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MECHANICAL SUPPORT AND TRANSPORT SYSTEM USED FOR THE NEUTRINO HORN SYSTEM AT BROOKHAVEN NATIONAL LABORATORY*

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ABSTRACT

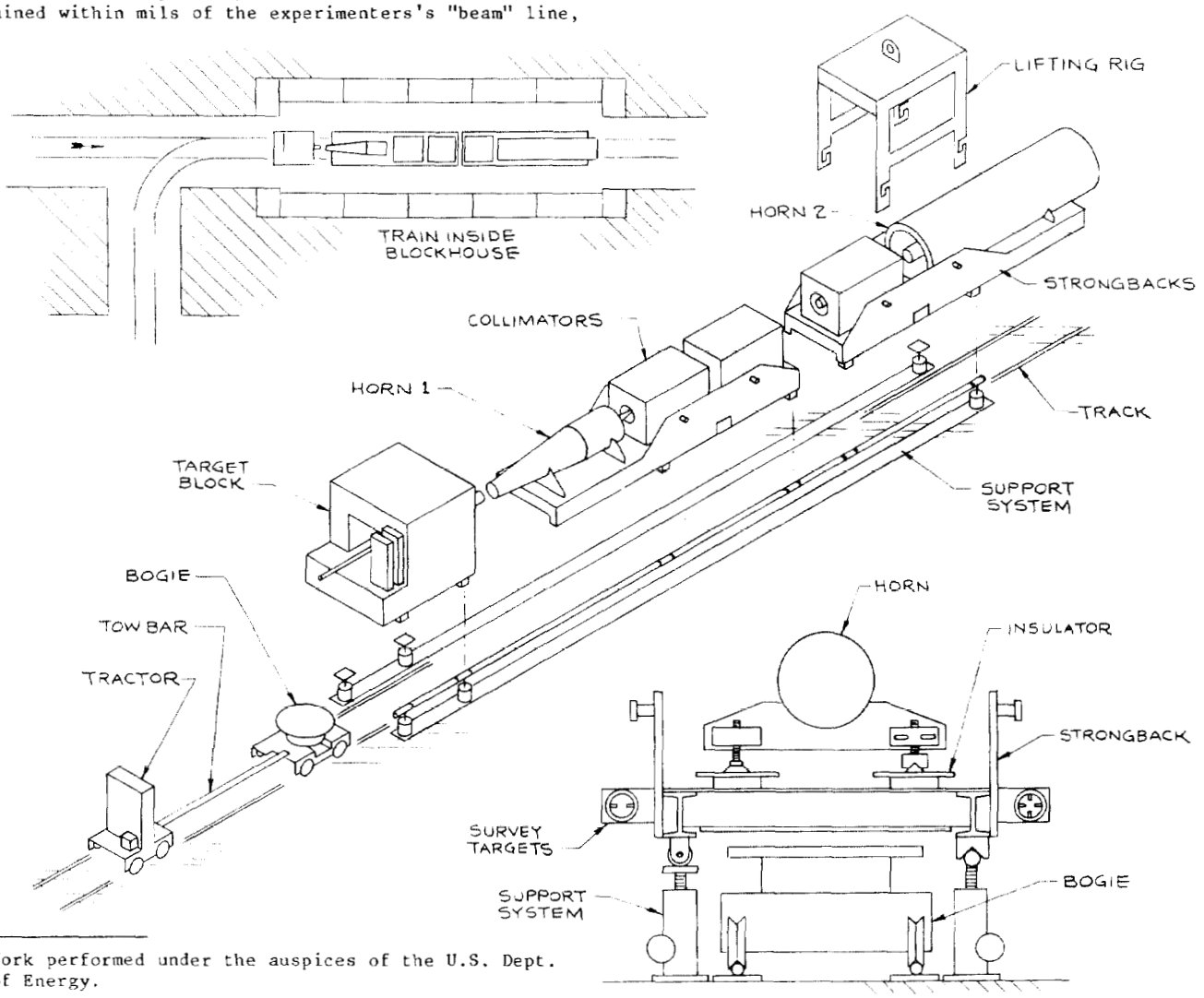
The study of neutrinos at the Alternating Gradient Synchrotron (AGS), Brookhaven National Laboratory (BNL), requires hardware for their initiation and control. The basics consists of a target, two horns and three collimators. This paper describes the installation, support and positioning of these components within a settling concrete blockhouse.

INTRODUCTION

The Narrow Band train consists of one target block, two horns, and three massive collimators. The length of the train exceeds forty feet, height six, width five. Its components are shoe horned into an eight foot high, ten foot wide, semi-circular tunnel from a right angle penetration of similar size, tunnels constricted by cable trays and piping. Its final working location is within a rectangular cave of large removable concrete blocks, the floor settling under their weight. Each train component is replaceable, its centerline spatially located, verified and maintained within mils of the experimenters's "beam" line, approximately four feet above the floor. In operation, the train and environs have become highly radioactive.

The design implemented is to install the longest assemblies of preadjusted components the tunnel configuration allows, to roll and rotate these into working position, to lower them onto adjustable pre-surveyed pedestals, and then make all connections or adjustments as far from the radiation sources as possible. There are three such assemblies: the five ton, five foot long target block; the five ton, seventeen foot long upstream strongback, Horn #1 and two collimators; the three ton, seventeen foot long downstream strongback with one collimator and Horn #2. Should removal be required and rollout impractical, the cave roof can be removed and these assemblies fished out with crane and special four-hook lifting rig. This rig has proven invaluable in handling the assemblies during fabrication, pre-survey, and shipping.

The simpler Broad Band experiment, which followed, was designed to use similar mounting concepts, the same insertion and surveying capabilities.



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STRONGBACK ASSEMBLIES

Horn and collimation data supplied by the experimenter define the internal envelope of the working train. Practical construction, supports, assembly, cooling, electrical connections, insulations and installation mandate the rest. The result is five manageable working components on two supporting frames. The frames are called strongbacks.

Each working component has four feet: two elevation adjustable swivel pads, two elevation and transverse adjustable cloven hooves (inverted vees). The pads rest on flat plates of the strongback, the hooves on inverted angles; the latter allow each component to be removed and replaced with relative position unchanged. Horn feet are electrically insulated from the strongbacks with plates of polyimide glass fabric laminate (Norplex G30); surface creep, high potential to ground, is four inch minimum. Collimator feet require no insulation. The vertical distance from component centerlines to the top plate of the strongback exceeds eighteen inches. This leaves only thirty inches to the floor for the strongback frame, the support, and the transport system.

Individual component weights vary from a six hundred pound Horn #1 to a forty-five hundred pound collimator segment. Five components perched on two strongbacks yield two top heavy unsymmetrically balanced train assemblies, the heaviest weighing approximately five tons, each positioned in the cave on cloven hooves and skids similar to that of the working components. As previously mentioned, each assembly must swivel to traverse the right angle bend from access tunnel to main tunnel. This swivel point must be under the assembly's center-of-gravity, and thereby defines the location of transport support and of the lifting rig. Each completely loaded strongback assembly is hung by the lifting rig and balanced level with lead bricks secured to the strongback top.

The strongback, approximately four feet wide by sixteen long, is made of aluminum with standard structural shapes, welded clips, and bolted construction. The I-beam stringers are ten inches, the main cross members seven. At locations selected to minimize deflection, two cloven hooves are bolted to the bottom of one stringer, two wheeled skids to the other. Bolted over the entire top is a quarter inch thick plate. At the swivel point, recessed beneath, is bolted a "foot" of half inch plate. Three quarter inch thick stiffener plates are bolted to the sides, bottom cutouts indicating the swivel point location. Bolted to them are pickup trunnions, the survey targets and other support components. Strategically used roll pins insure minimum shifting of parts during pickup and transportation.

TARGET BLOCK

The target shielding block consists of four specially shaped concrete blocks stacked to leave a cavity through which the experimental beam passes. The working target and its necessary instrumentation are keyed into this cavity so that they can be replaced and their relative positions maintained. Long removable handles minimize exposure during storage and replacement. Four inch thick sliding metal doors protect upstream personnel. Survey targets locate the working target. Secured to the bottom of this five ton assembly is an aluminum plate with two cloven hooves and two wheeled skids. These are oriented in the same manner and at the same dimensions as those of the strongbacks. The cave supports of target block and strongback assemblies are identical.

In the Broad Band Trains, the target block is used for instrumentation and shielding only. The working target is an integral part of Horn #1.

SUPPORT SYSTEM

As previously stated, the cave floor settles, and anything on it likewise. It was therefore necessary to make the train supports vertically adjustable. Since the environment would be radioactive, all surveying and adjustments had to be done remotely from upstream. The supports are spaced wide enough to allow passage of a transport cart called a bogie, are sturdy enough to transversely engage the cloven hooves of the respective strongbacks and target block, are narrow enough to fit the cave and wall piping.

The system consists of two parallel rows of components bolted to the floor. A five ton screw jack is located under each cloven hoof and wheeled skid of the three train assemblies; six jacks per row, each jack adjustable by an individual drive shaft extending upstream to common termination. Braced against lateral motion, the jacks under the cloven hooves are capped by cylindrical rollers, those under the wheeled skids by flat plates. The rollers and plates are accurately located in reference to the beam line. Pipe rails span the rollers to help guide the train assemblies into position.

The building where the train components are assembled has a stable floor. A simplified support system is installed here; four sturdy bolted-down roller pedestals for the strongback cloven hooves, loose plate supports for the wheeled skids. The rollers are accurately adjusted for alignment and height; the plates shimmed for height. No provisions are made to support the target block since its internal components are adjusted in the cave.

The supports in cave and assembly area are used without modification for both the Narrow and Broad Band trains. A cruder system, in an auxiliary concrete blockhouse, is being used for short term storage of used radioactive assemblies.

TRANSPORT SYSTEM

Each part of the train must be picked up at its center-of-gravity, carried up a ramp into the access tunnel, simultaneously rotated and translated in the constricted main tunnel junctions, transported to the cave, then settled sidewise and down to lock cloven hooves and skids to the support. These four motions require directional control, complex mechanisms, motors and wiring; most incompatible with long term radiation and must therefore be removed during experimental runs. This necessitates remote power and control through umbilical cords, positioning indicators and additional consideration for personnel safety.

The system consists of three major parts: the tracks, the bogies, and the tractor.

Tunnel and train component configuration forced us into a narrow twenty-six inch gauge track with a bend in the tunnel junction, its mean radius less than eleven feet. The curved section consists of one inch pipe welded to curved flame cut plates, the straight sections of one and three eights inch diameter solid rod welded to rectangular stock, all bolted solid to the floor, all accurately positioned laterally. The main track extends in both directions from the access tunnel, the curve bears to the right. A manually movable track switchyard allows access to both branches, a value for temporary storage and the installation of auxiliary beam components.

The bogie rides the track on four eight inch vee wheel swivel casters, the normally trailing offset of each outbound, those wheels traveling the curved inside track closer together than those on the outside. The underslung carriage between the casters supports a plate on oilite discs. This plate can be motor driven sidewise a little more than one inch each side of its central position. Fastened to the plate and directly over the discs are three interconnected motor driven five ton screw jacks. A support plate is secured to the top of the jack screws, its total design travel three and one half inches vertically. Secured by thrust and king post bearings, a turntable rotates on top of this plate. The edge of the turntable is converted into a bull gear by the addition of an imbedded roller chain. This is rotated by a sprocket and motor drive fastened to the support plate. There is no stop or limits to the degree of rotation. The bogie is operated through trailing extension cords. Push buttons on a controller give it directions. Range and limit switches activate indicator lights. Safety switches and an audible signal warn of possible damage in case of limit switch failure or possible phase reversal.

The minimum height to the top of the thirty five inch diameter turntable is approximately twenty one and a half inches. This leaves a little more than one inch clearance under the strongback foot when cloven hooves and skids are on the support. Each train assembly perched on its turntable must have its center-of-gravity above and inside the triangle roughly twenty-four inches on a side as defined by the centers of the elevation jacks. Bogie and burden cannot be nested or clamped together. Balance is therefore critical. The turntable tops are slightly canted to allow cloven hooves to engage before wheeled skids settle.

There are three bogies, one for each of the train assemblies. A single unit is used for the target block, a linked pair for the strongbacks. The pair is connected by a fixed length remotely disconnectable bar. When one bogie is correctly positioned under its strongback by a stop or other means, its mate is likewise under the other. A removable rigid towbar is used to push or pull the bogie or bogie pair. This bar connects to the tractor.

The tractor is a weighted motorized cart riding on the same track. All four wheels are driven for maximum traction by a 208V 3PH variable speed reversible motor with inline brake. A short wheelbase along with variable diameter wheels on one side allow it to function on the curved track sections without a differential and with a minimum of slip. A control box at the end of a 20 foot long cable allows the operator complete control of the cart's functions.

With minor modifications, the entire transport system is designed to function from either upstream or downstream of the train assemblies.

POSITIONING AND SURVEY

The upstream and downstream strongbacks, complete with horns, collimators, and all auxiliary components are assembled on the precisely positioned simplified supports in the assembly building. Each strongback has two survey targets per side plate, in line, parallel but offset from the beam line; four in line on two strongbacks, one line each train side, eight target total. Each target on one side of the train has two vertical and two horizontal pointed pins, points inward, each opposing pair adjustable axially, radially and transversely. The four targets on the opposite side have two opposing horizontal pins only. The surveyor, his instrument upstream, can sight through four targets at one time, focus on each in turn, and adjust all converging points to intersect on a sight line parallel to and at known coordinates from the beam line. The vertical pins record the strongback lateral locations, the horizontals their height and level. The components mounted on the strongbacks are precisely adjusted to these targets by their respective cloven hoof and pad feet. Their axial location, less critical, is maintained by clamp screws at the feet. The strongbacks deflect under component loads, but since they are identically supported in the cave, this is a constant and can be ignored.

The completed downstream assembly, surveyed and mechanically disconnected from its neighbor, is now loaded onto a flat bed truck and transported to the tunnel site. Bolted to its foot is a mechanical stop to position the downstream edge of its bogie turntable. The tractor and bogie transport it into the cave and onto the supports, its axial position determined by a mechanical flag system visible from upstream. The upstream strongback is now handled the same way. It, however, does not have a stop on its foot, its axial position is mechanically located by protruding bolts between the strongbacks. The target block follows, its axial position located visually.

With the target block securely on its tunnel support, the working target is visually sighted from upstream and positioned onto the beam line using adjustments built into its self-locating holder. The block's survey targets are then fixed and their coordinate recorded; two targets on one side with four pins, one target opposite with two. The surveyor, still upstream, checks the survey targets on the two strongback assemblies for elevation. If necessary, the support jacks are adjusted at the drive shaft terminations twelve feet upstream from the target block. All survey targets remain visible from the relatively cooler upstream position for periodic checks and necessary adjustments.

Both Narrow and Broad Band train assemblies are identically positioned and surveyed. The same target block is used for both without internal readjustment.

REMOVAL

The working target and its flag can be removed and replaced without disturbing the target block. Their long handles and the concrete shielding minimize personnel radiation dosage. If main component removal is necessary, the target block is first removed and stored on its bogie in the branch upstream of the access tunnel. All necessary disconnections are made. The tractor now positions the two linked bogies under the remaining train and is axially located by the mechanical stop of the downstream strongback. Tractor speed is slow and controllable. The upstream bogie then picks up its burden and is removed, the unused downstream bogie trailing behind, the downstream strongback still in position. Removing the downstream strongback can then handled with the tractor and single bogie. Both strongbacks cannot be removed from the tunnel simultaneously. The curved track and tight junction make this impossible.

BNL REFERENCE DRAWINGS

Tunnels and Blockhouse	D14-1166-C-6
Switchyards and Tracks	RR04-1507-5
Tunnel Supports	RR04-1566-5
Target Block	D13-M-5262-5
Narrow Band Neutrino Beam	RR04-1540-5
Broad Band Neutrino Beam	RR04-1691-5
Bogie	RR04-1867-5
Lifting Rig	RR04-1626-4