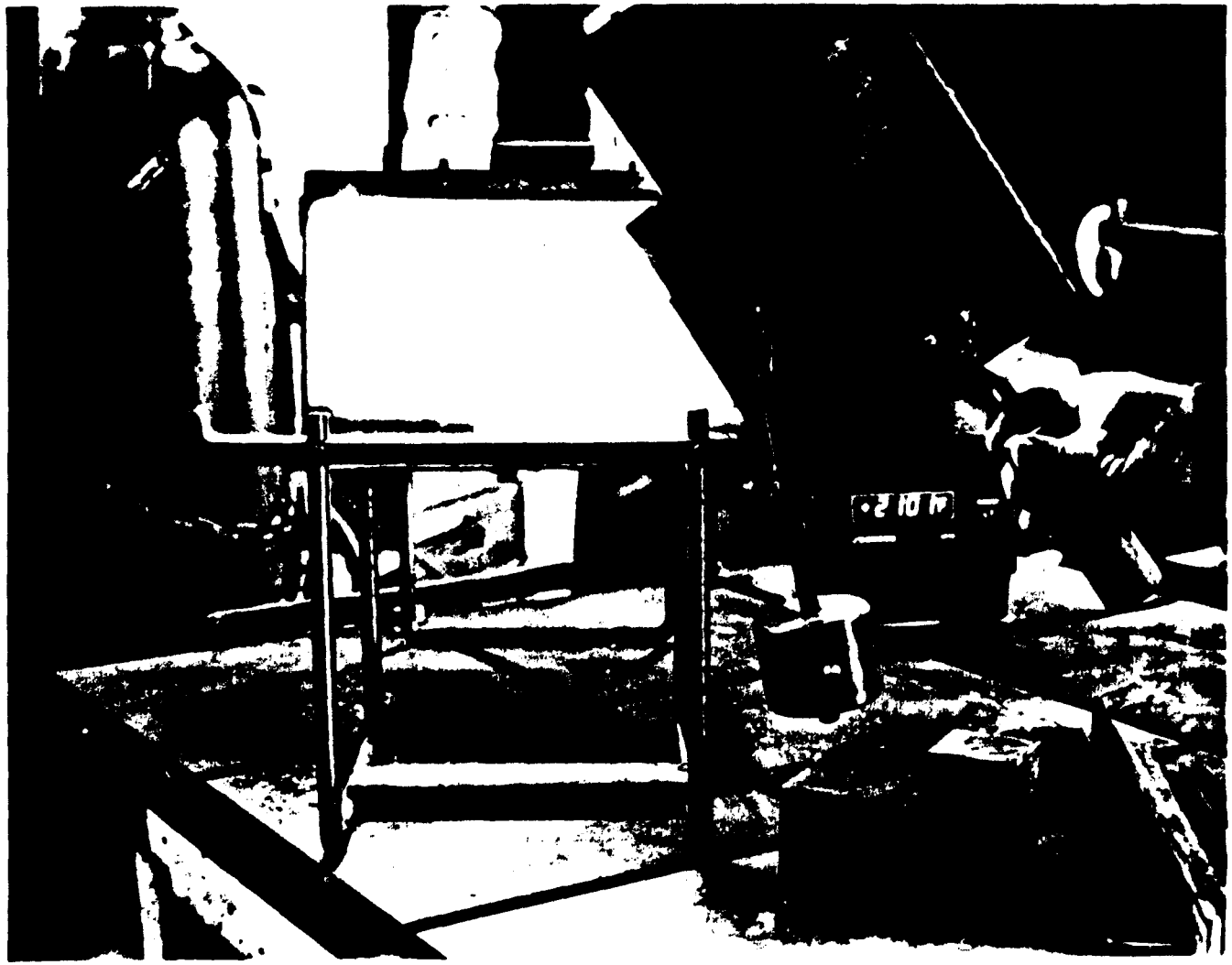


Photo 3

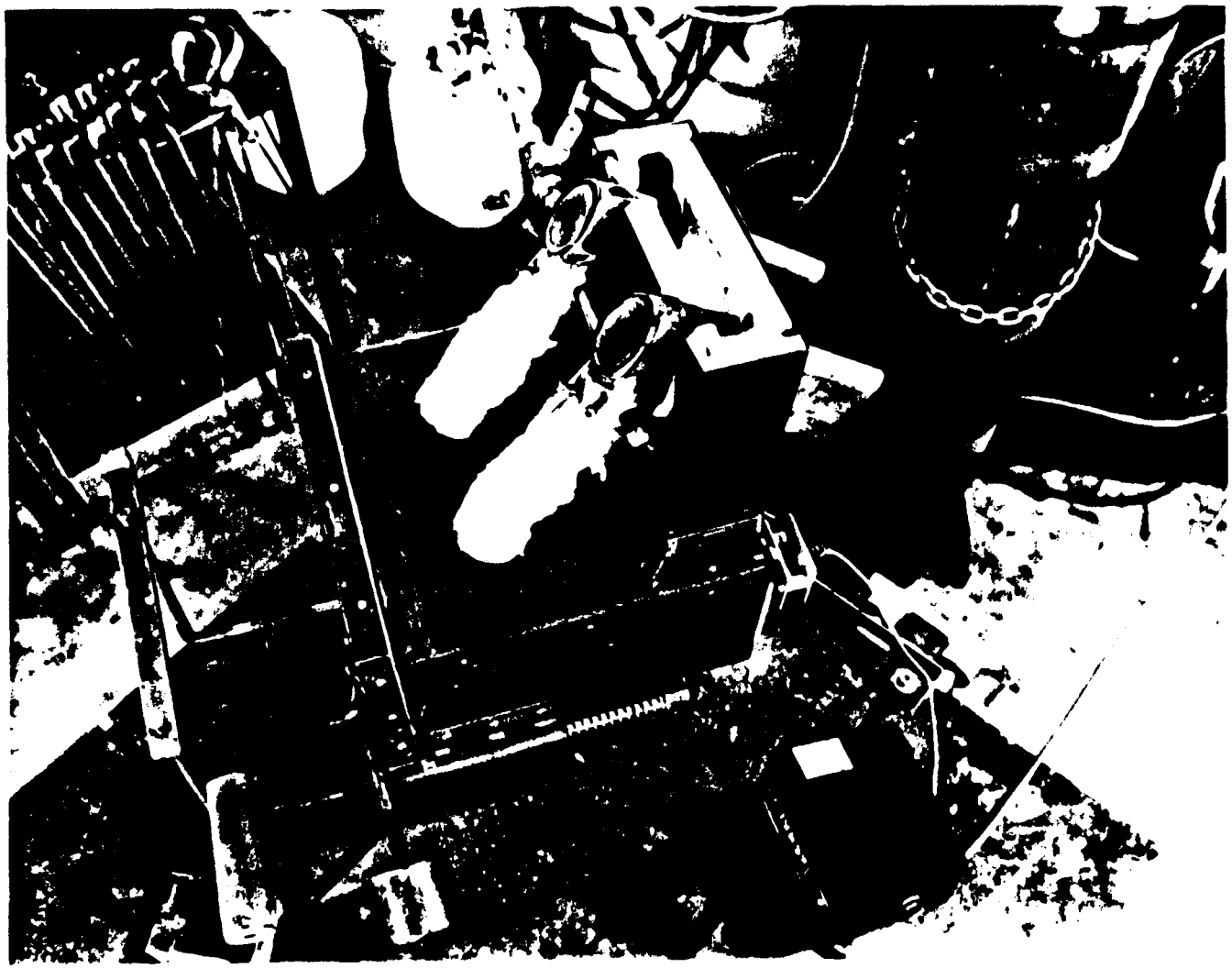


Photo 4

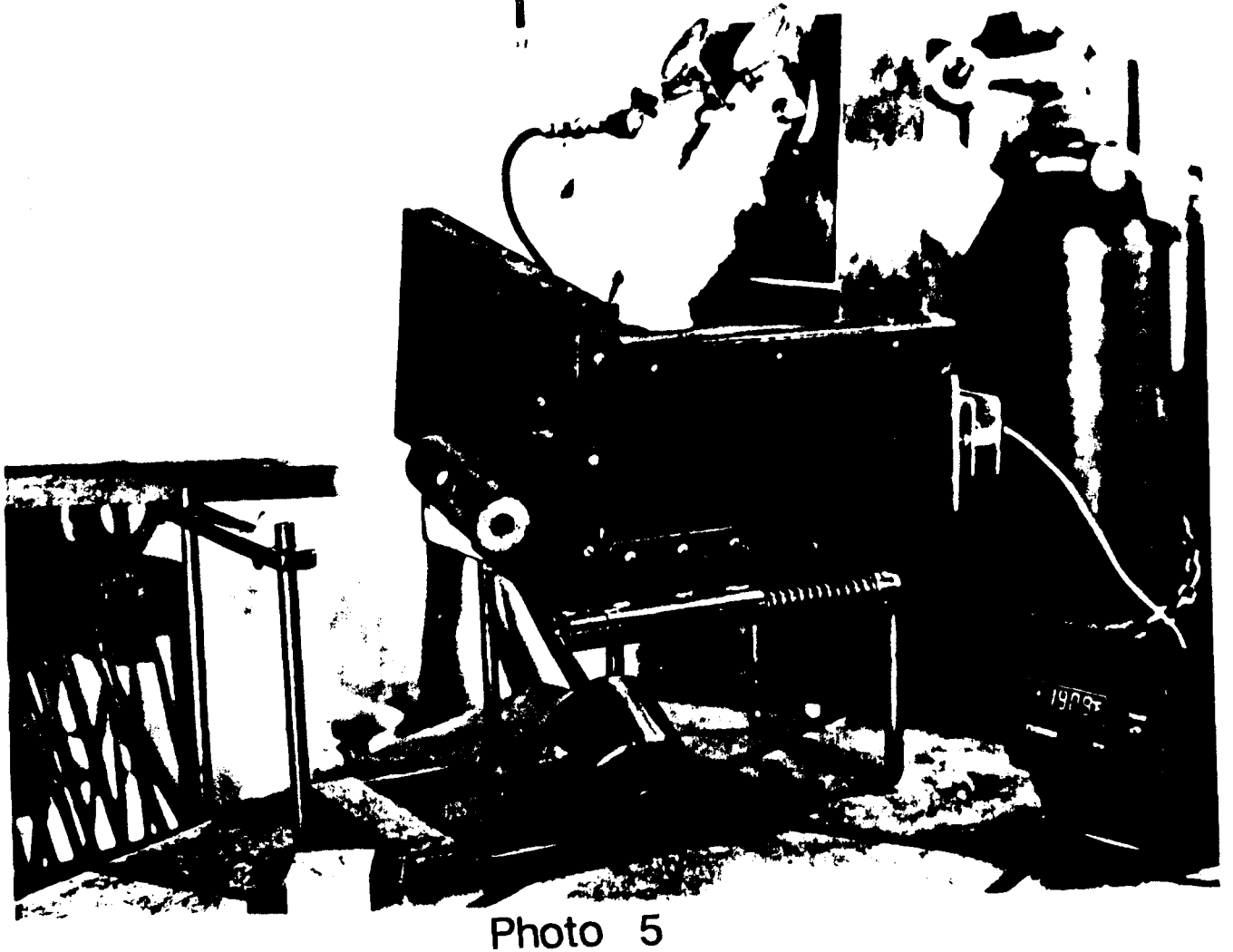


Photo 5