IEEE Transactions on Nuclear Science, Vol. NS-30, No. 4, August 1983

STATUS OF THE SNS

G H Rees
Rutherford Appleton Laboratory
Chilton, England

Summary

The current status of the SNS Project is outlined, with more emphasis on the details of the 50 Hz, 800 MeV proton synchrotron than on the high intensity neutron target. Points of interest in the synchrotron and target hardware are given.

Introduction

The spallation neutron source project is described in the references 1-6. A 50 Hz, 800 MeV proton synchrotron is designed to provide $2.3\ 10^{13}$ protons per pulse at a heavily shielded U238 target. A system of neutron moderators and reflectors will provide slow neutrons for up to 18 neutron beam lines and instruments.

The synchrotron injector is a 70.4 MeV H^- linac, rebuilt from an earlier Nimrod linac. It first operated at low current in January of this year. Synchrotron and beam line components are now being installed and it is planned to begin H^- stripping tests in the injection straight next July and synchrotron commissioning in the Fall. The first production synchrotron bending magnet is due to arrive and the remaining nine should be delivered at two weekly intervals.

Tests on the 47-53 Hz magnet power supply will commence once all the main quadrupole and bending magnets and vacuum system components are installed. Then will follow tests on the 250-turn charge exchange injection process and on the synchrotron diagnostics. Initial acceleration tests will be with two RF cavities. A further two cavities will be installed before the end of 1983 and the fast extraction system by the Spring of 1984. Four cavities will allow acceleration to 550 MeV and the first target tests will be undertaken at this energy. Neutron beams should be available by the Fall of 1984.

Synchrotron Hardware

Items of synchrotron hardware are shown in the Photographs 1-8. The first three photographs are of injection system[2] components. A dc septum magnet (6 turns, 4000 A) is used to deflect the input H^- beam by 285 mr into the aperture of the second of four pulsed ferrite injection bump magnets (1 turn, 14000 A). Seen in photograph 1 is the clamping mechanism for the two halves of the septum magnet which allows easy removal of the septum coil. The 6 turn coil has Al_2O_3 plasma spray insulation to reduce the effects of radiation damage. One of the four identical ferrite bump magnets is shown in photograph 2. It is of a single turn septum design with a high density manganese zinc ferrite as yoke. The third photograph shows a one quarter micron H^- stripping foil of dimensions 120 mm x 30 mm with one 120 mm edge unsupported. A number of such Al_2O_3 foils have been produced. A sheet of aluminium is part masked, the open surface then anodysed in a weak electrolyte, the mask removed and the aluminium backing dissolved from the Al_2O_3 film. Finally, the foil is separated along one long edge bordering the aluminium backing. A refractory material has been chosen for the foil to withstand the temperature cycling between 160°C and 260°C, caused by energy loss from the full injected beam on multiple foil traversals and by the subsequent cooling. The temperature range assumes that stripped electrons do not recirculate in the foil and that the injected beam bump is switched off rapidly after injection to remove the circulating and accelerated protons from the foil region.

Photograph 4 shows a number of the large ceramic[3] synchrotron vacuum chambers. The black covers obscure the large ceramic end flanges which mate to adjacent stainless steel flanges with V-band clamps using indium 'T' seals. The outgassing rate for the chambers after ten hours pumping at room temperature has been found to be $2.5\ 10^{-9}$ Torr l s^{-1} cm^{-2}. A ceramic flange may be seen in more detail in photographs 5 and 6 where a chamber is shown inserted in a bending magnet. Within the chamber is an RF shield formed of stainless steel side plates and wires. The shield is connected directly to a neighbouring chamber at one end of the magnet but is coupled via ceramic chip capacitors at the other end. One such capacitor is displayed in photograph 6. The shield plates and wires run parallel to the beam direction. Resonant modes associated with the lengths of the wires are resistively damped. Care is taken to reduce the longitudinal and transverse beam coupling impedance of all vacuum components in the ring; RF finger contacts are used at the vacuum section junctures, RF shields are used in all ceramic chambers and bellows units and discontinuities in the vacuum chamber envelope are minimised.

The magnet lattice[4] contains quadrupole doublets, trim quadrupoles, quadrupole singlets and combined function bending magnets. All quadrupoles have been received and measured and most are now installed in the synchrotron ring together with their ceramic vacuum chambers. Measurements have also been completed on the prototype bending magnet shown in photograph 5. The end laminations had to be all modified and re-measured before specifying the end sections for the production units. The magnets in the ten superperiods are linked successively in series with the ten coupled secondaries of a common choke. Capacitors are added across the secondaries to form a 50 Hz resonant network. The main ac power loss in the network is due to the eddy current loss in the magnet coils which is significantly greater than the core hysteresis and eddy current loss. Measurements on the magnets have indicated different values of tan δ for the quadrupoles than for the bending magnets, resulting in quadrupole tracking errors at mid-cycle. Such errors are to be corrected by means of the trim quadrupoles[5] which are adjacent to the doublet quadrupoles. If the main bending magnets are found to have significant differences in their tan δ values, compensating resistors will be added across the coils to reduce the resulting effect on the horizontal closed orbit deviations. Two alternative modes of operation are considered for the magnet power supply, either running locked to the mains (47-53 Hz) or at fixed frequency. The ac power source is a single phase alternator driven by a speed controlled dc motor. The cable lengths in the system are relatively long, leading to low frequencies for the delay line modes. It may be necessary to damp the lower modes if non-linear saturation effects lead to mode excitation.

0018-9499/83/0800-3044$01.00© 1983 IEEE

A ferrite tuned RF cavity is shown in photograph 7, together with its retractable RF power amplifier. Six such units are finally required. The single ended cavity has two accelerating gaps, connected in parallel by two coaxial arms which also carry the bias tuning currents. The operating frequency is 1.3 to 3.1 MHz, which corresponds to RF harmonic number 2. The two ferrite sections each contain 35 ferrite toroids, sandwiched between water cooled copper discs. The electrical length of each ferrite section is one-sixteenth of a wavelength and resonance is achieved by adding vacuum capacitors (2000 pF) across the accelerating gaps. The ferrite permeability is tuned over the range $\mu = 72$ to $\mu = 13$ by a single turn cavity wall current varying from 200 to 2300 A. Higher transmission line modes of the cavity are at a sufficiently high frequency that they are well damped. There remains a higher mode caused by the coaxial coupling arms and the gap capacitors. This mode is damped by the addition of a third coaxial link between the gaps, one which contains some series resistance. The power amplifiers each contain two RCA type 4648 tetrodes, one operating in Class B for low beam operation and one in Class A for beam loading compensation.[4] Ceramic insulators at the location of the accelerating gaps separate the synchrotron vacuum from the main body of the cavity. The peak RF voltage per gap is 13.5 kV, required at mid cycle. Two cavities are installed in the ring and a further two will be added in August. Initial operation of the power amplifiers will be with the Class B stages only.

Photograph 8 is of a coaxial thyratron switch, part of the vertical fast extraction system.[6] There are three push-pull ferrite fast kicker magnets, all located in one medium length straight section. Each half magnet is powered via one of the coaxial switches. The voltage on the system is 40kV, the peak current 5000 A and the required kick rise time 225 ns. The pulse forming networks use lumped delay lines, impedance 3.5Ω and there is a pulse shaping section ahead of the switch. At the switch output there is a 7Ω resistive termination and a long 7Ω feeder system of 7, 50Ω cables in parallel. Each kicker is a lumped ferrite element of rectangular section with a ground plane between the two halves to minimise the longitudinal beam coupling impedance. The total vertical deflection due to the three kickers is 14.2 mr and this, coupled with a slow beam bump, is sufficient to divert the high energy beam into a 1T dc septum extraction magnet. The length of the unit is 1.8 m, the deflection angle 368.8 mr and it is of a sector design with the yoke and septum turns external to the vacuum system. The septum turns are again insulated by a radiation resistant layer of Al_2O_3. The curved vacuum chamber is joined to the top of the long straight section beneath; the former is non-magnetic but the latter is made of mild steel to reduce the septum leakage field to an acceptable level for the low energy synchrotron beam. The extraction system is scheduled for completion in April 1984. In the same long straight section that houses the extraction septum there are a number of beam loss protection units; the low energy units are made of copper and graphite and the high energy units of stainless steel.

Diagnostic systems include 17 radial and 17 vertical beam position detectors, 2 intensity monitors and 5 beam profile detectors. Beam position is sensed by split induction electrodes and the information is collected by means of 2 microprocessors. Intensity is monitored using current transformers to an accuracy of 0.1%. Horizontal and vertical profiles are measured by collecting the ions from the residual gas of the vacuum system using a channel electron multiplier on a channel plate. Data is collected by a microprocessor before being passed to the control computer system. The computers are GEC type 4070; three are used as satellites and one as a main coordinating computer. At present the satellites for the linac and main ring are installed and the main console computer is to be installed in the near future. The message networking system development is in its final stages. CAMAC message receive/send/buffer modules are in production commercially and near completion. The equipment interfacing system (GPMPX) is at the production stage; about 800 standard user interface modules are required, in about 80 crates. Most console equipment is commercial. The CERN DICO-DIME graphics system will be used. The system touch screens will be driven by dedicated microprocessor systems, currently being developed.

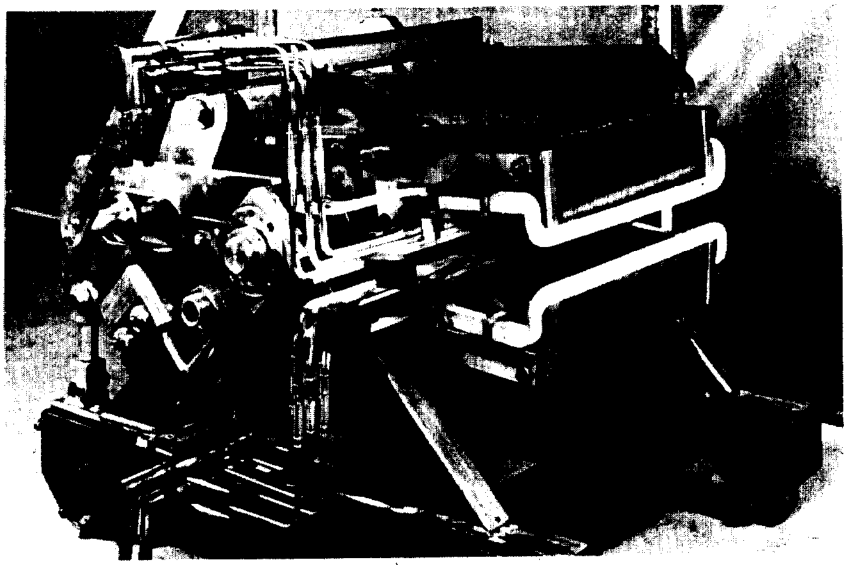
Target Station Hardware

Initial construction of the target station is shown in photograph 9. There are four main parts, the target and its services, the target assembly (moderators, reflectors, decouplers), the bulk shield and shutter system and the remote handling facility.[6] The target material is depleted U238 in the form of 90 mm discs of varying thickness and clad in Zircaloy-2. The U238 is put in a Zircaloy-2 cup and cover plate, sealed by electron beam welding and a bond formed by isostatic pressing at 2000 bars in argon at 800°C for 3 hours. Two sets of plates will be obtained by August next, mounted in rectangular picture frames. The cooling channels between plates are 1.75 mm wide and the coolant D_2O. The life time of the target due to damage mechanisms is estimated at not less than 1 year. There are to be 4 moderators, 2 ambient water above the target and 2 cryogenic below. One cryogenic moderator is liquid methane and the other para hydrogen at 20°K. The reflector is of beryllium and D_2O and envelops the target. The overall length of the target is 343 mm and the reflector dimensions 680 x 500 x 790 mm^3.

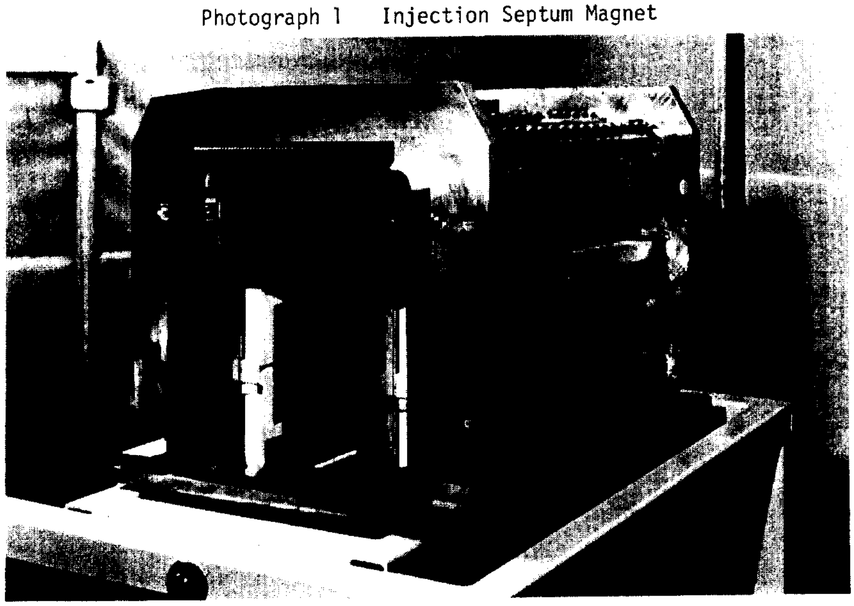
The bulk shield is formed from machined cast iron of depth > 4 m with an outer 0.25 m of boron loaded concrete. The external radiation is < 7.5 μSv/hr. In the shield is a target void vessel with an atmosphere of helium, shielding inserts and a shutter system for each beam line. Downstream of the shield is a remote handling cell for storing and replacing targets.

References

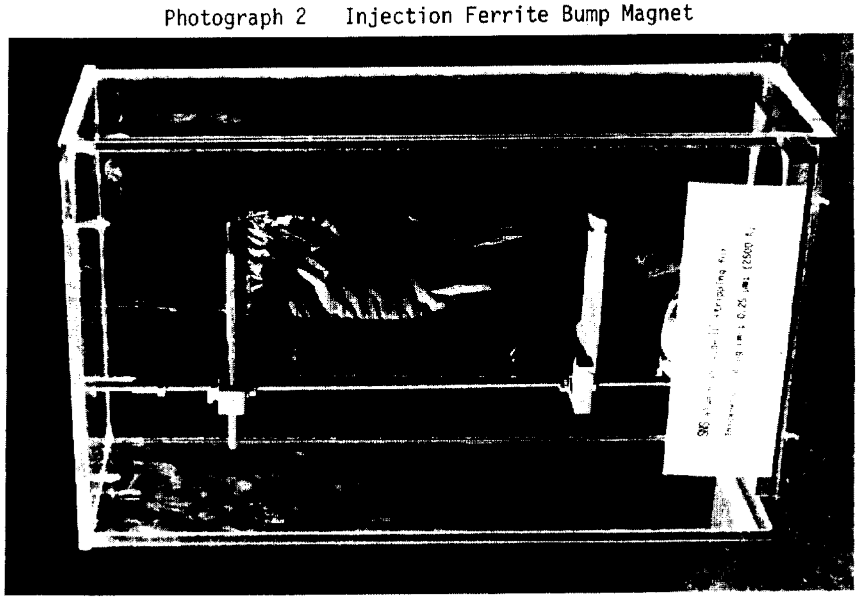
1. G H Rees et al, A Pulsed Spallation Source for Neutron Scattering Research, IEE Trans on Nucl Sc, Vol NS-24, No 3, June 1977, p989.
2. V C Kempson, C W Planner and V T Pugh, Injection Dynamics and Multiturn Charge Exchange Injection into the Fast Cycling Synchrotron for the SNS, IEEE Trans on Nucl Sc, Vol NS-28, No 3, June 1981, p3085.
3. J R J Bennett and R J Elsey, Glass Jointed Alumina Vacuum Chamber, IEEE Trans on Nucl Sc, Vol NS-28, No 3, June 1981, p3336.
4. G H Rees, Features of the Beam Dynamics for the SNS Synchrotron, IEEE Trans on Nucl Sci, Vol NS-28, No 3, June 1981, p2125.
5. R T Elliott, J A Lidbury and M R Harold, Synchrotron Magnets for the SNS, IEEE Trans on Nucl Sc, Vol NS-26, No 3, June 1979, p3922.
6. B Boardman et al, Spallation Neutron Source: Description of Accelerator and Target, RL Report RL-82-006, March 1982.



Photograph 1   Injection Septum Magnet

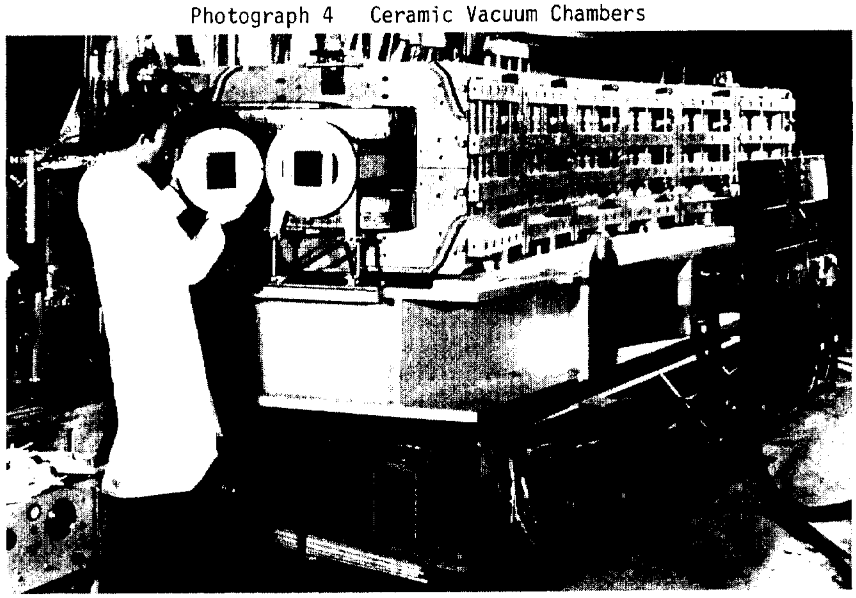


Photograph 2   Injection Ferrite Bump Magnet

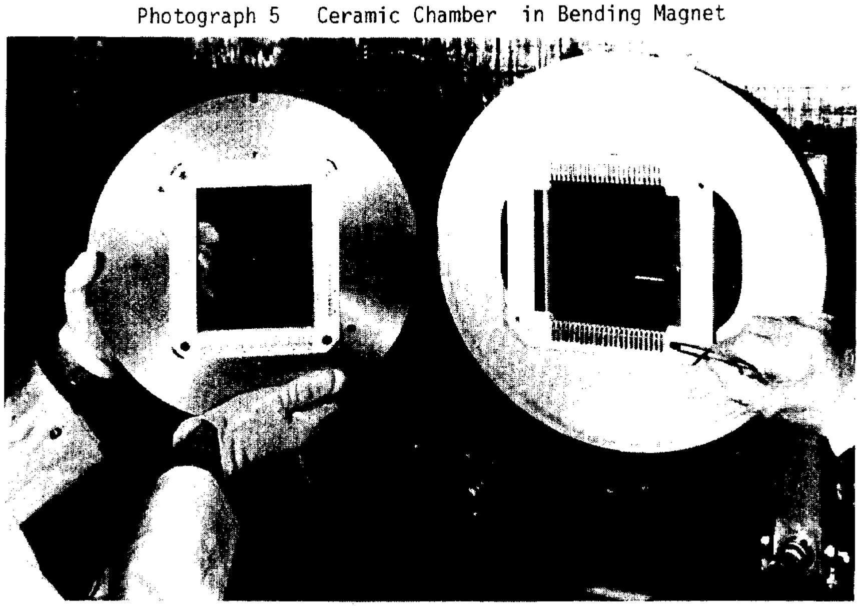


Photograph 3   Large Al_2O_3 Stripping Foil

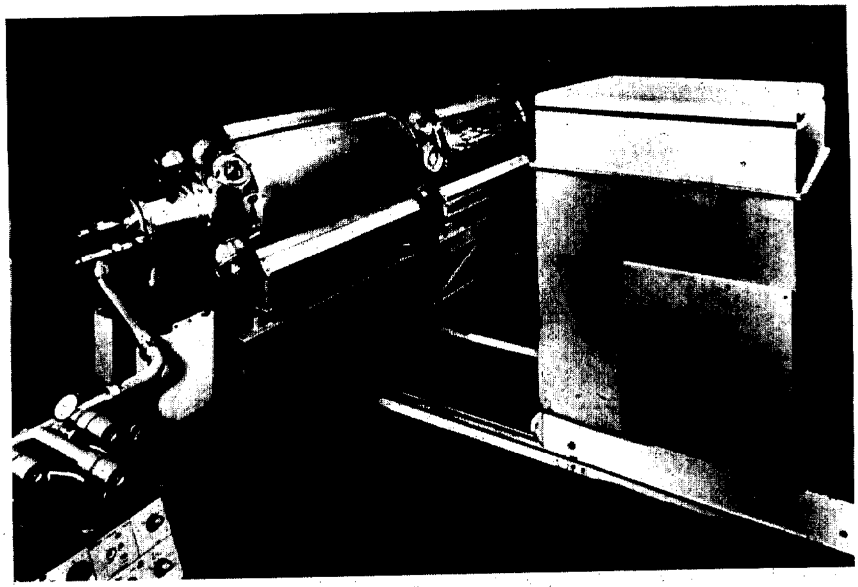
Photograph 4 Ceramic Vacuum Chambers



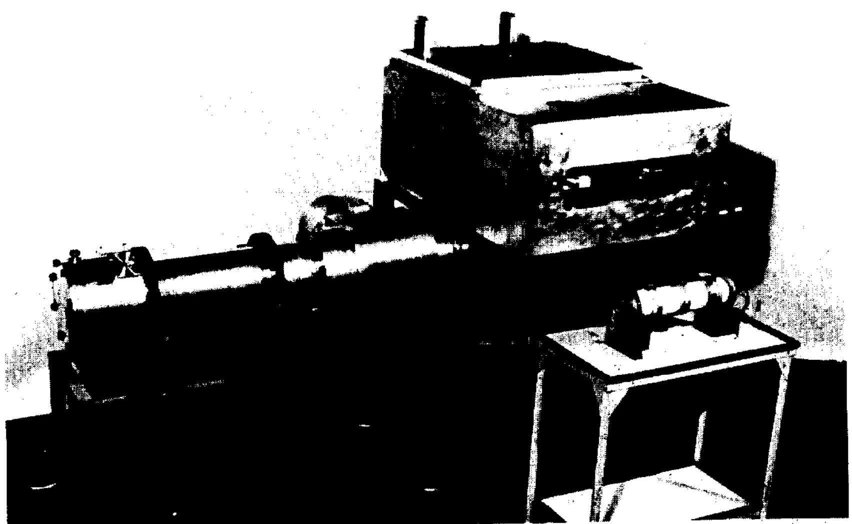
Photograph 5 Ceramic Chamber in Bending Magnet



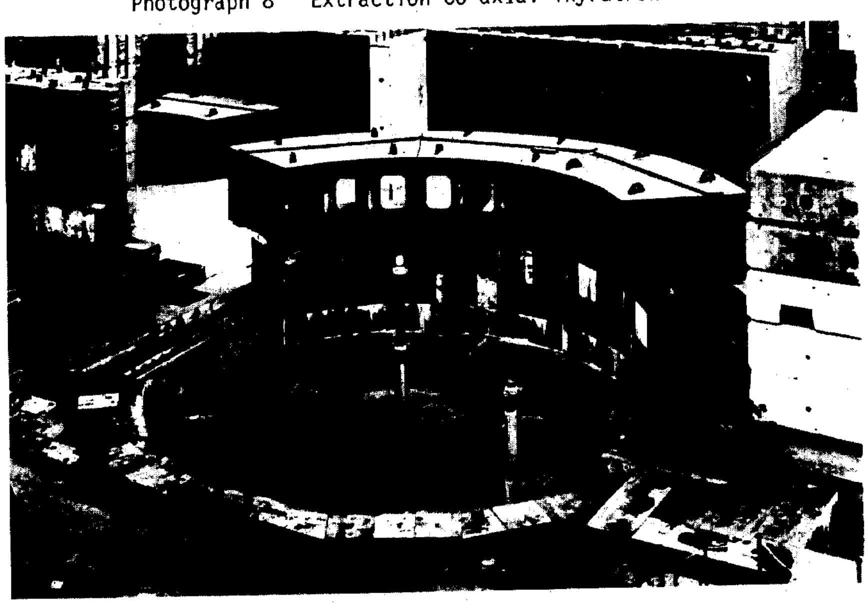
Photograph 6 RF Shield in Ceramic Chamber



Photograph 7 RF Cavity and Power Amplifier



Photograph 8 Extraction Co-axial Thyratron Switch



Photograph 9 Start of Target Station Construction